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Financial Analysis, Corporate Finance and Risk Management

Edited by
Eulália Mota Santos and Margarida Freitas Oliveira

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Guest Editors

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Preface

The reprint *Financial Analysis, Corporate Finance and Risk Management* combines eighteen articles that explore the key aspects of financial analysis, corporate financing strategies, and risk management. This Book offers new approaches to understanding and tackling financial challenges in a constantly changing economic landscape.

The articles within this reprint discuss topics such as corporate debt in Portuguese firms, the relationship between debt and earnings quality in small- and medium-sized enterprises, and how gender diversity and managerial behavior influence financial decisions. Additionally, this reprint explores how risk management can be enhanced with new methodologies and technologies, such as artificial intelligence.

Other themes covered include sustainability in finance, financial market volatility, and the impact of economic changes in emerging countries. These contributions are vital for improving financial decision-making and promoting stability within organizations.

This reprint is an essential read for researchers, professionals, and policymakers interested in innovative and resilient financial practices.

Eulália Mota Santos and Margarida Freitas Oliveira

Guest Editors

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Editorial

Special Issue "Financial Analysis, Corporate Finance and Risk Management"

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1. Introduction

In an era of rapid economic transformation, evolving regulatory landscapes, and technological advancements, the need for robust financial analytics, effective corporate financial strategies, and risk management frameworks has never been more critical. Companies must navigate financial uncertainty, optimize their capital structures, and implement sustainable financial practices to ensure long-term stability and success. In response to these challenges, this Special Issue presents a collection of eighteen high-quality research contributions that explore innovative methodologies and emerging trends in these areas.

Financial analysis plays a crucial role in informed decision-making, enabling the assessment of corporate performance and understanding of an organization's financial health. In today's context, where markets face constant challenges, the evolution of financial practices and the adoption of new approaches are essential to ensuring business resilience and competitiveness.

2. A Short Review of the Contributions to This Special Issue

This Special Issue brings together eighteen significant contributions that address various aspects of financial analysis and its practical applications.

2.1. Financial Analysis and Capital Structure

The contribution titled "Determinants of Corporate Indebtedness in Portugal: An Analysis of Financial Behaviour Clusters" (Tavares et al. 2024) investigates corporate debt patterns in Portuguese firms, while "Features of the Association between Debt and Earnings Quality for Small and Medium-Sized Entities" (Sequeira et al. 2024) explores the relationship between debt and earnings quality in small and medium-sized enterprises.

2.2. Corporate Finance Strategies and Risk Management

Corporate finance strategies continue to evolve, incorporating insights from behavioral finance and sustainable finance practices. In this context, "Board Gender Diversity and Risk Management in Corporate Financing" (Askarany et al. 2025) and "Risk Management in Product Diversification: The Role of Managerial Overconfidence in Cost Stickiness" (Parsaei et al. 2024) delve into how governance structures and managerial behavior influence capital structure decisions and risk management.

Risk management remains a cornerstone of financial stability, requiring sophisticated models to measure and mitigate uncertainties. Several papers in this Special Issue contribute to this discussion, including "Mapping the Landscape of Key Performance and

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Key Risk Indicators in Business" (Ionescu et al. 2024) and "The Role of Credit Consortia in the Financial Structure of Sardinian Companies During the SARS-CoV-2 Crisis" (Desogus et al. 2024), both of which highlight innovative approaches to managing financial risks in volatile environments. Advances in quantitative risk management (QRM) are also explored in "Uncertainty Reduction in Operational Risk Management Process" (Burstein and Zuckerman 2024), which presents novel methodologies for assessing and mitigating financial uncertainties.

2.3. Information Asymmetry and Financial Risk

Information asymmetry also stands out as a critical factor in financial markets. "Nonparametric Testing for Information Asymmetry in the Mortgage Servicing Market" (Jedidi and Dionne 2024) investigates the presence of information asymmetry in the mortgage market, while "Impact of Audit Fees on Earnings Management and Financial Risk: An Analysis of Corporate Finance Practices" (Daryaei et al. 2024) assesses the relationship between audit fees, earnings management, and financial risk.

2.4. Macroeconomics and Financial Stability

Macroeconomic issues and their implications for financial stability are explored in "The Role of Personal Remittances in Economic Development: A Comparative Analysis with Foreign Direct Investment in Lebanon" (Abou Ltaif et al. 2024a) and "Government Borrowing and South African Banks' Capital Structure: A System GMM Approach" (Mabandla and Marozva 2024), highlighting the impact of economic policies in emerging markets. "Lebanon's Economic Development Risk: Global Factors and Local Realities of the Shadow Economy Amid Financial Crisis" (Abou Ltaif et al. 2024b) examines economic risks in Lebanon in the face of the shadow economy.

2.5. Sustainable Finance and Technological Innovation

Sustainable finance and its role in shaping corporate financial decisions is another key theme in this Special Issue. "Robust Portfolio Optimization with Environmental, Social, and Corporate Governance Preference" (Escobar-Anel and Jiao 2024) investigates how sustainability considerations are increasingly integrated into financial decision-making, reinforcing the growing recognition that sustainable finance practices contribute to long-term financial resilience.

Technological advancements, particularly in artificial intelligence and machine learning, are transforming financial risk assessment. "Effective Machine Learning Techniques for Dealing with Poor Credit Data" (Nkambule et al. 2024) examines how machine learning models improve credit risk assessment, enhancing predictive accuracy and decision-making processes in financial analysis and risk management.

On the other hand, empirical studies on financial market volatility and its implications for investment strategies are explored in "Simulation of Dynamic Performance of DeFi Protocol Based on Historical Crypto Market Behavior" (Grigorova et al. 2024). This paper highlights the increasing importance of understanding market volatility, particularly in emerging sectors like decentralized finance (DeFi), and its impact on investment strategies. "A Financial Stability Model for Iraqi Companies" (Ibrahim et al. 2024) develops a financial stability model tailored to the specificities of the Iraqi economic context. "Dividend-Based Labor Remuneration and Tradable Shares in Worker Cooperatives" (Tortia 2025) examines how financial behavior and capital structure decisions impact firm outcomes and economic performance. Finally, "Shareholders in the Driver's Seat: Unraveling the Impact on Financial Performance in Latvian Fintech Companies" (Rupeika-Apoga et al. 2024) investigates how the presence of shareholders in management positions affects the financial performance of fintech companies.

3. Conclusions

This Special Issue reflects the diversity of approaches and methodologies used in financial analysis, contributing to a broader understanding of the challenges and opportunities shaping the global economic landscape. The 18 articles presented here reinforce the need for innovative strategies in optimizing financial planning, risk management, and business sustainability. We are confident that this Special Issue will serve as a valuable resource for researchers, industry professionals, and policymakers, strengthening the development of more robust and resilient financial practices.

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Article

Determinants of Corporate Indebtedness in Portugal: An Analysis of Financial Behaviour Clusters

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Abstract: Corporate indebtedness is a powerful tool in determining a company's financial health with impacts on its image and reputation. The main objective of this research is to study the determining factors in corporate indebtedness in Portugal. It also has the secondary objectives of creating clusters of companies' behaviour in relation to the use of credit and verifying their differences in relation to the characteristics of the companies. It uses a quantitative methodology based on a questionnaire survey of 1957 Portuguese companies. The results of the factor analysis show the formation of six determining factors in corporate indebtedness, namely the negotiating relationship with banks, financing, cycle and indebtedness, company operating performance, guarantees used to obtain bank financing and financing risk analysis as well as secondary forms of bank financing. The application of cluster analysis to the six factors formed led to the classification of companies into three clusters: the resilient financial cluster, the operational excellence cluster and the strategic financial cluster. There are several statistically significant differences in the corporate financing factors in relation to the clusters to which they belong. The evidence of the factors and clusters explaining company financing provides insights for improving credit access practices and for implementing public policies that facilitate access to credit and promote economic development.

Keywords: financial management; financing strategies; credit evaluation; financial structure; alternative forms of financing

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1. Introduction

Financial ratios are strong indicators of a company's likelihood of bankruptcy (Magnanelli and Izzo 2017). According to Pacheco et al. (2019), the ratios that demonstrate the greatest predictive power of bankruptcy are indebtedness, solvency, return on equity, return on assets, financial autonomy and the ratios Working Capital/Total Assets; EBIT/Total Assets and Turnover/Total Assets. In addition to the financial variables, the authors refer to two non-financial variables, namely exports and the number of employees, which are negatively related to company bankruptcy in the construction sector in Portugal. This indicates that companies in this sector with a greater presence abroad are less likely to go bankrupt, as is the size effect.

For Tavares et al. (2021) and Santos et al. (2022), image risks are linked to the company's reputation, which it transfers abroad. On the other hand, these authors consider

that financial risks are associated with the economic and financial capacity of companies and the way they carry out their business, an idea corroborated by Almeida (2023). Financial risks are distinguished between short-term and medium- and long-term risks. In the short term, the importance of liquidity is emphasised in order for companies to maintain a positive and balanced net cash position. In the medium and long term, there is a focus on solvency, which reduces the likelihood of bankruptcy (Santos et al. 2022). According to Tavares et al. (2021), strategic planning is essential for companies, as they need to have a clear vision of the economic, social and political changes that are taking place in the ecosystem in which they operate.

Many family businesses survive over generations when management is professionalised and there is a separation between ownership and control of the company, which increases the company's chances of growth (Santos et al. 2022). The perception of operational risk positively influences the perception of financial risk in family businesses. In a family business, its longevity leads to the consolidation of the link between the company name and the family name (Tavares et al. 2015; Santos et al. 2022).

The aspects that are most evident in the perception of risk management planning are having a management plan that includes the relationship with customers, suppliers and employees (medium and long term) and also an up-to-date security plan (Tavares et al. 2023). There are statistically significant differences in risk management planning, with the larger the organisation, the greater the importance given to risk management planning (Forti et al. 2011).

Authors such as Mutamimah et al. (2021), Zhang et al. (2022), and Ogunmokun et al. (2024) argue that the provision of credit to companies is based on the analysis of corporate information to assess repayment capacity. However, the information asymmetry between banks and companies poses a challenge, making credit risk a critical concern. These same authors point to the relationship between banks and companies as one of the factors reducing information asymmetry, creating better conditions for companies to obtain credit.

Bhatia and Kumar (2023) investigated the relationship between the debt efficiency, operational efficiency and performance of Indian companies in the period between 2013 and 2019. The authors found evidence through a GLS regression model of a positive association between operational efficiency and business performance, as well as the cost of capital. They highlighted operational efficiency as a relevant factor in corporate financial performance and debt acquisition, and these findings are supported by Aziz and Abbas (2019), Boshnak (2023), and Ye et al. (2023).

The main objective of this work is to study the determining factors in corporate indebtedness in Portugal. Its secondary objectives are to create clusters of companies' behaviour in relation to the use of credit and to verify their differences in relation to the characteristics of the companies. The present study represents a significant advancement in the investigation of financing for Portuguese SMEs, notable for its originality in employing cluster analysis. By addressing existing gaps in the literature concerning this market, it provides a broader and more detailed perspective on SME financing dynamics, contributing to a more robust and informed knowledge base in this field of the Portuguese economy. In order to achieve the proposed objectives, this work is divided into five sections. In addition to this introduction, the next section reviews the literature. Then, the methodology is presented, and in the fourth section, the results are presented and discussed. Finally, the conclusions are presented.

2. Literature Review

2.1. Corporate Reputation and the Business Relationship with Banks

For Mehtap and Kokalan (2013), corporate reputation is an increasingly emphasised issue in management and organisational studies and is considered a very valuable intangible asset that is determined by the evaluations and perceptions of the parties. Thus, according

to the authors, different groups and stakeholders can perceive a company's reputation from different points of view and different perspectives.

Companies whose boards are larger become less effective because problems and parasitism arise and decisions are more difficult to make in a timely manner (O'Sullivan et al. 2016). But, on the other hand, with a larger board it is easier to detect the sometimes opportunistic behaviour of managers. However, too many directors and managers become difficult to control and will jeopardise performance (Forti et al. 2011). The presence of women on boards of directors reduces debt costs and perceptions of default risk by fund providers, while board independence and board size do not have a significant impact on debt costs (Aksoy and Yilmaz 2023). The results indicate that corporate social responsibility reporting has a positive association with debt access and a negative association with its cost of debt (Uyar et al. 2024).

2.2. Financing, Growth Cycle and Indebtedness

According to Rodrigues et al. (2018), earnings before interest on taxes (EBIT) are not relevant to indebtedness, but they are relevant to investment. For the authors, the same can be said for return on equity (ROE). However, the tangibility of the asset, the cost of debt and the value of the asset are relevant when it comes to debt. Rosa et al. (2018) assessed the impact of corporate social performance (CSP) on the cost of debt capital and leverage. The authors found that the level of corporate social performance significantly affects the cost of debt capital and leverage in times of stability, because in times of crisis, companies are expected to focus their efforts on maintaining profitability and the manifestation of corporate social responsibility is generally understood by creditors as a strategy that companies adopt to hide negative performance. According to Rodrigues et al. (2018), the tangibility of assets is important for accessing debt. The cost of debt (interest payable) restricts access to debt. According to Rosa et al. (2018), the higher the social performance, the better they are able to grow, in their opinion, because they disclose more information about future strategies. Creating a more transparent and cooperative corporate culture reduces suspicions of opportunistic behaviour, creates trust between stakeholders and promotes involvement, thereby reducing information asymmetries, agency costs and capital restrictions. The relationship between the cost of debt and indebtedness naturally involves the company's ability to pay. Although companies always seek the best composition of the capital structure, their freedom to achieve an optimal capital structure faces problems due to the set of restrictions that characterise imperfect capital markets (Rodrigues et al. 2018).

Rosa et al. (2018) observed that companies with higher CSP not only have a stronger corporate image but also create expectations of better ongoing financial performance and lower exposure to risk. In times of economic stability, lenders tend to perceive CSP as a strategic project and companies that adopt this approach can obtain loans at lower interest rates. According to Lemma (2015), high levels of perceived corruption lead companies to use higher levels of perceived corruption lead companies to use higher levels of short-term leverage, lower levels of long-term leverage and debt with shorter maturities.

For Ghouma et al. (2018), a stronger board of directors (in terms of composition and structure) ensures greater protection of investors' rights and therefore reduces agency problems within the company. These reduced agency problems within the company represent an important aspect that allows companies to enjoy a lower cost of debt financing. Lower information asymmetry, through the company's disclosure policy, also explains the negative relationship between the cost of debt and the quality of corporate governance (Tavares et al. 2023). Rosa et al. (2018) also found a positive correlation between company size and corporate social performance and that the impact of corporate social performance on the cost of debt capital is more significant for small companies. The authors understand that lenders perceive that small companies are generally less inclined to intervene in corporate social performance due to budgetary constraints, so they are more willing to finance small companies when they decide to engage in corporate social performance.

Magnanelli and Izzo (2017) conclude that there is a positive relationship between corporate social performance and the cost of debt, demonstrating that corporate social responsibility is a value factor with an impact on the company's risk profile. Companies in countries with higher levels of perceived leverage in terms of corruption respond to the weaknesses of enforcement institutions through greater concentration of ownership and greater participation in the control block (Chai et al. 2019). Corruption makes law enforcement institutions ineffective and therefore distorts corporate governance (Lemma 2015).

Magnanelli and Izzo (2017) recommend publishing and disseminating non-financial information about the company, as this strengthens relations between key stakeholders and can stabilise the market. The effective implementation of corporate social responsibility activities has an effect on risk reduction (Pacheco et al. 2019; Tavares et al. 2021). Magnanelli and Izzo (2017) conclude that the higher the risk of companies, the higher the cost applied by banks, and the better the reputation for responsibility or performance of companies, the lower the risk and consequently the cost of debt financing.

2.3. Company Operating Performance

According to Forti et al. (2011), performance measured by return on assets (ROA) and market value assessed by the market-to-book ratio are positively affected by companies' cash retention. They also consider, with regard to the relationship between cash management and business performance, that effective cash management is an important contribution to maximising operating profit. In this way, companies that adopt efficient cash management that is consistent with a contemporary view of the subject have a better chance of prospering in today's competitive environment.

According to Soares et al. (2012), companies' financial statements and public information can be used to determine the credit ratings of Brazilian companies with reasonable accuracy. According to the authors, an increase in the generation of operating income over total financial expenses reduces credit risk and increases the credit rating.

The characteristics of loans to small- and medium-sized enterprises (size of the loan, length of the loan, information required that is not always complete) require concern on the part of financial institutions in order to assess their creditworthiness (Chai et al. 2019). Thus, because of the asymmetric information and nature of loans to companies, it is very difficult for financial institutions to accurately assess their credit risk, and restricted access to finance hinders the development of companies.

Yazdanfar and Öhman (2015) confirm that debt ratios in terms of trade credit, short-term debt and long-term debt negatively affect the performance of companies in terms of profitability. On the other hand, a high debt ratio increases agency costs and the risk of losing control of the company, owners and managers of small and medium enterprises (SMEs), which tend to finance their businesses with equity to a fairly high degree, according to Rosa et al. (2018). Chai et al. (2019) believe that due to the very different nature of the various sectors and the great variation in the size and terms of loans between the different sectors, it is not appropriate to assess credit risk for all companies using the same credit rating system. These authors have shown that for small companies, non-financial factors are more influential in predicting default risks than financial factors.

Yazdanfar and Öhman (2015) confirmed that profitable SMEs tend to use equity and retained earnings more than external financing. They also found that SMEs use short-term debt more than medium- and long-term debt, which can reduce costs related to information asymmetry and agency conflicts. The lower the level of leverage, the lower the agency costs of external investments, the lower the debt and the higher the company's profitability (Rosa et al. 2018). According to Yazdanfar and Öhman (2015), there is a negative relationship between age and profitability, which can be explained by the life cycle theory.

Ugwueze et al. (2019) point out that in the presence of asymmetric information, a company is financed more by internally generated funds than by external funds. The authors conclude that long-term debt and retained earnings are not statistically significant in

turnover, unlike short-term debt. To reduce information asymmetry and moral hazards between SMEs and financial institutions such as banks, SME owners and managers should also be aware of the importance of transfer measures that can improve their relationship with financial institutions in the business environment (Yazdanfar and Öhman 2015). According to Amarna et al. (2024), in a study conducted on European companies, investors negatively value Environmental Social Governance disclosure, leading to an increase in the cost of equity capital, while creditors positively value it, resulting in a reduction in the cost of debt.

2.4. Guarantees Used to Obtain Bank Financing

The deficiency in the process of analysing companies' credit leads to the existence of non-performing loans (Manuel et al. 2018). According to Jucá et al. (2016), the higher the levels of assets that can be used as collateral, the higher the level of financial leverage; the higher the level of non-current assets (fixed assets), the higher the maturity of the debts; the higher the level of current assets (stocks and accounts receivable), the lower the maturity of the debts and the assets that can be used as collateral are more relevant for companies that contract bank debts. Thus, the authors conclude that assets that can be used as collateral are of fundamental importance in contracting long-term debt, while stocks and receivables are more geared towards making short-term debt viable. These assets are more relevant for companies that do not have access to the capital markets, i.e., that rely on bank debt (Tavares et al. 2015). Sometimes some investment projects do not meet the necessary conditions for approval, but when it comes to projects linked to state initiatives, public banks are called upon to support them (Manuel et al. 2018). In their study, Ogunmokun et al. (2024) found that during periods of economic restructuring, the lack of government intervention and the presence of banks have a negative and significant impact on loans to small businesses.

Ono and Uesugi (2009) consider that the use of collateral is complementary to relationship-based financing and point out that collateral plays an important role in facilitating the relationship between borrowers and lenders. In this way, they understand that banks whose claims are backed by collateral monitor more intensively, and that borrowers who have a long-term relationship with their main banks are more likely to offer collateral. Unlike collateral, personal guarantees have a weaker complementarity with relationship-based financing (Manuel et al. 2018). For Calcagnini et al. (2014) the presence of guarantees, mainly collateral, affects the cost of credit for Italian companies, systematically reducing interest rates on loans. Guarantees are a more powerful instrument for riskier borrowers than for safer ones (Jucá et al. 2016).

Ono and Uesugi (2009) found that personal guarantees are more often required of smaller, more owner-orientated companies, with the aim of limiting the risk of mixing the personal assets of business representatives. According to Calcagnini et al. (2014), the likelihood of secured loans increases with the company's higher risk perception and during economic crises. Thus, the probability of posting guarantees is lower the longer the relationship between banks and clients and the greater the number of banks for each company.

Ono and Uesugi (2009) found that the use of collateral was more likely to be associated with the more frequent submission of relevant documents and a longer-term relationship with the bank. For Mayordomo et al. (2021), the use of personal guarantees and collateral by a major Spanish banking group and its subsidiaries increased to improve the credit risk of loans and meet regulatory capital requirements. Personal guarantees were required more often than collateral, especially in subsidiaries with lower capital ratios (Ugwueze et al. 2019). Mayordomo et al. (2021) documented that subsidiaries with lower capital ratios significantly increased the use of personal guarantees after the changes in the collateral policy, highlighting the importance of these changes for the financial institution as a whole and for each of the subsidiaries. On the other hand, Calcagnini et al. (2014) found that during the financial crisis, guarantees helped banks to improve their screening of companies,

which resulted in lower interest rates for guaranteed loans. Interest rate variability is higher among larger banks (Manuel et al. 2018).

2.5. Analysing Financing Risk

Tavares et al. (2015) analysed the forms of financing and products most used by SMEs in the Porto district of Portugal. In their study, they found that the most commonly used sources of finance are bank credit, self-financing and, to a lesser extent, European Union funds. As for the importance given to the products used by companies, they concluded that the most important products identified by companies are bank current accounts, medium- and long-term loans, leasing and/or renting, financing of foreign operations, bank guarantees and short-term loans, among other things.

There are signs that better governance practices reduce credit constraints for companies, i.e., companies that adopt better governance practices have greater access to resources in the financial market (Cicogna et al. 2007). The continuous innovation of financial products is a general reality in the financial services industry and is important for maintaining competitiveness (Li and Li 2021). Van Osnabrugge (2000) concludes that venture capitalists are very concerned about exiting their investments in the future and also have higher expected and partially realised rates of return on their venture investments than business angel investors. With regard to the relevance of guarantees for obtaining financing, Tavares et al. (2015) found that the most commonly used guarantees are: the promissory note subscribed by the company with a personal guarantee, the promissory note subscribed by the company, the mutual guarantee, the mortgage guarantee and the pledge of securities.

2.6. Secondary Forms of Bank Financing

Gonçalves et al. (2018), in a study carried out in Brazil, found that self-financing, followed by indebtedness, is the most-used primary source of financing. According to Myers and Majluf (1984), financing begins with the use of equity, followed by external financing through the issue of debt and finally the issue of shares. This hierarchy is justified by the fact that internally generated resources (retained earnings) have no transaction costs for the company to finance itself.

Increased credit risk reduces bank profits (Manuel et al. 2018). Managers should therefore pay more attention to the role of cost efficiency and risk-taking (Belkhaoui et al. 2020).

According to Mura and Buleca (2012), in order to secure investment projects and increase performance, the company needs to finance its own activity. If the company does not have sufficient sources of its own, it will try to obtain it from external sources (Santos et al. 2022).

3. Methodology

3.1. Characterisation of the Population and Sample

The target population for this study is Portuguese companies with a turnover of more than EUR 500,000.00, whose emails were obtained from the SABI database (Iberian Balance Sheet Analysis System). The sampling method used was non-probabilistic for convenience, as only companies included in this database were used. It should be noted that although the sampling method is not probabilistic, all companies that received the invitation by email have the same probability of responding to the questionnaire. The study population comprises Portuguese companies with sales volumes exceeding EUR 500,000.00 in the year 2021, totalling approximately 60,000 companies, from which 1957 valid responses were obtained.

The sample consists of 1957 Portuguese companies that responded to the questionnaire. Regarding the characterisation of the questionnaire respondents, they were mostly male (62.1%, n = 1216) and aged between 20 and 85 years, with an average of approximately 46 years (SD = 10.35). Regarding the roles they perform in their companies, 33.3% (n = 652) were managing partners, 26.3% (n = 514) were administrative, 23.2% (n = 455) were administrators or managers and 17.2% (n = 336) were directors. On average, these

companies have been on the market for approximately 25 years (*SD* = 19.36), with 50% of companies operating on the market for 21 years or less.

Table 1 presents the elements that characterise the responding companies. Thus, of the 1957 companies that participated in the study, the majority (50.6%, *n* = 991) are characterised by being small companies. The companies belonged to different areas of activity, with commerce, services and industry representing 67.9% (*n* = 1330) of responding companies, but only 17.3% (*n* = 340) of companies operated in the international market.

Table 1. Characterisation of companies.

Variables	Categories	*n*	%
Number of employees	Less than 10	633	32.3
	From 10 to 49	991	50.6
	From 50 to 249	275	14.1
	More than 250	58	3.0
Sector/area of activity commerce	Business	522	26.7
	Services	449	22.9
	Manufacturing industry	359	18.3
	Construction	343	17.5
	Tourism	96	4.9
	Transport	68	3.5
	Restoration	46	2.4
	Agriculture	34	1.7
	Gas, electricity, water	27	1.4
	Extractive industry	13	0.7
Main market where the company has the highest sales volume	National market	870	44.5
	Regional market	401	20.5
	Local market	346	17.7
	International market	340	17.3
Type of company	Family	1328	67.9
	Unfamiliar	629	32.1
Type of society	Quota company	1603	81.9
	Anonymous society	349	17.8
	Cooperative	3	0.2
	Limited partnership	1	0.1
Company life cycle phase	Rapid growth	35	1.8
	Healthy and growing	776	39.7
	Stabilised	967	49.4
	Decline	173	8.8
Accounts certified by an external entity	Yes	1247	63.7
	No	710	36.3

Source: Own elaboration.

The majority of companies surveyed were family-owned (67.9%, *n* = 1328) and the two types of company that stand out most are the limited liability company (81.9%, *n* = 1603) and the public limited company (17.8%, *n* = 349). As for companies' life cycle phases, in general, they were stabilised (49.4%, *n* = 967) or healthy and fast growing (41.5%, *n* = 811). Regarding certification, the majority (63.7%, *n* = 710) had accounts certified by an external entity.

3.2. Data Collection Instruments

The instrument used was a questionnaire survey composed of two parts. In the first part, the respondents were characterised (age, sex and role they perform in the company) and the companies were characterised (number of employees, sector or area of activity, year of founding of the company, main market where it has the largest sales volume, type

of company, type of society, phases of the company's life cycle, certification). In the second part, we analysed the determining factors in corporate debt.

To measure the importance of determining factors in corporate debt, 40 items were used (see Table 2 for a more detailed understanding of the items and corresponding variables), constructed while taking into account the works of (Tavares et al. 2015, 2021, 2023) and using a 5-point Likert scale (1—Not at all important; 5—Very important).

Table 2. Matrix of factor loadings of the determining factors in corporate debt.

	Loadings
Factor 1: Business relationship with banks (α = 0.913)	
R4. Increase negotiating power with banks	0.792
R6. Have the option to choose which bank you want to work with	0.770
R3. Possibility of reducing interest rates charged	0.756
R7. Caution about a financial institution	0.752
R2. Diversity of advice to support the activity	0.746
R5. Possibility of obtaining higher amounts of financing	0.732
R8. Increase acceptance of credit applications	0.723
R1. Variety of products and services offered	0.718
R9. Share the risk across more than one bank	0.695
Factor 2: Financing, life cycle and debt (α = 0.887)	
F4. The debt capital/own capital ratio of other companies in the same sector of activity	0.772
F5. The business life cycle phase	0.741
F7. The fact that new financing signals to competitors that the company will not reduce installed capacity or production	0.733
F3. The fact that the use of foreign capital is limited provides customers and suppliers with a stable financial situation	0.720
F6. The volatility of cash flows	0.709
F8. A new level of debt signals the company's ability to grow results	0.680
F1. The fact that the level of debt discourages potential buyers	0.657
F9. The rating classification	0.649
F2. The nature of your business	0.642
Factor 3: Company operational performance (α = 0.849)	
D3. Standard operating procedures are helpful to employees at work	0.823
D5. Instructions for the operations to be carried out are important for employees at work	0.818
D4. Harmonious working relationships are important to the company	0.807
D2. Company regulations inform employees about what is expected of them	0.746
D1. Details of job requirements and instructions are important	0.650
D6. Preserving public image is one of the company's main policies	0.635
Factor 4: Guarantees used to obtain bank financing (α = 0.838)	
G2. Promissory note signed by the company with personal guarantee	0.784
G4. Mutual guarantee	0.782
G1. Declaration signed by your company	0.731
G5. Financing using mutual guarantee	0.681
G3. Mortgage guarantee	0.645
Factor 5: Financing risk analysis (α = 0.820)	
A2. Analysis of managers' hobbies	0.820
A3. Way of life of company managers	0.818
A4. Analysis of the political exposure of company managers	0.707
A5. Company succession assured	0.701
A1. Duration of the relationship with suppliers	0.645
Factor 6: Secondary forms of bank financing (α = 0.800)	
FS2. Loan discount	0.740
FS1. Factoring	0.738
FS3. Discount on promissory notes	0.733
FS5. Confirming	0.700
FS4. Financing/foreign operations	0.633

Source: Own elaboration.

3.3. Data Collection and Analysis Procedures

After a literature review, a questionnaire was created and subjected to a pre-test. After carrying out the pre-test, the proposed suggestions were taken into consideration and the questionnaire was created using the Google Forms tool. Subsequently, between the months of March and May 2021, the questionnaire link was sent to the companies that make up the population under analysis, accompanied by a short text, inviting the companies to participate in the present study. In this invitation, the objectives of the study were defined and the anonymity and confidentiality of the information provided were guaranteed.

After data collection, the IBM SPSS Statistics 28 software was used. To characterise the company representatives in the responses to the questionnaire and characterise the companies, descriptive statistics techniques were used (descriptive measures and absolute and relative frequencies). According to Kline (2016), the sensitivity of the items was initially analysed using the asymmetry ($|Sk| \leq 3$) and flatness ($|Ku| \leq 10$) coefficients.

The suitability of applying an exploratory factor analysis (AFE) to items that assess the determining factors in corporate debt was assessed using the KMO—the Kaiser–Meyer–Olkin index—and Bartlett's sphericity test. According to Hair et al. (2014), KMO values greater than 0.8 reveal a good adequacy of the sample and a statistically significant Bartlett's test of sphericity ($p < 0.05$) indicates that there are sufficient correlations between the items to continue the analysis. To obtain the determining factors in corporate debt, EFA was applied, using the main components method and the Kaiser criterion (eigenvalues greater than 1) and the varimax method were used to extract the factors. According to Hair et al. (2014), factor loadings must be above 0.50 to translate more than 25% of the variable's variance.

The reliability of the factors obtained with the application of EFA were evaluated using the calculation of the Cronbach's alpha value. Values greater than 0.7 are considered acceptable (Hair et al. 2014).

After defining the determining factors of corporate debt, cluster analysis was applied in order to group companies into groups with common characteristics. Finally, to compare, in the clusters found, the determining factors of corporate debt between the various characteristics of the companies, Student's *t*-test for independent samples and Welch's test were applied. In cases where the intention is to compare two independent samples, Student's *t*-test was used, and in cases where it is intended to compare more than two independent samples, ANOVA or Welch's test was used in cases of the violation of the assumption of homogeneity of variances (Marôco 2018).

4. Results and Discussion

4.1. Determining Factors in Business Debt

The Kaiser–Meyer–Olkin (KMO) sampling measure and Bartlett's sphericity test revealed a very good sample adequacy ($\chi^2(741) = 37830.95$, $p < 0.001$, KMO = 0.902) for the application of exploratory factor analysis to the 39 items that make up the determining factors in business debt (Hair et al. 2014).

Table 2 shows that six factors were retained, which together explain 58.50% of the total variance. The first factor explains 13.70% of the variance and is the business relationship with banks (items R1, R2, R3, R4, R5, R6, R7, R8 and R9), as it is composed of items that address aspects related to the importance that companies give to the closeness of their relationship with banks.

The second factor refers to items related to a company's financing decision, are related to the company's life cycle and also take into account debt at the beginning and end of the financing operation (items F1, F2, F3, F4, F5, F6, F7, F8 and F9). This factor explains 12.42% of the variance and is known as financing, cycle and debt.

The third factor is the company's operational performance (items D1, D2, D3, D4, D5 and D6) and explains 9.23% of the variance. The items in this factor address aspects related to the importance that companies give to their operational part and to their good structuring and consolidation. The fourth factor explains 7.98% of the variance and involves guarantees used to obtain bank financing (items G1, G2, G3, G4 and G5). The items in this

factor refer to essential guarantees, or of first concern, used in company financing. The fifth factor is financing risk analysis (items A1, A2, A3, A4, A5 and A6) and explains 7.76% of the variance. The items in this factor are related to what companies do not consider important when analysing the risk of financing a company, that is, they are aspects that companies tend to underestimate when taking out financing.

The sixth, and last, factor is secondary forms of bank financing (items FS1, FS2, FS3, FS4 and FS5) and explains 7.41% of the variance. The items in this factor relate to the use of bills and promissory notes, factoring and other forms of financing.

Regarding the loading values of all items, these are greater than 0.5 (minimum value of 0.633), which is in accordance with Hair et al. (2014). Regarding the reliability of each factor, this is considered, according to Hair et al. (2014), very good for the factor of business relationship with banks (factor 1: $\alpha = 0.913$) and good for the remaining factors (factor 2: $\alpha = 0.887$; factor 3: $\alpha = 0.849$, factor 4: $\alpha = 0.838$, factor 5: $\alpha = 0.820$ and factor 6: $\alpha = 0.800$).

These results aggregate the determining factors of corporate debt. In short, it can be seen that there are six factors that as a whole are considered when companies resort to debt. Thus, when companies resort to debt, the company's business relationship with banks, its life cycle and its operational performance, as well as the guarantees required by the bank, are decisive, with the need to carry out a risk analysis financing, as well as secondary forms of bank financing.

4.2. Cluster Analysis

The dendrogram in Figure 1 shows that the six determining factors in corporate debt lead to the formation of three clusters.

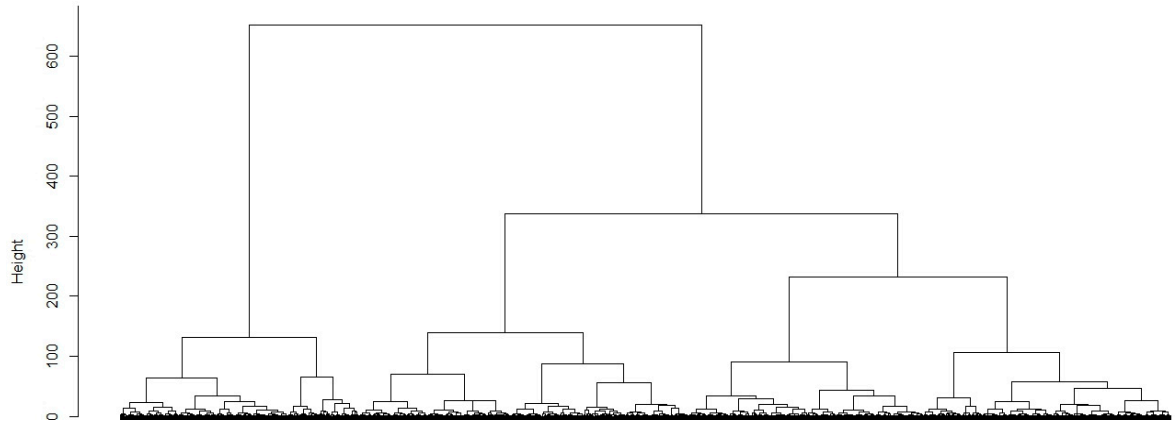

Figure 1. Dendrogram of clusters related to the determining factors in corporate indebtedness. Source: Own elaboration.

Cluster 1 in Figure 2 contains the largest number of companies ($n = 946$, 48.3%) and presents high levels in the factors of business relationship with banks ($M = 3.88$, $SD = 0.56$) and company operational performance ($M = 4.09$, $SD = 0.49$). As for the financing factor, the cycle and debt factor presents reasonable levels ($M = 3.28$, $SD = 0.66$). In the remaining factors, the levels are low, falling below the midpoint of the scale used (three points). Thus, cluster 1 will be called the "Resilient Financial Cluster", as it has a strong relationship with banks and excellent operational performance. The authors Mehtap and Kokalan (2013) and O'Sullivan et al. (2016) mentioned that corporate reputation is a very valuable intangible asset and this helps to maintain a good relationship with banks. Soares et al. (2012) and Chai et al. (2019) refer to the importance of the operational part of the company being healthy, and that in small- and medium-sized companies, non-financial factors are more influential than financial factors.

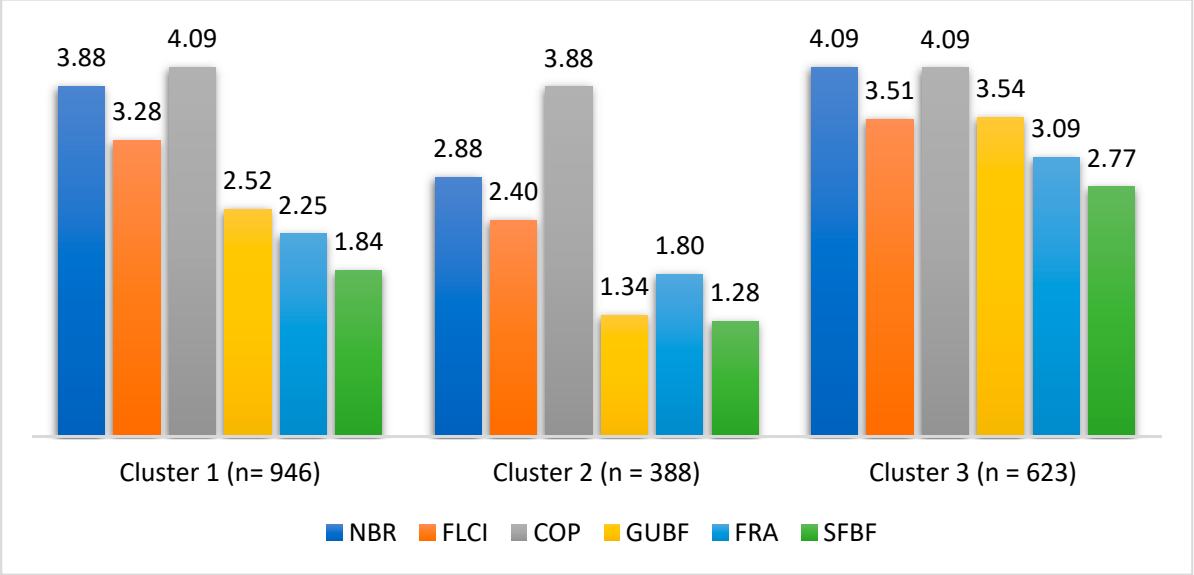

Figure 2. Averages of the determining factors in corporate debt by cluster. Legend: Cluster 1—Resilient Financial Cluster; Cluster 2—Operational Excellence Cluster; Cluster 3—Strategic Financial Cluster; NBR—negotiating relations with banks; FLCI—financing, life cycle and indebtedness; COP—Company's operational performance; GUBF—guarantees used to obtain bank financing; FRA—financing risk analysis; SFBF—secondary forms of bank financing. Source: Own preparation.

Cluster 2 is made up of 388 (19.8%) companies and presents a high level only in the company's operational performance factor (M = 3.88, SD = 0.72). In all other factors, the levels are below the midpoint of the scale. Therefore, cluster 2 will be called the "Operational Excellence Cluster", reflecting its prominence only in the company's operational performance factor, while the other factors present levels below average. Santos et al. (2022) state that the perception of operational risk positively influences the perception of financial risk. Also, for Soares et al. (2012) an increase in operating income over total financial expenses reduces credit risk and increases the credit rating.

Cluster 3 consists of 623 (31.8%) companies and is characterised by presenting high average levels in four of the determining factors: business relationship with banks (M = 4.09, SD = 0.50); financing, cycle and debt (M = 3.51, SD = 0.61); company operational performance (M = 4.09, SD = 0.60); and guarantees used to obtain bank financing (M = 3.54, SD = 0.66). The factor of financing risk analysis is slightly above the midpoint of the scale (M = 3.09, SD = 0.71) and the factor of secondary forms of bank financing presents low levels (M = 2.77, SD = 0.91). Taking the above into account, cluster 3 will be called the "Strategic Financial Cluster", as it stands out by presenting high average levels in four determining factors, indicating a strategic and balanced approach in relation to financial and operational aspects. Strategic planning is essential for companies. Authors such as Tavares et al. (2023), Rodrigues et al. (2018) and Pacheco et al. (2019) allude in their work to strategic planning and risk management, as well as their alignment with the companies' life cycle.

It should be noted that in all clusters the company's operational performance factor presents high levels.

4.3. Comparative Analysis by Clusters

In Table 3, after applying Student's t-test for independent samples, it was observed that, in the Resilient Financial Cluster, there are statistically significant differences in the financing risk analysis factor between family and non-family companies (t = 2.052, $p < 0.05$), with family companies being those that attribute greater importance to this factor. In the Strategic Financial Cluster, there are statistically significant differences in the factor of secondary forms of bank financing between family and non-family companies (t = −3.022,

$p < 0.01$), with non-family companies being those that attribute greater importance to this factor. This verification is in line with what was mentioned by Santos et al. (2022).

Table 3. Comparative analysis of the determining factors in corporate indebtedness between family and non-family companies by cluster.

Clusters	Factors	Type of Company						*t*-Test
		Family			Non-Family			
		n	***M***	***SD***	***n***	***M***	***SD***	
Cluster Financial Resilient	NBR	641	3.89	0.56	305	3.86	0.57	0.663
	FLCI	641	3.30	0.66	305	3.23	0.66	1.576
	COP	641	4.10	0.49	305	4.08	0.48	0.574
	GUBF	641	2.54	1.00	305	2.47	1.00	1.022
	FRA	641	2.29	0.84	305	2.17	0.76	2.052 *
	SFBF	641	1.81	0.72	305	1.90	0.70	−1.843
Cluster of Excellence Operational	NBR	247	2.81	1.09	141	2.98	1.00	−1.517
	FLCI	247	2.38	0.95	141	2.44	0.94	−0.648
	COP	247	3.84	0.75	141	3.94	0.67	−1.350
	GUBF	247	1.34	0.42	141	1.36	0.50	−0.466
	FRA	247	1.82	0.81	141	1.75	0.77	0.829
	SFBF	247	1.29	0.50	141	1.27	0.47	0.408
Cluster Financial Strategic	NBR	440	4.09	0.50	183	4.10	0.51	−0.336
	FLCI	440	3.52	0.61	183	3.51	0.63	0.155
	COP	440	4.09	0.59	183	4.07	0.64	0.344
	GUBF	440	3.52	0.66	183	3.59	0.66	−1.228
	FRA	440	3.07	0.69	183	3.15	0.75	−1.204
	SFBF	440	2.70	0.88	183	2.94	0.96	−3.022 **

Legend: NBR—negotiating relations with banks; FLCI—financing, life cycle and indebtedness; COP—company's operational performance; GUBF—guarantees used to obtain bank financing; FRA—financing risk analysis; SFBF—secondary forms of bank financing. Note: ** $p < 0.01$; * $p < 0.05$. Source: Own preparation.

In Table 4, we intend to compare the determining factors of corporate debt between the ages of the companies, by cluster. To this end, two groups were considered, one encompassing companies aged less than 25 years and the other with the remaining companies (the value of 25 is justified as it is the average value of the companies' ages). Thus, as we want to compare two age groups, we used Student's *t*-test for independent samples, and it was observed that, in the Operational Excellence Cluster, there were statistically significant differences in the financing, cycle and debt factor ($t = -1.975$, $p < 0.05$), with companies under 25 years old being those that attribute greater importance to this factor. In the Strategic Financial Cluster, there were statistically significant differences in the secondary forms of bank financing factor ($t = -2.117$, $p < 0.05$), with companies under 25 years old being those that attribute greater importance to this factor.

In Table 5, we intend to compare the determining factors of corporate debt between certified and non-certified companies, by cluster. Student's *t*-test for independent samples was applied, as the aim was to compare two groups of companies (certified and non-certified). The company's operational development factor is the only one that presents statistically significant differences in the three clusters under analysis, with certified companies being those that attribute greater importance to this factor.

Table 4. Comparative analysis of the determining factors in corporate indebtedness between companies under 25 years old and 25 years old or more by cluster.

Clusters	Factors	Company Age						*t*-Test
		Under 25 Years Old			25 Years or Older			
		n	M	SD	n	M	SD	
Cluster Financial Resilient	NBR	571	3.88	0.58	375	3.87	0.54	−0.272
	FLCI	571	3.29	0.64	375	3.26	0.68	−0.638
	COP	571	4.09	0.49	375	4.09	0.48	0.092
	GUBF	571	2.52	0.98	375	2.51	1.03	−0.154
	FRA	571	2.24	0.83	375	2.27	0.79	0.576
	SFBF	571	1.87	0.74	375	1.80	0.67	−1.585
Cluster of Excellence Operational	NBR	226	2.88	1.09	162	2.87	1.03	−0.079
	FLCI	226	2.48	0.94	162	2.29	0.96	−1.975 *
	COP	226	3.86	0.71	162	3.90	0.74	0.497
	GUBF	226	1.37	0.47	162	1.30	0.42	−1.602
	FRA	226	1.78	0.77	162	1.82	0.83	0.461
	SFBF	226	1.30	0.46	162	1.26	0.53	−0.805
Cluster Financial Strategic	NBR	387	4.08	0.52	236	4.10	0.48	0.522
	FLCI	387	3.53	0.60	236	3.49	0.64	−0.797
	COP	387	4.10	0.61	236	4.07	0.59	−0.564
	GUBF	387	3.56	0.62	236	3.51	0.72	−0.833
	FRA	387	3.11	0.71	236	3.06	0.71	−0.937
	SFBF	387	2.83	0.93	236	2.67	0.86	−2.117 *

Legend: NBR—negotiating relations with banks; FLCI—financing, life cycle and indebtedness; COP—company's operational performance; GUBF—guarantees used to obtain bank financing; FRA—financing risk analysis; SFBF—secondary forms of bank financing. Note: * $p < 0.05$. Source: Own preparation.

Table 5. Comparative analysis of the determining factors in corporate indebtedness between certified and non-certified companies by cluster.

Clusters	Factors	Has Accounts Certified by an External Entity						*t*-Test
		Yes			No			
		n	*M*	*SD*	*n*	*M*	*SD*	
Cluster Financial Resilient	NBR	606	3.91	0.54	340	3.83	0.59	1.954
	FLCI	606	3.30	0.63	340	3.25	0.71	0.909
	COP	606	4.14	0.47	340	4.01	0.51	3.982 ***
	GUBF	606	2.50	1.01	340	2.55	0.99	−0.725
	FRA	606	2.23	0.77	340	2.28	0.89	−0.880
	SFBF	606	1.87	0.71	340	1.79	0.72	1.841
Cluster of Excellence Operational	NBR	227	2.90	1.05	161	2.84	1.08	0.512
	FLCI	227	2.36	0.93	161	2.46	0.97	−1.058
	COP	227	3.96	0.68	161	3.75	0.77	2.840 **
	GUBF	227	1.34	0.45	161	1.35	0.46	−0.212
	FRA	227	1.82	0.78	161	1.77	0.82	0.548
	SFBF	227	1.29	0.52	161	1.28	0.45	0.201
Cluster Financial Strategic	NBR	414	4.09	0.52	209	4.10	0.46	−0.298
	FLCI	414	3.54	0.63	209	3.47	0.57	1.203
	COP	414	4.13	0.60	209	4.01	0.60	2.273 *
	GUBF	414	3.55	0.67	209	3.51	0.64	0.667
	FRA	414	3.10	0.72	209	3.07	0.69	0.541
	SFBF	414	2.74	0.90	209	2.82	0.92	−0.970

Legend: NBR—negotiating relations with banks; FLCI—financing, life cycle and indebtedness; COP—company's operational performance; GUBF—guarantees used to obtain bank financing; FRA—financing risk analysis; SFBF—secondary forms of bank financing. Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$. Source: Own preparation.

From the analysis of Table 6 and applying Student's *t*-test for independent samples, it is observed that, in the financing risk analysis factor, there are statistically significant differences in both the Resilient Financial Cluster ($t = -3.470$, $p < 0.01$) and the Strategic Financial Cluster ($t = -2.288$, $p < 0.05$), with companies with less than 50 employees being those that attach greater importance to this factor. In the Resilient Financial Cluster, there are also statistically significant differences in the business relationship with banks factor ($t = 2.325$, $p < 0.05$), with companies with 50 or more employees being those that attribute greater importance to this factor. In the Strategic Financial Cluster, there were statistically significant differences in the guarantees used to obtain bank financing factor ($t = 2.095$, $p < 0.05$), with companies with 50 or more employees attaching greater importance to this factor. It appears that small companies are more focused on resilience and larger companies are more focused on strategic planning.

Table 6. Comparative analysis of the determining factors in corporate indebtedness between companies with less than 50 employees and companies with 50 or more by cluster.

Clusters	Factors	Number of Workers						*t*-Test
		Less Than 50 Workers			50 or More Workers			
		n	*M*	*SD*	*n*	*M*	*SD*	
Cluster Financial Resilient	NBR	788	3.86	0.57	158	3.97	0.51	2.325 *
	FLCI	788	3.29	0.67	158	3.24	0.57	−0.957
	COP	788	4.08	0.49	158	4.15	0.47	1.600
	GUBF	788	2.52	0.99	158	2.52	1.04	−0.053
	FRA	788	2.28	0.85	158	2.08	0.62	−3.470 **
	SFBF	788	1.84	0.72	158	1.88	0.67	0.661
Cluster of Excellence Operational	NBR	326	2.84	1.08	62	3.05	0.93	1.540
	FLCI	326	2.41	0.96	62	2.32	0.91	−0.694
	COP	326	3.86	0.74	62	3.95	0.61	0.814
	GUBF	326	1.35	0.47	62	1.30	0.36	−0.823
	FRA	326	1.82	0.83	62	1.67	0.56	−1.790
	SFBF	326	1.29	0.51	62	1.24	0.36	−0.979
Cluster Financial Strategic	NBR	510	4.09	0.52	113	4.11	0.45	0.389
	FLCI	510	3.51	0.62	113	3.55	0.58	0.688
	COP	510	4.08	0.62	113	4.11	0.54	0.466
	GUBF	510	3.51	0.66	113	3.65	0.65	2.095 *
	FRA	510	3.12	0.72	113	2.96	0.65	−2.288 *
	SFBF	510	2.78	0.92	113	2.74	0.83	−0.338

Legend: NBR—negotiating relations with banks; FLCI—financing, life cycle and indebtedness; COP—company's operational performance; GUBF—guarantees used to obtain bank financing; FRA—financing risk analysis; SFBF—secondary forms of bank financing. Note: ** $p < 0.01$; * $p < 0.05$. Source: Own preparation.

Table 7 shows that, by applying Student's *t*-test for independent samples, there are statistically significant differences in the company's operating performance factor in both the Resilient Financial Cluster ($t = -2.846$, $p < 0.01$) and the Strategic Financial Cluster ($t = -2.327$, $p < 0.05$), with companies whose life cycle is in the stabilised or declining phases attaching greater importance to this factor. In the Resilient Financial Cluster, there are also statistically significant differences in the business relationship with banks factor ($t = -2.010$, $p < 0.05$), with companies whose life cycle is in the stabilised or declining phases being those that attribute greater importance to this factor. In the Strategic Financial Cluster, there were statistically significant differences in the factor of guarantees used to obtain bank financing ($t = 3.157$, $p < 0.01$), with companies whose life cycle is in the phases of rapid and healthy growth being those that attribute greater importance to this factor. It appears that the importance given to the guarantees required to obtain bank financing is essential for companies undergoing rapid and healthy growth.

Table 7. Comparative analysis of the determining factors in corporate indebtedness between the phases of the company's life cycle by cluster.

Clusters	Factors	Company Life Cycle Phase						*t*-Test
		Fast and Healthy Growth			Stabilised or Declining			
		n	*M*	*SD*	*n*	*M*	*SD*	
Cluster Financial Resilient	NBR	539	3.85	0.55	405	3.92	0.58	−2.010 *
	FLCI	539	3.31	0.67	405	3.25	0.64	1.376
	COP	539	4.05	0.48	405	4.14	0.49	−2.846 **
	GUBF	539	2.52	1.01	405	2.52	0.99	−0.002
	FRA	539	2.28	0.80	405	2.22	0.84	1.079
	SFBF	539	1.84	0.72	405	1.85	0.71	−0.193
Cluster of Excellence Operational	NBR	238	2.85	1.07	150	2.91	1.05	−0.525
	FLCI	238	2.47	0.96	150	2.28	0.92	1.925
	COP	238	3.87	0.70	150	3.89	0.76	−0.268
	GUBF	238	1.36	0.47	150	1.32	0.42	0.806
	FRA	238	1.80	0.83	150	1.80	0.74	−0.020
	SFBF	238	1.30	0.52	150	1.26	0.44	0.858
Cluster Financial Strategic	NBR	363	4.08	0.49	256	4.11	0.53	−0.845
	FLCI	363	3.53	0.63	256	3.50	0.59	0.522
	COP	363	4.04	0.61	256	4.15	0.59	−2.327 *
	GUBF	363	3.61	0.67	256	3.44	0.63	3.157 **
	FRA	363	3.11	0.74	256	3.07	0.66	0.656
	SFBF	363	2.82	0.94	256	2.70	0.86	1.638

Legend: NBR—negotiating relations with banks; FLCI—financing, life cycle and indebtedness; COP—Company's operational performance; GUBF—guarantees used to obtain bank financing; FRA—financing risk analysis; SFBF—secondary forms of bank financing. Source: Own preparation. ** $p < 0.01$; * $p < 0.05$.

In Table 8, after applying Welch's test as an alternative to ANOVA, the assumption of homogeneity of variances was violated, and it can be seen that, in the secondary forms of bank financing factor, there are statistically significant differences both in the Resilient Financial Cluster ($F = 7.357$, $p < 0.001$) and in the Strategic Financial Cluster ($F = 3.380$, $p < 0.05$), with companies operating in the national market attaching greater importance to this factor. The Games–Howell multiple comparison test showed that, in the Resilient Financial Cluster, there are significant differences between companies operating in the local market and those operating in the national market ($p < 0.001$); between those operating in the local market and those that operate in the international market ($p < 0.05$); and between those that operate in the regional market and those that operate in the national market ($p < 0.01$). In the Strategic Financial Cluster, there are significant differences only between companies operating in the regional market and those operating in the national market ($p < 0.05$), with companies operating in the national market being those that attribute greater importance to the factor secondary forms of bank financing.

In the Resilient Financial Cluster, there are also statistically significant differences in the financing risk analysis factor ($F = 5.203$, $p < 0.01$), with companies operating in the local market being those that attribute greater importance to this factor. Using the Games–Howell multiple comparison test, significant differences were verified between companies operating in the local market and those operating in the international market ($p < 0.05$) and between those operating in the regional market and those operating in the international ($p < 0.05$). It was therefore observed that companies operating in the national market give greater importance to secondary forms of bank financing, which is in line with what was mentioned by Tavares et al. (2015).

In Table 9, after applying Student's *t*-test to compare two independent samples (private limited company and public limited company), it was observed that there were no statistically significant differences in the determining factors of corporate debt between companies that have limited liability companies and public limited companies in any of the clusters.

Table 8. Comparative analysis of the determining factors in corporate indebtedness between the markets in which companies operate by cluster.

Clusters	Factors	Markets in Which Companies Operate												Welch's Test
		Local Market			Regional Market			National Market			International Market			
		n	M	SD	n	M	SD	n	M	SD	n	M	SD	
Cluster Financial Resilient	NBR	158	3.83	0.61	208	3.88	0.57	408	3.89	0.55	172	3.91	0.55	0.636
	FLCI	158	3.24	0.75	208	3.29	0.62	408	3.30	0.65	172	3.27	0.61	0.273
	COP	158	4.06	0.53	208	4.07	0.45	408	4.12	0.47	172	4.07	0.52	1.078
	GUBF	158	2.37	0.98	208	2.48	1.01	408	2.54	0.97	172	2.66	1.05	2.396
	FRA	158	2.39	0.89	208	2.37	0.87	408	2.19	0.79	172	2.13	0.71	5.203 **
	SFBF	158	1.67	0.71	208	1.75	0.70	408	1.94	0.70	172	1.88	0.73	7.357 ***
Cluster of Excellence Operational	NBR	82	2.85	1.11	85	2.91	1.08	149	2.88	1.04	72	2.85	1.05	0.063
	FLCI	82	2.41	0.99	85	2.28	0.89	149	2.45	0.98	72	2.43	0.90	0.664
	COP	82	3.98	0.64	85	3.85	0.58	149	3.87	0.75	72	3.82	0.90	0.856
	GUBF	82	1.37	0.42	85	1.28	0.42	149	1.34	0.49	72	1.38	0.45	0.834
	FRA	82	1.77	0.80	85	1.88	0.80	149	1.82	0.83	72	1.69	0.70	0.926
	SFBF	82	1.25	0.43	85	1.34	0.59	149	1.30	0.49	72	1.21	0.41	1.212
Cluster Financial Strategic	NBR	106	4.11	0.55	108	4.09	0.52	313	4.10	0.49	96	4.05	0.47	0.268
	FLCI	106	3.43	0.60	108	3.45	0.55	313	3.55	0.63	96	3.56	0.64	1.586
	COP	106	4.04	0.65	108	4.07	0.59	313	4.10	0.60	96	4.10	0.57	0.310
	GUBF	106	3.58	0.66	108	3.46	0.59	313	3.54	0.69	96	3.56	0.61	0.861
	FRA	106	3.19	0.72	108	3.09	0.73	313	3.10	0.69	96	2.97	0.71	1.527
	SFBF	106	2.67	0.86	108	2.60	0.85	313	2.88	0.94	96	2.72	0.88	3.380 *

Legend: NBR—negotiating relations with banks; FLCI—financing, life cycle and indebtedness; COP—company's operational performance; GUBF—guarantees used to obtain bank financing; FRA—financing risk analysis; SFBF—secondary forms of bank financing. Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Source: Own preparation.

Table 9. Comparative analysis of the determining factors in corporate indebtedness between types of society by cluster.

Clusters	Factors	Type of Company						*t*-Test
		Limited Liability Company			Anonymous Society			
		n	M	*SD*	*n*	*M*	*SD*	
Cluster Financial Resilient	NBR	763	3.87	0.58	181	3.93	0.49	−1.592
	FLCI	763	3.27	0.67	181	3.35	0.58	−1.594
	COP	763	4.09	0.49	181	4.11	0.47	−0.579
	GUBF	763	2.51	0.98	181	2.56	1.08	−0.559
	FRA	763	2.26	0.84	181	2.20	0.69	1.057
	SFBF	763	1.85	0.73	181	1.82	0.66	0.441
Cluster of Excellence Operational	NBR	322	2.84	1.09	64	3.07	0.92	−1.730
	FLCI	322	2.38	0.97	64	2.51	0.85	−1.085
	COP	322	3.85	0.73	64	3.99	0.71	−1.345
	GUBF	322	1.35	0.46	64	1.31	0.40	0.721
	FRA	322	1.82	0.84	64	1.71	0.50	1.483
	SFBF	322	1.30	0.51	64	1.23	0.36	1.329
Cluster Financial Strategic	NBR	518	4.08	0.51	104	4.15	0.46	−1.214
	FLCI	518	3.51	0.60	104	3.55	0.64	−0.605
	COP	518	4.09	0.58	104	4.05	0.70	0.687
	GUBF	518	3.52	0.64	104	3.61	0.75	−1.168
	FRA	518	3.11	0.71	104	3.01	0.72	1.360
	SFBF	518	2.76	0.91	104	2.78	0.89	−0.163

Legend: NBR—negotiating relations with banks; FLCI—financing, life cycle and indebtedness; COP—company's operational performance; GUBF—guarantees used to obtain bank financing; FRA—financing risk analysis; SFBF—secondary forms of bank financing. Source: Own preparation.

5. Conclusions

The main objective of this work was to study the determining factors in corporate indebtedness in Portugal. It also had the secondary objectives of creating clusters of companies' credit behaviour and verifying their differences in relation to company characteristics. Thus, in this study, we can see that the determining factors of corporate indebtedness in Portugal are the negotiating relationship between companies and banks; the intended financing, the company's level of indebtedness and the stage of its life cycle; the company's operating performance; the guarantees used to obtain bank financing; the analysis of financing risk; and secondary forms of bank financing. It was also found that the six determining factors in corporate indebtedness lead to the formation of three clusters of companies. One was called the "Resilient Financial Cluster", which has a strong relationship with banks and an excellent operational performance. The cluster called the "Operational Excellence Cluster" reflects the company's excellent operational performance, and the cluster called the "Strategic Financial Cluster" is characterised by high average levels in four determining factors, namely strong relationships with banks; desired financing, level of indebtedness and stage of the company's life cycle; the company's operational performance; and guarantees used to obtain bank financing.

Through comparative cluster analysis, it is concluded that there are statistically significant differences as follows:

- In the "Strategic Financial Cluster", in secondary forms of bank financing, where non-family companies attach greater importance to this factor when compared to non-family companies;
- In the "Operational Excellence Cluster", companies under 25 years old attach greater importance to the financing, cycle and debt factor;
- The "operational development of the company" factor is the only one that presents statistically significant differences in the three clusters, with certified companies attaching greater importance to this factor;
- In the "financial risk analysis" factor, in the "Resilient Financial Cluster" and in the "Strategic Financial Cluster", companies with less than 50 employees attribute greater importance to this factor;
- In the "operational performance" factor, there are differences in the "Resilient Financial Cluster" and the "Strategic Financial Cluster", with companies that are in the stabilised or declining phase of the life cycle being those that attach greater importance to this factor;
- In the "business relationship with banks" factor, in the "Resilient Financial Cluster", companies whose life cycle is in the stabilised or declining phases attribute greater importance to this factor;
- In the factor "secondary forms of bank financing", there are differences in the "Resilient Financial Cluster" and the "Strategic Financial Cluster", with companies operating in the national market being those that attach greater importance to this factor;
- In the "financing risk analysis" factor, the "Resilient Financial Cluster" presents differences, with companies operating in the local market being those that attach greater importance to this factor.

Practical Implications for Companies

A practical implication of this study is that understanding the determinants of corporate indebtedness is crucial for companies to grasp the factors influencing their debt and cost of capital, enabling them to gather the necessary information to gain advantages. This study provides data on this research field for market segmentation and financing strategies, through the formation of three distinct clusters. This study points to the need to segment the market and adapt financing strategies according to the specific characteristics of each cluster. Thus, different business groups should have differentiated approaches. A detailed and personalised analysis is required, depending on the cluster to which companies belong. The operational development factor of a company emerges as a key consideration in all

clusters, with certified companies assigning greater importance to this aspect. Additionally, the relationship with banks is a crucial element, especially for companies in specific stages of their life cycle. Therefore, strategies aimed at improving operational performance and strengthening bank relations may be prioritised for financial and operational success. For example, family and non-family businesses may have different perspectives on secondary forms of bank financing, while younger companies may prioritise financing and the company's life cycle. These differences should be taken into account when developing financing and risk management strategies. This work also provides information for policymakers to formulate policies supporting access to credit by Portuguese SMEs. In summary, companies in Portugal should adopt strategic and personalised approaches to financing and risk management, taking into account the determinants of corporate indebtedness and the specific characteristics of each market segment identified by clusters.

It is hoped that this work will contribute to a better understanding of the factors determining bank financing by companies, the banking sector, the community in general and the academic world in particular. It is also expected that it can contribute to the implementation of public policies by the state, so as to better be able to create lines that facilitate access to credit for companies and thus promote economic development.

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Board Gender Diversity and Risk Management in Corporate Financing: A Study on Debt Structure and Financial Decision-Making

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Abstract: Purpose: This study examines the role of board gender diversity in shaping corporate financial decisions, particularly in terms of debt structure and risk management. Focusing on the Tehran Stock Exchange, it explores how female representation on boards influences long-term and short-term leverage decisions, focusing on the moderating effect of board compensation. **Design/Methodology:** Utilising a quantitative ex post facto design, the study analyses data from 114 companies listed on the Tehran Stock Exchange between 2017 and 2021. Multivariate regression techniques, including year- and industry-fixed effects, are employed to investigate the relationship between board gender diversity, debt structure, and risk-taking behaviour. **Findings:** The results reveal a significant negative relationship between female board representation and long-term debt, suggesting that companies with more female directors tend to adopt more conservative debt structures, thereby reducing risk. Additionally, the findings demonstrate that board compensation moderates this relationship by curbing managerial risk-taking, further improving financial decision-making. **Originality/Value:** This research provides novel insights into the intersection of board gender diversity and risk management in financial decision-making, particularly in the context of a developing economy like Iran. It also offers practical implications for firms seeking to optimise their debt structures while maintaining sound risk management practices.

Keywords: board gender diversity; debt structure; risk management; corporate financing; Tehran Stock Exchange

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1. Introduction

The role of gender diversity on corporate boards has become a pivotal area of interest as firms strive for balanced financial decision-making and effective risk management strategies. This study builds on this discourse by examining how female representation on corporate boards influences debt structure and risk-taking in financing decisions, particularly in the context of emerging markets such as Iran. While traditional finance theory emphasises the importance of strategic debt management to maintain liquidity and mitigate

agency conflicts, this research investigates whether the presumed risk aversion attributed to female directors contributes to more conservative debt structuring. Through exploring board diversity within Iran's distinct socio-cultural and regulatory environment, this study highlights the potential of gender-diverse boards to foster financial resilience and ethical governance practices in response to market uncertainties.

The impact of gender diversity on corporate decision-making, particularly concerning financial decisions and risk management, has received growing attention in recent years. In today's dynamic business environment, strategically managing debt and risk is crucial to ensuring corporate financial sustainability. This study builds on this growing body of research by examining the influence of board gender diversity on financial risk management, particularly in the context of corporate debt structure in Iran.

Rooted in traditional finance theories, firms must carefully manage various risk factors, such as liquidity and refinancing risks, to achieve optimal financial outcomes. Debt maturity decisions are crucial in managing financial risks by balancing short-term obligations with long-term financial stability. This study investigates whether female directors, perceived as more risk-averse, prefer debt structures that reduce financial risk and mitigate potential agency conflicts between shareholders and managers.

By exploring the moderating role of board compensation, this research aims to provide further insights into how gender diversity and financial incentives influence corporate risk management. Iran's unique socio-cultural and regulatory context presents an opportunity to contribute to the broader literature on gender diversity and risk management in emerging markets. The findings of this study are expected to offer practical implications for corporate governance and risk management frameworks, aligning with the themes of the special issue on financial analysis and risk management.

2. Literature Review

The impact of female directors on corporate decision-making has garnered extensive scholarly attention, particularly in promoting diversity and enhancing governance practices. This study builds upon this foundation by investigating the influence of female board representation on financing decisions and debt structure choices within the unique context of Iran. Unlike Western countries, where corporate governance structures and cultural norms differ significantly, Iran presents a distinctive setting to explore these dynamics. The gender ethics framework suggests that women exhibiting higher moral standards may prefer shorter-maturity debt to align with shareholder interests, thus mitigating debt-related agency problems. Additionally, behavioural perspectives propose that female directors, presumed to exhibit greater risk aversion, may opt for longer-maturity debt to effectively manage liquidity and refinancing risks.

Rooted in traditional finance theories, corporations navigate various factors to determine the optimal debt maturity structure, including liquidity/refinancing risk, mispricing risk, and under/overinvestment problems. This choice is crucial for financial policy and serves as a regulatory mechanism to address manager–shareholder agency conflicts. Long-term debt financing allows managers to shield themselves from constant monitoring, potentially deviating from the optimal debt maturity choice and imposing costs on shareholders.

In recent years, scholars have extensively probed the impact of female directors on corporate decision-making across various domains, including dividend policy, executive compensation, and mergers and acquisitions. Studies have shown that female directors tend to emphasise monitoring and accountability, which can influence decisions related to debt maturity structure. The gender ethics framework posits that women, exhibiting higher moral standards, are more attuned to ethical concerns than men. Applying this framework to debt maturity structure choices suggests that female directors may display

less self-interest, potentially preferring longer-maturity debt to align with shareholder interests and mitigate debt-related agency problems.

Additionally, considering managerial risk aversion, it has been proposed that female directors, presumed to exhibit greater risk aversion, may make safer financial decisions than their male counterparts. Short-term debt is considered costlier for risk-averse executives due to higher liquidity/refinancing risk costs and increased external monitoring through refinancing.

This research seeks to unravel the impact of board gender diversity on companies' financing decisions and debt maturity structure choices, explicitly focusing on Iran's unique socio-cultural and regulatory environment. It questions whether female representation on the board decreases long-term leverage, aligning with the gender ethics framework, or increases it, aligning with the behavioural perspective. Additionally, the study explores the moderating role of board compensation in this relationship.

In contrast to prior studies like Abobakr and Elgiziry (2016) and Harris (2014), which focus on how board characteristics influence corporate financial leverage, our study brings a unique perspective by examining not only the direct effect of board gender diversity on debt structure but also how this relationship is moderated by board compensation. This additional layer of analysis provides novel insights into how compensation structures shape the impact of gender diversity on financial decision-making. This topic has not been extensively covered in prior research. Furthermore, our focus on the Tehran Stock Exchange (TSE) offers valuable context from a developing economy, contributing to the broader literature on how cultural and regulatory environments influence the dynamics of corporate governance, particularly in non-Western contexts. This focus on the Iranian market adds depth to the discussion by examining how women in leadership positions function within a patriarchal society, providing insights distinct from those of the studies mentioned.

Empirical testing was conducted on data from 114 companies listed on the Tehran Stock Exchange (TSE) from 2017 to 2021, utilising multivariate regression with year- and industry-fixed effects. The results align with the gender ethics framework, revealing that female representation on the board reduces long-term leverage. Furthermore, the findings indicate that board compensation strengthens this relationship, underscoring the positive impact of higher board compensation on aligning management and shareholder interests and reducing managerial risk-taking.

This research contributes to the literature by examining the impact of board gender diversity on financing decisions and debt maturity structure choices in Iran, a developing country with distinct cultural and governance practices. Additionally, it pioneers in exploring the moderating role of board compensation, providing valuable insights into the complex dynamics of corporate governance and financial decision-making in a non-Western context.

Gender diversity has received substantial attention in the business literature (Labelle et al. 2015; Richards 2003; Rosser et al. 2024). The literature on board gender diversity and its impact on corporate decision-making has burgeoned in recent years, reflecting a growing recognition of the importance of diversity in governance structures (Duppati et al. 2020; Peng et al. 2023; Said et al. 2022; Ullah et al. 2020). Studies have examined various aspects of corporate behaviour influenced by female board representation, including dividend policy, executive compensation, and mergers and acquisitions.

One area of particular interest is the relationship between board gender diversity and debt maturity structure choices. Li and Zeng (2019) found systematic differences in debt maturity structure choices with the presence of female directors, suggesting that female directors may prefer short-term debt to align managerial and shareholder interests. This finding aligns with the gender ethics framework, which posits that women exhibiting higher

moral standards may be more attuned to ethical concerns and less self-interested in their decision-making than men.

Adams and Ferreira (2009) also highlight the positive role of female directors in monitoring and holding managers accountable, which can influence decisions related to debt financing. The emphasis on monitoring and accountability may lead female directors to prefer shorter-maturity debt, which subjects managers to more frequent external monitoring through refinancing.

From a behavioural perspective, Brockman et al. (2010) suggest that short-term debt may be costlier for risk-averse executives due to higher liquidity/refinancing risk costs. Female directors, presumed to exhibit greater risk aversion, may opt for longer-maturity debt to mitigate these costs and make safer financial decisions.

The literature suggests that female board representation can influence debt maturity structure choices through various mechanisms, including monitoring, accountability, and risk aversion. The empirical evidence supports the notion that board gender diversity is associated with differences in corporate financial decision-making, highlighting the importance of diversity in governance structures for effective risk management and shareholder value creation.

In the study by Datta et al. (2021), the relationship between board gender diversity and financing decisions is also examined. However, the leverage decision in our research is different. In Datta et al. (2021), decisions related to debt maturity were considered. The data were used as follows. Compustat item codes are provided in parentheses: ST3: Percentage of debt maturing in three years or less divided by total debt. ST5: Percentage of debt maturing in five years or less divided by total debt. However, in our research, the basis is on long-term and short-term debt according to the balance sheet. Although Iran has banned interest-based activities according to Islamic laws, the bank interest rates (and market rates) differ for short-term and long-term financing, with higher bank interest rates for short-term facilities. In Datta et al. (2021), the impact of compensation on the relationship between board gender diversity and financing decisions was also addressed. Still, they defined compensation based on Compustat as executive equity-based compensation. The sum of the value of new stock options (using the modified Black–Scholes method) is granted to the firm's CEO and CFO as a percentage of the total compensation paid to them. However, in Iran, it is not possible to use data related to stock-based compensation because they include only a few companies, reducing the sample size, and it is not usually disclosed. We used board compensation disclosed in general financial reports. Therefore, the differences presented in the reporting structure in Iran may affect research findings. Given Iran's economic and political environment, such as the lack of effective governance mechanisms, weak risk management practices, and a weak culture of responsibility, it seems that examining the impact of board gender diversity on long-term debt (specifically in the present study) and the moderating effect of board compensation on this relationship is valuable.

3. Theoretical Framework and Hypotheses

3.1. Debt Structure

This study is situated within the Agency Theory paradigm, a foundational corporate finance framework that examines the relationships and conflicts of interest between principals (shareholders) and agents/management (Daryaei et al. 2022; Zadeh et al. 2022; Pouryousof et al. 2022; Shandiz et al. 2022; Zadeh et al. 2023). Within this context, exploring debt structure choices, financial decisions, and corporate governance, particularly regarding board gender diversity, is inherently linked to addressing agency conflicts. By investigating how the composition of the board, specifically the inclusion of women, influences decision-making processes, managerial risk-taking behaviour, and the alignment of inter-

ests between directors and shareholders, this study seeks to contribute to understanding agency dynamics in corporate settings.

According to traditional finance theory, companies must carefully weigh various factors, such as liquidity/refinancing risk, mispricing risk, and underinvestment/overinvestment problems, to achieve an optimal debt maturity structure. The choice between long- and short-term debt can serve as a robust monitoring mechanism for reducing agency conflicts within organisations. Short-term debt, for example, can effectively lower agency costs by subjecting managers to more frequent external monitoring due to the necessity of refinancing (Rajan and Winton 1995; Stulz 2001). However, separating ownership and control may incentivise managers to deviate from the optimal debt maturity structure to avoid monitoring, often at the expense of the shareholders.

Debt structure, a critical determinant of corporate success and growth, is pivotal in a company's ability to thrive and survive in competitive markets (Mohammadi and Zanjirdar 2020). Abor (2008) underscores the heightened risk of bankruptcy associated with elevated debt levels, highlighting the delicate balance required in managing debt obligations. In addition to shareholder–manager conflicts, a fundamental conflict of interest exists between shareholders and creditors, further complicating the decision-making process surrounding debt maturity structure. This complexity is compounded by agency problems, information asymmetry, firm size, and financial distress, significantly influencing companies' optimal debt structure choices (Huang et al. 2016).

Research findings on the relationship between leverage and debt maturity (leverage structure decisions such as short-term or long-term debt) present diverse perspectives and conclusions. Diamond (1991), for instance, argues that companies with high leverage may prefer long-term debt to mitigate the risk of inefficient liquidation, thereby providing additional time for debt repayment. Conversely, Flannery (1986) posits that higher debt levels enable companies to manage refinance risk effectively by issuing long-term debt securities. However, Shan (2019) presents a contrasting viewpoint, suggesting a negative impact of leverage on debt maturity and proposing that agency costs may be alleviated by reducing leverage or shortening debt maturity periods (Hosni Al-Ghar and Rahimian 2018). The interplay between leverage and debt maturity, influenced by firm value, market conditions, and regulatory environments, remains a nuanced and evolving study area within corporate finance.

The focus of the paper is on debt structure. Our research refers to debt structure as using short-term versus long-term debt. We have used the structure in the balance sheet for long-term debt and the long-term debt ratio (long-term debt to assets) to measure leverage structure decisions. Thus, we do not focus on debt maturity. However, some arguments regarding debt maturity are cited. According to the theoretical and empirical foundations presented in the article, three different arguments about the impact of women on the board of directors on debt structure are provided, including risk aversion view, ethical view, and the view that gender diversity of the board has no relationship with debt structure decisions. If the impact of board gender diversity on long-term leverage is positive, the risk aversion view of women is confirmed. If negative, the ethical view of women is confirmed. The third view (no relationship) is confirmed if there is no significant relationship. The article text was reviewed for clarification, and additional explanations were provided.

This study's theoretical framework draws upon the rich literature within Agency Theory and traditional finance theory to elucidate the complex dynamics of debt structure choices, financial decision-making processes, and corporate governance practices. By examining the impact of board gender diversity on these phenomena, this research aims to contribute valuable insights to academic scholarship and practical policymaking in corporate finance and governance.

3.2. Board Gender Diversity

Gender theory posits that women contribute uniquely to economic success, stemming from their distinct moral development and values. Empirical evidence consistently supports that women often exhibit higher ethical standards, demonstrating greater sensitivity to social relationships and more vital adherence to rules and regulations. Within corporate governance contexts, gender diversity on boards has been recognised as a significant determinant of decision-making processes, particularly in corporate risk-taking behaviours (Barnett et al. 1994; Geiger and O'Connell 1998; Chun 2005; Datta et al. 2021; Levi et al. 2014; Linley et al. 2007; Peterson and Seligman 2003).

Female representation on corporate boards has emerged as a critical factor influencing various dimensions of corporate governance, financial performance, and risk management. Research indicates that the presence of female directors contributes to enhanced corporate governance practices, reduced risk-taking, and improved financial performance outcomes (Catalyst 2017; Chen et al. 2017; Sila et al. 2016). From an Agency Theory perspective, female directors are perceived as effective monitors of managerial behaviour, often demanding greater accountability and exhibiting lower tolerance for opportunistic behaviours (Adams and Ferreira 2009; Sepasi and Abdoli 2015).

The value of gender diversity within corporate boards extends beyond mere representation to encompass a broader range of competencies, perspectives, and decision-making styles. Studies have shown that diverse boards, including those with a significant proportion of female members, are likelier to engage in thorough deliberation, consider a more comprehensive array of viewpoints, and make more informed decisions. This diversity of perspectives is precious in complex and dynamic business environments, where innovative solutions and adaptive strategies are essential for organisational success.

Furthermore, research suggests that gender-diverse boards are better equipped to navigate and mitigate various forms of corporate risk. Women, on average, exhibit greater risk aversion than men, leading to more cautious decision-making processes and a reduced propensity for engaging in high-risk activities (Sun and Zhang 2021). This risk-averse behaviour can serve as a valuable counterbalance to the potentially overconfident and risk-seeking tendencies often associated with male-dominated leadership structures (Adams and Ferreira 2009). As such, the presence of female directors can contribute to a more balanced and prudent approach to risk management within organisations.

Moreover, gender diversity on corporate boards has been linked to improved stakeholder relations and enhanced corporate reputation. Companies with diverse boards are perceived as more inclusive, socially responsible, and attuned to the needs and preferences of various stakeholder groups, including employees, customers, and investors (Terjesen et al. 2016). This positive perception can translate into tangible organisational benefits, including increased brand loyalty, employee morale, and investor confidence.

In addition to its effects on corporate governance and risk management, gender diversity on boards can also have significant implications for organisational innovation and performance. Research suggests that diverse teams, including individuals with diverse gender identities, are more innovative and better able to adapt to changing market conditions (Carter et al. 2017). By bringing together individuals with different backgrounds, experiences, and perspectives, gender-diverse boards can foster a culture of creativity, collaboration, and open-mindedness, thereby driving organisational innovation and competitive advantage.

However, despite the growing recognition of the benefits of gender diversity on corporate boards, women continue to be underrepresented in leadership positions within many organisations. The "glass ceiling" phenomenon, systemic barriers, and unconscious biases often impede women's advancement to senior leadership roles (Hoyt and Murphy 2016).

Addressing these barriers and promoting greater gender diversity within corporate leadership structures requires concerted efforts from organisations, policymakers, and society.

In conclusion, gender diversity on corporate boards plays a crucial role in shaping organisational outcomes, including corporate governance practices, risk management strategies, stakeholder relations, innovation, and performance. By harnessing female directors' unique perspectives, experiences, and decision-making styles, organisations can enhance their effectiveness, resilience, and competitiveness in today's dynamic business environment. Efforts to promote greater gender diversity within corporate leadership structures are a matter of social justice and equality and a strategic imperative for sustainable business success.

3.3. Board Gender Diversity and Debt Structure

Research exploring the intersection of board gender diversity and debt structure offers valuable insights into the complex dynamics of corporate decision-making processes. Evidence suggests that women, on average, exhibit greater moral and ethical sensitivities than their male counterparts. Surveys and studies across various professions, including accounting, auditing, sales, and among students, consistently indicate higher levels of moral development, conservative ethical viewpoints, and greater adherence to ethical standards among women (Bernardi and Arnold 1997; Larkin 2000; O'Donnell and Johnson 2001; Dawson 1997; Pierce and Sweeney 2010; Albaum and Peterson 2006).

The choice of a company's leverage and debt maturity structure is a critical decision that can significantly impact its financial health, performance, and risk profile. According to Agency Theory, managers may be motivated by self-interest and select a debt maturity structure that is not aligned with the best interests of shareholders. Specifically, managers may opt for long-term debt to avoid the frequent external monitoring associated with refinancing short-term debt (Brockman et al. 2010; Datta et al. 2005).

In the context of board gender diversity, the presence of women in executive and boardroom positions introduces a potentially moderating influence on debt structure decisions. Assuming that female executives possess higher moral and ethical sensitivities, they may be more inclined to make decisions that align with shareholders' interests and corporate governance principles. As such, female executives may prefer short-term debt, which offers enhanced transparency, accountability, and alignment with shareholder interests, without fearing market scrutiny or external monitoring.

However, the relationship between board gender diversity and debt structure is multifaceted and influenced by various factors, including organisational culture, industry dynamics, and regulatory frameworks. While the presence of women in leadership roles may contribute to more ethical and transparent decision-making processes, it is essential to recognise that gender diversity alone may not guarantee optimal outcomes. Effective governance mechanisms, robust risk management practices, and a culture of accountability are equally crucial for ensuring sound debt structure decisions and safeguarding shareholder interests.

Moreover, the impact of board gender diversity on debt structure may vary across different contexts and organisational settings. Cultural norms, societal expectations, and institutional factors can shape how gender diversity influences company decision-making processes. For example, in patriarchal societies where traditional gender roles are deeply entrenched, the presence of women in leadership positions may face more severe resistance (resistance of other leadership officials of the organisation) or encounter implicit biases that hinder their influence on strategic decisions, including debt structure choices (Datta et al. 2021).

However, it is essential to note that although the presence of women in strategic roles may improve ethical and transparent decision-making processes, this impact requires the

presence of effective governance mechanisms, robust risk management practices, and a culture of responsibility. In other words, the effect of board gender diversity on leverage decisions may vary across different contexts and organisational settings, including cultural norms, social expectations, and institutional factors. In Iran, we witness weak corporate governance, risk management, and a culture of responsibility. Additionally, cultural norms, such as the patriarchal society of Iran, may prevent women from significantly influencing financial decisions, like leverage decisions, despite their physical presence in strategic decision-making processes. Therefore, this raises the question of whether the presence of women on the board of directors in Iran, based on the existing literature and empirical evidence, can lead to more ethical and transparent financing decisions or whether organisational settings and cultural norms prevent this impact.

Empirical research on the relationship between board gender diversity and debt structure has yielded mixed findings, highlighting the need for further investigation and nuanced analysis. While some studies suggest a positive association between female representation on boards and adopting more conservative debt policies (Datta et al. 2021; Choi et al. 2017; Ho et al. 2015; Larkin 2000), others find no significant relationship or even observe contradictory results (Bajtelsmit and VanDerhei 1997; Hinz et al. 1997; Jianakoplos and Bernasek 1998; Levin et al. 1988; Sundén and Surette 1998). These inconsistencies underscore the complexity of the underlying mechanisms and the importance of considering contextual factors in understanding the impact of gender diversity on corporate decision-making.

Future research could explore the mediating and moderating factors influencing the relationship between board gender diversity and debt structure. Longitudinal studies tracking changes in board composition and debt policies over time could provide valuable insights into the causal mechanisms underlying observed associations. Qualitative research methods, such as interviews and case studies, could offer deeper insights into the decision-making processes and dynamics within boardrooms and executive suites.

In conclusion, the relationship between board gender diversity and debt structure is a complex and multifaceted phenomenon that warrants careful examination and analysis. While the presence of women in leadership positions may contribute to more ethical, transparent, and shareholder-aligned decision-making processes, the impact of gender diversity on debt policies is contingent upon various contextual factors and organisational dynamics. By advancing our understanding of these dynamics, researchers can contribute to developing more effective governance practices and strategies for promoting diversity, equity, and inclusion within corporate boardrooms.

3.4. Hypotheses Development

Exploring the intricate relationship between board gender diversity and debt structure involves synthesising various theoretical perspectives and empirical evidence to formulate hypotheses that capture the nuanced dynamics. This section delineates three main arguments guiding the investigation into the impact of board gender diversity on debt structure choices. Subsequently, it proposes hypotheses grounded in theoretical frameworks and empirical observations.

- First Argument: Ethical Inclinations and Debt Structure

The first argument posits that female executives with higher ethical inclinations and moral standards tend to make decisions that align more closely with shareholder interests, particularly in debt structure choices. Drawing from the gender ethics framework, which suggests that women are more attuned to ethical considerations such as disclosure, integrity, and conflicts of interest (Ho et al. 2015; Larkin 2000), it is hypothesised that firms with female directors will exhibit a preference for shorter-term debt.

Female executives, presumed to be less self-interested than their male counterparts, are expected to opt for shorter-term debt to avoid the scrutiny associated with long-term financing arrangements. This expectation stems from the notion that shorter debt maturity structures impose more immediate accountability and transparency, mitigating potential agency conflicts between management and shareholders (Choi et al. 2017). Consequently, female executives are anticipated to encounter fewer debt-related agency problems, leading to a more optimal alignment of debt maturity structures with shareholder interests.

- Second Argument: Risk Aversion and Debt Maturity Structure

The second argument centres on the risk tolerance of directors, mainly focusing on the risk-averse nature often attributed to female executives. Building upon the premise that risk-averse individuals exhibit a preference for safer financial decisions and tend to avoid exposure to uncertainty (Bajtelsmit and VanDerhei 1997; Hinz et al. 1997; Jianakoplos and Bernasek 1998; Levin et al. 1988; Sundén and Surette 1998), it is hypothesised that female directors will opt for a more conservative approach to debt maturity structure.

Under this perspective, female executives are expected to favour longer-term debt arrangements to mitigate liquidity and refinancing risks associated with short-term financing. Short-term debt instruments, characterised by higher liquidity/refinancing risk costs and increased external monitoring through refinancing, may be perceived as less favourable by risk-averse female directors (Brockman et al. 2010). Therefore, it is posited that female directors will exhibit a propensity towards more extended debt maturity structures, reflecting their risk-averse nature and preference for safer financial strategies.

- Third Argument: Competing Perspectives and Firm Performance

The third argument acknowledges the existence of mixed evidence regarding the impact of board gender diversity on firm performance, introducing competing perspectives that warrant further exploration. While some studies have suggested a positive relationship between board gender diversity and various performance metrics (e.g., Catalyst 2017; Chen et al. 2017; Sila et al. 2016), others have found inconclusive or even negative associations (e.g., Adams and Ferreira 2009).

In light of these conflicting findings, it is imperative to consider the potential moderating effects of factors such as directors' compensation on the relationship between board gender diversity and firm performance (Jane Lenard et al. 2014; Datta et al. 2021; Cumming et al. 2024; Gormley et al. 2023). Directors' compensation is a way to match the interests of management and shareholders and influences managerial risk-taking behaviours (Brockman et al. 2010; Datta et al. 2021). Therefore, it is hypothesised that the relationship between board gender diversity and financial leverage is contingent upon the level of board compensation, with higher compensation levels strengthening the association between gender diversity and leverage decisions.

3.5. Formulated Hypotheses

H1. *Board gender diversity has a significant effect on the long-term leverage of companies.*

The literature suggests that female executives with higher ethical inclinations and lower self-interest are more likely to favour shorter debt maturity structures, aligning better with shareholder interests. Consequently, it is hypothesised that firms with greater board gender diversity will prefer shorter-term debt arrangements, leading to lower long-term leverage ratios compared to those with less diverse boards.

H2. *Board compensation strengthens the relationship between gender diversity and financial leverage.*

Directors' compensation is a mechanism to align management and shareholders' interests and influences managerial risk-taking behaviours. Higher levels of board compen-

sation are expected to reinforce the impact of board gender diversity on financial leverage decisions, with firms offering higher compensation packages exhibiting a stronger association between gender diversity and leverage choices.

The hypotheses in this study are developed to explore the nuanced impacts of board gender diversity on debt structure choices, informed by ethical and risk aversion theories. Female directors are often associated with heightened ethical standards and a preference for conservative financial strategies. This suggests that board gender diversity may reduce reliance on long-term debt. This aligns with the hypothesis that a gender-diverse board structure reduces agency conflicts by enhancing transparency and aligning with shareholder interests. Additionally, by investigating the moderating role of board compensation, this study extends prior research to assess whether compensation structures amplify the risk-averse inclinations of female directors, potentially curbing excessive leverage. These hypotheses contribute to a deeper understanding of how board diversity shapes financial risk management, particularly within developing economies.

4. Research Methodology

4.1. Design

The research methodology adopted for this study is a quantitative ex post facto design chosen to rigorously investigate the formulated hypotheses regarding the relationship between board gender diversity and debt structure choices among companies listed on the Tehran Stock Exchange (TSE). This design facilitates examining causal relationships between variables by analysing data collected after the events of interest have occurred (Nassirzadeh et al. 2023).

Methodological Choices and Exclusion of Certain Industries

This study adopted a quantitative ex post facto design, which allowed the authors to investigate the causal relationships between board gender diversity and debt structure by analysing data after the events of interest have occurred. This approach provided reliable insights into the effects of gender diversity on financial decision-making.

a. Exclusion of Certain Industries: The study explicitly excluded financial institutions, investment companies, banks, insurance firms, leasing companies, and financial intermediaries from its sample. These sectors were left out to maintain data homogeneity because these industries operate under distinct regulatory and financial conditions that could skew the analysis. Financial institutions, for instance, often have different debt structures due to capital adequacy regulations and specific leverage rules that do not apply to non-financial firms. By focusing on operating companies, the study ensured that its findings regarding gender diversity and debt decisions were relevant and comparable across industries without distortions caused by sector-specific factors.
b. Contextual Relevance: The study drew on a sample from the Tehran Stock Exchange (TSE)-listed companies over five years (2017–2021). The selected companies were required to have consistent fiscal years and active trading without significant interruptions, ensuring the analysis reflected the firms' ongoing business activities. By selecting firms that have not undergone prolonged trading halts, the study ensured that the data were not biased by irregular trading patterns that could misrepresent a firm's financial stability.

4.2. Data Collection

Data for this study were primarily sourced from the Rahavard Novin 3.8 software and the audited financial statements released by the TSE. These sources provided comprehen-

sive and reliable information for thoroughly analysing the investigated variables. Audited financial statements ensured the accuracy and credibility of the financial data used in the study (Eghbal et al. 2024; Zadeh et al. 2023).

4.3. Population and Sample

The population under scrutiny encompasses all companies listed on the TSE during the five years from 2017 to 2021. To ensure the sample's representativeness and validity findings, specific criteria were employed for sample selection:

Excluding certain entity types, such as investment companies, financial intermediaries, holdings, banks, insurance firms, and leasing companies, from the sample maintained homogeneity and focus on operating companies relevant to the study's objectives.

Consistency in activity and fiscal year: The selected companies needed to maintain consistent activity and fiscal year throughout the observed period to facilitate accurate comparison and analysis of financial data.

Accessibility of information: Adequate information required for calculating the research variables needed to be accessible for each selected company to ensure the feasibility of data analysis.

Exclusion of instances with prolonged trading halts: Instances of trading halts lasting longer than three months were considered exclusionary to avoid potential data distortions due to irregular trading activity irregularities.

Fiscal year-end alignment: The selected companies' fiscal year-end needed to align with the calendar year-end (20 March) to ensure consistency in reporting periods and facilitate comparability of financial data across companies.

Based on these criteria, a systematic sample comprising 114 companies was derived, totalling 570 firm years of observation. The sample selection process ensured the inclusion of companies that are representative of the population under study while adhering to the specified criteria for sample inclusion.

4.4. Analytical Approach

The analytical approach employed in this study involved Ordinary Least Squares (OLS) regression analysis, incorporating year- and industry-fixed effects. OLS regression is a widely used statistical technique for estimating the relationships between variables in regression models. By including year- and industry-fixed effects in the regression model, the analysis controlled for potential time and industry-specific factors that could influence the variables of interest, thereby enhancing the robustness and reliability of the results.

4.5. Hypotheses Testing

The hypotheses regarding the relationship between board gender diversity and debt structure choices were rigorously tested using the OLS regression analysis. The regression model allowed for examining the hypothesised relationships while controlling for potential confounding variables. Statistical tests, such as *t*-tests and F-tests, were conducted to assess the coefficients' significance and the regression model's overall fit.

4.6. Validity and Reliability

Ensuring the validity and reliability of the study findings was paramount to drawing accurate conclusions and making meaningful interpretations. To enhance internal validity, rigorous data cleaning procedures were implemented to eliminate errors and inconsistencies in the collected data. Additionally, sensitivity analyses were conducted to assess the robustness of the results to different model specifications and assumptions.

The research methodology employed in this study was designed to provide a comprehensive and rigorous analysis of the relationship between board gender diversity and

debt structure choices among companies listed on the Tehran Stock Exchange. By adopting a quantitative ex post facto design, utilising reliable data sources, employing stringent sample selection criteria, and employing advanced statistical techniques, the study aimed to generate valuable insights into the factors influencing debt structure decisions in the context of board gender diversity.

4.7. Model and Variables

Following Datta et al. (2021) and as it is described in Table 1, the following model was used to test the hypotheses:

$$\begin{aligned} Leverage_{it} = \quad & \alpha + \beta_1 Female_{it} + \beta_2 Comp + \beta_3 Comp * Female_{it} + \beta_4 Size_{it} + \beta_5 MTB_{it} \\ & + \beta_6 FixedAssets_{it} + \beta_7 Profitability_{it} + \beta_8 ROA_{it} + \beta_9 AGE_{it} \\ & + \beta_{10} SalesGrowth_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

Table 1. Variables and measurements.

Variable		Label	Measurement
Dependent	Leverage structure	Leverage	Long-term debt divided by the market value of total assets
Independent	Board gender diversity	Female	Equal to 1 if there is at least one female board member and 0 otherwise
	Board compensation	Comp	Equal to 1 if board compensation is greater than the industry average, and 0 otherwise
Control	Firm size	Size	Natural log of total assets
	Market-to-book ratio	MTB	Market-to-book value of total assets
	Fixed asset ratio	Fixed assets	Plant, property, and equipment (PPE) divided by total assets
	Profitability	Profitability	Income reported for the current period
	Return on assets	ROA	Earnings before interest and tax divided by total assets
	Firm age	AGE	Current fiscal year minus first fiscal year

4.8. Findings

The descriptive statistics presented in Table 2 offer valuable insights into the variables under examination. Net financing, represented by debt, demonstrates a mean of 9,028,997, indicating considerable variability in the funding amounts across the sample companies. The maximum observed value of 399,976,695 in 2018 for Iran Khodro Company highlights the substantial financing undertaken by certain firms, while the minimum value of 45,543 in 2016 for Piazar Agro Industrial Company underscores the diversity in financing needs among companies.

Table 2. Descriptive statistics of the variables.

Variable	Mean	Median	SD	Max.	Min.	Skewness	Kurtosis
Leverage	0.5568	0.5501	0.206704	1.27394	0.03143	0.12557038	0.01155
Female	0.0323	0	0.164572	1	0	3.7551189	4.21278
MTB	6.11	3.21	2.89	51.68	0.250	0.9149	1.2670
Fixed Assets	43,335,584	442,779	16,492,437	18,476,568	9737	5.967334	4.77706

Table 2. *Cont.*

Variable	Mean	Median	SD	Max.	Min.	Skewness	Kurtosis
Profitability	2,078,434	257,788	156,487	382,775,011	−155,050,040	−3.165395	4.5467
ROA	0.15	0.12	0.1631	0.83	−0.40	0.5437	0.8525
AGE	25.66	22.00	13.6914	66	6	1.15041	0.32694
Sales Growth	0.47	0.36	0.8552	15.28	−0.91	3.59613	0.67899

Regarding debt structure choice, as measured by leverage, the mean value stands at 0.5568, indicating the average proportion of debt to total assets across the sample companies. The range of Leverage values is considerable, with a maximum of 1.27394 observed for Iran Khodro Company in 2017 and a minimum of 0.03143 for Shahdiran Company in 2019. These variations in leverage reflect differences in companies' debt management strategies and risk preferences.

In terms of board gender diversity, represented by the proportion of female directors (Female), the mean value is 0.0323, indicating limited diversity in board composition across the sample companies. Out of 570 firm years and 114 companies over five years, only 59 instances exhibit gender diversity on the board, reflecting the underrepresentation of women in corporate leadership roles in the context of the Tehran Stock Exchange.

An analysis of skewness and kurtosis coefficients for all variables indicates positive skewness, suggesting that the data distribution is skewed towards higher values, and kurtosis coefficients are within an acceptable range, indicating normal distribution. Notably, the composition of the board of directors exceeds the industry average in 38% of the sample, showing variations in board diversity across companies.

Following a thorough assessment of regression assumptions, multivariate regression analysis incorporating year- and industry-fixed effects was conducted to explore the relationship between board gender diversity, long-term leverage, and the moderating role of board compensation, as presented in Table 3.

Table 3. Summary estimation results.

$$Leverage_{it}=\alpha+\beta_1 Female_{it}+\beta_2 Comp+\beta_3 Comp*Female_{it}+\beta_4 Size_{it}+\beta_5 MTB_{it}+\beta_6 FixedAssets_{it}+\beta_7 Profitability_{it}+\beta_8 ROA_{it}+\beta_9 AGE_{it}+\beta_{10} SalesGrowth_{it}+\varepsilon_{it}$$

Variable	Coefficient	SE	t-Statistic	Sig.	VIF
Constant	−3.53	4.7	−0.75	0.45	-
Female	−1.09	0.49	−2.23	0.02	1.57
Comp	0.056	0.34	3.14	0.035	2.65
Comp*Female	0.089	0.47	4.04	0.018	3.18
Size	0.2	0.089	2.24	0.04	1.156
MTB	0.14	0.078	1.84	0.065	2.03
Fixed Assets	−0.15	0.075	−2.07	0.038	1.78
Profitability	−3.4	0.72	−5.97	0.00	2.5
ROA	−0.63	0.63	−1.00	0.31	1.79
AGE	−0.18	0.64	−0.27	0.78	2.38
Sales Growth	0.15	0.64	0.23	0.82	2.59
R^2	0.38		Adjusted R^2		0.30
F-statistic (*p*-value)	44.76 (0.00)		Durbin–Watson statistic		2.12

The reported F-statistic, with a p-value smaller than 0.05 (p-value < 0.05), signifies the overall model's significance, indicating that the independent variables jointly explain a significant portion of the variance in the dependent variable. The coefficient of determination (R^2) of 0.38 means that the variables included in the regression model explain 38% of the observed variation in long-term leverage.

The regression coefficient for board gender diversity (Female) is estimated at -1.09, with a p-value of 0.0254. This negative coefficient suggests that an increase in board gender diversity is associated with a decrease in long-term leverage, supporting the first hypothesis. The statistically significant p-value indicates that this relationship is unlikely to have occurred by chance alone, providing robust evidence for the negative association between board gender diversity and long-term leverage.

Furthermore, the regression coefficient for the interaction term between board gender diversity and board compensation (Comp*Female) is estimated at 0.089, with a p-value of 0.018. This positive coefficient suggests that board compensation amplifies the impact of board gender diversity on long-term leverage, supporting the second hypothesis. The statistically significant p-value indicates that the moderating effect of board compensation on the relationship between board gender diversity and long-term leverage is unlikely due to random variation, providing strong evidence for the moderating role of board compensation.

Overall, the multivariate regression analysis findings support the hypothesised relationships between board gender diversity, board compensation, and long-term leverage among companies listed on the Tehran Stock Exchange. These findings contribute to a deeper understanding of the factors influencing debt structure decisions in the context of board diversity and compensation practices, with implications for corporate governance and financial management strategies.

4.9. Robustness Tests: Addressing Endogeneity

Endogeneity issues, such as omitted variable bias and reverse causality, must be addressed to improve the credibility of the findings. One approach would be introducing an instrumental variable (IV) analysis to help mitigate these concerns. For example, external factors, such as changes in gender equality policies or legal requirements for female board representation, could serve as valid instruments. These instruments would isolate the exogenous variation in gender diversity, thus addressing concerns of reverse causality between board diversity and leverage. Additionally, the paper should discuss how factors like firm culture or the external regulatory environment may have been omitted from the analysis and how these factors could potentially bias the results.

We used robustness tests to address potential endogeneity issues affecting the relationship between board gender diversity and leverage decisions. We applied Heckman's (1979) model combined with an instrumental variable to address potential selection bias.

In the Heckman model, the base model we tested (in Table 3) deals with endogenous issues related to "self-selection", meaning that female directors may join companies with specific characteristics. We used a conditional logistic regression model to estimate the probability of creating gender diversity as a function of firm-specific characteristics (X variables include size, profitability, growth opportunities, leverage, abnormal returns, fixed asset ratio, and the standard deviation of stock returns over the fiscal year).

Table 4 tests for endogeneity to strengthen the reliability of its conclusions.

$$Female_{it} = \alpha + Y_s + \tau_t + \beta_1 Gender\ Equality_{it} + \theta X_{it} + \varepsilon_{it} \quad (2)$$

The results in Table 4 indicate that the coefficient of gender diversity, without considering the dependent variable used and without fixed effects, is positive and statistically

significant at the 1% level. Therefore, our results support previous findings in favour of the first hypothesis, confirming that gender diversity is an important and influential factor in a company's leverage decisions. Including fixed effects, the coefficient remains positive and statistically significant at the 1% level, further supporting our findings that gender diversity is a crucial characteristic impacting corporate leverage decisions.

Table 4. Instrumental variables regression and Hausman test for endogeneity.

Variable	Coefficient (t-Statistic)
Female	2.37 (0.01)
Size	−0.087 (0.67)
Profitability	0.056 (0.045)
MTB	−0.035 (0.098)
Lev	−0.078 (0.108)
ABN_Earn	−0.091 (0.99)
Fixed-Asset	−0.187 (0.98)
RET_STD	0.87 (0.98)
Adjusted R^2	0.246

The endogeneity of the board gender diversity variable was examined. The gender diversity of the board of directors is an endogenous variable, and the average gender diversity in the industry can be an instrumental (exogenous) variable. Therefore, the endogeneity of this variable was checked using the 2SLS method.

$$〖\text{Female}〗\_it = \alpha + \beta\_1 \ 〖\text{Ind-Female}〗\_it + \sum \text{Controls} + \varepsilon\_it \quad (3)$$

In this model, Ind-Female is the average gender diversity of the industry, and ∑ Controls are the control variables of the model (1).

Fisher's statistic in this estimate is 2.87, and its significance level is 0.003, which indicates the effect of the instrumental variable (gender diversity of the industry) on the independent variable (gender diversity).

In the second stage, the dependent variables (Leverage) are regressed on the predicted values obtained from the gender diversity of the first stage along with the control variables:

$$\begin{aligned} 〖\text{Leverage}〗\_it = \alpha + \beta\_1 \ 〖\text{Female-Predicted}〗\_it + \beta\_2 \text{ Comp} + \\ \beta\_3 \text{ Comp*Female-Predicted}〗\_it + \sum \text{Controls} + \varepsilon\_it \end{aligned} \quad (4)$$

This stage examines the impact of the exogenous component of board gender diversity on debt structure, isolating any potential endogeneity. If the coefficient on the predicted board gender diversity is statistically significant in the second stage, it indicates a causal impact on debt structure.

The coefficient β_1 (Female-Predicted) has an estimation of −0.98, and its significance level and t-statistics are 0.002 and 2.43, respectively, which indicates the significant impact of gender diversity on the debt structure. Also, the β_3 coefficient (Comp*Female-Predicted) is 0.073, and its significance level and t-statistics are 0.034 and 3.48, respectively, which shows that the remuneration of the board of directors highlights the effect of gender diversity on the debt structure.

4.10. Ethical Considerations

The study recognises the need for ethical diligence throughout the research process. Although no explicit participant interaction or sensitive personal data are involved in the study, ethical issues related to data privacy and confidentiality are paramount. The study utilises publicly available audited financial statements and data from the Rahavard Novin software, which compiles financial data for listed companies on the TSE.

Potential ethical issues stem from using secondary data related to corporate governance, such as board compensation details and debt structure decisions, which could reflect corporate strategies. As such, the researchers ensure that no confidential or proprietary information that could harm individual firms or stakeholders is disclosed. Data anonymisation and compliance with the ethical guidelines of financial research, such as respecting the corporate governance laws in Iran and abiding by data protection regulations, are upheld throughout the study.

Additionally, the research navigates the socio-cultural sensitivity surrounding gender roles in Iran, ensuring that the results are interpreted objectively without cultural bias despite the patriarchal context in which the study is situated.

5. Discussion

The role of a company's board of directors is crucial in overseeing executive management and safeguarding shareholder interests. Extensive research has highlighted the value of board diversity, noting that female members bring unique experiences and ethical perspectives. Board diversity can manifest through observable characteristics such as race, gender, and age as well as intangible qualities like education and work experience. Our study supports the notion that female directors exhibit a heightened focus on monitoring activities and tend to prefer short-term debt instruments to align the interests of managers and shareholders. This finding underscores the belief that increased female representation enhances corporate risk management practices. From both social and economic perspectives, it is imperative to advocate for gender equality in management positions, as discriminatory practices can hinder effective human resource utilisation and impede organisational performance.

Our study has revealed a negative association between board gender diversity and long-term leverage, which aligns with the gender ethics framework. Contrary to behavioural perspectives suggesting women's risk aversion influences debt structure decisions, our findings suggest otherwise, consistent with prior research. We found that board compensation strengthens the relationship between board gender diversity and debt structure. This indicates that higher levels of board compensation contribute to better alignment of management and shareholder interests while mitigating managerial risk-taking behaviours. These results align with the literature by Brockman et al. (2010) and Datta et al. (2021), highlighting the importance of board composition and compensation practices in shaping corporate financial decisions.

Agency Theory provides a robust framework for describing the results of this study. Agency Theory elucidates the conflicts of interest between principals (shareholders) and agents (managers). This theory is particularly apt for examining corporate governance issues, such as board composition and its impact on financial decisions.

Agency Theory posits that agents may act in their self-interest, potentially at the expense of principals. Female directors, hypothesised to exhibit higher ethical standards, can mitigate these conflicts by aligning debt structure decisions more closely with shareholder interests.

The study supports the hypothesis that companies with female directors prefer shorter-term debt, reducing long-term leverage. This decision aligns with the principal's interest by enhancing transparency and accountability and mitigating agency conflicts.

Agency Theory also addresses risk-taking behaviours in corporate decision-making. Female directors, being more risk-averse, are expected to favour financial strategies that minimise risk, thereby protecting shareholder value. Female directors' preference for longer-term debt reflects a conservative approach to debt management, reducing liquidity and refinancing risks, which aligns with shareholders' desire for stability and lower risk exposure.

Agency Theory highlights the complexity of incentive structures. Directors' compensation plays a crucial role in aligning the interests of managers and shareholders, influencing risk-taking behaviours and financial decisions. The study reveals that directors' compensation moderates the impact of board gender diversity on financial leverage. Higher compensation levels strengthen the relationship between gender diversity and conservative leverage decisions, indicating that well-compensated female directors are more effective in reducing agency costs.

In summary, Agency Theory comprehensively explains the study's findings. Female directors on corporate boards contribute to more ethical, risk-averse decision-making and enhanced alignment of managerial actions with shareholder interests. The moderation effect of directors' compensation further underscores the importance of incentive structures in mitigating agency conflicts and achieving optimal corporate governance outcomes. This theoretical framework supports the empirical results and offers valuable insights into the dynamics of board composition and financial decision-making in the context of gender diversity. Here are some of the contributions of the current study:

5.1. Novel Insights in Financial Decision-Making and Risk Management

a. Gender Influence on Corporate Financing: This study provides new evidence on how female board representation impacts financial decisions, specifically in debt structure and risk management. The research shows that female directors tend to favour more conservative financial strategies, such as reducing long-term debt. This risk-averse behaviour supports the view that gender diversity can act as a moderating force in corporate risk-taking, promoting stability during periods of financial decision-making. This is particularly valuable in corporate governance frameworks where risk mitigation is critical.

b. Moderating Role of Board Compensation: A key finding of this study is the moderating effect of board compensation on the relationship between gender diversity and debt structure. This insight is novel because it highlights how compensation structures can influence the extent to which female directors' risk-averse behaviours affect financial decisions. It suggests that well-compensated female directors may be better positioned to ensure financial prudence and alignment with shareholder interests.

c. Application to a Developing Economy: The study's focus on Iran adds value to the existing literature by exploring gender diversity in a non-Western context. Iran's distinct socio-cultural and regulatory environment, which includes Islamic finance principles and corporate governance limitations, offers a unique setting to understand how gender diversity influences financial behaviour. The research expands the discussion beyond Western economies, providing insights into how female board rep-

resentation could influence risk management strategies in emerging markets. This is particularly relevant for economies where corporate governance structures might not be as robust as those in more developed countries.

5.2. Contribution to the Broader International Literature

a. Broader Implications for Gender Diversity: By focusing on a developing economy like Iran, the paper offers significant contributions to the global literature on gender diversity and corporate governance. It highlights how cultural and institutional factors affect the role of women in decision-making, offering comparative insights for other developing economies with similar socio-economic characteristics. For example, the patriarchal norms in Iran may limit female directors' influence. Still, the study shows that where they can exert influence, they can significantly impact financial risk management decisions.

This study adds value to the global discussion on gender diversity and corporate governance by illustrating how these factors play out in an Iranian context. The Iranian market, characterised by complex regulatory structures and societal norms regarding gender roles, provides an ideal setting to explore the broader impact of female participation in board decisions. The study extends the conversation beyond the typical Western-centric perspectives, where much of the literature has focused. It highlights how board gender diversity affects financial risk-taking and management, which may differ based on cultural and regulatory environments. The research underscores the necessity of promoting gender diversity in corporate governance to improve decision-making processes, especially in emerging markets. It highlights the potential benefits of including women in key decision-making roles to enhance risk management strategies in corporate finance.

b. Expanding the Scope of Corporate Governance Studies: Most studies on gender diversity have concentrated on developed economies, with Western governance structures at the forefront. This paper contributes to the global discussion by showing that even in countries with weaker governance mechanisms, gender diversity still plays a crucial role in shaping ethical financial decisions. The unique challenges faced by Iranian corporations—such as economic instability and regulatory limitations—allow for a broader understanding of how board gender diversity can drive better risk management outcomes across different economic and cultural landscapes.
c. Contextual Significance: Iran's Islamic finance system, where interest-based transactions are prohibited, creates a unique backdrop for studying financial decision-making. This context further emphasises the need for ethical governance and conservative financial practices—to which female directors can contribute significantly. The findings suggest promoting gender diversity in such contexts could lead to more ethical and transparent financial management. This provides a valuable case study for international governance bodies and policymakers looking to enhance global diversity and risk management practices.

In conclusion, the paper provides new perspectives on how board gender diversity intersects with corporate financial risk management in emerging markets like Iran. Its insights into the role of female directors in promoting conservative debt structures and its focus on the moderating role of compensation systems enrich the global discourse on corporate governance, diversity, and risk management.

6. Conclusions

This study highlights the critical role of board gender diversity in corporate risk management and financial decision-making. The findings indicate that female directors

contribute to more conservative debt structures, reducing overall financial risk, mainly through shorter-term debt instruments. Furthermore, the moderating effect of board compensation strengthens the alignment between management and shareholder interests, enhancing risk mitigation and improving the ethical governance of the firms.

From a practical perspective, the results underscore the importance of promoting gender diversity on corporate boards to optimise financial decision-making and manage risk effectively. Companies prioritising diversity can benefit from improved risk management practices and more sustainable financial structures. Policymakers and regulators may also consider these findings when developing frameworks to encourage gender diversity and robust governance practices in corporate boards, particularly in emerging markets.

6.1. Study Limitations and Their Impact on Generalizability

6.1.1. Geographical and Cultural Context

The study is conducted within Iran's specific socio-cultural and regulatory framework, a developing economy with distinct cultural and institutional norms. These norms, particularly regarding gender roles and corporate governance, differ significantly from those in Western and other global economies. Iran's patriarchal context may impose implicit biases and resistance against female board members, which might not be as pronounced in different regions. Therefore, while the findings offer valuable insights into the influence of board gender diversity on debt structure and risk management, they may not be readily generalisable to countries with different governance standards, regulatory frameworks, and cultural settings.

6.1.2. Exclusion of Specific Industries

The study excludes several vital industries, including financial institutions, banks, insurance firms, and investment companies. Due to regulatory and financial constraints specific to their sectors, these industries tend to have distinct capital structures, leverage practices, and risk management approaches. The exclusion ensures data homogeneity but limits the scope of the findings. Thus, the results might not apply to industries where sector-specific regulations influence leverage and debt decisions. Further studies that include a broader range of industries could provide more comprehensive insights.

6.1.3. Timeframe of the Study

The data collection spans five years (2017–2021), a relatively short period to capture long-term trends in board gender diversity and financial decision-making. While the study does account for fixed-year effects, longer-term studies might reveal different patterns or changes in gender dynamics and risk management over time, especially in crisis periods or periods of economic recovery. Extending the time limit could also mitigate the influence of short-term economic conditions, such as market fluctuations or changes in government policies, which may have influenced the results within the selected period.

6.1.4. Corporate Governance and Board Compensation

The study highlights board compensation as a moderating factor in the relationship between board gender diversity and debt structure. However, the specific governance mechanisms in place in Iran, such as weaker corporate governance structures and lack of transparency, may further limit the applicability of the results to other countries with more robust governance frameworks. In economies with better-developed accountability and transparency standards, the moderating effect of board compensation on financial decision-making might operate differently.

6.1.5. Data Source and Availability

The reliance on the Rahavard Novin software and audited financial reports ensured the study's accuracy. However, these sources may not fully capture the nuanced dynamics of board discussions or the informal influences in boardrooms. Additionally, this reliance on secondary data limits the study's ability to incorporate qualitative insights into how gender diversity shapes financial decision-making.

6.1.6. Recommendations for Future Research

Future research could benefit from expanding the geographical scope to include cross-country comparisons, especially in countries with differing levels of board gender diversity and corporate governance structures. Additionally, longitudinal studies could assess the long-term effects of female board representation on financial decision-making, especially during economic volatility. Researchers could also explore qualitative data, such as interviews or case studies, to better understand the interpersonal dynamics within diverse boards. The study's limitations, such as its focus on companies listed on the Tehran Stock Exchange, suggest that future research should explore the broader application of these findings across different industries and regions. Further exploration of other factors, such as economic instability and regulatory frameworks, could provide deeper insights into the relationship between board composition, risk management, and corporate finance.

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Dividend-Based Labor Remuneration and Tradable Shares in Worker Cooperatives

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Abstract: This paper analyzes the possibility of creating worker cooperatives in which members are paid not through wages but through dividends calculated on the organization's residual income, as stipulated by the economic theory of the labor-managed firm. It is shown how dividends paid to members can be linked to the value of their financial participation in the capital of the cooperative. In the presence of a financial market, cooperative shares would be issued and allocated to both members and non-member outside investors, thus addressing the problem of the under-capitalization of worker cooperatives. It is hypothesized that the strong financial incentives of this type of capital structure, together with involvement in the democratic governance of the cooperative, peer pressure, and other horizontal monitoring mechanisms, would support members' intrinsic motivation to work and help overcome the problem of free-riding in the labor process. Flexible economic and financial structure in the absence of fixed wages would promote job stability, as already observed in existing worker cooperatives.

Keywords: worker cooperative; dividends; wages; cooperative shares; employment relation; free-riding

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> "...reorganization of labor in the form of association to replace the current wage system will, we believe, be the basis of the future economic world." (Giuseppe Mazzini 1861)

1. Introduction

This paper aims to show how a different interpretation of labor remuneration for worker members of worker cooperatives in terms of dividends from net enterprise income rather than wages may allow the development of new financial instruments, or cooperative shares, that can enable this kind of mutualistic organization, at least in principle, to achieve efficient capitalization and competitive effectiveness, as demanded in the seminal contributions of Vanek (1970, 1977), Furubotn and Pejovich (1970), Furubotn (1976), Jensen and Meckling (1979), and Pejovich (1990). This paper is developed as a thought experiment since, to the author's best knowledge, the proposed financial instruments have not yet been introduced in any worker cooperative. Some examples of similar capital structures and financial instruments, however, do exist in other cooperative forms (worker and non-worker). They are introduced in the reminder of the article for explanatory purposes.

The theoretical argument starts from Ward's (1958), Vanek's (1970), and Meade's (1972) neoclassical model of the labor-managed firm (Bonin et al. 1993; Uvalic 2010; Pérotin 2013). In this model, designed to analyze the ownership rights of productive organizations in the former Republic of Yugoslavia, members of worker cooperatives are remunerated through dividends of the enterprise net income (EBIT or Earning Before Taxes, that is

value added net of the cost of capital, depreciation, and amortization), and not through wages, which instead represent the cost of labor in investor-owned, or capitalist, companies. While in capitalist companies the dividend is usually defined as a sum of money paid by a company to its shareholders from net profits, in cooperative enterprises the dividend paid to members is defined as a refund or rebate. As it discusses the possibility of introducing tradable cooperative shares, this paper also uses the concept of dividend in cooperatives (Mikami 2016).

Dividend-based compensation is consistent with worker cooperatives' economic and institutional nature, since worker members are not employees but have membership or control rights over it. On the other hand, it is well known that the historical and institutional evolution of worker cooperatives in market economies, especially in Western countries, led them to pay members as salaried employees, just like in capitalist firms. In most countries, for example, in Italy, members are salaried workers. At the same time, an additional associational relationship is established with the worker cooperative, which confers rights of membership or control over it (Fici 2016). In some cases, such as the Mondragón group in Spain, worker members receive, in addition to wages, rebates as shares in the net earnings at the end of each accounting period. This discrepancy between economic theory and institutional evolution creates a case for new theoretical elaboration to consider the economic and financial implications of distributive models that replace wages with dividend-based compensation.

This paper is organized as follows: Section 2 discusses the economic nature of the employment relationship in capitalist enterprises and shows how dividends can substitute for wages in worker cooperatives. Section 3 proposes a new model of worker cooperatives in which cooperative shares are introduced in the hands of worker members and also (potentially) outside investors and remunerated through value-added distribution (dividends), including the issuance and pricing of shares to members, new entrants, and outside investors. Section 4 addresses some relevant organizational consequences of introducing cooperative shares having to do with labor productivity, free-riding, worker livelihood, and layoffs. Section 5 concludes the paper.

2. Overcoming the Employment Relation

In recent years, some authors, both from the Marxist and radical liberal traditions, have developed a series of microeconomic and organizational theoretical and philosophical arguments that demand the overcoming, in worker cooperatives, of the hierarchical relation between employer and salaried workers or employees (Ellerman 1984, 2005, 2016, 2021; Screpanti 2001). Underlying these arguments is the idea that the labor contract is the instrument through which capitalist enterprises establish the subordination of wage earners to investors through the imposition of a hierarchical relationship. This implies the use of the productive capacities of workers in a relationship of authority (Screpanti 2017), as also affirmed by neo-institutionalist classics (Coase 1937; Simon 1951).

The imposition of hierarchy results from the payment of a wage—the equilibrium price of labor as a factor of production in the labor market—by the employer in exchange for the worker ceding the right to use her/his labor services. The creation of democratic worker-led enterprises based on the "one head or one member, one vote" rule of governance, i.e., the worker cooperative or labor-managed firm (Vanek 1970, 1977), would require overcoming both hierarchy (the employment relation) and the remuneration form inherent in that relation, that is the wage as fixed payment for labor services (see also Ellerman 1984, 2005; Dow 2003; Cheney et al. 2014; Screpanti 2017). To these are added some other observations typical of the radical neoliberal tradition that spread in recent decades, which emphatically evidence the importance of remunerating entrepreneurial work activity based

on the dimension of the enterprise residual and not in terms of a fixed contractual wage (Kiyosaki 2017).

Philosophical arguments have also been proposed as a basis for overcoming the employment relation since the transfer of labor services from the employee to the employer would imply the transfer of subjective responsibility for the decisions made by the worker. This transfer is incompatible with the Western tradition of both natural rights in Locke's (1690) labor theory of property and also the theory of subjective rights as inalienable and non-transferable or duplicable personal rights, analogous to civil and political rights (Ellerman 2005, 2016, 2021). In Locke's (1690) labor theory of property, natural rights require that all the product of labor be appropriated by those who produced it.

In this paper, such economic and philosophical propositions enter as necessary premises into the proposal of financial instruments that deny both the hierarchy between employer and employee and the payment of a fixed salary for labor services. On the other hand, members' control rights in the cooperative enterprise are interpreted as personal rights that cannot be alienated, duplicated, or transferred. The delegation (*concessio*) of decision-making responsibility to elected representatives in a mutualistic and democratic governance structure in cooperatives replaces the transfer (*translatio*) or alienation of responsibility that characterizes capitalist companies (Ellerman 2005, 2016, 2021; Cheney et al. 2014).

2.1. Dividends in Worker Cooperatives as Payment of Labor Contributions and Remuneration of Capital Shares

The thought experiment envisaged in this paper begins by considering the simplest possible form of labor remuneration. It then makes it more complex and realistic as new elements of the functioning of labor markets, financial markets, and organization are added to the initial picture.

The simplest form of remuneration for work is the (self-)payment of residual income to a self-employed or independent worker, such as a professional or artisan. Radical liberal and socialist traditions in political economy, for example, Mazzini (1860) in Italy and Mill (1871) in the UK, interpreted worker cooperatives simply as associative and mutualistic business forms, in which the members are independent or self-employed workers who join together to establish a mutually beneficial, non-hierarchical, and democratic economic venture. The same interpretation formed the legal basis for the creation of the consumer cooperatives of the Rochdale equitable pioneers in England in 1844 and the Mondragón group of workers' cooperatives in the 1950s in the Basque region of Spain (Whyte and Whyte 1991; Morrison 1989; Marcuello 2023). In the Basque context, the military regime of Francisco Franco did not prohibit the formation of worker cooperatives but considered them to be associations of self-employed workers. Still today, in Mondragón, the monthly remuneration of worker-members is not considered a real salary, but an "advance" on residual net income. It is supplemented at the end of the year by rebates on the company's overall economic result (Whyte and Whyte 1991; Morrison 1989). In this tradition, this paper considers worker cooperatives as self-employed associations in which labor compensation is equivalent to a self-employed worker's labor income when calculated as part of the collective net income earned by the cooperative. Taken literally, in the absence of wage labor, this implies that the cost of labor or wage bill in this kind of organization is zero.

In financial terms, on the other hand, the dividend is interpreted as the return on the financial investment in the equity capital of a company. The apparent incompatibility between these two definitions lies in considering dividend-based labor compensation as a share of the net economic residual *in the absence of labor costs* (wages). In the financial definition, on the other hand, dividend refers to a share of net income or profit *after subtracting labor costs*. The two definitions can be reconciled if the dividend in its financial

definition coincides with the remuneration of labor. This can happen when workers control the firm and are paid a share of the net residual. This paper illustrates how dividend-based compensation corresponds to the economic value of members' financial participation in the cooperative's capital. It will be performed in conceptual terms, using simple calculations and discussing real cases of employee financial participation in employee-owned companies and member-owned cooperatives (not necessarily worker cooperatives).

2.2. In the Absence of Capital Markets: The Capital Structure in the Mondragón System and the Slovenian Proposal of European ESOP

When worker cooperatives or worker-owned enterprises are characterized by collective or individual ownership, but workers cannot exchange their membership or financial positions in a market, the value of those positions remains implicit, since the only measurable parts of value added are labor income paid to members and the cost of capital. Paid labor income may correspond to some market value of workers' financial participation, but this is indeterminate in the absence of supply and demand for financial positions. In fact, some well-known worker financial participation schemes and capital structures of worker cooperatives, such as the Mondragón group in Spain or the generality of worker cooperatives in Italy, do not take into account the market valuation of cooperatives' assets, and do not link it to the position of individual members, preferring instead to use other accounting measures, such as book value or net asset value (NAV). In these cases, members' financial positions are valued and repaid at their nominal value (plus interest), as in Mondragon's system of internal capital accounts (Ellerman 1986). This solution has the advantage of referring to true accounting records such as the balance sheet, economic statement, and cash flow statement that do not suffer from high valuation volatility in financial markets. However, it may not provide a realistic representation of the real value of these assets in terms of expected earnings.

In systems similar to Mondragon's, members accumulate their rebates annually in internal capital accounts proportional to the dimension of realized profits (Whyte and Whyte 1991; Morrison 1989). Rebates are automatically capitalized to increase the net worth of the enterprise and to finance investment projects (Tortia 2007). As a general rule, capitalized rebates cannot be cashed out by members before the termination of the membership status, i.e., before voluntary resignation, dismissal, or retirement (Ellerman 1986).

As a different example, it is possible to consider ESOPs (Employee Stock Ownership Plans; Kelso and Adler 1958). While ESOPs have been common in the United States since the pension fund reform of 1974 (ERISA, Employee Retirement Income Security Act, which included defined-benefit plans and defined-contribution plans, such as 401(k) plans, 403(b) plans, and profit-sharing plans), ESOP-type financial participation is much rarer in Europe. A recent reform project of the Slovenian government, in cooperation with the Institute for Economic Democracy in Ljubljana, has introduced an ESOP-like financial participation scheme that mixes the Mondragón internal capital account system and the U.S. ESOP scheme (Ellerman et al. 2022a, 2022b). This proposal foresees the transformation of capitalist companies into worker cooperatives based on the allocation of company shares to workers and their payment to investor-owners according to the NAV valuation. The workers' shares would be held in a trust fund and would not be attributed to members until the debt issued to purchase the company is repaid (the trust fund would serve as collateral for the purchase). Once the transition process is completed, members' shares would not be exchanged in the market, but their value would increase with realized profits (not expected future profits) in the form of rebates or year-end dividends.

In contrast to the Mondragón system and the U.S. ESOP scheme, in Slovenian ESOPs the distribution of accumulated value in individual accounts can be collected by members before retirement, based on a predetermined schedule or rollover mechanism, which would

depend on the amount of net profits earned by the cooperative, the amount of reinvestment of realized profits needed to finance investment programs, and the speed with which new incoming members are able to replace the amounts of financial interest paid out to incumbent members. This way, members' financial positions could be partially liquidated, usually within a few years (Ellerman et al. 2022a, 2022b). While this mechanism can reduce or eliminate the problem of undercapitalization in some cases, it may not be able to fully account for the future economic performance of the organization and may not provide sufficient guidance for members to invest and innovate because it is based on the accumulation of realized profits, not prospective profit (Tortia 2007, 2021; Galor 2015; Galor and Sofer 2019).

2.3. U.S. ESOPs and the Presence of a Market for Employee Equity Shares

In systems where employee shares can be traded based on supply and demand, such as ESOPs in the United States, there is a market valuation for these securities. In the U.S., employee shares in ESOP companies can be bought back by the company on the market or issued anew and then awarded to workers. ESOP shares are held in a trust, which collectively represents workers at the company's shareholder meetings. Rather than replacing wages, employee shares are an addition to fixed wages in compensation packages in the form of a supplementary private pension plan. ESOP shares are redeemed at the current market price at the time of retirement (partially also at the time of voluntary resignation; Rosen 2023). This form of financial participation has shown important potential in increasing labor productivity and competitiveness ESOP companies. Several empirical studies measure an increase in labor productivity of close to 5 percent or more in the presence of an ESOP plan (Rosen and Quarrey 1987; Kumbhakar and Dunbar 1993; Blasi et al. 2013; O'Boyle et al. 2016; Kruse 2022) and also high firm longevity and job stability in ESOP firms compared to non-ESOP firms (Blair et al. 2000). In the United States, although in most cases exchanges take place on private markets, a significant number of companies that have adopted an ESOP (about a thousand) are publicly traded. In ESOP plans, holding employees' shares in a trust and limiting or blocking their capacity to sell (in some cases temporarily, in others permanently) eliminates the risk of workers' shares being sold to outside investors. Similar patrimonial solutions (holding employee shares in a trust) are followed by many (not all) U.K. and U.S. employee-owned companies, although these solutions can vary substantially from company to company (e.g., in some cases shares are redeemable, in others not; Erdal 2012). Among the best-known cases of employee-owned companies is the John Lewis Partnership in England, which began the process of converting to employee co-ownership in 1929 and completed the conversion in 1950 (Storey et al. 2014; Salaman and Storey 2016).

As the percentage of total shares held by employees increases, there is less room for the establishment of a real market for the company's shares due to the thinness of these markets, in which the financial and strategic decisions of employees prevail over outside investors. When the percentage of shares held by workers is high enough to control the company, market share prices may be an imperfect and distorted signal of company's value (Ang 1992). For this reason, the share price of ESOPs is usually defined by specialized professionals using various valuation methods, such as capitalization by discounted cash flows, EBITDA multiples, and the NAV (net asset value).

2.4. Example of Cooperative Enterprises Exchanging Shares on the Market

To the author's knowledge, examples of cooperatives selling tradable shares to outside investors are rare and none are found among worker cooperatives. However, a few recorded examples of the issuance of shares or share-like securities are found among other types of

cooperatives, particularly financial, consumer, and producer cooperatives and also in some large worker cooperatives. At the theoretical level, Mikami (2016) discusses introducing transferable shares in the main types of cooperatives, workers, producers, and consumers, proposing specific changes to corporate law that would allow cooperatives to exchange shares in a manner similar to investor-owned companies. Under this approach, the market for cooperative shares is limited to members. Ridley-Duff (2009), on the other hand, explores the trade-off between collective reserves and individual ownership in worker cooperatives and discusses the possible impact of individual ownership, without delving into the issue of shares marketability (Cfr. also Tortia 2007, 2021).

Other theoretical contributions deal with ownership and capital structure in specific cooperative types, especially agricultural producer cooperatives, a very common phenomenon in both developed and developing countries. Chaddad and Cook (2004) discuss the so-called "New Generation Cooperatives" (NGCs) and propose the introduction of tradable shares. The authors outline a continuum from traditional cooperatives that capitalize their self-financing (positive residuals) through collective reserves and members' non-tradable shares to classic capitalist corporations owned by investors, which trade most of their shares on the market. NGCs are characterized by transferability of residual rights, providing liquidity and capital appreciation through secondary market valuation. Ownership rights are limited to patron members, membership is closed, and members are required to make initial investments in delivery rights in proportion to patronage. With the same contribution, the model of "Investor-Share Cooperatives" can acquire third-party equity capital without converting to an IOF. It usually issues separate classes of shares in addition to traditional member ownership rights. Investor shares can bundle different ownership rights in terms of return, risk bearing, control, redeemability, and transferability and include preferred shares, non-voting common shares, and participation certificates. In the remainder of the paper, a proposal similar to that for investor-share cooperatives will be made in the case of worker cooperatives, contemplating the same type of shares for both worker members with control rights and non-member investors.

Regarding empirical contributions, Fulton and Larson (2009) discuss the introduction of marketable shares in the Saskatchewan Wheat Pool (SWP), a Canadian grain marketing and input supply cooperative, in 1996. This capital restructuring led to financial difficulties in the early 2000s and complete demutualization in 2007. The SWP converted its members' capital into non-voting common shares, which were first offered to members and then traded on the Toronto Stock Exchange. Ordinary shares held by outside investors had no voting rights, while voting common shares (A Shares) held by cooperative members were not transferable and not appreciable (Chaddad and Cook 2004). The roots of the negative outcome of capital conversion have been identified in agency problems combined with management overconfidence and hubris (Fulton and Larson 2009). It should be noted, however, that in the SWP, members' A shares were not transferable and were not appreciable. In other words, the A-shares had no market valuation that took into account expected future earnings, and could not be sold to outside investors, giving members little incentive to monitor managers (reducing agency costs) and implement industrial strategies effectively.

Among worker cooperatives, Eroski is a large multi-stakeholder cooperative in which both employees and customers are members. It is part of the Mondragón group of worker cooperatives and the largest Spanish-owned retail chain in Spain. In 2009, Eroski had 48,000 employees, 2367 stores in Spain and abroad, 661,000 members, and sales of nearly EUR 8500 million. To increase its capitalization, between 2002 and 2007 it issued 660 million euros in perpetual non-redeemable bonds, which paid a fixed dividend. These bonds were listed on the Spanish stock exchange. The price of perpetual bonds can fluctuate widely,

similar to the price of stocks, due to the strong influence of long-term earnings expectations. After the 2009 economic crisis, the price of Eroski perpetual bonds fell significantly, losing more than 50 percent of their par value. The economic and financial crisis forced Eroski to restructure, and the perpetual bonds were repurchased in 2014 with a total loss to investors of 30 percent of their face value, ending this financial experiment, which, however, allowed Eorski to survive a difficult decade (EFE: Agro 2014; Medina-Albaladejo 2017).

Finally, Volksbanks are credit institutions established in the form of joint-stock cooperative societies, following the tradition started by Franz Hermann Schulze-Delitzsch in Germany in 1850. *Banca Popolare di Milano* (BPM), one of Italy's largest Volksbanks, was listed on the Italian stock exchange in May 1994 and continued to be a cooperative bank issuing marketable shares until 2016. Being a cooperative bank, only members, who owned varying amounts of shares in the bank, had voting rights under the "one member, one vote" mutualistic rule. Following the financial difficulties caused by the 2011 Italian sovereign debt crisis, in 2015 the Italian government passed a law reforming popular banks (d.l. 3/15). The largest *banche popolari* (with a net worth of more than EUR 8 billion) had to demutualize and convert to investor ownership. In March 2016, BPM merged with Banco Popolare to form Banco BPM, an investor-owned commercial bank (Romani 2005).

3. A New Proposal for Cooperative Shares in Worker Cooperatives

A new proposal regarding the possibility and implementation of new forms of share ownership for worker members of worker cooperatives starts, at the theoretical level, from the agency relationship between employer and employee in capitalist companies. The agency model proposed by Jensen and Meckling in 1976 stipulates that the relationship between shareholder owners and managers is characterized by conflicting interests. By extension, the existence of conflicting interests can also be easily demonstrated in the employer/employee relationship in capitalist companies because of the inverse relationship between wages, which are a cost, and the net earnings of the firm. As wages increase, profits decrease, and vice versa (cfr. Sraffa 1960). The contractual relationship between employer and employee requires the latter to agree to perform the production operations specified in the contract in exchange for a fixed wage. The employee will then choose his or her optimal level of effort based on the labor income (wage) received and the structure of economic incentives and penalties for noncompliance with the contract (Prendergast 1999; Handy 2022; Angus 2023). In the presence of information asymmetries, the employer/employee agency relationship gives rise to agency costs, i.e., costs of controlling and incentivizing employees' work effort. These costs can be reduced by introducing appropriate monetary incentives and control mechanisms, but never eliminated, resulting in a second-best solution that deviates from the socially optimal solution (Prendergast 1999; Tortia 2022). This contract structure is characterized by wage rigidity, which is a dominant and stable feature of all capitalist market economies and can exacerbate business cycle fluctuations at the macro level (Keynes 1936; Weitzman 1986; Screpanti 2001; Albanese et al. 2019).

This paper applies the same tools and arguments that the agency literature has been applying to the conflict of interest and agency costs in the capitalist corporation (both between managers and shareholders and between employers and employees; Prendergast 1999) to address the serious negative impact that agency costs can have on the efficiency of the relation between worker members as investor-owners and external, non-member investors in worker cooperatives. The objective is to align, economically and financially, the objectives of worker members with those of non-member investors.

In a dividend-based labor remuneration scheme, members' remuneration can be equated to that of the shares held by non-member investors. When the remuneration of the shares owned by the two categories is exactly the same, the contrast of interests

between worker members and investors can be limited or eliminated, since both will have the dividends they receive and the value of the shares they own as their dominant objective. The possibility of this type of alignment had already been pointed out in the best-known work of Jensen and Meckling (1976), in which the authors hypothesized that competing interests between shareholder owners and managers or directors can be reduced by introducing appropriate financial incentives—e.g., shares and/or stock options—for top executives (cf. Berle and Means 1932, on the separation of ownership and control in capitalist corporations), as these instruments can encourage managers' focus on performance, productivity, and profitability rather than on their own income and leisure (Jensen and Meckling 1976; Jensen and Smith 1985; Hill and Snell 2017).

3.1. The Introduction of Worker Shareholding

In purely economic terms, consistent with Meade's (1972, 1986, 1989) work on the capital/labor partnership, labor services are a flow, while human capital is a stock that grows with work experience, training, and investment in education, while it depreciates with age (Schultz 1961; Becker 1993). Similarly, financial capital is a stock that is remunerated by a stream of dividends or net income paid-out (Lintner 1962; Farsio et al. 2004; Skinner and Soltes 2009). Members of worker cooperatives invest their human capital and are remunerated in the same way as an investor. In this sense, worker members can be called "internal investors", while investors who only contribute financial capital without using their labor services in the cooperative should be defined as "external investors" or "financial investors".

To align the financial objectives of internal and external investors and eliminate potential conflicts of interest, in the proposal of this paper both categories hold the same financial security, which can be defined "common cooperative stock". However, the right to elect representatives to organizational bodies is considered a personal, inalienable, and non-duplicable right that belongs exclusively to worker members on a per capita basis, rather than according to the number of shares held (Cheney et al. 2014). In addition to conceiving of rights as personal and inalienable, this solution is also functional in avoiding the possible reemergence of conflicting interests between two different stakeholder groups within governing bodies (Ellerman 2005, 2016, 2021).

The difference between the cooperative's common stock held by working members and non-member investors can be likened to Class A and Class B shares in capitalist corporations, which means that the issuance and allotment of Class A shares would be limited to working members, while Class B shares would be issued to and saleable by non-member investors (Class A and Class B common shares in capitalist corporations may be limited to founders and/or managers). For example, specific issues of new shares (either as IPOs for Class B shares or as secondary offerings) may be restricted to Class A or Class B shares. Apart from limited allocations, outside investors would hold the same common shares as working members, featuring the same value and dividends. All classes of shares would have no voting rights, as voting rights would be given according to the "one member, one vote" rule.

In fact, corporate governance scholars and financial analysts increasingly view the issuance of non-voting shares as beneficial or non-harmful even for capitalist corporations, as non-voting shares can make corporate governance more efficient by lowering the cost of capital (reducing agency and transaction costs). They distribute voting power among informed shareholders who value their voting rights, while uninformed and "weakly motivated" shareholders need not vote (Lund 2019). In this paper, the issuance of non-voting common stock sold to outside investors helps increase the capitalization of worker cooperatives, which historically have often been plagued by underinvestment and under-

capitalization, production efficiency, and financial performance, because it forces voting members of the cooperative to implement more transparent and effective financial and production policies, with the goal of increasing the value of all classes of common stock.

Excessive concentration of share ownership in the hands of outside investors could lead to the formation of an unbalanced capital structure, with worker owners owning too small a share of the total, insufficient, for example, to provide adequate collateral to obtain financial support (loans and mortgages) from banking intermediaries (McCain 1977). For this reason, it may be advisable for worker members to hold a minimum percentage of the total share capital. Above this minimum, they may be allowed to sell their shares on the market, thus collecting the market valuation, a transaction that would be equivalent to an insider share sale (Jeng et al. 2003).

As already observed in existing worker cooperatives, members' dividend income is expected to be more volatile than wages. However, since the entire organizational system and financial structure is built around providing a stable livelihood and job security for worker members, these types of cooperatives are expected to make decisions to limit income volatility, in some cases at the cost of increasing share price volatility, and to establish labor income for their members first. Of course, the trade-off between risk and reward in financial markets requires that higher share price volatility is matched by higher dividend payouts, so members in cooperatives will have to strike a reasonable balance between labor income volatility and share price volatility (McCain 1977). On the other hand, it should also be considered that the cost structure in this type of organization is more flexible than that of capitalist enterprises and traditional cooperatives, as members' wage costs are absent, making it easier to stabilize income and jobs.

3.2. Market Valuation of Cooperative Shares

When introducing tradable shares, it is necessary to make explicit the mechanisms through which such securities would be issued and allocated to members, and how it would be possible to calculate their nominal value. This calculation can be, in the first instance, simple and made through an example. Assuming, for simplicity, that each worker member receives the same labor income and owns a single share of the cooperative capital, if the member's dividend in the net income of the cooperative is equal to x (for example, EUR 30 thousand per year) and the average shareholder dividend paid in the financial markets by companies with similar characteristics is equal to some percentage d of the market value of the shares (for example, an average of 10%), the presumed nominal value of the single member's financial stake is x/d (30,000/0.1 = EUR 300,000 in the example). Cooperative shares could be issued on the market at this nominal or par value. Fractional shares could be sold to outside investors at, say, 1/30,000 of their par value, or EUR 10. Obviously, market prices of shares can differ significantly from par value because share prices are influenced by a wide array of organizational and macroeconomic circumstances, primarily the expected future profitability of the company.

Although capitalist enterprises and cooperatives may deal with share valuation and marketability problems in partially different ways, the financial nature of these problems can be considered equivalent. The residual income of the cooperative would be allocated to all existing shares held by both members and outside investors following the same proportionality rule, since uncertainty about these quantitative dimensions would imply that outside investors could not be involved. In addition, cooperatives, like capitalist companies, can issue shares to outside investors at a premium or discount (Koller et al. 2020).

In the initial phase of issuing cooperative shares, before shares are traded on the market (private or public), specialized professionals and consulting companies such as the Baxi Partnership in Scotland (Erdal 2012) can calculate the nominal price, based on the

dimension of the dividends paid to members, the balance (assets, liabilities, and equity), the income and cash flow statements, and the average dimension of dividends paid or retained in similar companies in the same sector.

The price of shares held by both members and non-member investors can move in either direction for several reasons. Increases can occur either because of an increase in expected future profitability, which could cause the exchange price of shares to rise, even in the absence of an increase in income (dividends) paid to members, or because of an increase in income paid to members, when the net realized profits of the cooperative increase. In the latter case, other things being equal (e.g., average dividends in percentage points paid by stocks in the same industry), an increase in dividends paid to members and outside investors implies a proportional increase in the implied share price due to higher profitability. In the above example, an increase in labor income from EUR 30,000 to EUR 40,000 would imply the same proportional increase in dividends paid to outside investors and also a proportional increase in the implied value of shares held by members from EUR 300,000 to EUR 400,000. Since the vast majority of cooperative enterprises issuing shares to non-member investors will not be quoted on a stock exchange, in most cases, exchanges and valuations will take place in private equity markets. Being controlled by worker members, these organizations are expected to set first the value of dividend-based labor incomes to provide for members' livelihood.

Attribution of shares to incoming and quitting members. Shares can be attributed to incoming members for free, at a discount, or at full price depending on the internal policy of the cooperative, the financial constraints undergone by the new member, his/her abilities (human capital), and the financial health of the cooperative (e.g., owned cash liquidity and reserves of retained earnings). When a market price for cooperative shares exists, shares can be attributed (and their number calculated) or sold to incoming members at their market price or at their par value depending on the cooperative's policy (share market price can be higher or lower than par value). Shares can be allocated to new entrants through new issues, market repurchases, and allocation of existing treasury stock. This type of common cooperative shares would be nonredeemable, like all common shares, so as not to put financial pressure on the organization, especially in times of crisis (Tortia 2018, 2021).

Setting the nominal price of the cooperative's shares is very important in the absence of a market price, since, for example, it would signal to incoming members the presumed value of their financial stake in the cooperative. If a new member receives entry income equal to, say, 50 percent of the income received by existing members, he or she will be allocated exactly 50 percent of the number of shares held by existing members, valued at their par price.

Quitting members (resigning or retiring members) would be registered as external shareholders, would receive the same dividends as incumbents, and would be able to sell their shares on the secondary market to other (private and/or institutional) investors or also to the cooperative itself. In this way, incumbent members would have the greatest incentive to increase the competitive potential and market value of the cooperative and recruit new, highly qualified members since they would only sell their shares when they resign or retire based on market assessments of future profitability at exit. The cooperative can increase the amount of dividend income paid out to members at will, but this type of transaction will likewise increase the dividends distributed to outside investors. This may reduce the market value of cooperative shares due to increased dividend outflows.

Attribution of shares to incumbent members and outside investors. Within the organization, shares can be allocated to current members by issuing them from scratch, buybacks, or treasury stock. As is already the practice in capitalist companies, repurchased or new shares can be used as part of an additional compensation package for members or to implement

stock option plans (Song 2002; Bens et al. 2003). The issuance of new shares to members (both new and incumbent) may cause outside investors to sell their holdings because of an increase in the total number of shares outstanding, or dilution, to avoid capital losses. For this reason, the issuance of new shares must be carefully considered and usually occurs when there are significant increases in the firm's productivity and profitability prospects, an eventuality that, when it materializes, can counteract or reverse dilution and share price declines (e.g., when the returns to scale of the technology used by the firm are increasing; Larrain and Urzúa 2013).

Shares issued to outside investors can be sold in private equity markets for unlisted companies but, in principle, can also be publicly traded. Since the market price of shares issued by listed and unlisted companies is very difficult for investors to predict, specialized intermediaries such as venture capitalists, business angels, or crowdfunding can finance new and emerging cooperatives that might also seek to move from private to public status through an IPO (Capizzi and Carluccio 2016; Blackburn et al. 2017; Bonini and Capizzi 2019).

3.3. Disparity in Share Value Due to Voting Right

The proposal in this paper features a productive organization that is a pure workers' cooperative, in which share ownership does not coincide with voting rights also in the case of worker members, not just outside investors. Share ownership, on the other hand, would be a kind of pure financial ownership, linked only qualitatively but not quantitatively to the personal rights of control.

The introduction of different types of shares (e.g., voting and non-voting; common and preferred) for working members and outside investors would imply different pricing mechanisms and lead investors, who are not in control of the organization, to be skeptical about buying shares in the cooperative, fearing that the price of the shares they buy is unduly skewed downward and thus perceiving a negative price difference as a violation of distributive equity. If investors gave up buying shares in the cooperative, underinvestment and undercapitalization would likely result again (Vanek 1970, 1977). Indeed, voting shares held by corporate owners are generally traded at a higher price than non-voting shares held by investors because voting rights confer additional benefits, such as influence over corporate governance and strategic decisions. The need to align the interests and goals of members and investors as closely as possible and to avoid the danger of undervaluing investors' shares confirms the requirement that the shares held by worker members and external investors be exactly the same.

Equalizing the characteristics of members' and investors' shares would force members to be as transparent and effective as possible in both the management of the production organization and their financial policies (e.g., the issuing of new shares, stock option plans, etc.), as non-transparent and ineffective policies would inevitably cause investors not to invest or to sell, lowering the share price for both categories. On the other hand, if members and investors owned different types of shares, there would be no true market for the members' shares, as they could only sell their holdings to other members (Mikami 2016). The absence of a true open market for common shares would cripple and distort financial incentives, eventually damaging production processes as well, as inefficient valuation of shares would result in the inability to pursue optimal investment plans. This is one of the main reasons why the share issue experiment initiated in 1996 by the Saskatchewan Wheat Pool probably proved deficient and failed as early as 2003, causing demutualization in 2007. Outside investors owned a different type of shares than the voting shares held by members, which were non-transferable and non-appreciable (Chaddad and Cook 2004; Fulton and Larson 2009).

Worker members may be required by law to own a minimum percentage of the total net worth (equity) of the organization, to create capital stability and collateral guarantees, and to avoid the danger of violating the law of increasing risk (McCain 1977), which in this case implies that insufficient equity held by members induces the market to demand higher average returns, i.e., a lower market value of the shares. Special emissions of new shares and stock options could be granted only to members, in much the same way that they are granted to particular types of employees (e.g., top executives) in capitalist corporations.

This capital structure leaves open the possibility of issuing other equity and non-equity asset classes. For example, preferred shares and perpetual bonds. As it is well known, preferred shares are part of equity, i.e., they are not redeemable but issued at a par value that is usually not much different from their market value because they pay a (non-mandatory) dividend to shareholders and do not have voting rights. They are more similar to bonds than to actual equity. Perpetual bonds can also be issued, as in the case of Eroski in Spain. Perpetual bonds resemble preferred shares because they have no voting rights, are not redeemable, and pay a fixed yield. However, they are not part of equity because they can be repurchased at any time by the issuing entity, and payment of a dividend is mandatory.

4. Organizational Issues: Labor Productivity, Free-Riding, Workers' Livelihoods, and Dismissal

The introduction of cooperative shares would have important organizational consequences, mainly having to do members' livelihood, including the risk of free-riding in the labor process and layoffs, through its ability to achieve adequate labor productivity. These issues are addressed in turn in this section.

4.1. The Organization of Work, Motivation, and the Problem of Free-Riding

When hierarchy is replaced by horizontal coordination and self-organization, so-called "collective action failures", are likely to be generated, as in the foundational contributions of Commons (1950), Olson (1965), Hardin (1968), and Ostrom (1990). In a mutualistic organizational structure, managerial control and entrepreneurial action can be considered collective (Cook and Plunkett 2006; Bijman and Doorneweert 2010; Lomuscio 2024), while decision-making power is delegated from members to their representatives (Ellerman 2005, 2016).

Severe criticism has been raised against the possibility of achieving adequate productive efficiency through collective self-organization of labor because of collective action failures, especially free-riding. Workers would reduce average work effort in an attempt to opportunistically take advantage of the work effort of other workers, since effort is a cost that the worker wants to minimize, while joint production is a (semi-)public good that can be enjoyed by all workers in the collective enterprise. Indeed, the value added produced and capital in worker cooperatives can be considered commons in that they are rivals, but not excludable (Ostrom 1990; Tortia 2018). In the presence of nonexcludability and rivalry, free-riding leads to sub-optimal production efficiency that negatively deviates from the social optimum for the organization (Alchian and Demsetz 1972; cfr. Bowles and Gintis 1993; Putterman 1988 for a favorable response to democratic firms). In capitalist enterprises, instead, the owner's goal is to maximize the enterprise net profitability or market valuation. The owner, therefore, will put in place those control mechanisms over the labor process that can ensure an optimal (efficient) allocation of work effort, resulting in the second-best solution net of agency costs (Alchian and Demsetz 1972; Jensen and Meckling 1976).

Because free-riding always afflicts collective action and cooperation, it has been in the spotlight of theoretical and empirical research since Alchian and Demsetz (1972) and Jensen and Meckling (1979) and other well-known contributors (see Holmstrom 1982). Advocates of worker cooperatives have defended the possibility of democracy in the workplace,

seeking to explain how free-riding can be overcome or appropriately limited (e.g., Ben-Ner 1988; Ben-Ner and Jones 1995; Putterman 1988; Bowles and Gintis 1993).

Real-world cooperatives have developed control tools and monitoring processes that can control free-riding, ranging from peer pressure to financial incentives to involvement in decision-making processes to sanctions proportional to the severity of the breaches perpetrated by free-riding members (Ostrom 1990; Malleson 2013; Tortia 2022). The introduction of financial incentives, such as a market for member rights, has been shown to effectively combat free-riding, as in plywood worker cooperatives in the U.S. Pacific Northwest (Craig and Pencavel 1992, 1994; Pencavel 2001). The presence of a market for membership rights in these cooperatives implied that members could realize the market value of productivity gains in terms of higher prices for their membership positions, supporting the achievement of high levels of labor productivity (Craig and Pencavel 1992, 1994; Pencavel 2001; Dow 1986, 2003; Tortia 2022).

Some recent empirical results, however, seem to confirm the existence of fairly relevant phenomena of productivity reduction and free-riding concerning members of worker cooperatives in Uruguay (Blanchard et al. 2024). The evidence on wages lower than in capitalist firms also seems to point in the same direction, although free-riding is certainly not the only determinant of negative wage differentials between capitalistic enterprises and cooperatives. Worker member characteristics, such as educational level, and the level of capitalization of the firm, also play a key role (Pencavel et al. 2006; Clemente et al. 2012).

In this study, it is hypothesized that financial participation through member ownership of cooperative shares can exert a direct positive impact on job performance, including helping to combat free-riding in team production, as confirmed by empirical studies on the effects of the ESOPs on labor productivity in the United States (Blasi et al. 2013; Kruse 2022). The proposed ownership and organizational model sees financial incentives as directly linked to members' labor income as a means of workers' livelihood. These incentives are the main tools that can be effective in combating the free-riding problem, as financial losses in terms of cooperative share valuation resulting from members' opportunistic behavior directly affect members' livelihoods. Furthermore, the cooperative would be forced to implement effective control mechanisms, the specifics of which should be delegated to the decisions of individual organizations (e.g., increasing supervisory staff, increasing or reducing smart working, implementing workplace control, etc.).

The backbone of this approach lies in the conjugation of the market valuation of members' financial holdings and the involvement processes that characterize the governance and management of worker cooperatives (Rosen and Quarrey 1987; Winther and Marens 1997; Logue et al. 2001). The feedback mechanism to reduce or eliminate free-riding would occur through involvement in cooperative governance and collective recognition that behavioral outcomes in the production process are directly reflected in the value of financial holdings, mediated by collective productivity. This feedback mechanism has a strong cognitive and motivational dimension that depends on collective impacts within a unifying organizational framework, which can be termed "proactive collective rationality." In turn, maintaining or strengthening workers' intrinsic motivation to work will likely foster organizational resilience and reduce the need for supervision.

The role of collective rationality. Collective rationality refers to the rational ways of solving collective action problems and the framing effects induced by coordination mechanisms in governance. Framing is understood as a cognitive process in which individuals identify relevant organizational dimensions that support their decision-making by linking motivations (goals) and expected behavioral outcomes. Bacharach (2006) introduces the concept of "we frame", as a collective process that supports the pursuit of common goals. For Schoemaker and Russo (2016), rationality as a collective phenomenon requires fram-

ing, that is, anchoring decision-making to simple cues in the organizational environment. Framing is also crucial in the production of shared knowledge in terms of shared conceptualization that facilitates sensemaking, understanding, and collective action (Hecker 2012). Socialization processes within organizations enable concerted practices and a partial overcoming of bounded rationality, as individuals can see themselves as part of a common venture in which they can coordinate cognitively and express common productive motivations (Shulman and Carey 1984; Lindenberg and Foss 2011). In the evolutionary literature, the collective side of rationality dynamically emerges and crystallizes from the development of rules and routines in inter- and intra-organizational interactions through institutionalization or "structuration" (DiMaggio and Powell 1983).

Free-riding, productivity, and intrinsic motivation. The cognitive aspects of organizational processes and financial incentives must be combined with worker motivation, especially intrinsic motivation. Classical studies have shown that control mechanisms, punishment, and extrinsic incentives can crowd out intrinsic motivation to work (Frey 1997; Frey and Jegen 2001). In the approach followed in this paper, financial participation can increase the economic performance of worker cooperatives, but only when combined with member involvement in a nonhierarchical organizational environment and governance, since participation and commitment, which support intrinsic motivation to work, maintain a crucial role in achieving higher productivity and long-term resilience (Tortia et al. 2021).

Herzberg et al. (1959) and Herzberg (1987) introduced the two-factor model to explain workplace motivation and job satisfaction. Hygiene factors, such as salary, supervision, and job security, do not lead to satisfaction but prevent dissatisfaction. Motivating factors refer to intrinsic motivators, such as the job itself and recognition. In worker-managed systems, hygiene factors such as procedural fairness, governance, and cooperative structures are critical. However, intrinsic motivators such as autonomy, decision-making involvement, and transparency in governance often drive worker engagement, as democratic decision-making processes improve procedural fairness, fostering job satisfaction and a sense of inclusion and trust (Tortia 2008; Tortia et al. 2021). Monitoring is necessary for efficiency, but it should be in line with inclusive cooperative governance, as too much monitoring can undermine intrinsic motivation. When applied to democratic governance, Herzberg's (1987) two-factor model shows that worker empowerment and accountability can foster creativity and innovation (Sacchetti 2015). On the other hand, hygiene factors such as clear communication of rules, predictable schedules, and a sense of job security are essential to minimize dissatisfaction and transaction costs. It can be hypothesized that inclusive, noncontrolling governance, characterized by low degrees of monitoring and supervision, may foster or otherwise not harm intrinsic motivation and play a positive mediating role between financial participation and work performance. Instead, the relationship between monitoring and job performance is likely complex and nonlinear. The recent contribution of Mugerman et al. (2024) shows that too little monitoring may lead to detrimental effects on collective productivity due to the prevalence of free-riding, while, in contrast, too tight supervision does not lead to higher productivity but to disengagement and crowding out due to the displacement of intrinsic motivation. In fact, monitoring and supervision appear to be particularly low in worker cooperatives, as shown by Bartlett et al. (1992), who found smaller supervisory staff in Italian industrial cooperatives, as compared to similar capitalistic firms in the same sectors (cf. also Jones and Svejnar 1985).

Recent HRM results from Chinese data show that financial stress (which is an indicator of financial involvement) is positively related to job performance, while work engagement, which results from worker involvement in decision making, mediates the positive relationship between financial stress and job performance. Emotional exhaustion, which can be a negative indicator of intrinsic motivation, negatively moderates the mediation relationship

between financial stress, work engagement, and job performance. In other words, low levels of intrinsic motivation weaken the positive relationship between financial participation and performance through lower engagement (Wei et al. 2024; Miao et al. 2024). The positive impact of financial incentives on productivity and motivation works through cooperative governance to reduce the need for monitoring mechanisms (supervision and sanctions), which would generate additional agency costs, thus improving overall organizational efficiency (Barnard 1938).

4.2. Risks to Worker Livelihoods in Dividend-Based Compensation

In dividend-based compensation, workers' income is directly linked to the residual earnings of the enterprise. If earnings are too low, workers' livelihoods are at risk. This problem is common to worker cooperatives and capitalist enterprises alike, as the former may not be able to pay sufficient incomes, while the latter may be prone to resort to layoffs when going through economic or financial difficulties. In the scheme of the present work, the absence of wage labor implies the absence of labor cost, which would reduce total costs substantially, weakening the constraints that the cooperative must meet to remain economically solvent and viable, compared to other enterprise forms (Weitzman 1986; Meade 1989). Dividends as labor income would certainly be more volatile than wages, but on average they should be higher, although this specific question (whether dividend income is on average higher or lower than wages) will require further analysis and empirical testing. Certainly, dividend-based compensation serves the same economic function as wages in securing livelihoods.

In addition, this type of cooperative is not prevented from establishing reserves, either divisible or indivisible (collective), which can be used to supplement members' incomes in times of crisis. Losses can be absorbed through retained earnings, debt financing, or collective reserves, as in more traditional cooperative forms (for example, all Italian cooperatives, not only worker cooperatives, are required by law to reinvest at least 30% of their net earnings in indivisibles reserves). The introduction of collective reserves can have a significant negative impact on financial incentives and share value of the cooperative. However, indivisible reserves have the advantage of stabilizing capital ownership and creating an insurance fund that ensures job stability during economic crises, something of central importance in worker cooperatives (Navarra 2011, 2016; Tortia 2018, 2021). In addition, this type of organization may not increase paid-out labor income too much, lest it increase the risk of bankruptcy and job loss (Miyazaki and Neary 1983; Craig and Pencavel 1995; Burdín and Dean 2012). Indeed, it has been repeatedly shown that worker cooperatives are more risk-averse than capitalist enterprises in their investment policies, and one of the main reasons lies precisely in the need to avoid job losses for members (Hansmann 1996; Dow 2003; Holmstrom 1982; Ben-Ner and Jones 1995; Bonin et al. 1993; Craig and Pencavel 1995; Pérotin 2013).

In case of economic problems and financial difficulties, the cooperative form studied in this paper would have to pay at least a minimum income to all members to support their livelihood. In many circumstances, there would be no economic rationale for laying off members, even during an economic crisis, since layoffs of members do not reduce the dividends that must be paid to investors (laid-off members would become external investors).

Crises can be absorbed in the short to medium term through the use of debt and reserves, but not in the medium to long term. If the cooperative is no longer economically or financially viable, it must be liquidated or acquired by stronger organizations. During economic crises, skilled workers are likely to leave first because of better outside options in the labor market, although leaving the cooperative implies giving up quasi-rents and

other returns on specific human capital investments made in the past (Williamson 2000). When the crisis becomes very severe and the income guaranteed by the cooperative falls below some critical threshold (the participation constraint in the external labor market), the economic rationale for this type of organization evaporates as well. Finally, when marketable shares perform poorly and the economic conditions of the organization are negative, members may choose to demutualize and return to the capitalist form, or buy back the cooperative's shares at much lower prices to sustain their valuation and restart the capitalization process.

4.3. The Dismissal of Worker Members

While in investor-owned enterprises dismissal for economic reasons is considered a routine and necessary practice due to wage rigidity (the enterprise is forced to dismiss workers with fixed incomes, when worsening profitability may harm its development prospects or engender bankruptcy), several theoretical and empirical contributions have shown that cooperative enterprises, not only worker cooperatives, can be able to significantly reduce dismissals compared to their capitalist counterparts, even during negative economic phases (Weitzman 1986; Meade 1989). The main reason is that cooperatives are created to provide a stable flow of goods and services to their members, in a logic similar to that of clubs, and thus to the production of collective goods (Ben-Ner and van Hoomissen 1991; Pérotin 2013). Since the cooperative will tend to keep the supply of goods and services to members stable even during a crisis, employment in the cooperative will also be stable (Borzaga et al. 2022).

The tendency of worker cooperatives not to lay off workers even during a crisis can also be explained by the provision of employment services to members, as worker cooperatives will continue to provide employment opportunities on better terms than in the open labor market and save jobs even in adverse economic conditions, that is, even when profitability is low or negative (Bartlett et al. 1992; Craig and Pencavel 1992, 1994; Pencavel et al. 2006; Berman and Berman 1989; Burdín and Dean 2009; Delbono and Reggiani 2013). During recessions, members will take a range of actions to minimize the likelihood of job losses, from reducing hourly wages and hours worked to using reserves to offset declines in demand and output (Miyazaki and Neary 1983; Craig and Pencavel 1993; Navarra 2011, 2016; Navarra and Tortia 2014; Albanese et al. 2019; Tortia 2022).

In the cooperative model presented in this paper, the nature and economic relevance of employment termination change substantially. Even if the associative relationship between the member and the cooperative is terminated through voluntary resignation or involuntary layoff, the ex-member becomes an outside investor and remains in possession of his or her financial stake, which continues to receive the corresponding dividends. Termination of membership eliminates membership rights, including any additional benefits, such as receiving additional shares or stock option plans. On the other hand, from the organization's perspective, in terms of existing financial positions, layoffs result in no cost gain, unlike in capitalist enterprises. In other words, fixed wages as an economic rationale for laying off workers would be overcome. Reducing layoffs would also forestall negative macroeconomic implications, such as decreases in aggregate consumption (Pérotin 2013; Tortia 2022).

5. Conclusions

As already hypothesized by Ward in his 1958 foundational model of the labor-managed firm, the present paper hypothesizes the creation of worker cooperatives in which members' earned income is not a fixed contractual wage, as in an employer/employee agency relation-

ship, but a dividend-based remuneration scheme consisting of shares in the organization's net income in the absence of wage costs.

Paying dividends instead of wages would uniquely link the labor income of cooperative members to the par value of their financial participation in the enterprise's capital. In the absence of a capital market, the par value of the cooperative's shares corresponds to the value of the members' financial interest in the enterprise's net worth. If there is a capital market, instead, shares can be sold on a private equity market or even on a public stock exchange. The cooperative's shares could be issued and traded on the same terms of value and remuneration not only for cooperative members but also for non-member outside investors.

A number of existing examples of cooperative capital structures or employee ownership that include the issuance of shares or other share-like securities (e.g., perpetual bonds) were presented and discussed, covering not only worker cooperatives and employee ownership but also other cooperative forms (production, consumer and credit cooperatives). In worker-owned enterprises, for example, members own at least part of the company's capital, although there may or may not be shares and capital markets. The case of Mondragon cooperatives, the ESOP scheme in the United States, and worker cooperatives in the U.S. Pacific Northwest were brought up for discussion, showing the attempts that have been made to date to introduce employee and member financial participation in equity in a structured way. The presence of a market for member rights and ESOPs have been identified as among the most refined examples of tradable worker ownership, along with employee ownership in the John Lewis Partnership tradition.

Finally, it was pointed out that in the worker-owned cooperative model proposed in this paper, dividends as members' labor income and also the value of cooperative shares could have a relatively stable and increasing trend over time, in line with members' livelihood needs and their productivity improvements. They have also been found to be effective in counteracting free-riding and other collective action problems in the entrepreneurial action. On the other hand, cooperative governance has been shown to have the potential to increase productivity and performance by sustaining intrinsic work motivation. Only in the event of economic or financial difficulties in the enterprise would one expect labor income to undergo significant (downward) adjustments, while positive economic performance would lead to a steady increase in members' labor compensation.

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Nonparametric Testing for Information Asymmetry in the Mortgage Servicing Market

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Abstract: Our objective is to test for evidence of information asymmetry in the mortgage servicing market. Does the sale of mortgage servicing rights (MSR) by the initial lender to a second servicing institution unveil any residual asymmetric information? We are the first to analyze the originator's selling choice of MSR. We use a large sample of U.S. mortgages that were securitized through the private-label channel during the period of January 2000 to December 2013 (more than 5 million observations). We propose a new nonparametric instrumental variable testing procedure to account for potential endogeneity. For robustness, we present parametric analyses to corroborate our results using instrumental variables. Our empirical results provide strong support for the presence of second-stage asymmetric information in the mortgage servicing market during the period of analysis and before the risk retention reform of 2014.

Keywords: mortgage servicing market; securitization; information asymmetry test; parametric model; nonparametric model; kernel estimation; instrumental variable; causality

JEL Classification: C14; C23; C26; G14; G21; G33

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1. Introduction

Rapid development of financial markets and advances in structured finance have enabled lenders to overcome the traditional lending scheme by removing mortgages they originate from their balance sheets before the scheduled maturity through securitization. Securitization enables mortgage originators to sell mortgage-related cash flows to third-party investors in the form of liquid interest-bearing securities traded on financial markets (commonly known as Mortgage-Backed Securities, MBSs). The two main advantages of securitization for banks are to improve liquidity and to reduce regulatory capital requirements. The process of securitization involves numerous entities, such as the mortgage servicer (Gorton and Metrick 2012).

Once the securitization process is achieved and the underlying MBSs are sold to investors, the mortgage servicer ensures the ongoing management and upkeep of interest payments. In general, the main task of a mortgage servicer is collecting principal and interest payments from borrowers and passing the proceeds on to the underlying MBS investors in the secondary market. These cash flows are passive claims linked to the pool of mortgages packaged by the Special Purpose Vehicle (SPV) and held by MBS investors. Typically, the mortgage originator can act as the servicer of the deal by guaranteeing the connection of cash-flow streams between borrowers and MBS investors. However, originators are also able to further modify the borrower's default risk by selling the underlying mortgage servicing rights (MSRs) to a third party, hereafter referred to as the MSR purchaser or new servicer. In such cases, the new servicer replaces the originator in ensuring ongoing mortgage management; borrowers become directly linked to the new servicer, to whom they make debt payments.

In case of borrower delinquency, the servicing cost of mortgages increases significantly as the servicer incurs additional costs related to managing these loans, which can significantly reduce the profitability of the servicing activity. For instance, the mortgage servicer is required to deploy additional resources to investigate and collect delinquent payments, to perform loss mitigation activities, or to manage a foreclosure process. Mortgage servicers could incur additional significant costs related to unreimbursed foreclosure costs and real-estate owned losses. For these reasons, servicing inferior-quality mortgages could hinder the performance of mortgage servicing.

The main objective of this study is to test for evidence of information asymmetry in the mortgage servicing market. We are the first to analyze the following main question: Does selling the mortgage servicing rights unveil any residual asymmetric information in the servicing market? In a typical principal-agent relationship, we hypothesize that the mortgage originator (the agent) possesses an informational advantage over the MSR purchaser (the principal) in the market for mortgage servicing rights. This privileged information about both loan risk characteristics and borrower credit quality is collected at the time of the original mortgage underwriting, and the originator could have inducements to adversely exploit this information asymmetry. It is now well documented that soft information is private and not verifiable by the principal (Agarwal and Hauswald 2010; Bubb and Kaufman 2014; Filomeni 2024; Gete and Reher 2021; Passmore and Sparks 2024; Agarwal and Ben-David 2018; Liberti and Petersen 2018). Mortgage originators can transmit quantitative information about loan risk and borrower quality, but it is very difficult or costly for the MSR purchaser to access the soft information that may affect the loan default probability.

Although a large body of theoretical and empirical literature has examined asymmetric information through the securitization process (see Ambrose et al. 2005; Keys et al. 2010, 2012; Agarwal et al. 2012; Krainer and Laderman 2014; Malekan and Dionne 2014; Albertazzi et al. 2015; Elul 2016, among many others), we are the first to investigate this second-stage asymmetric information problem. The above-mentioned studies focus on information asymmetry between lenders and investors at the first stage of securitization. The main research question for most studies that test for asymmetric information through the securitization process is investigating the originators' decision to securitize a given loan. For instance, most studies compare the ex-ante risk characteristics as well as the ex-post default likelihood of mortgages that the originator chooses to securitize versus those kept on its balance sheet. In this study, we focus on mortgages that have already been securitized. We consequently dig deeper into the data as we scrutinize these securitized mortgages to test for second-stage information asymmetry. The previous estimations of asymmetric information in the securitization market may have underestimated the information problem in the securitization market by not taking into account this intermediary or second-stage information problem between the originator and the servicer.

To empirically test for evidence of asymmetric information in the market for mortgage servicing rights, we analyze the originator's selling choice of MSRs using a large sample of U.S. mortgages that were issued and securitized through the non-agency channel during the period of January 2000 to December 2013. In the first step, we contrast the ex-ante risk profile of mortgages for which the originator chooses to sell the underlying servicing rights to a third party with those for which it chooses to hold and service. In the second step, we compare the ex-post default risk of observably similar mortgages. Our econometric methodology is merely nonparametric in the sense that we do not make any restrictive assumptions about either the conditional distribution of the originator's MSR selling decision or the functional form of the relationship between the decision to switch the mortgage servicer and the mortgage default risk. The main advantage of this methodology is that inferences about the distribution are made purely from the data, and the density estimation is thus more data-driven than it would be if the density function were constrained to fall in a given parametric family. Our methodology is inspired by the nonparametric test of asymmetric information proposed by Su and Spindler (2013).

The test is mainly driven by kernel density estimation methods. We are also the first to propose a new nonparametric two-stage instrumental variable testing procedure to account for potential endogeneity. For robustness, we employ the nonparametric testing procedure of Chiappori and Salanié (2000). We also present a battery of parametric analyses to corroborate our results after controlling for observable risk characteristics, econometric misspecification errors, and endogeneity issues using the instrumental variable estimation procedure developed by Dionne et al. (2009, 2015).

Our empirical results provide strong support for the presence of second-stage residual asymmetric information in the mortgage servicing market. After controlling for available hard information, we obtain a significant positive association between the lenders' decision to switch the servicer of the deal and the average probability of mortgage default. For instance, our results show that the higher the likelihood of switching the mortgage servicer, the higher the probability that the borrower defaults.

Our evidence suggests that originating lenders are indeed taking advantage of privileged information about both loan risk characteristics and borrower credit quality, which they obtain at the time of the original underwriting. Since this information is not observable by the second servicing institution, it seems clear that asymmetric information influences the decision of mortgage originators about whether to keep servicing mortgages they originate or to sell the underlying servicing rights to a third party. Two explanations based on contract theory are possible. First, the originator may be retaining superior-quality loans with a low probability of default in its servicing portfolio and, conversely, selling lemons with a high default risk, an outcome related to adverse selection. Alternatively, the transfer of mortgage servicing rights may be reducing the originator's efforts to screen applicants and monitor borrowers, as soon as the underlying servicing rights are planned to be sold to another servicer; an outcome related to moral hazard. Separating the two information problems, as Keys et al. (2012, rule of thumb with GSE loans) and Dionne et al. (2013, with insurance dynamic data) do with parametric modeling, is beyond the scope of this paper.

Our contribution must be considered as an additional motivation for the 2014 change in regulation of the securitization market. The new retention program destinated to increase the skin in the game of the originators should not only reduce the effect of the first stage of asymmetric information between the originator and the investors but also reduce incentives for the originator to transfer the management of bad loans to independent servicers.

The remainder of this paper proceeds as follows. Section 2 introduces the servicing activity and briefly describes the income stream of mortgage servicers. We also present and discuss the main risks that mortgage servicers encounter. We introduce the nonparametric kernel density estimation techniques in Section 3 and present the proposed nonparametric information asymmetry test in Section 4. Section 5 describes the data as well as the variables used in our study. Section 6 reports the main empirical results of the nonparametric testing procedure. For robustness, we also report the results of commonly used parametric tests with instrumental variables. Finally, we extend our nonparametric test to account for potential endogeneity. Section 7 concludes the paper.

2. Overview of the Mortgage Servicing Activity

2.1. Representation of Mortgage Servicing Process

Figure 1 shows the various contracted parties involved in the mortgage servicing process along with the generated cash flows in every step. A typical mortgage lending process starts with a borrower applying for a mortgage in order to buy a property or to refinance an existing mortgage to take advantage of lower interest payments. Usually, the mortgage originator is a commercial bank, a credit union, or a non-depository retail lender. Whatever the case, the mortgage originator manages the complete loan-granting process. Based on its information set, the originating lender expends effort to assess the borrower's reliability and creditworthiness. Eventually, if the borrower meets the lending requirements, the mortgage application is approved, and funds are released as represented by cash flow

1 in Figure 1. The debt payments in the absence of securitization are represented by cash flow **2**.

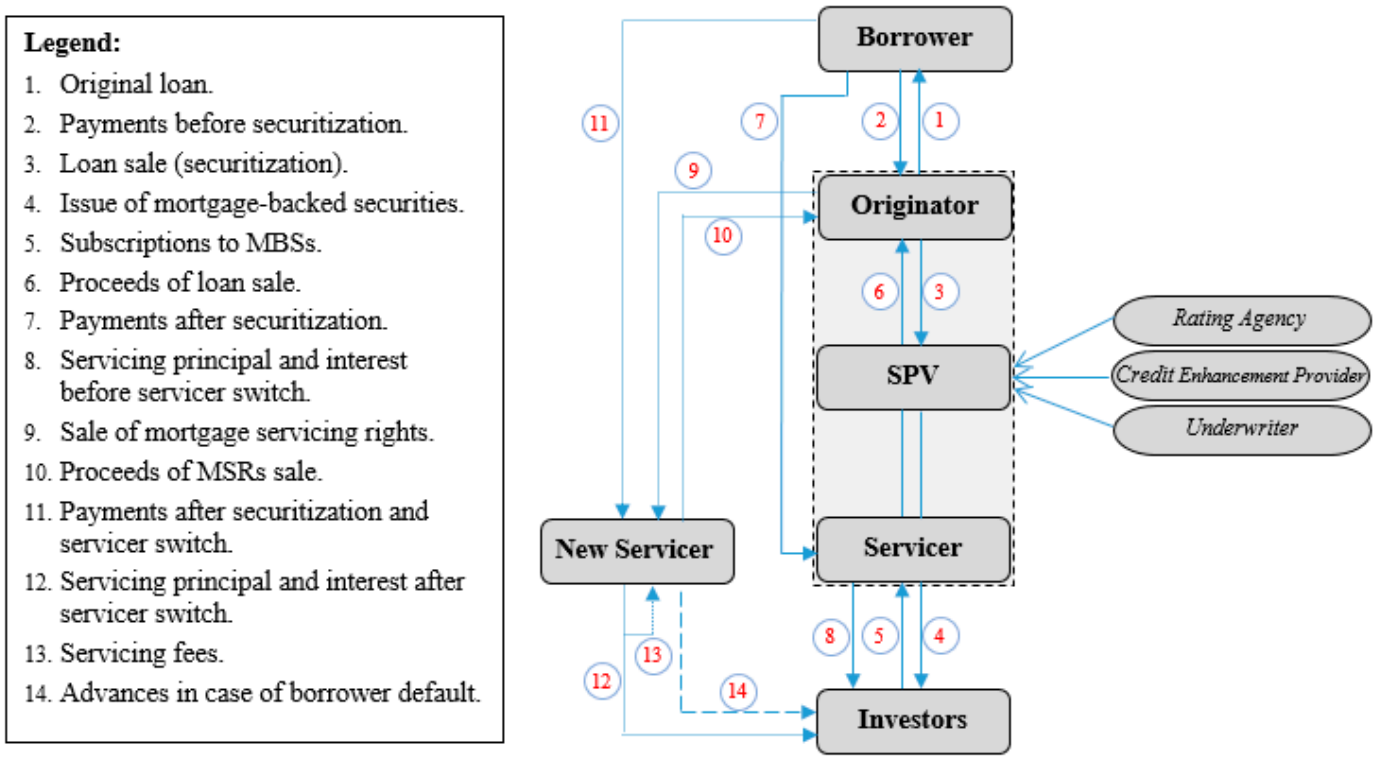

Figure 1. Lending and securitization processes.

This securitization is defined as the process whereby illiquid loans extended to borrowers are converted into liquid securities traded on financial markets. This process is summarized in steps **3** to **6**. In the first step of the securitization process, the originating institution transfers the mortgage to a special purpose vehicle defined as a legally separate entity created to handle the securitization process. The mortgage transfer is marked by cash flow **3**. This process of handling securitization involves external parties such as the underwriter that assists with the sale, the credit enhancement agency, and the credit rating agency that rates the interest-bearing securities. Once the tradable MBS are created and rated, the SPV sells them to investors, as depicted in cash flows **4** to **5**. Finally, the SPV uses the proceeds of the MBSs sale to pay back the entity that originated the underlying debt, as illustrated by cash flow **6**.

Once the securitization process is completed, the mortgage servicer ensures ongoing management and the upkeep of the payments. The main task of a mortgage servicer is collecting principal and interest payments from the borrower (cash flow **7**) and passing the proceeds along to the underlying MBS investors in the secondary market (cash flow **8**). Thus, as the borrower makes interest and principal payments, the servicer of the deal ensures that the cash flows are paid back to investors in accordance with the terms laid out in the securities prospectus. The mortgage originator can act as the servicer of the deal or it can sell the mortgage servicing rights (MSR) to a third party involved in this process, hereafter referred to as the new servicer or the MSR purchaser.

The sale of mortgage servicing rights and the corresponding cash proceeds are indicated by cash flows **9** and **10**, respectively. In this case, the buyer of the mortgage servicing rights replaces the original servicer of the deal and ensures the ongoing mortgage management. Therefore, borrowers become directly linked to the new servicer to whom they continue making monthly debt payments (cash flow **11**) that the former passes along to the MBS investors in the secondary market, as indicated by cash flow **12**. Customarily, in return for these services, the new mortgage servicer is paid a monthly fee generally specified as a

fixed percentage of the declining unpaid balance of the underlying mortgage loan. The new servicer is also entitled to collect other fees such as float income, late payment fees, and other ancillary income. All these income streams are represented by cash flow **13**. Finally, if a delinquent borrower defaults on a loan and stops making monthly payments due to financial distress, the new mortgage servicer is required to advance funds to MBS investors in the secondary market in keeping with the terms and conditions of the loan servicing contract, as indicated by cash flow **14**.

At this point, it is crucial to note that neither the new mortgage servicer nor MBS investors in the secondary market observe all the information that the originating lender possesses. In fact, information detained by the lender could be classified into two main forms: hard and soft (Agarwal and Hauswald 2010; Keys et al. 2010, 2012; Malekan and Dionne 2014; Agarwal and Ben-David 2018; Liberti and Petersen 2018, among others). Hard information includes quantitative records of data such as credit scores and financial records. Soft information includes information that cannot be quantified or stored such as opinions, and self-made judgments. In such an environment, the originating lender could (partially) provide hard information to a third party while soft information is privately held.

2.2. Cash Flows and Risks of the Servicer [1]

The most important source of revenue for a mortgage servicer is the servicing fee, generally specified as a fixed percentage of the declining unpaid balance of the underlying mortgage. Servicers do not collect servicing fee revenue for non-performing loans for which borrowers are delinquent.

There are three main risks associated with the mortgage servicing activity: prepayment risk, default risk, and operational risk. The prepayment risk is defined as the possibility of an early, unscheduled, full repayment of the loan. The default risk is defined as the hazard that a borrower will be unable to honor the required principal and/or interest payments on the mortgage agreement in a timely manner. The risks due to the operational side of the servicing business are of an entirely different nature. For example, in servicing the deal, there is the possibility that the initial mortgage was made based on fraudulent information. In this study, we focus on the risk of borrower default.

3. The Nonparametric Estimation Framework

3.1. Motivation for Nonparametric Methods

The primary advantage of nonparametric estimation methods is robustness, as they can be applied in a broader range of situations even where the parametric conditions of validity are not met. Another notable advantage of nonparametric approaches is the ability to handle various data types (e.g., continuous, ordinal, and ranked data) even if the data comprise outliers, anomalies widely recognized to seriously affect the routine of parametric tests. Finally, as shown by Su and Spindler (2013), nonparametric tests may have stronger power than parametric tests.

Our empirical analysis considers the nonparametric kernel density estimation (KDE) technique to estimate the probability density function (PDF) of random variables drawn from unspecified probability distributions. Although we will assume that the distribution has a deterministic PDF, the estimation methodology will be entirely data-driven in the sense that data will be allowed to speak for themselves more than would be the case if the PDF were constrained to fall in a given parametric family.

3.2. Multivariate Kernel Density Estimation with Mixed Data Types

Consider a continuous random variable X^c with a probability density function f_{X^c}. Let $\{X_i^c\}_{i=1}^n$ represents a sample of n independent and identically distributed i.i.d. data points drawn from an unknown probability distribution family. Technically, a *kernel* $k(\cdot)$ is defined as a function that weights sampled observations X_i^c based on their distance from a specific evaluation point x^c within a fixed range known as the bandwidth, h. The weights given by the kernel function to observations in the sample are known as *local* weights. The

nonparametric estimator $\hat{f}_{X^c}$ is commonly referred to as the Rosenblatt–Parzen estimator (Rosenblatt 1956; Parzen 1962).

For multivariate data under the i.i.d. assumption, the kernel-based estimator of the joint PDF is expressed as the product of univariate kernel functions. The considered approach uses the concept of "generalized product kernels" (Li and Racine 2007; Racine 2008). Accordingly, the estimator of the joint PDF of q continuous variables can be written as follows:

$$\hat{f}_{X^c}\left(x_1^c,\ x_2^c,\ldots,x_q^c\right) = \frac{1}{n}\sum_{i=1}^{n}\prod_{s=1}^{q}\hat{h}_s^{-1}k\left(\frac{X_{i,s}^c - x_s^c}{\hat{h}_s}\right). \tag{1}$$

We use $X_{i,s}^c$ to denote the s-th component of the q-dimensional space of continuous regressors, where $s = \{1,\ldots q\}$ and $i = \{1,\ldots n\}$. $\hat{h}_s$ refers to the estimated bandwidth of the s-th regressor. For the purpose of this paper, we consider the case where X is a vector containing a mix of discrete and continuous variables. Let $X = (X^c, X^d)$ define the ensemble of q continuous and p discrete random variables. The joint density function for both categorical and continuous data using the generalized kernel product method can be formulated as follows:

$$\hat{f}_X\left(x_1^c,\ldots,x_q^c,\ x_1^d,\ldots,x_p^d\right) = \frac{1}{n}\sum_{i=1}^{n}\prod_{s=1}^{q}\hat{h}_s^{-1}k\left(\frac{X_{i,s}^c - x_s^c}{\hat{h}_s}\right)\cdot\prod_{r=1}^{p}l\left(X_{i,r}^d, x_r^d, \hat{\gamma}_r\right), \tag{2}$$

where $l(\cdot)$ is a weighting kernel function that depends on the estimated bandwidth $(\hat{\gamma})$. $X_{i,r}^d$ denotes the r-th component of the p-dimensional space of discrete regressors, $r = \{1,\ldots p\}$ and $i = \{1,\ldots n\}$. The mixed-type kernel allows for having a nonparametric counterpart for discrete choice parametric models such as probit and logit.

3.3. Conditional Kernel Density Estimation for Information Asymmetry Test

The core of our information asymmetry test is the estimation of the conditional density function. Let $f_{Y|X}$ denotes the conditional density function of Y given X. Since our dependent variable Y is discrete, the conditional kernel-based estimator is given by:

$$\hat{f}_{Y|X}(y|x^c,x^d) = \frac{\frac{1}{n}\sum_{i=1}^{n}K(X_i^c,x^c)\cdot L(X_i^d,x^d)\cdot l(Y_i,y,\hat{\gamma}_y)}{\frac{1}{n}\sum_{i=1}^{n}K(X_i^c,x^c)\cdot L(X_i^d,x^d)}, \tag{3}$$

where, for expositional simplicity, $K(X_i^c,x^c) = \prod_{s=1}^{q}\hat{h}_s^{-1}k\left(\frac{X_{i,s}^c - x_s^c}{\hat{h}_s}\right)$ denotes the standard product kernel of s continuous variables. Similarly, $L(X_i^d,x^d) = \prod_{r=1}^{p}l(X_{i,r}^d, x_r^d, \hat{\gamma}_r)$ denotes the product kernel functions of r discrete variables. Note that x^c and x^d are $p\times 1$ and $q\times 1$ vectors of evaluation points, respectively. $l\left(Y_i,y,\hat{\gamma}_y\right)$ denotes the univariate kernel density estimator for discrete variable Y with an estimated bandwidth $\hat{\gamma}_y$. For the purpose of the information asymmetry testing procedure, our object of interest is the cumulative distribution function (CDF) estimated by the kernel-based density estimation approach. Let $F_{Y|X}$ denotes the conditional CDF of Y given X. A nonparametric estimate of $F_{Y|X}$ is given by the following expression:

$$\hat{F}_{Y|X}(y|x^c,x^d) = \frac{\frac{1}{n}\sum_{i=1}^{n}K(X_i^c,x^c)\cdot L(X_i^d,x^d)\cdot I(Y_i\le y)}{\frac{1}{n}\sum_{i=1}^{n}K(X_i^c,x^c)\cdot L(X_i^d,x^d)}, \tag{4}$$

where $I(Y_i \le y)$ denotes an indicator function. This equation represents the core of the nonparametric test proposed by Su and Spindler (2013). In Section 4, we provide a detailed description of the testing procedure along with the hypothesis to be tested. The estimated value for the bandwidth (denoted $\hat{h}$ for the continuous variable kernel and $\hat{\gamma}$ for the discrete variable kernel) is the value minimizing the integrated mean square error, or IMSE, simply

defined as a measure of the discrepancy between the estimated density $\hat{f}_h$ and the true density f:

$$\begin{aligned} IMSE_{\hat{f}_h(x)} &= E\left\{ \int \left(\hat{f}_h(y) - f(y)\right)^2 dy \right\} \\ &= \int Biais\left(\hat{f}_h(y)\right)^2 dy + \int Var\left(\hat{f}_h(y)\right) dy. \end{aligned} \tag{5}$$

The optimal bandwidth is a function of the second derivative of the true density, which is unknown in the model. The bandwidth approximation methods use some underlying assumptions about the true density, which are useful in an application with a large number of variables or a large sample size, as in our empirical application.

4. Nonparametric Information Asymmetry Test

We want to test if the data contains residual asymmetric information effects in the relationship between mortgage default and the decision to use a new servicer. We hypothesize that their informational advantage influences the behavior of mortgage originators by selling mortgage servicing rights. Formally, let Y denote the dependent variable or outcome, X the set of exogenous control variables, and Z a decision variable. In our context of mortgage servicing, Y refers to the event of default mortgage, X includes mortgage risk characteristics and borrower credit quality variables that are observable by both parties (hard information), while Z denotes the originator's decision to sell the mortgage servicing rights rather than to keep servicing. In a principal-agent context, the decision variable, Z, should provide no useful information on mortgage default if and only if the prediction of $F(Y)$ given X and Z jointly coincides with its prediction given X alone (Dionne et al. 2001, 2006). If this is the case, the information asymmetry hypothesis is rejected. The above statement could be formally written in terms of conditional probability functions:

$$F(Y/X, Z) = F(Y/X), \tag{6}$$

where $F(Y/X, Z)$ denotes the conditional cumulative density function (CDF) of mortgage default. Equation (6) means that the original lender's action to switch the servicer or to continue servicing the deal does not convey any additional information useful in predicting the probability of default of a given mortgage as long as all loan and borrower observable risk characteristics (hard information) reveal all necessary information to compute the CDF of mortgage default.

Given a set of n i.i.d. randomly drawn observations $\{Y_i, Z_i, X_i^c, X_i^d\}_{i=1}^n$, the nonparametric test is resumed in comparing the following two conditional CDF estimates $\hat{F}(y|x^c, x^d, z = 1)$ and $\hat{F}(y|x^c, x^d, z = 0)$ as presented in Equation (4) but augmented by the decision variable Z as follows:

$$\hat{F}(y|x^c, x^d, z) = \frac{\frac{1}{n}\sum_{i=1}^n K(X_i^c, x^c) \cdot L(X_i^d, x^d) \cdot I(Y_i \leq y) \cdot I(Z_i = z)}{\frac{1}{n}\sum_{i=1}^n K(X_i^c, x^c) \cdot L(X_i^d, x^d) \cdot I(Z_i = z)}. \tag{7}$$

A test statistic measures the variation in $\hat{F}(y|x^c, x^d, z)$ across possible values of z and different observations as follows:

$$D^* = \sum_{i=1}^n [\hat{F}(y_i|x_i^c, x_i^d, z_i = 1) - \hat{F}(y_i|x_i^c, x_i^d, z_i = 0)]^2 \cdot a(x_i^c), \tag{8}$$

where $a(\cdot)$ is a uniformly bounded nonnegative weight function with compact support that lies within the support of X_i^c. This quantity serves to perform trimming in areas of sparse support of the continuous conditioning variable. It can be formulated as follows:

$$a(x_i^c) = \prod_{s=1}^q I\big(q_s(0.025) \leq X_{i,s}^c \leq q_s(0.975)\big), \tag{9}$$

where $q_s(\alpha)$ denotes the α-th sample quantile of the s-th component of X_i^c and q is the total number of continuous variables. The test statistic D^* in Equation (8) could be viewed as the difference between the expected probability of default depending on whether the originator switches the servicer or not. We can show that D^* is asymptotically normally distributed under the null hypothesis of independence. We implement a bootstrap procedure to obtain the corresponding p-values. In Section 6.3, we propose an extension of the test in order to consider a causal relationship between Z and Y.

5. Data, Variables, and Summary Statistics

5.1. Data Source and Sample Construction

To empirically test for asymmetric information in the mortgage servicing market, we use a large data set provided by MBSData, LLC, River Edge NJ. The data comprise U.S. mortgages that were securitized through the non-agency channel. Mortgages securitized through the private-label channel have fundamental risk characteristics that make them riskier than average. In general, mortgages securitized through this channel do not conform to the prudent lending guidelines set by the government-sponsored enterprises (GSE) Freddie Mac, Fannie Mae, and Ginnie Mae. For example, most of the mortgages do not meet the GSE requirements in terms of loan size (e.g., jumbo loans with original loan amounts exceeding the conforming loan limits), documentation (e.g., loans with no or low level of documentation), and loan-to-value ratios (e.g., LTV ratio above 80%).

Owing to the lack of a government guarantee, holding these private-label securities carries a significantly higher risk than carrying the agency counterparts. For instance, without government back-up, private-label mortgage originators rely on both credit rating agencies and credit enhancements to attract MBS investors and convince them that the underlying mortgage is safe. The non-agency market had witnessed tremendous growth during the pre-crisis period. For instance, the outstanding quantity of non-agency mortgages grew from roughly $600 billion at the end of 2003 to $2.2 trillion at its peak in 2007, according to JP Morgan. The bad risk management of this tremendous growth in the non-agency market is widely recognized by both researchers and practitioners as being one of the main triggers of the financial crisis.

Our dataset consists of mortgages issued between January 2000 and December 2013. The initial sample consists of more than 25 million mortgages that were originated throughout the U.S. and granted by diverse types of lenders ranging from top investment banks to regional small retailers. The yearly distribution of loan origination follows a pattern similar to that observed in the entire U.S. mortgage market. The MBSData, LLC database consists of two main datasets. The first static file reports detailed information collected at the time of mortgage origination. For instance, it reports the borrower's FICO credit score, loan-to-value (LTV) ratio, loan purpose, payment type, initial interest rate, private insurance coverage, etc. It also provides information regarding the property backing the loan, which includes the house value, state, city, and zip code. For the originating entity, the database reports the originating lender's name and type, the name of the original mortgage servicer, as well as the most recently updated servicer name. The second dynamic file reports information that has been collected over the loan lifetime on a monthly basis. Key variables recorded in the monthly remittance files are the current loan balance, current interest rate, next due date, and a monthly delinquency code (current, paid-off, +30, +60, or +90 days delinquent, in foreclosure, in bankruptcy, or real estate owned). The dataset also provides information on losses and loan modification. Loss files mainly report loan-level loss amount, loss severity, recovery amount, loan liquidation proceeds, and current value at liquidation.

While constructing our sample, we impose several restrictions in order to create a homogenous loan sample. We focus on mortgages in a first-lien position on the property securing the mortgage and exclude second mortgages and home equity lines of credit (HELOCs). Our choice is primarily motivated by the fact that first-lien mortgages have priority over all other subsequent claims (i.e., second-lien or junior) on a property in the

event of borrower default. We restrict our attention to single-family owner-occupied homes and exclude multifamily and/or non-owner occupied properties. We also exclude loans whose main purpose is designated as home improvement and retain loans with the main purpose identified as a house purchase or refinancing an existing mortgage (both cash-out and no cash-out). We also exclude planned unit developments (PUDs) and mobile homes. All these restrictions result in a final sample including 5,591,353 distinct observations that originated between January 2000 and December 2013 and were tracked until December 2015 on a monthly basis.

5.2. Variables and Hypotheses

The main variable of interest in our empirical analysis is the mortgage servicer switching indicator, denoted as Switch_Servicer. This variable is a dummy indicator that equals 1 if the originating lender sells the mortgage servicing right to another servicer and 0 if the lender continues servicing the mortgage it originates. The second most important variable of interest is the standard Default dummy variable, which denotes whether a given mortgage becomes 90+ days delinquent (i.e., when a loan is first reported as the borrower having missed three or more consecutive monthly payments). For robustness, we also report results with 60+ days delinquent in the online Appendix A.

The set of covariates includes several explanatory variables recorded at the time of origination. All variables are defined in Table A1 of the online Appendix A. The first variable we consider is the borrower's FICO score. In general, the FICO score measures individuals' creditworthiness by taking into account their payment history, length of credit history, current level of indebtedness, and types of credit used. The score ranges from 300 to 850, and, typically, a FICO score above 660 is indicative of a good credit history. We expect that the originator will keep servicing mortgages with high FICO scores.

The second independent variable is the loan-to-value ratio, LTV, calculated by lenders as the percentage of the first-lien mortgage to the total appraised value of the purchased property. The LTV ratio is one of the key risk factors used by U.S. lenders when qualifying borrowers for a mortgage. In the United States, mortgagors with LTV ratios higher than 80% are required to buy private mortgage insurance to protect the lender from the default risk, which increases the cost of borrowing. The LTV ratio also measures the equity stake of borrowers in a given property. The higher the LTV ratio, the lower the down payment, so the lower the borrower's equity stake in that house. Since a high LTV ratio mirrors a risky mortgage, where the borrower holds a lower equity stake in a given house, we expect the lender's decision to switch the servicer of the deal will be positively correlated with the LTV ratio.

Another key explanatory variable in our analysis is no/low documentation, a dummy variable indicating whether the lender has collected the required level of documentation on the borrower. Typically, a borrower is asked to fill out a credit application and provide several statements and proofs of employment status and income when applying for a loan. Based on this documentation, the lender expends effort to assess the borrower's creditworthiness. Therefore, a no/low documentation loan is a loan for which the lender has not gathered a sufficient level of information on the borrower's income. In terms of default risk, we can presume that no/low documentation loans will default more frequently.

The next independent variable is the ARM indicator; ARM stands for adjustable-rate mortgages (commonly referred to as variable-rate mortgages). The ARM variable indicates whether the interest rate paid on the outstanding balance of a given mortgage varies according to a specific benchmark. Usually, the initial interest rate is fixed for a period of time, after which it is reset periodically, often every month. The interest rate paid by the borrower is usually based on a benchmark plus an additional spread, called the ARM margin. In terms of risk, ARM-type mortgages transfer part of the interest-rate risk from the lender to the borrower. Indeed, these mortgages are generally used when interest rates fluctuate and are difficult to predict (which makes fixed-rate mortgages, FRMs, difficult to

obtain). In terms of servicing choice, a positive statistical relationship is expected between terms of servicing choice and interest rate.

We also include a GSE conforming indicator to denote loans that obey the GSEs' lending guidelines. The GSE_conforming dummy variable indicates whether the mortgage was eligible to be sold to the GSEs at origination. Following the GSEs' recommendations, we classify a mortgage as conforming if the borrower's FICO score is above 660 and the loan amount is below the conforming loan limit in place at the time of origination and the LTV is either less than 80 percent or the loan has private mortgage insurance if the LTV is greater than 80 percent. Given that conforming loans meet the GSE lending standards, we expect a negative correlation with the default event. Indeed, falling within the GSE prudence guidelines should significantly reduce the probability of default. Regarding the choice of switching the servicer, we presume that both signs are plausible. On the one hand, being GSE-conforming increases the ease of finding a buyer of the underlying MSRs. For instance, because these loans are originated following the GSE standards, it would be easier to find buyers of the securitized pool of loans in the market. Thus, a positive sign is expected. On the other hand, being GSE-conforming increases the probability that the lender will be paid back as scheduled. Lenders may therefore keep these good-quality loans on their balance sheets because the risk of default on these loans is significantly low. Therefore, the sign of the conforming coefficient is an empirical matter.

5.3. Descriptive Statistics

We start the empirical analysis by providing summary statistics of some of the key variables used in our analysis. Since we are focusing on the non-agency market, we pay special attention to the role of credit scores, loan-to-value ratios, the amount of documentation collected by the lender, and some interest rate features. Table A2 reports descriptive statistics over the entire study period from January 2000 to December 2013 as well as segmented by origination year. Table A3 breaks down the sample by payment type (FRM vs. ARM), loan type (prime vs. subprime), before/after financial crisis, default status, and servicer switch status.

The first two columns of Table A2 provide a comprehensive picture of the evolution of the non-agency segment of the mortgage market over the 14-year study period. At first glance, mortgage origination has witnessed two major trends explained by the financial crisis. First, the market expanded rapidly from 2000 to 2006 and reached its highest level just before the financial crisis. Afterwards, mortgage origination plunged dramatically. During 2008 and 2009, the market also sustained a dramatic drop in origination of new mortgages. After the financial crisis (2010 and beyond), origination increased slightly but remained far from its level before the financial crisis.

The third column of Table A2 displays the average FICO credit score in the sample. The average credit score is 4 points lower than the 660 threshold. The evolution of the FICO credit score over the years is interesting. For instance, borrowers' credit quality was below the 660 threshold before the financial crisis (655) but above it afterwards (671). The credit score averaged 615 and 644 in years 2000 and 2002. However, after the crisis, credit quality improved significantly as the average FICO score is consistently higher than 770 in the 2010–2013 period.

Figures A1 and A2 of the online Appendix A examine the evolution of borrowers' credit quality. They depict the evolution of FICO scores by payment type (ARMs vs. FRMs) and by loan type (prime vs. subprime). As shown in Figure A1, ARM borrowers have lower credit scores than FRM borrowers, on average. For example, in 2002, the average FICO scores for ARMs and FRMs were 619 and 672, respectively. This trend is almost verified for the period before the financial crisis, after which the difference in credit scores is reduced to 10 points. Table A3 shows that the ARM-FRM FICO score differential over the study period is about 34 points, statistically significant at the 1% level. Figure A2 suggests that, unsurprisingly, the average credit score for subprime loans is significantly lower than for prime loans. For illustration, in 2002 the average FICO score for subprime loans is

almost 120 points lower than for prime borrowers (616 versus 735). Table A3 indicates that over the study period, the average FICO scores for prime and subprime borrowers are 731 and 635, respectively. The difference of 96 FICO points is statistically significant at the 5% level. After the financial crisis, the average credit score tended to improve each year, mainly due to the drop in subprime lending. As column 4 of Table A2 indicates, almost all loans originated after the financial crisis have a credit score higher than 660.

Regarding the loan-to-value (LTV) ratio of sampled mortgages, columns 5 and 6 of Table A2 show that the average LTV ratio in the sample is 77% and that 60% of loans in the sample have an LTV ratio higher than 80%. Regarding the evolution of the LTV ratio over the years, the LTV ratio plunged significantly soon after the financial crisis. For instance, column 6 of Table A2 shows that more than 60% of loans have an LTV ratio higher than 80% throughout the pre-crisis period. However, this proportion drops to almost 20% in the 2010–2013 post-crisis period. We further split our sample according to payment type (ARMs versus FRMs) and loan type (prime versus subprime). Table A3 shows the results over the entire studied period.

We also investigate the lender's effort to gather all documentation required at the date of original underwriting. The statistics show that lenders did not gather sufficient documentation on applicants in almost half of the cases (47% of the time, lenders granted funding to borrowers but gathered little or no documentation on borrowers' income and employment status). Yearly statistics show that this practice of granting funding without the required documentation increased steadily in the early 2000s. As shown in Figure A3, the high proportion of no/low documentation is mainly driven by the practice in the subprime segment; this proportion peaked at 70% from 2005 through 2007.

In general, the lending strategy appears to radically change after the financial crisis. This shift in lending strategy entailed (i) increasing loans granted for borrowers with good credit quality, (ii) reducing loans with a small down payment (LTV ratio higher than 80%), and (iii) reducing the proportion of loans granted with insufficient documentation. These changes in underwriting patterns are consistent with lenders looking for new ways to limit risk exposure after the financial crisis.

To motivate our empirical analysis, we contrast the ex-ante risk characteristics of mortgages for which the originator chooses to sell the underlying servicing rights to another servicer with mortgages that it chooses to continue to service. Overall, we note that, for 54.7 percent of the sampled mortgages (3,060,083 mortgages), the originator chooses to switch the mortgage servicer. For the remaining loans (45% of the sample), the originator keeps servicing mortgages it originates and holds them in its servicing portfolio until maturity. Table A3 shows that the average servicing fee is 44 bp, which does not change very much before and after the crisis. On average, lenders in the sample tend to charge significantly higher fees than the average servicing fees applied by the GSEs and the FHA/VA, at 25 bp and 19 bp, respectively.

Regarding the borrower's credit quality, the results show that lenders tend to keep servicing loans granted to borrowers with superior credit quality. For illustration, the average credit score for loans held in the originator's servicing portfolio is 661, while the average credit score for loans for which the lender decides to switch servicing is 654, namely 3 basis points below the sample average. The two-sample mean difference (untabulated) is 6.39 points, statistically significant at the 1% level. Table A3 also shows that the fraction of loans granted for borrowers with FICO scores higher than the 660 threshold is significantly larger for loans held in a portfolio (51% for non-switch versus 46% for switch).

These results indicate that lenders switch servicing of the deal for loans that are riskier and keep servicing mortgages that are less risky. For instance, the pool of loans for which the servicer has changed is characterized by higher loan-to-value ratios and slightly higher debt-to-income ratios. Regarding the subprime loan type, the primary statistics are not informative in that the propensity to switch the servicer of the deal is 52% for prime loans and slightly higher, at 56%, for subprime loans. The results also suggest that 15% of loans for which the servicer is switched follow the GSEs' prudent lending guidelines, whereas

this percentage increases to 20% for loans held in the originator's servicing portfolio. The proportion of loans that conform to the GSE lending guidelines at origination represents only 17% of the sample.

To summarize, based on the observable risk characteristics of originated mortgages, these preliminary results are consistent with the evidence of lenders selling MSR rights for low-quality loans to other servicers and retaining high-quality mortgages in their own servicing portfolios. To better understand the originators' motive to switch the servicing of the deal, we further break down the mortgage sample by default status. The statistics show that, not surprisingly, lower FICO scores, higher LTV ratios, higher debt-to-income ratios, and higher interest rates are the risk characteristics that are more likely to be associated with the default outcome. For instance, 55% of loans that never entered delinquency are granted to borrowers with FICO scores above the 660 thresholds. In addition, 72% of loans identified as being in default exhibit an LTV ratio higher than 80%. Not surprisingly, following the GSE guidelines significantly reduces the observed default frequency in that only 10% of defaulting loans follow the GSE prudent lending guidelines.

Contrasting the distribution of loans that were chosen for servicer switch with the default outcome yields additional interesting findings. When comparing the default propensities between the switch and non-switch groups, the results show that 50% of loans defaulting have the servicer switched, compared with 18% of loans in the non-default category. In general, these preliminary results suggest a positive association between the originator's decision to switch servicers and the default outcome.

6. Empirical Results

6.1. Nonparametric Methods

We consider two nonparametric testing procedures proposed to isolate the evidence of asymmetric information in the automobile insurance market. The first approach, from Chiappori and Salanié (2000), is based on a sequence of Pearson's χ^2 nonparametric test of independence (see also the recent extension by Maliar and Salanié 2023). The second approach is mainly driven by kernel density estimation techniques and was proposed by Su and Spindler (2013).

6.1.1. The Chiappori and Salanié (2000) Method

We investigate the relationship between the originator (agent)'s action to sell the mortgage servicing right of a given mortgage and the likelihood of mortgage default. The null hypothesis to be tested is that there is no significant residual correlation between the decision to switch the servicer of the deal and the mortgage default event. Since the testing methodology considers only binary variables, we convert continuous variables into dummies. The final set of explanatory variables are FICO660, LTV80, ARM, no/low documentation, balloon, GSE conforming, subprime, and prepayment penalty. We use various variable inclusion configurations for robustness purposes. The upper part of Table 1 displays the different configurations that we use to define the set of control variables to be included in the analysis.

Table 1. Results of the Chiappori and Salanié nonparametric test. The table reports the results of the Chiappori and Salanié (2000) nonparametric testing methodology. The overall sample includes 5,591,353 U.S. mortgages originated over the period from January 2000 to December 2013. The mortgages have been securitized through the non-agency channel. The upper panel of the table reports 10 different configurations of the control variables. The table displays the number of variables included in each configuration as well as the resulting number of cells. KS *p*-value is the *p*-value of the Kolmogorov-Smirnov nonparametric test. $\chi^2_{(1)}$ crit. value is the theoretical value of the χ^2 distribution at the 5% significance level. Rejection rate provides the frequency of rejection of the null hypothesis of independence among all individual cells. S value is the sum of individual test statistics among all cells.

Configuration	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**IIX**	**IX**	**X**	**XI**
FICO.660	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LTV.80	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ARM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No/Low doc.	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Balloon	-	-	Yes	-	-	-	Yes	Yes	Yes	Yes	Yes
GSE Conf.	-	-	-	Yes	-	-	Yes	-	-	Yes	-
Subprime	-	-	-	-	Yes	-	-	Yes	-	-	Yes
Prep. penalty	-	-	-	-	-	Yes	-	-	Yes	Yes	Yes
# variables	3	4	5	5	5	5	6	6	6	7	7
# cells (M)	8	16	32	32	32	32	64	64	64	128	128
Method 1:											
KS *p*-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Method 2:											
$\chi^2_{(1)}$ crit. value	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84
Rejection rate	0.75	1.00	0.81	0.92	1.00	0.91	0.75	0.81	0.83	0.73	0.83
Method 3:											
$\chi^2_{(M)}$ crit. value	15.51	26.30	46.19	46.19	46.19	46.19	84.82	84.82	84.82	124.34	124.34
S value	6388.6	4491.4	6840.3	5577.2	4491.4	9638.9	7628.9	6840.3	11,089.8	11,230.5	11,089.8

The testing procedure could be summarized in the following steps. First, we select a set of m control variables. Since variables are binary, we construct $M = 2^m$ cells in which mortgages have the same values of a selected control variable. We then conduct the Pearson's χ^2-test of independence in each cell. This procedure produces M Pearson's test statistics.

Table 1 displays the results of Chiappori and Salanié's (2000) testing procedure. The table reports the number of control variables included in each configuration and the total number of cells. We first examine *p*-values of the Kolmogorov-Smirnov (KS) test. Clearly, using all possible combinations, we unequivocally reject the null hypothesis at the 1% significance level. Using the second method, the rejection rate of the null hypothesis of independence in individual cells is high for all configurations. For instance, almost all test statistics within individual cells exceed the $\chi^2_{(1)}$ critical value of 3.84 (at a 5% significance level). The highest rejection rate is reached with configuration II, which includes four control variables FICO660, LTV80, ARM, and NoLow_doc. The latter method confirms these findings where the aggregate test statistic is above the critical values of the $\chi^2_{(M)}$ theoretical distribution according to all configurations.

6.1.2. The Su and Spindler (2013) Method

We begin by documenting how well kernel-based estimation fits our data. Figures A4 and A5 in the online Appendix A display histograms for two continuous variables: the borrower's FICO score and LTV ratio. For comparison, histograms are augmented with curves of the nonparametric kernel-based estimator and that of the parametric normal density function. From the two figures, it is clear that the kernel-based PDF much better fits the actual data than the parametric counterpart does. For illustration, the histogram of the LTV ratio

suggests that loans with LTV ratios falling in the 75–80% interval are over-represented in the sample. The parametric normal density underestimates that proportion by 5.5%, whereas the KDE provides better estimates.

Figure A6 highlights the key role of the bandwidth smoothing parameter in the estimation and displays the sensitivity of the kernel density estimation technique fitting to the data. The figure displays the KDE fitting for three different values of the bandwidth: high, optimal, and low values. It is obvious that failing to select the optimal bandwidth could be costly since it may result in over-fitting or under-fitting. In fact, the bandwidth, as a smoothing parameter, controls the size of the neighborhood around a given point of estimation. We use the Maximum Likelihood Cross-Validation (MLCV) method to estimate the bandwidth from the sample by optimizing the loss objective function on the true density. The estimation results show that the optimal bandwidth values are 3.357 for the FICO score and 0.716 for the LTV based on the MLCV method. These values of optimal bandwidths suggest a significant kernel density estimate because the bandwidths are higher than zero. We also include additional discrete binary control variables such as indicator variables for the ARM payment type, balloon loan type, no/low documentation, Subprime, and GSE conformity indicator. For all discrete variables, optimal bandwidth values are within the [0, 1] interval, which, according to Li and Racine (2007) and Racine (2008), means that variables are relevant to the model.

To display the results of the nonparametric testing framework, we use graphical representations where the borrower's FICO continuous variable serves as a support. Our choice is motivated by the fact that FICO represents a direct measure of a borrower's credit quality that the originator may use to assess the likelihood of default. Thus, this variable could be directly linked to both mortgage default and the originator's decision to switch the servicer.

Figure A7 displays the conditional probability of mortgage default using the kernel density estimation method. Conditional means that the probability of mortgage default is conditional on observed risk characteristics for both borrower and mortgage. For comparison purposes, Figure A7 displays fitted values of a linear parametric model. This model suggests a statistically significant negative coefficient for the FICO score when predicting mortgage default in a linear-imposed relationship. The kernel density estimation corroborates this finding.

Now we turn to the core of the nonparametric test for asymmetric information. Figure 2 displays the estimated probability of mortgage default conditional on all observed risk characteristics observed at the time of original underwriting. Moreover, the conditioning set for the estimated probability is now augmented with the agent (originator)'s action to switch the servicer of the deal. Formally, the figure displays two plots that correspond to $\hat{f}(y_i|x_i^c, x_i^d, z_i = 1)$ and $\hat{f}(y_i|x_i^c, x_i^d, z_i = 0)$, respectively. In simple words, the plots labelled "Switched" and "No Switched" refer to the probability of mortgage default conditional on various control variables and the originator's decision to switch or not the servicer of the mortgage.

Both plots show that the conditional probability of mortgage default decreases as the borrower's credit quality improves. However, the plots display a significant shift in the estimated default likelihood when the conditioning set accounts for the agent's action to switch the mortgage servicer. For illustration, mortgages granted for borrowers with an average FICO credit score of 550 display an estimated likelihood of mortgage default of 40% if the mortgage servicer was not switched. However, all other things held constant, changing the decision to switch the servicer of the deal increases the estimated probability of mortgage default by 10%. This 10% increase in the conditional probability of mortgage default is also observed over all FICO score intervals. This evidence suggests that the decision to switch the servicer increases the occurrence of mortgage default by almost 10%, other characteristics being equal. Note that mortgages under consideration share almost many characteristics since they belong to the same FICO score cohort. The only variable that makes the difference here is the agent's action to switch the servicer of the deal.

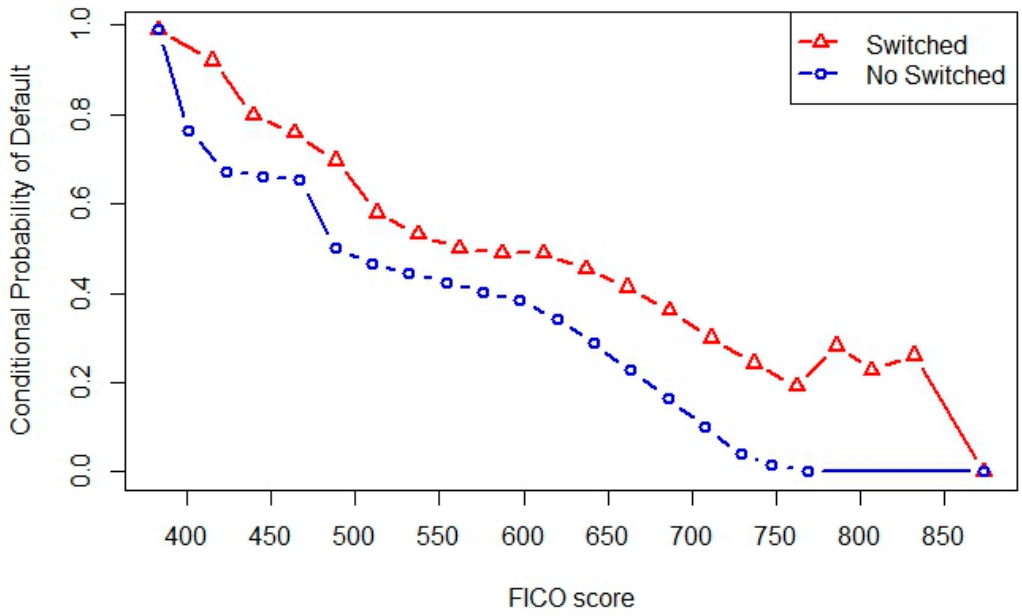

Figure 2. Switched decision vs. conditional probability of default.

Figure 2 also shows that this pattern is valid not only for low-quality borrowers but also for those with superior credit quality. Although the expected default likelihood drops significantly by almost 70% if we consider high-quality borrowers (FICO score above 700), the default likelihood still drops if the originator keeps the securitized mortgage on its servicing portfolio. For illustration, if we consider loans granted to borrowers with FICO scores higher than 750, the estimated conditional probability of default is about 19% if the originator sells the underlying MSRs while nearly zero if the latter keeps servicing the mortgage.

These results are in line with those found using Chiappori and Salanié's (2000) method. For instance, KDE-based results suggest a positive relationship between the conditional probability of mortgage default and the originator's decision to switch the servicer of the deal. In fact, we find that observably similar mortgages (i.e., with comparable risk factors and granted to borrowers with similar credit scores) experience more default risk if the mortgage originator sells the underlying MSR to a new servicer.

We use the bootstrap technique to obtain the p-values and conclude our asymmetric information test. First, we generate B bootstrap samples (with replacement), which we denote as $(X_i^{cb},\ X_i^{db}, Y_i^b, Z_i^b)$ where the superscript b denotes the b^{th} sample of data, $b = \{1 \dots B\}$. Next, each bootstrap sample b estimates the conditional kernel density of mortgage default given all observed characteristics along with the originator's switching decision to calculate the corresponding test statistic as in Equation (8). Let $\hat{D}^b$ denote the estimated test statistic using bootstrap sample $b = \{1 \dots B\}$. The bootstrap p-value is given by:

$$\hat{p}_B\left(\hat{D}^*\right) = 2\, min\left(\frac{1}{B}\sum_{b=1}^{B} \mathrm{I}\left(\hat{D}^* \leq \hat{D}^b\right), \frac{1}{B}\sum_{b=1}^{B} \mathrm{I}\left(\hat{D}^* > \hat{D}^b\right)\right), \tag{10}$$

where I(.) is an indicator function and $\hat{D}^*$ refers to the estimated test statistic as in Equation (8) from the real sample (Fisher and Hall 1990; MacKinnon 2009).

The set of explanatory variables that we consider in our computation is FICO, LTV80, ARM, no/low documentation, balloon, GSE conforming, subprime, and prepayment penalty. For robustness, we try several inclusion combinations of control variables as we did for the Chiappori and Salanié (2000) analysis (see upper panel of Table 1). The total number of bootstrap replications is set to B = 1000. For all possible configurations, we find that the bootstrap p-value is below the 5% statistical level. Clearly, low p-values enable us to conclude the statistical significance of our test, i.e., $\hat{F}(y_i|x_i^c, x_i^d, z_i = 1)$ and

$\hat{F}(y_i|x_i^c, x_i^d, z_i = 0)$ being statistically different for every $i = \{1, \dots n\}$. In other words, the results suggest that in all cases we are able to reject the null hypothesis of absence of asymmetric information at the 5% level. This means there exists a significant residual relationship between the likelihood of mortgage default and the decision to sell the servicing right of a given mortgage.

6.2. Robustness Checks: Results of the Parametric Methods

We provide additional support for our evidence based on commonly used parametric models. We first employ the parametric probit model to investigate the determinants of mortgage default. This testing procedure is documented in Dionne et al. (2001, 2006), who establish that we can interchange the roles of Y and Z so that testing $F(Y/X, Z) = F(Y/X)$ is equivalent to testing $F(Z/X, Y) = F(Z/X)$. The latter equation means that the mortgage default does not provide useful information to predict the originator's decision to switch the mortgage servicer. Dionne et al. (2001, 2006) state that verifying either equality is indicative of the conditional independence of Y and Z given a set X of conditioning variables.

Table A4 displays the estimation results for the standard probit model where the dependent variable is the mortgage default binary variable. The table reports various inclusion configurations for the set of control variables. The proposed configurations control for (i) fundamental borrower and loan risk characteristics, (ii) general economic conditions, (iii) housing market conditions, (iv) bond market conditions, and (v) state legal structure. All explanatory variables display the expected signs. The Wald test and the likelihood-ratio test statistics show that all regressors' coefficients are statistically significant.

The parametric counterpart of the information asymmetry test consists primarily of scrutinizing the statistical link between the decision to switch the servicer and the likelihood of mortgage default. However, such methodology would potentially be problematic as it suffers from various issues, notably endogeneity, econometric misspecification, and simultaneity (Dionne et al. 2009, 2015). To deal with, we employ three different parametric methods. First, we use the two-stage instrumental variable probit model in order to account for potential endogeneity. We also employ the two-step estimation procedure proposed by Dionne et al. (2015) to account for econometric misspecification error and to correct for imposed linearity. Additionally, we employ the bivariate probit model in order to jointly estimate both binary outcomes in a system of simultaneous equations (Chiappori and Salanié 2000). Estimation results for the three models are reported in Table 2.

The first two columns of Table 2 display results of the two-stage instrumental variable probit model. The first stage regression estimates the mortgage default likelihood using Income and Divorce as instruments. Both aggregate instruments must be correlated with mortgage default but uncorrelated with the decision to switch the mortgage servicer. As expected, the first-stage regression shows that income growth is negatively correlated with mortgage default likelihood with a negative coefficient statistically significant at the 1% level. In contrast, the divorce rate is positively related to mortgage default, suggesting that marital breakdown represents a key factor in determining mortgage default. All other coefficients have the expected sign similar to previous findings in Table A4. The first-stage regression provides an estimate of the likelihood of borrower default that the originator formulates based on hard information.

Accordingly, the second-stage regression uses the expected likelihood of default as a regressor to investigate the originator's decision to switch the servicer of the deal. The results show a statistically significant positive coefficient (0.53) for the predicted mortgage default. This positive link is further confirmed after controlling for econometric misspecification via imposed linearity in the vein of Dionne et al. (2015). The statistically significant coefficient (0.487) on the predicted default variable highly suggests that expected mortgage default (based on the originator's private information) provides useful information to predict the originator's decision to switch the mortgage servicer. Such a result sheds light on the existence of information asymmetry in the U.S. mortgage servicing market. This result is further confirmed by using the default variable (0.32 + 0.17).

Table 2. Results of the two-stage and bivariate probit models. The table reports the estimation results using three parametric approaches: the two-stage instrumental variable probit, the two-stage linear model (Dionne et al. 2015), and the bivariate probit. The sample includes 5,591,353 mortgages originated over the period from January 2000 to December 2013. Income and Divorce are instruments for the endogenous variable Default. Income is the annual growth rate of the U.S. household income. Divorce is the annual rate of divorce in the U.S. Pr(Default = 1) denotes the predicted probability of default from the first stage probit regression. Ê(Default) denotes the predicted default from the 1st stage linear model. Default denotes mortgage default (i.e., it is labelled as +90 days delinquent). Switch serv. denoting whether the originator switched the servicer of the deal. FICO score is the borrower's Fair Isaac Corporation score attributed at origination. LTV ratio denotes the initial loan-to-value ratio. ARM abbreviates adjustable-rate mortgages. Balloon refers to balloon payment mortgages. No/Low doc. indicates whether the originator collected no/low documentation. GSE conf. denotes loans that conform to the GSE's lending guidelines. GDP growth and HPI growth are the growth rates of the U.S. Gross Domestic Product and the House Price Index, respectively. σ interest refers to interest-rate volatility. Credit Spread is the yield difference between AAA and Baa bond indexes. Judicial denotes states that require judicial procedures to foreclose on a mortgage. SRR stands for Statutory Right of Redemption, and denotes states that have statutory redemption laws. R^2 is expressed in percentage and refers to the pseudo R^2 for probit models and the adjusted R^2 for linear models. ρ is the estimated correlation coefficient for the bivariate probit. The asterisks *** refer to the significant coefficients at the 1% significance level.

Model	**Two-Stage IV Probit**		**DLB Linear Model**			**Bivariate Probit**	
	1st Stage	**2nd Stage**	**1st Stage**	**2nd Stage**	**2nd Stage**	**Default**	**Switch Serv.**
Dependent Var.	**Default**	**Switch Serv.**	**Default**	**Switch Serv.**	**Switch Serv.**		
Instruments							
Income	−0.0007 ***		−0.0002 ***				
Divorce	0.2896 ***		0.2104 ***				
Pr(Default = 1)		0.5334 ***					
Ê(Default)				0.4871 ***	0.1683 ***		
Default					0.3188 ***		
FICO score	−0.0035 ***		−0.0011 ***			−0.0035 ***	−0.0001 ***
LTV ratio	0.0180 ***	0.0029 ***	0.0051 ***	0.0004 ***	0.0004 ***	0.0180 ***	0.0030 ***
ARM	0.1212 ***	−0.1867 ***	0.0430 ***	−0.0795 ***	−0.0795 ***	0.1184 ***	−0.1707 ***
Balloon	0.4129 ***	−0.0225 ***	0.1596 ***	−0.0525 ***	−0.0525 ***	0.4085 ***	0.0582 ***
No/Low doc.	0.3395 ***	0.1579 ***	0.1062 ***	0.0437 ***	0.0437 ***	0.3416 ***	0.1699 ***
GSE Conf.	−0.1537 ***	0.0777 ***	−0.0432 ***	0.0699 ***	0.0699 ***	−0.1524 ***	0.0020
GDP growth	−4.9640 ***	4.4784 ***	−1.8759 ***	3.5329 ***	3.5329 ***	−1.9603 ***	−0.5005 ***
HPI growth	−7.5731 ***	−5.8147 ***	−2.5375 ***	−0.8476 ***	−0.8476 ***	−7.5398 ***	−7.7918 ***
σ interest	0.9305 ***	0.6387 ***	0.2736 ***	0.0887 ***	0.0887 ***	1.0688 ***	0.8380 ***
Credit spread	1.9934 ***	1.1789 ***	0.6298 ***	0.0044 ***	0.0044 ***	1.8957 ***	1.9713 ***
Judicial	−0.0425 ***	0.0129 ***	−0.0129 ***	0.0066 ***	0.0066 ***	−0.0426 ***	0.0018
SRR	−0.0844 ***	0.0321 ***	−0.0267 ***	0.0145 ***	0.0145 ***	−0.0851 ***	0.0321 ***
R^2	11.7	38.0	13.8	31.2	38.2		
ρ						0.5965 ***	

The last two columns of Table 2 show the results of the bivariate probit model, which estimates the joint occurrence of both events (mortgage default and servicer switch). All regressors remain statistically significant and preserve their expected signs. Most importantly, the models display a statistically significant estimated correlation coefficient of 0.60, which confirms the positive residual relationship between mortgage default and servicer switch. This last result does not test for causality, however.

For robustness purposes, we reproduce the parametric results using (i) a different definition of mortgage default and (ii) a different study period. We use an alternative default definition that identifies a given mortgage in default when it first becomes 60+ days

delinquent (i.e., when reported as the borrower having missed two or more monthly payments). We also consider a pre-crisis sampling period that covers the period from January 2001 to December 2006 with the main objective to immunize the empirical results from potential effects of the financial crisis. As shown in the online Appendix A (Tables A5–A10), our empirical results are robust to these alternatives observed in the literature.

6.3. Causality: Results of the Two-Stage Nonparametric Framework

In the first part of the empirical analysis, we presented the results of the nonparametric kernel density estimation technique. The main goal was to estimate the conditional CDF of mortgage default, $\hat{F}(Y/X,Z)$. Our results show a positive correlation between the decision to switch the servicer of the deal and mortgage default. However, a positive relationship does not necessarily indicate a causal relationship as estimated in the preceding section.

We now propose a new nonparametric two-step instrumental variable estimation procedure to establish a causal relationship between the default and switching variables while considering any potential simultaneous effects. As for the parametric two-step regressions, we exploit the fact that we can interchange the roles of Y and Z and test $F(Z/X,Y) = F(Z/X)$ instead of testing $F(Y/X,Z) = F(Y/X)$.

In a first step we perform a nonparametric estimation of the conditional density of mortgage default using instrumental variables, and in the second step we consider the nonparametric equivalent of the parametric second-stage regression. We are aware of the literature on nonparametric instrumental variable regressions (Horowitz 2011; Das 2005; Centorrino and Florens 2021). However, the implementation of such approaches to our data is problematic given that the literature proposes nonparametric regression models that are appropriate when at least one variable of interest is continuous. This is not the case in our application because both variables of interest, Y and Z, are binary.

Our two-stage methodology relies on kernel density estimates and can be summarized as follows. In the first stage, we estimate the conditional density function of mortgage default using the KDE technique as described in Section 3. The set of covariates includes exogenous independent variables (e.g., FICO score, LTV ratio, documentation status) along with the two instruments of mortgage default (income growth and divorce rate) of the parametric analysis presented in Section 6.2. The first-stage KDE estimation is represented as follows:

$$\hat{f}(y|x^c,x^d,v_1,v_2) = \frac{\frac{1}{n}\sum_{i=1}^{n} K(X_i^c,x^c)\cdot L(X_i^d,x^d)\cdot K(V_i,v)\cdot l(Y_i,y,\hat{\gamma}_y)}{\frac{1}{n}\sum_{i=1}^{n} K(X_i^c,x^c)\cdot L(X_i^d,x^d)\cdot K(V_i,v)}, \tag{11}$$

where $K(V_i,v) = \prod_{n=1}^{2} \hat{h}_n^{-1} k_h(V_{i,n},v_n)$ denotes the product kernel function for the two-dimensional vector of instrumental variables V_n, $n = \{1,2\}$, and v_1 and v_2 denote the evaluation points for instruments V_1 and V_2. Figures A8 and A9 show how the estimated conditional density function of mortgage default varies in relation to our two instruments.

In the second stage, we include the kernel-based estimator of mortgage default as a covariate while estimating the conditional density of the decision to switch mortgage servicers. To simplify the notation, let $Def^+ \equiv \mathrm{I}(\hat{f}(y|x^c,x^d,v_1,v_2) > \tau^*)$ and $Def^- \equiv \mathrm{I}(\hat{f}(y|x^c,x^d,v_1,v_2) \leq \tau^*)$ define the events where the expected mortgage default probability is high and low, respectively. $I(.)$ refers to an indicator function and τ^* is a fixed threshold, $\tau^* \in [0,1]$. In our context, Def^+ and Def^- represent the originating lender's expectations of mortgage default based on the information set collected at the time of the original underwriting. As stated above, this two-step instrumental variable estimation procedure allows us to (1) account for potential simultaneity effects, and (2) establish a causal relationship between mortgage default and the decision to switch servicers.

We then perform our information asymmetry test, where the statistic can be formulated as follows:

$$W^* = sup[\hat{F}(z_i|x_i^c,x_i^d,Def^+) - \hat{F}(z_i|x_i^c,x_i^d,Def^-)] \tag{12}$$

The test is performed using the nonparametric Kolmogorov–Smirnov (KS) test of the equality of distributions. In a two-sample environment, the test is designed to verify the null hypothesis that both samples are drawn from the same distribution, i.e., both samples have the same distributional shaping parameters. In the context of asymmetric information, the null hypothesis to be tested is that the shape of the conditional distribution of the decision to switch deal servicers is independent from the mortgage default likelihood. If the null hypothesis is respected, this should be interpreted as indicative that the likelihood of mortgage default has no significant impact on the originator's decision to switch servicers.

When applied to empirical data, the KS test statistic could be expressed as the maximum value of the difference between two empirical cumulative distribution functions. The KS test could be written as in (12). When (12) is applied to our context of asymmetric information testing in the mortgage servicing market, the KS test aims to measure the maximum difference between two CDFs of the decision to switch the servicer of the deal (z_i) conditional on a set of conditioning variables (x_i^c, x_i^d, Def).

To calculate W^*, we first split the empirical estimation sample based on a Def dummy indicator, called the high-default Def^+ and low-default Def^- expectations subsamples. Then, the empirical CDFs are calculated for both subsamples $\hat{F}(z_i|x_i^c, x_i^d, Def^+)$ and $\hat{F}(z_i|x_i^c, x_i^d, Def^-)$. W^* is obtained by comparing these two CDFs. In our application, whether we use the entire sample or randomly selected subsamples, the KS test statistics (W^*) are strictly positive, and all p-values are zero, which enables us to reject the null hypothesis of distributional similarities at all significance levels.

For a visualization of the test, one could plot $\hat{F}(z_i|x_i^c, x_i^d, Def^+)$ against $\hat{F}(z_i|x_i^c, x_i^d, Def^-)$ using a continuous conditioning variable as support. Figure 3 provides an illustration where we plot the conditional PDF functions of the decision to switch the deal servicer (Y-axis) versus the FICO score conditioning continuous variable (X-axis). The divergence between the two conditional PDFs (red and blue lines in Figure 3) arises from the conditioning variables Def^+ and Def^-, which denote the expected likelihood of mortgage default (estimated in Stage 1).

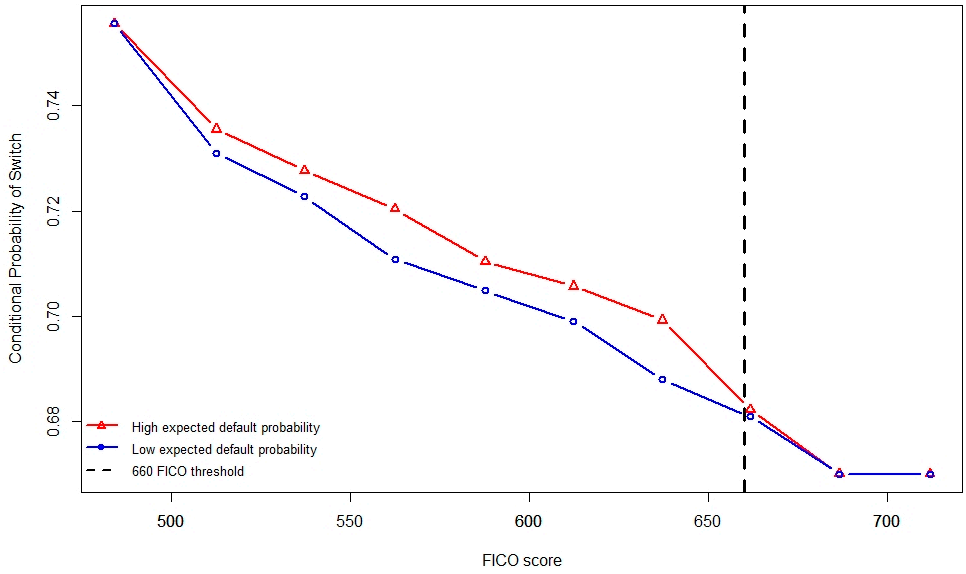

Figure 3. Instrumental-variable two-stage nonparametric estimator of switching mortgage default.

Figure 3 shows that the conditional probability of switching the servicer of the deal is a decreasing function of borrower-observed quality. This confirms our previous results using the parametric models where the coefficient of the FICO score was negative and statistically significant. The plot shows divergence between the two lines, each of which is conditioned by the expected likelihood of mortgage default. In the figure, τ^* is set at the mean of 0.37.

In terms of economic interpretability, all other things held constant, if the originating lender expects a high probability of mortgage default from his private information, it is more likely he will sell the underlying servicing right to another servicer. At each point of the X-axis of Figure 3, the probability of switching the servicer conditional on a higher expected probability of default is higher (Y-axis).

The vertical line on Figure 3 refers to a FICO score cut-off point of 660, which is the GSEs frontier for FICO score. This cut-off point represents a rule of thumb established by the GSEs to control mortgage lending in the U.S. market. Following the GSE prudent lending guidelines, a borrower above the 660 thresholds should be attributed a mortgage without restriction, while borrowers falling below should have constrained funding. Keys et al. (2010) exploit a different cut-off point of 620 to investigate the ease of securitization. The authors document a clear shift in the securitization ease around their decision rule.

Figure 3 delivers similar inferences to those by Keys et al. (2010). The figure shows a clear divergence in the conditional probability of switching mortgage servicer given the expected probability (calculated in the first stage estimation) of default is high or low. Nevertheless, this low/high expected default divergence is more pronounced below the 660 thresholds (left-hand side of the vertical line) than above the 660 cut-off. This shift in divergence could be explained by the significance of the quality in the signal provided by the GSE frontier.

Recall that mortgage originators decide whether to sell the MSRs based on both hard and soft information. Also, information asymmetry should be more pronounced in situations where the distinction between soft and hard information is critical. To better interpret our result, let us use the FICO score as a proxy for hard information in Figure 3 (without loss of generality) since it can be observed by a third party. However, high/low expected probability of mortgage default calculated in the first-stage kernel-based estimation contains both sources of information. Mortgages granted for borrowers with a FICO score above the GSE's 660 rule of thumb naturally exhibit a low probability of mortgage default. However, we still observe a discrepancy between hard and soft information.

The two-step instrumental variable nonparametric testing procedure that we proposed establishes a causal relationship between the agent's decision variable Z and the outcome Y. The results strongly suggest that the expected likelihood of mortgage default influences the originator's decision to switch the servicer of the deal, which confirms our hypothesis that second-stage asymmetric information existed in the U.S. mortgage servicing market during our period of analysis.

7. Conclusions

In this paper, we analyze the servicing switching decision in the securitization market. Our main objective is to verify whether information asymmetry between servicer and originator affects mortgage default. Specifically, we investigate whether a first-level originator decision to sell the mortgage servicing rights to a second-level servicer reveals any residual information asymmetry in the mortgage servicing market.

Figure 4 summarizes the key relationships and results of the article. Once the securitization process is implemented and MBSs are sold to investors, a mortgage servicer ensures the management of cash flows between investors and the originator. The originator can manage these cash flows with its own servicer (own servicer) or sell the management activity to an independent servicer (MSR purchaser). We assumed there was asymmetric information about loan quality between the originator and the MSR purchaser. Our goal was to test this assumption by verifying that the average default probability of loans sold by the originator and managed by its own servicer is lower than the average default probability of loans sold by the originator and managed by a new independent servicer.

Our empirical results reveal interesting and important conclusions related to the US mortgage servicing market during our period of analysis. We observe that information asymmetry between originators and servicers influences servicing-switch decisions significantly. The mortgage originator uses its private information advantage to sell riskier loans to the MSR purchaser or new servicer.

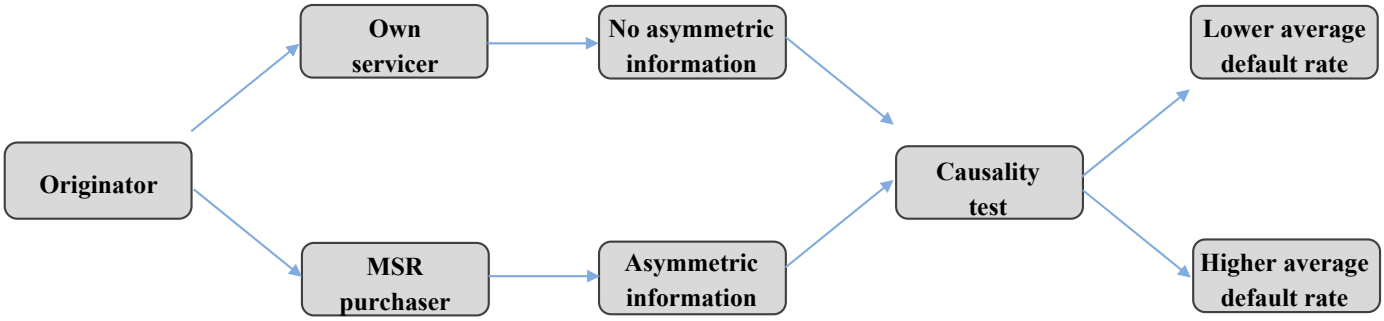

Figure 4. Graphical illustration of model and empirical analysis.

This result has important consequences for the securitization market. Recent regulations have introduced a retention provision for originators that use securitization. Since December 2014, originators must keep an economic interest (retention) in the credit risk of the securitized assets (Morgan 2018). Only the original originator must keep the economic interest.

The main goal of the 2014 reform was to increase the amount of skin in the game for originators of asset-backed securities transactions under asymmetric information. Under asymmetric information in the securitization market, originators have less incentive to screen loan applicants (adverse selection) and to monitor loan recipients over the life of the contract (moral hazard), particularly when all potential credit losses are transferred to investors.

Without any retention rules, the originators have incentives to sell bad loans to investors since, with securitization, they are not exposed to the credit risk of these loans. Moreover, they have incentives to sell the servicing management to independent servicers to avoid the administrative expenses associated with borrower defaults and lack of monthly payments.

Risk retention rules were implemented under the Dodd-Frank Act to increase originator incentives. Under these rules, originators must retain exposure to loan defaults. Recent empirical studies have found support for the risk-mitigation hypothesis of risk retention (Begley and Purnanandam 2017; Ashcraft et al. 2019).

These analyses focused on the first-stage asymmetric information problem between lenders and investors. They may have underestimated the effect of asymmetric information in the securitization market by not considering the second-stage information problem between the originator and servicers that is documented in this article.

It would be interesting to investigate how this new rule may impact the type of information asymmetry effect we have measured. Intuitively it should reduce the incentive to pass on bad loans to an independent servicer because with risk retention, fewer bad loans will be securitized. This means that empirical results documenting the positive effect of risk retention in the securitization market should be associated with both forms of asymmetric information problems.

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Appendix A

Table A1. Variable definition and source.

Name	Type	Description	Source
Switch Servicer	Binary	Denotes the decision of the originating lender to sell or to retain the mortgage servicing right of a given loan. Takes the value of 1 if the originator decides to sell the underlying MSR and 0 if he retains the MSR and continues servicing the loan.	MBSData
Default	Binary	Denotes mortgage default. Takes the value of 1 if the borrower of a given mortgage misses three or more consecutive monthly payments (i.e., when the mortgage status is first labeled as 90+ days delinquent).	MBSData
FICO score	Continuous	The borrower's FICO score created and calculated by the Fair Isaac Corporation. It measures the credit quality of borrowers by taking into account an individual's payment history, length of credit history, current level of indebtedness, and types of credit used by the borrower.	MBSData
FICO660	Binary	Takes the value of 1 if the borrower's FICO score is above 660 and 0 otherwise. In general, a FICO score above 660 indicates that the individual has a good credit history.	MBSData
LTV	Continuous	The loan-to-value ratio calculated as the percentage of the first-lien mortgage to the total value of the property. It is one of the key risk factors used by U.S. lenders when qualifying borrowers for a mortgage. A high LTV ratio mirrors a loan with a low down payment for which the borrower has little equity stake in the property.	MBSData
LTV80	Binary	Takes the value of 1 if the LTV ratio is equal to or higher than 80%.	MBSData
DTI	Continuous	The debt-to-income ratio calculated as the fraction of monthly mortgage payments to the borrower's monthly income. DTI measures the borrower's ability to honor periodic debt payments as it compares debt payments to the borrower's income.	MBSData
No/Low doc.	Binary	Takes the value of 1 if the documentation level is labelled "missing" or "low", and 0 otherwise. No- or low documentation mortgages designate loans for which the lender did not gather a sufficient level of information on the borrower's reliability and credit worthiness.	MBSData
ln Amount	Continuous	The natural logarithm of the initial balance of the mortgage. Does not include either interest, taxes, or fees.	MBSData
Interest	Continuous	The interest rate was initially applied at the time of original underwriting. Higher interest rates usually reflect loans granted to borrowers with inferior credit quality, which increase their monthly debt payments.	MBSData
ARM	Binary	Takes the value of 1 if the loan type is an adjustable-rate mortgage and 0 if fixed-rate mortgage. ARM indicates whether the interest rate of a given mortgage is fluctuating over time based on a benchmark index plus an additional spread, called an ARM margin.	MBSData
ARM margin	Continuous	A fixed component added to the interest rate for ARM mortgages. The margin is constant throughout the lifetime of the mortgage, while the benchmark index fluctuates over time according to general market conditions.	MBSData
Balloon	Binary	Takes the value of 1 if the mortgage has a balloon payment structure, 0 otherwise. Balloon mortgagors make only interest payments during the lifetime of the loan. At the term end, the borrower repays the entire principal at once.	MBSData

Table A1. *Cont.*

Name	Type	Description	Source
GSE conforming	Binary	Takes the value of 1 if the lender follows the GSEs' lending guidelines and 0 otherwise. Following the GSEs' recommendations, we classify a mortgage as conforming if the borrower's FICO score is above 660 and the loan amount is below the conforming loan limit in place at the time of origination and the LTV is either less than 80% or the loan has private mortgage insurance in the case that the LTV ratio is above 80%. Since conforming loans meet the GSE lending standards, the conforming dummy variable indicates whether the mortgage was eligible to be sold to the GSEs at origination.	MBSData
Subprime	Binary	Denotes subprime mortgages. A mortgage is labelled "Subprime" at origination if the borrower's FICO score is lower than 580 or the LTV ratio is higher than 90%.	MBSData
Prime	Binary	Denotes prime mortgages. A mortgage is considered as "Prime" if the borrower's FICO score is higher than 660 and the LTV ratio is lower than 80%.	MBSData
Prep. Penalty	Binary	Equals to 1 if the mortgage contract includes a prepayment penalty clause and 0 otherwise. Accordingly, the borrower will pay a penalty if he chooses to pre-pay the loan within a certain time period. The penalty is based on the remaining mortgage balance and the number of months worth of interest.	MBSData
Purchase	Binary	Takes the value of 1 if the loan purpose is labeled "Purchase" a property and 0 otherwise.	MBSData
Refin. cash-out	Binary	Equals to 1 if the loan is granted for the purpose of refinancing an existing loan with "cash-out". A cash-out refinance mortgage is a new loan in which the amount is greater than the existing mortgage amount, which will be refinanced. Since the borrower refinances for more than the amount owed, he/she takes the difference in cash.	MBSData
Refin. no cash-out	Binary	Equals to 1 if the loan is granted for the purpose of refinancing an existing loan with "no-cash-out". A no-cash-out refinance mortgage is a new loan in which the amount is equal to or lower than the existing mortgage amount. The main purpose of such loans is usually to lower the interest rate charge on the loan.	MBSData
Service fee	Continuous	The servicing fee that the servicer of the deal charges as compensation for costs he bears. It is expressed as a fixed percentage of the declining balance of the mortgage.	MBSData
Age at default	Continuous	The age-at-default is measured as the total number of months since origination when the default is first recorded.	MBSData
Default N	Binary	Denoting the fraction of mortgages that default within N months since origination.	MBSData
Income	Continuous	The annual growth rate of personal income, which is defined as an individual's total earnings from wages, investment interest, and other sources. The seasonally unadjusted U.S. real disposable (after deducting tax) personal income data is retrieved from the US. Bureau of Economic Analysis' web site.	bea.gov
Divorce	Continuous	The annual divorce rate calculated as the ratio of the number of marriages contracted and ended in divorce to the number of all marriages contracted in the same year. The divorce rate is commonly used as an indicator of social stress in the society. The seasonally unadjusted divorce rate is retrieved from the U.S. Census Bureau's web site.	census.gov
GDP growth	Continuous	The annual growth rate of the U.S. Real Gross Domestic Product. The real GDP is collected from the Federal Reserve Bank of St. Louis' web site.	stlouisfed.org

Table A1. *Cont.*

Name	Type	Description	Source
HPI growth	Continuous	The annual growth rate of the House Price Index for the U.S. We use the seasonally unadjusted purchase-only HPI index retrieved from the Federal Reserve Bank of St. Louis' web site.	stlouisfed.org
σ interest	Continuous	The interest rate volatility calculated as the volatility on the 1-Year Treasury Constant Maturity Rate over the 24 months before origination. The monthly seasonally unadjusted treasury rate is collected from the Federal Reserve Bank of St. Louis' web site.	stlouisfed.org
Credit spread	Continuous	The yield spread between AAA and Baa bond indexes. It is calculated as the interest rate difference between Moody's Aaa and Baa Corporate Bond Yields. Both variables are seasonally unadjusted, recorded on a monthly basis, and retrieved from the Federal Reserve Bank of St. Louis' web site.	stlouisfed.org
Judicial	Binary	Takes the value of 1 if the state laws require judicial procedures to foreclose on a mortgage and 0 if not. The variable is compiled based on information from the National Center for State Courts' web site.	ncsc.org
SRR	Binary	Stands for Statutory Right of Redemption and takes the value of 1 if the state has statutory redemption laws. The variable is compiled based on information from the National Center for State Courts' web site.	ncsc.org

Table A2. Summary statistics by origination year. The table reports summary statistics for the sample of U.S. mortgages originated over the period from January 2000 to December 2013. The mortgages have been securitized through the non-agency channel. The first row reports statistics over the 2000–2013 study period for the total sample of 5,591,353 distinct mortgages, while the next rows report statistics by origination year. The first two columns, Volume (in %) and Volume (in $B), refer to the total origination volume expressed in percentage of the total sample and in US$ billions, respectively. FICO score abbreviates the borrower's Fair Isaac Corporation score attributed at origination. FICO.660 denotes the fraction of loans granted to borrowers with FICO scores higher than 660. LTV abbreviates the initial loan-to-value ratio. LTV.80 denotes the fraction of loans with LTV ratios higher than 80%. DTI stands for the debt-to-income ratio. No/Low doc. indicates whether the originator collected either no or low documentation. Interest rate is the coupon rate applied at origination. Balloon denotes balloon payment mortgages. ARM and ARM margin denote adjustable-rate mortgages and the corresponding margin. GSE conf. denotes the fraction of loans that conform to the Government-Sponsored Enterprises' prudent lending guidelines. Prep. Penalty measures the fraction of loans with prepayment penalties.

Origination Year	Volume (in %)	Volume (in $B)	FICO Score	FICO. 660	LTV Ratio	LTV. 80	DTI	No/Low Doc.	Interest Rate	Balloon	ARM	ARM Margin	GSE Conf.	Prep. Penalty
All period	100.0	1509.1	657.12	0.48	76.93	0.60	38.65	0.47	6.97	0.06	0.63	5.00	0.17	0.49
2000	1.05	8.87	615.49	0.31	78.20	0.62	38.65	0.34	10.08	0.07	0.34	6.13	0.17	0.41
2001	2.47	32.07	648.33	0.47	76.87	0.56	37.74	0.29	8.56	0.03	0.36	6.09	0.23	0.33
2002	5.74	69.08	644.97	0.42	77.47	0.58	37.84	0.33	7.92	0.02	0.54	5.92	0.21	0.38
2003	11.46	170.89	670.12	0.56	75.14	0.51	36.95	0.38	6.60	0.01	0.49	5.18	0.25	0.31
2004	16.93	232.68	657.75	0.49	77.60	0.60	36.81	0.44	6.30	0.00	0.70	4.75	0.19	0.52
2005	27.28	411.36	658.81	0.49	76.97	0.62	38.33	0.51	6.51	0.02	0.69	4.91	0.16	0.53
2006	27.11	422.92	650.45	0.44	77.44	0.63	39.90	0.52	7.44	0.15	0.66	5.07	0.12	0.57
2007	7.79	153.39	668.92	0.56	75.92	0.56	39.17	0.57	7.32	0.12	0.52	4.50	0.15	0.47
2008	0.02	0.60	717.06	0.80	73.25	0.44	36.59	0.40	7.16	0.03	0.48	3.13	0.03	0.17
2009	0.00	0.21	774.60	1.00	53.11	0.06	36.00	0.30	4.79	0.00	0.83	2.04	0.03	0.00
2010	0.01	0.43	772.33	1.00	61.78	0.17	32.48	0.02	4.93	0.00	0.08	1.64	0.01	0.21
2011	0.02	1.17	770.62	1.00	66.60	0.23	32.98	0.17	4.72	0.00	0.06	1.83	0.01	0.16
2012	0.06	2.79	773.08	1.00	66.42	0.20	34.00	0.03	4.06	0.00	0.02	2.25	0.00	0.13
2013	0.06	2.67	771.14	1.00	66.24	0.19	30.80	0.00	3.91	0.00	0.01	2.53	0.00	0.01

Table A3. Summary statistics by loan type and status. The table reports summary statistics for the sample of 5,591,353 U.S. mortgages originated over the period from January 2000 to December 2013. The mortgages have been securitized through the non-agency channel. The table breaks down the sample by payment type (FRM vs. ARM), loan type (prime vs. subprime), financial crisis era (before vs. after), default status, and servicer switch status. FICO score abbreviates the borrower's Fair Isaac Corporation score at origination. FICO.660 denotes the fraction of loans granted to borrowers with a FICO score higher than 660. LTV abbreviates the initial loan-to-value ratio. LTV.80 denotes the fraction of loans with LTV ratios greater than 80%. DTI stands for the debt-to-income ratio. No/Low doc. indicates whether the originator collected either no or low documentation. Interest rate is the coupon rate applied at origination. Balloon denotes balloon payment mortgages. ARM and ARM margin denote adjustable-rate mortgages and the corresponding margin. Subprime and prime are subprime loan classifiers. GSE conf. denotes the fraction of loans conforming to the GSEs' lending guidelines. Prep. Penalty indicates the fraction of mortgages with a prepayment penalty. Service fee is the mortgage servicer fee expressed as a percentage of the remaining balance. Switch servicer indicates the fraction of mortgages for which the originator switched the servicer of the deal. Default denotes the fraction of mortgages in default. Age at default is the average age of defaulting mortgages. Default 12, Default 18, and Default 24 refer to the fraction of loans defaulting within 12, 18, and 24 months since origination, respectively.

	All	Payment Type		Loan Type		Financial Crisis		Default		Switch Servicer	
		FRM	ARM	Prime	Subprime	Before	After	No	Yes	No	Yes
FICO score	657.12	678.00	644.84	730.93	634.87	655.92	671.02	669.62	635.77	660.62	654.23
FICO.660	0.48	0.61	0.41	1.00	0.33	0.48	0.57	0.55	0.37	0.51	0.46
LTV	76.93	73.89	78.73	63.48	80.99	77.04	75.72	74.86	80.48	76.49	77.30
LTV.80	0.60	0.48	0.67	0.00	0.78	0.60	0.55	0.53	0.72	0.58	0.61

Table A3. *Cont.*

	All	Payment Type		Loan Type		Financial Crisis		Default		Switch Servicer	
		FRM	ARM	Prime	Subprime	Before	After	No	Yes	No	Yes
DTI	38.65	37.64	39.08	35.71	39.10	38.60	39.09	37.63	39.91	38.02	38.95
No/Low doc.	0.47	0.46	0.48	0.63	0.43	0.46	0.55	0.45	0.50	0.49	0.45
Interest rate	6.97	7.10	6.89	5.57	7.39	6.94	7.26	6.71	7.41	6.86	7.05
Balloon	0.06	0.04	0.08	0.01	0.08	0.06	0.12	0.03	0.11	0.04	0.08
ARM	0.63	0.00	1.00	0.45	0.68	0.64	0.52	0.59	0.70	0.59	0.66
ARM margin	5.00	.	5.00	2.86	5.42	5.03	4.50	4.80	5.27	4.93	5.04
Subprime	0.77	0.66	0.83	0.00	1.00	0.77	0.72	0.70	0.89	0.75	0.78
Prime	0.23	0.34	0.17	1.00	0.00	0.23	0.28	0.30	0.11	0.25	0.22
GSE Conf.	0.17	0.25	0.12	0.56	0.05	0.17	0.15	0.21	0.10	0.19	0.15
Prep. Penalty	0.49	0.34	0.58	0.24	0.57	0.50	0.46	0.42	0.63	0.49	0.50
Purchase	0.37	0.30	0.42	0.22	0.42	0.38	0.30	0.36	0.40	0.36	0.39
Refin. cash-out	0.47	0.49	0.45	0.46	0.47	0.46	0.51	0.46	0.47	0.49	0.45
Refin. no cash-out	0.16	0.21	0.13	0.31	0.11	0.15	0.19	0.18	0.12	0.15	0.16
Service fee	0.44	0.38	0.47	0.33	0.47	0.44	0.39	0.42	0.46	0.41	0.46
Switch servicer	0.55	0.50	0.58	0.52	0.56	0.56	0.44	0.18	0.50	0.00	1.00
Default	0.37	0.30	0.41	0.18	0.43	0.35	0.54	0.00	1.00	0.26	0.62
Age at default	36.64	45.25	32.98	47.72	35.21	37.41	30.81	.	36.64	38.07	35.47
Default 12	0.11	0.06	0.12	0.03	0.12	0.10	0.12	.	0.11	0.09	0.12
Default 18	0.23	0.15	0.26	0.08	0.24	0.22	0.26	.	0.23	0.20	0.24
Default 24	0.35	0.24	0.40	0.15	0.38	0.34	0.44	.	0.35	0.32	0.37

Table A4. Results of the probit model. The table reports estimation results of the parametric probit regressions. The sample includes 5,591,353 mortgages originated over the period from January 2000 to December 2013. The dependent variable, Default, is a dummy variable denoting mortgage default (i.e., when a mortgage is labelled as +90 days delinquent). FICO score is the borrower's Fair Isaac Corporation score attributed at origination. LTV ratio denotes the initial loan-to-value ratio. ARM stands for adjustable-rate mortgages. Balloon refers to balloon payment mortgages. No/Low doc. indicates whether the originator collected no/low-level documentation. GSE conf. denotes mortgages that conform to the GSE's lending guidelines. GDP growth and HPI growth are growth rates of the U.S. Gross Domestic Product and the House Price Index, respectively. σ interest refers to interest-rate volatility. Credit Spread is the yield difference between AAA and Baa bond indexes. State FE specification controls for state fixed effects using state dummies. Judicial indicates whether the state requires judicial procedures to foreclose on a mortgage. SRR stands for Statutory Right of Redemption and denotes states that have statutory redemption laws. The Pseudo R^2 is expressed in percentage. Wald denotes the *p*-value of the Wald test for the null hypothesis that all coefficients are jointly equal to zero. LR refers to the *p*-value of the likelihood ratio test for the null hypothesis based on configuration II. The asterisks *** refer to significance levels of 1%.

Configuration	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**IIX**	**IX**
A. Fundamental loan and borrower characteristics									
FICO score	−0.0034 ***	−0.0034 ***	−0.0034 ***	−0.0034 ***	−0.0034 ***	−0.0034 ***	−0.0034 ***	−0.0034 ***	−0.0034 ***
LTV ratio	0.0169 ***	0.0172 ***	0.0170 ***	0.0171 ***	0.0169 ***	0.0175 ***	0.0170 ***	0.0172 ***	0.0179 ***
ARM	0.0980 ***	0.1324 ***	0.1290 ***	0.1064 ***	0.0866 ***	0.0755 ***	0.0940 ***	0.0911 ***	0.1206 ***
Balloon	0.6336 ***	0.5681 ***	0.5770 ***	0.5887 ***	0.6384 ***	0.6373 ***	0.6344 ***	0.6264 ***	0.4146 ***
No/Low doc.	0.3726 ***	0.3742 ***	0.3741 ***	0.3707 ***	0.3673 ***	0.3602 ***	0.3721 ***	0.3690 ***	0.3396 ***
GSE Conf.	−0.1939 ***	−0.1914 ***	−0.1895 ***	−0.1920 ***	−0.1905 ***	−0.1959 ***	−0.1918 ***	−0.1910 ***	−0.1567 ***
B. Economic general conditions									
GDP growth		−14.808 ***							−1.9725 ***
C. Housing market conditions									
HPI growth			−3.4660 ***						−7.6275 ***
D. Bond market conditions									
σ interest				0.4669 ***					1.0679 ***
Credit spread					0.3561 ***				1.8900 ***
E. State legal structure									
State FE						Yes			
Judicial							−0.0464 ***		−0.0421 ***
SRR								−0.0868 ***	−0.0853 ***
Intercept	0.2878 ***	0.6870 ***	0.5697 ***	−0.1014 ***	0.6244 ***	−0.1253 ***	0.3277 ***	0.3385 ***	1.9433 ***
Pseudo R^2	8.40	9.10	8.82	9.04	8.53	9.39	8.43	8.46	11.60
Log-likelihood	-3.37×10^6	-3.35×10^6	-3.36×10^6	-3.35×10^6	-3.37×10^6	-3.34×10^6	-3.37×10^6	-3.37×10^6	-3.25×10^6
Wald *p*-value									0.00
LR *p*-value									0.00

Table A5. Results of the probit model using the +60 days default definition. The table reports estimation results of the parametric probit regressions. The sample includes 5,591,353 mortgages originated over the period from January 2000 to December 2013. The dependent variable, Default, is a dummy variable denoting mortgage default (i.e., when a mortgage is labelled as +60 days delinquent). FICO score is the borrower's Fair Isaac Corporation score attributed at origination. LTV ratio denotes the initial loan-to-value ratio. ARM stands for adjustable-rate mortgages. Balloon refers to balloon payment mortgages. No/Low doc. indicates whether the originator collected no/low-level documentation. GSE conf. denotes mortgages that conform to the GSE's lending guidelines. GDP growth and HPI growth are growth rates of the U.S. Gross Domestic Product and the House Price Index, respectively. σ interest refers to interest-rate volatility. Credit Spread is the yield difference between AAA and Baa bond indexes. State FE specification controls for state fixed effects using state dummies. Judicial indicates whether the state requires judicial procedures to foreclose on a mortgage. SRR stands for Statutory Right of Redemption and denotes states that have statutory redemption laws. The Pseudo R^2 is expressed in percentage. Wald denotes the *p*-value of the Wald test for the null hypothesis that all coefficients are jointly equal to zero. LR refers to the *p*-value of the likelihood ratio test for the null hypothesis based on configuration II. The asterisks *** refer to significance levels of 1%.

Configuration	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**IIX**	**IX**
A. Fundamental loan and borrower characteristics									
FICO score	−0.0036 ***	−0.0036 ***	−0.0036 ***	−0.0035 ***	−0.0036 ***	−0.0036 ***	−0.0036 ***	−0.0036 ***	−0.0037 ***
LTV ratio	0.0164 ***	0.0166 ***	0.0165 ***	0.0165 ***	0.0164 ***	0.0168 ***	0.0165 ***	0.0166 ***	0.0173 ***
ARM	0.0773 ***	0.1117 ***	0.1087 ***	0.0858 ***	0.0660 ***	0.0587 ***	0.0735 ***	0.0713 ***	0.1010 ***
Balloon	0.6303 ***	0.5647 ***	0.5731 ***	0.5852 ***	0.6350 ***	0.6368 ***	0.6310 ***	0.6240 ***	0.4114 ***
No/Low doc.	0.3740 ***	0.3758 ***	0.3758 ***	0.3721 ***	0.3687 ***	0.3631 ***	0.3736 ***	0.3709 ***	0.3417 ***
GSE Conf.	−0.1844 ***	−0.1817 ***	−0.1798 ***	−0.1825 ***	−0.1810 ***	−0.1871 ***	−0.1823 ***	−0.1819 ***	−0.1475 ***
B. Economic general conditions									
GDP growth		−14.788 ***							−1.8866 ***
C. Housing market conditions									
HPI growth			−3.5125 ***						−7.6803 ***
D. Bond market conditions									
σ interest				0.4624 ***					1.0581 ***
Credit spread					0.3491 ***				1.8732 ***
E. State legal structure									
State FE						Yes			
Judicial							−0.0447 ***		−0.0412 ***
SRR								−0.0752 ***	−0.0737 ***
Intercept	0.5435 ***	0.9450 ***	0.8307 ***	0.1598 ***	0.8735 ***	0.1316 ***	0.5821 ***	0.5876 ***	2.1942 ***
Pseudo R^2	8.50	9.19	8.92	9.12	8.62	9.43	8.52	8.54	11.60
Log-likelihood	-3.41×10^6	-3.39×10^6	-3.40×10^6	-3.39×10^6	-3.41×10^6	-3.38×10^6	-3.42×10^6	-3.42×10^6	-3.30×10^6
Wald *p*-value									0.00
LR *p*-value									0.00

Table A6. Results of the probit model using the 2001–2006 period. The table reports estimation results of the parametric probit regressions. The sample includes 5,086,938 mortgages originated over the period from January 2001 to December 2006. The dependent variable, Default, is a dummy variable denoting mortgage default (i.e., when a mortgage is labelled as +90 days delinquent). FICO score is the borrower's Fair Isaac Corporation score attributed at origination. LTV ratio denotes the initial loan-to-value ratio. ARM stands for adjustable-rate mortgages. Balloon refers to balloon payment mortgages. No/Low doc. indicates whether the originator collected no/low-level documentation. GSE conf. denotes mortgages that conform to the GSE's lending guidelines. GDP growth and HPI growth are growth rates of the U.S. Gross Domestic Product and the House Price Index, respectively. σ interest refers to interest-rate volatility. Credit Spread is the yield difference between AAA and Baa bond indexes. State FE specification controls for state fixed effects using state dummies. Judicial indicates whether the state requires judicial procedures to foreclose on a mortgage. SRR stands for Statutory Right of Redemption and denotes states that have statutory redemption laws. The Pseudo R^2 is expressed in percentage. Wald denotes the *p*-value of the Wald test for the null hypothesis that all coefficients are jointly equal to zero. LR refers to the *p*-value of the likelihood ratio test for the null hypothesis based on configuration II. The asterisks *** refer to significance levels of 1%.

Configuration	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**IIX**	**IX**
A. Fundamental loan and borrower characteristics									
FICO score	−0.0034 ***	−0.0033 ***	−0.0034 ***	−0.0033 ***	−0.0034 ***	−0.0034 ***	−0.0034 ***	−0.0034 ***	−0.0035 ***

Table A6. *Cont.*

Configuration	I	II	III	IV	V	VI	VII	IIX	IX
LTV ratio	0.0169 ***	0.0169 ***	0.0168 ***	0.0172 ***	0.0169 ***	0.0170 ***	0.0170 ***	0.0170 ***	0.0178 ***
ARM	0.0978 ***	0.1157 ***	0.1028 ***	0.1191 ***	0.0820 ***	0.0824 ***	0.0942 ***	0.0930 ***	0.0885 ***
Balloon	0.6464 ***	0.6156 ***	0.6361 ***	0.5640 ***	0.6522 ***	0.6571 ***	0.6469 ***	0.6412 ***	0.4378 ***
No/Low doc.	0.3444 ***	0.3476 ***	0.3455 ***	0.3398 ***	0.3375 ***	0.3379 ***	0.3440 ***	0.3417 ***	0.3064 ***
GSE Conf.	−0.1921 ***	−0.1946 ***	−0.1928 ***	−0.1834 ***	−0.1869 ***	−0.1979 ***	−0.1902 ***	−0.1901 ***	−0.1474 ***
B. Economic general conditions									
GDP growth		−8.4588 ***							11.941 ***
C. Housing market conditions									
HPI growth			−0.7645 ***						−6.5539 ***
D. Bond market conditions									
σ interest				0.6250 ***					1.4068 ***
Credit spread					0.4258 ***				1.8676 ***
E. State legal structure									
State FE						Yes			
Judicial							−0.0413 ***		−0.0402 ***
SRR								−0.0621 ***	−0.0545 ***
Intercept	0.2735 ***	0.4876 ***	0.3351 ***	−0.2557 ***	0.6864 ***	−0.1608 ***	0.3083 ***	0.3090 ***	1.1864 ***
Pseudo R^2	8.22	8.41	8.24	9.37	8.42	9.21	8.24	8.25	11.50
Log-likelihood	-3.03×10^6	-3.03×10^6	-3.03×10^6	-2.99×10^6	-3.03×10^6	-3.00×10^6	-3.03×10^6	-3.03×10^6	-2.92×10^6
Wald *p*-value									0.00
LR *p*-value									0.00

Table A7. Results of the probit model using the 2001–2006 period and +60 days default definition. The table reports estimation results of the parametric probit regressions. The sample includes 5,086,938 mortgages originated over the period from January 2001 to December 2006. The dependent variable, Default, is a dummy variable denoting mortgage default (i.e., when a mortgage is labelled as +60 days delinquent). FICO score is the borrower's Fair Isaac Corporation score attributed at origination. LTV ratio denotes the initial loan-to-value ratio. ARM stands for adjustable-rate mortgages. Balloon refers to balloon payment mortgages. No/Low doc. indicates whether the originator collected no/low-level documentation. GSE conf. denotes mortgages that conform to the GSE's lending guidelines. GDP growth and HPI growth are growth rates of the U.S. Gross Domestic Product and the House Price Index, respectively. σ interest refers to interest-rate volatility. Credit Spread is the yield difference between AAA and Baa bond indexes. State FE specification controls for state fixed effects using state dummies. Judicial indicates whether the state requires judicial procedures to foreclose on a mortgage. SRR stands for Statutory Right of Redemption and denotes states that have statutory redemption laws. The Pseudo R2 is expressed in percentage. Wald denotes the *p*-value of the Wald test for the null hypothesis that all coefficients are jointly equal to zero. LR refers to the *p*-value of the likelihood ratio test for the null hypothesis based on configuration II. The asterisks *** refer to significance levels of 1%.

Configuration	I	II	III	IV	V	VI	VII	IIX	IX
A. Fundamental loan and borrower characteristics									
FICO score	−0.0036 ***	−0.0036 ***	−0.0036 ***	−0.0035 ***	−0.0036 ***	−0.0036 ***	−0.0036 ***	−0.0036 ***	−0.0037 ***
LTV ratio	0.0163 ***	0.0164 ***	0.0163 ***	0.0166 ***	0.0163 ***	0.0163 ***	0.0164 ***	0.0165 ***	0.0172 ***
ARM	0.0775 ***	0.0954 ***	0.0826 ***	0.0986 ***	0.0619 ***	0.0660 ***	0.0740 ***	0.0735 ***	0.0694 ***
Balloon	0.6409 ***	0.6099 ***	0.6303 ***	0.5582 ***	0.6465 ***	0.6543 ***	0.6414 ***	0.6367 ***	0.4336 ***
No/Low doc.	0.3452 ***	0.3486 ***	0.3465 ***	0.3407 ***	0.3383 ***	0.3402 ***	0.3448 ***	0.3431 ***	0.3080 ***
GSE Conf.	−0.1820 ***	−0.1845 ***	−0.1827 ***	−0.1733 ***	−0.1769 ***	−0.1885 ***	−0.1803 ***	−0.1803 ***	−0.1382 ***
B. Economic general conditions									
GDP growth		−8.4972 ***							11.542 ***
C. Housing market conditions									
HPI growth			−0.7942 ***						−6.5161 ***
D. Bond market conditions									
σ interest				0.6198 ***					1.3822 ***
Credit spread					0.4142 ***				1.8360 ***
E. State legal structure									
State FE						Yes			
Judicial							−0.0391 ***		−0.0388 ***
SRR								−0.0502 ***	−0.0428 ***
Intercept	0.5317 ***	0.7481 ***	0.5958 ***	0.0110	0.9336 ***	0.1011 ***	0.5649 ***	0.5605 ***	1.4420 ***
Pseudo R^2	8.31	8.49	8.32	9.43	8.49	9.25	8.32	8.33	11.51
Log-likelihood	-3.08×10^6	-3.07×10^6	-3.08×10^6	-3.04×10^6	-3.07×10^6	-3.04×10^6	-3.08×10^6	-3.08×10^6	-2.97×10^6
Wald *p*-value									0.00
LR *p*-value									0.00

Table A8. Results of the two-stage and bivariate probit models using +60 days default definition. The table reports the estimation results using three parametric approaches: the two-stage instrumental variable probit, the two-stage linear model (Dionne et al. 2015), and the bivariate probit. The sample includes 5,591,353 mortgages originated over the period from January 2000 to December 2013. Income and Divorce are instruments for the endogenous variable Default. Income is the annual growth rate of the U.S. household income. Divorce is the annual rate of divorce in the U.S. Pr(Default = 1) denotes the predicted probability of default from the 1st stage probit regression. Ê(Default) denotes the predicted default from the 1st stage linear model. Default denotes mortgage default (i.e., it is labelled as +60 days delinquent). Switch serv. denoting whether the originator switched the servicer of the deal. FICO score is the borrower's Fair Isaac Corporation score attributed at origination. LTV ratio denotes the initial loan-to-value ratio. ARM abbreviates adjustable-rate mortgages. Balloon refers to balloon payment mortgages. No/Low doc. indicates whether the originator collected no/low documentation. GSE conf. denotes loans that conform to the GSE's lending guidelines. GDP growth and HPI growth are the growth rates of the U.S. Gross Domestic Product and the House Price Index, respectively. σ interest refers to interest-rate volatility. Credit Spread is the yield difference between AAA and Baa bond indexes. Judicial denotes states that require judicial procedures to foreclose on a mortgage. SRR stands for Statutory Right of Redemption and denotes states that have statutory redemption laws. R2 is expressed in percentage and refers to the pseudo R2 for probit models and the adjusted R2 for linear models. ρ is the estimated correlation coefficient for the bivariate probit. The asterisks *** refer to the significant coefficients at the 1% significance level.

Model	**Two-Stage IV Probit**		**DLB Linear Model**			**Bivariate Probit**	
	1st Stage	**2nd Stage**	**1st Stage**	**2nd Stage**	**2nd Stage**	**Default**	**Switch Serv.**
Dependent Var.	**Default**	**Switch Serv.**	**Default**	**Switch Serv.**	**Switch Serv.**		
Instruments							
Income	−0.0006 ***		−0.0002 ***				
Divorce	0.3028 ***		0.2069 ***				
Pr(Default = 1)		0.5197 ***					
Ê(Default)				0.4443 ***	0.1183 ***		
Default					0.3260 ***		
FICO score	−0.0037 ***		−0.0012 ***			−0.0037 ***	−0.0001 ***
LTV ratio	0.0174 ***	0.0030 ***	0.0051 ***	0.0007 ***	0.0007 ***	0.0174 ***	0.0030 ***
ARM	0.1018 ***	−0.1840 ***	0.0371 ***	−0.0749 ***	−0.0749 ***	0.1005 ***	−0.1712 ***
Balloon	0.4097 ***	−0.0194 ***	0.1557 ***	−0.0435 ***	−0.0435 ***	0.4053 ***	0.0582 ***
No/Low doc.	0.3416 ***	0.1590 ***	0.1087 ***	0.0472 ***	0.0472 ***	0.3431 ***	0.1696 ***
GSE Conf.	−0.1446 ***	0.0785 ***	−0.0426 ***	0.0676 ***	0.0676 ***	−0.1434 ***	0.0015
GDP growth	−4.7726 ***	4.3899 ***	−1.8273 ***	3.5229 ***	3.5229 ***	−1.8682 ***	−0.5094 ***
HPI growth	−7.6137 ***	−5.8278 ***	−2.5897 ***	−0.9331 ***	−0.9331 ***	−7.6081 ***	−7.7881 ***
σ interest	0.9214 ***	0.6408 ***	0.2792 ***	0.1016 ***	0.1016 ***	1.0572 ***	0.8377 ***
Credit spread	1.9721 ***	1.1882 ***	0.6366 ***	0.0236 ***	0.0236 ***	1.8768 ***	1.9701 ***
Judicial	−0.0416 ***	0.0122 ***	−0.0130 ***	0.0062 ***	0.0062 ***	−0.0410 ***	0.0019
SRR	−0.0729 ***	0.0294 ***	−0.0233 ***	0.0118 ***	0.0118 ***	−0.0743 ***	0.0326 ***
$\mathbf{R^2}$	11.7	38.0	14.1	31.2	38.6		
ρ						0.6190 ***	

Table A9. Results of the two-stage and bivariate probit models using the 2001–2006 period. The table reports the estimation results using three parametric approaches: the two-stage instrumental variable probit, the two-stage linear model (Dionne et al. 2015), and the bivariate probit. The sample includes 5,086,938 mortgages originated over the period from January 2001 to December 2006. Income and Divorce are instruments for the endogenous variable Default. Income is the annual growth rate of the U.S. household income. Divorce is the annual rate of divorce in the U.S Pr(Default = 1) denotes the predicted probability of default from the 1st stage probit regression. Ê(Default) denotes the predicted default from the 1st stage linear model. Default denotes mortgage default (i.e., it is labelled as +90 days delinquent). Switch serv. denoting whether the originator switched the servicer of the deal. FICO score is the borrower's Fair Isaac Corporation score attributed at origination. LTV ratio denotes the initial loan-to-value ratio. ARM abbreviates adjustable-rate mortgages. Balloon refers to balloon payment mortgages. No/Low doc. indicates whether the originator collected no/low documentation. GSE conf. denotes loans that conform to the GSE's lending guidelines. GDP growth and HPI growth are the growth rates of the U.S. Gross Domestic Product and the House Price Index, respectively. σ interest refers to interest-rate volatility. Credit Spread is the yield difference between AAA and Baa bond indexes. Judicial denotes states that require judicial procedures to foreclose on a mortgage. SRR stands for Statutory Right of Redemption and denotes states that have statutory redemption laws. R^2 is expressed in percentage and refers to the pseudo R^2 for probit models and the adjusted R^2 for linear models. ρ is the estimated correlation coefficient for the bivariate probit. The asterisks *** refer to the significant coefficients at the 1% significance level.

Model	**Two-Stage IV Probit**		**DLB Linear Model**			**Bivariate Probit**	
	1st Stage	**2nd Stage**	**1st Stage**	**2nd Stage**	**2nd Stage**	**Default**	**Switch Serv.**
Dependent Var.	**Default**	**Switch Serv.**	**Default**	**Switch Serv.**	**Switch Serv.**		
Instruments							
Income	−0.0012 ***		−0.0004 ***				
Divorce	3.8303 ***		1.3157 ***				
Pr(Default=1)		0.6350 ***					
Ê(Default)				0.3639 ***	0.0550 ***		
Default					0.3089 ***		
FICO score	−0.0035 ***		−0.0011 ***			−0.0035 ***	−0.0001 ***
LTV ratio	0.0181 ***	0.0004 ***	0.0050 ***	0.0002 ***	0.0002 ***	0.0179 ***	0.0031 ***
ARM	0.0926 ***	−0.2652 ***	0.0328 ***	−0.0912 ***	−0.0912 ***	0.0866 ***	−0.2397 ***
Balloon	0.4051 ***	−0.0681 ***	0.1604 ***	−0.0403 ***	−0.0403 ***	0.4340 ***	0.0663 ***
No/Low doc.	0.2985 ***	0.0895 ***	0.0904 ***	0.0296 ***	0.0296 ***	0.3079 ***	0.1282 ***
GSE Conf.	−0.1384 ***	0.0823 ***	−0.0376 ***	0.0550 ***	0.0550 ***	−0.1427 ***	0.0196 ***
GDP growth	7.5664 ***	16.7512 ***	1.8333 ***	7.3254 ***	7.3254 ***	11.7905 ***	18.9797 ***
HPI growth	−3.3490 ***	−5.6139 ***	−1.1534 ***	−0.8432 ***	−0.8432 ***	−6.4116 ***	−6.9225 ***
σ interest	0.5626 ***	1.0320 ***	0.1439 ***	0.2578 ***	0.2578 ***	1.3962 ***	1.3139 ***
Credit spread	1.7920 ***	1.6191 ***	0.5576 ***	0.1905 ***	0.1905 ***	1.8542 ***	1.9820 ***
Judicial	−0.0420 ***	0.0109 ***	−0.0127 ***	0.0062 ***	0.0062 ***	−0.0410 ***	0.0088 ***
SRR	−0.0525 ***	0.0467 ***	−0.0162 ***	0.0161 ***	0.0161 ***	−0.0545 ***	0.0553 ***
R^2	12.1	38.0	14.0	30.4	37.3		
ρ						0.6004 ***	

Table A10. Results of the two-stage and bivariate probit models using the 2001–2006 period and +60 days default definition. The table reports the estimation results using three parametric approaches: the two-stage instrumental variable probit, the two-stage linear model (Dionne et al. 2015), and the bivariate probit. The sample includes 5,086,938 mortgages originated over the period from January 2001 to December 2006. Income and Divorce are instruments for the endogenous variable Default. Income is the annual growth rate of the U.S. household income. Divorce is the annual rate of divorce in the U.S Pr(Default = 1) denotes the predicted probability of default from the 1st stage probit regression. Ê(Default) denotes the predicted default from the 1st stage linear model. Default denotes mortgage default (i.e., it is labelled as +60 days delinquent). Switch serv. denoting whether the originator switched the servicer of the deal. FICO score is the borrower's Fair Isaac Corporation score attributed at origination. LTV ratio denotes the initial loan-to-value ratio. ARM abbreviates adjustable-rate mortgages. Balloon refers to balloon payment mortgages. No/Low doc. indicates whether the originator collected no/low documentation. GSE conf. denotes loans that conform to the GSE's lending guidelines. GDP growth and HPI growth are the growth rates of the U.S. Gross Domestic Product and the House Price Index, respectively. σ interest refers to interest-rate volatility. Credit Spread is the yield difference between AAA and Baa bond indexes. Judicial denotes states that require judicial procedures to foreclose on a mortgage. SRR stands for Statutory Right of Redemption, and denotes states that have statutory redemption laws. R^2 is expressed in percentage and refers to the pseudo R^2 for probit models and the adjusted R^2 for linear models. ρ is the estimated correlation coefficient for the bivariate probit. The asterisks **, and *** refer to the significant coefficients at the 5%, and 1% significance levels, respectively.

Model	**Two-Stage IV Probit**		**DLB Linear Model**			**Bivariate Probit**	
	1st Stage	**2nd Stage**	**1st Stage**	**2nd Stage**	**2nd Stage**	**Default**	**Switch Serv.**
Dependent Var.	**Default**	**Switch Serv.**	**Default**	**Switch Serv.**	**Switch Serv.**		
Instruments							
Income	−0.0012 ***		−0.0004 ***				
Divorce	3.7299 ***		1.3072 ***				
Pr(Default = 1)		0.5789 ***					
Ê(Default)				0.3292 ***	0.0136 ***		
Default					0.3156 ***		
FICO score	−0.0038 ***		−0.0012 ***			−0.0037 ***	−0.0001 ***
LTV ratio	0.0174 ***	0.0001 **	0.0049 ***	0.0004 ***	0.0004 ***	0.0172 ***	0.0031 ***
ARM	0.0734 ***	−0.2599 ***	0.0269 ***	−0.0881 ***	−0.0881 ***	0.0690 ***	−0.2402 ***
Balloon	0.4015 ***	−0.0562 ***	0.1566 ***	−0.0329 ***	−0.0329 ***	0.4295 ***	0.0663 ***
No/Low doc.	0.3003 ***	0.0931 ***	0.0929 ***	0.0319 ***	0.0319 ***	0.3090 ***	0.1280 ***
GSE Conf.	−0.1294 ***	0.0791 ***	−0.0370 ***	0.0531 ***	0.0531 ***	−0.1337 ***	0.0191 ***
GDP growth	7.3051 ***	16.9002 ***	1.8576 ***	7.4274 ***	7.4274 ***	11.4314 ***	18.9506 ***
HPI growth	−3.4066 ***	−5.7247 ***	−1.1831 ***	−0.9145 ***	−0.9145 ***	−6.4057 ***	−6.9189 ***
σ interest	0.5607 ***	1.0537 ***	0.1501 ***	0.2713 ***	0.2713 ***	1.3720 ***	1.3126 ***
Credit spread	1.7675 ***	1.6508 ***	0.5631 ***	0.2088 ***	0.2088 ***	1.8242 ***	1.9798 ***
Judicial	−0.0406 ***	0.0102 ***	−0.0125 ***	0.0058 ***	0.0058 ***	−0.0388 ***	0.0089 ***
SRR	−0.0409 ***	0.0438 ***	−0.0125 ***	0.0144 ***	0.0144 ***	−0.0435 ***	0.0558 ***
R^2	12.0	38.0	14.2	30.4	37.7		
ρ						0.6230 ***	

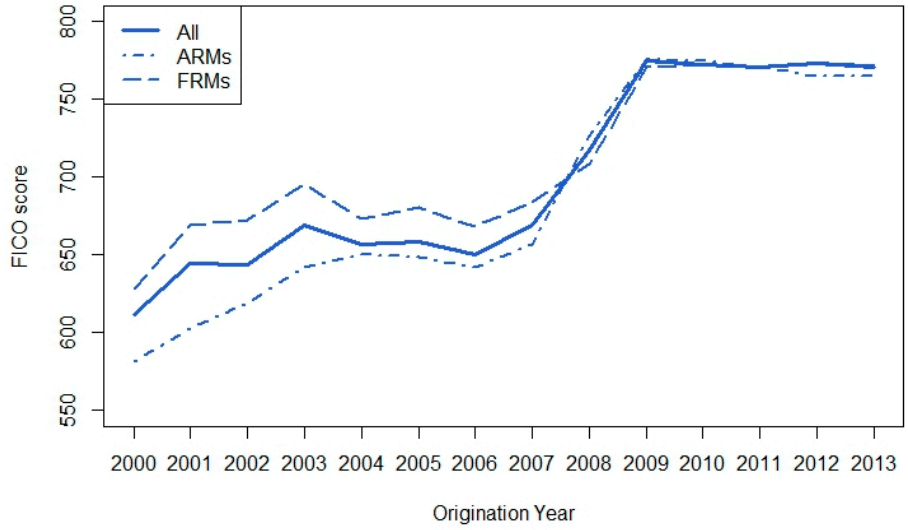

Figure A1. FICO scores at origination by payment type.

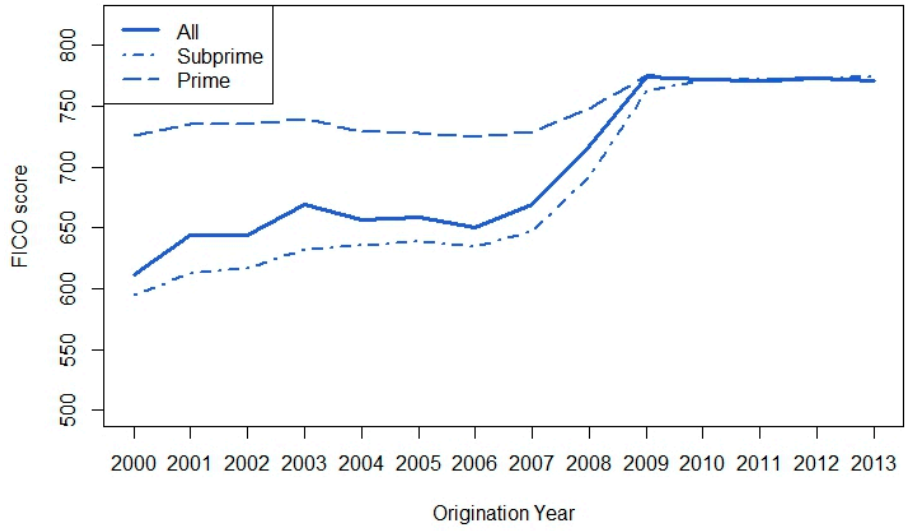

Figure A2. FICO scores at origination by loan type.

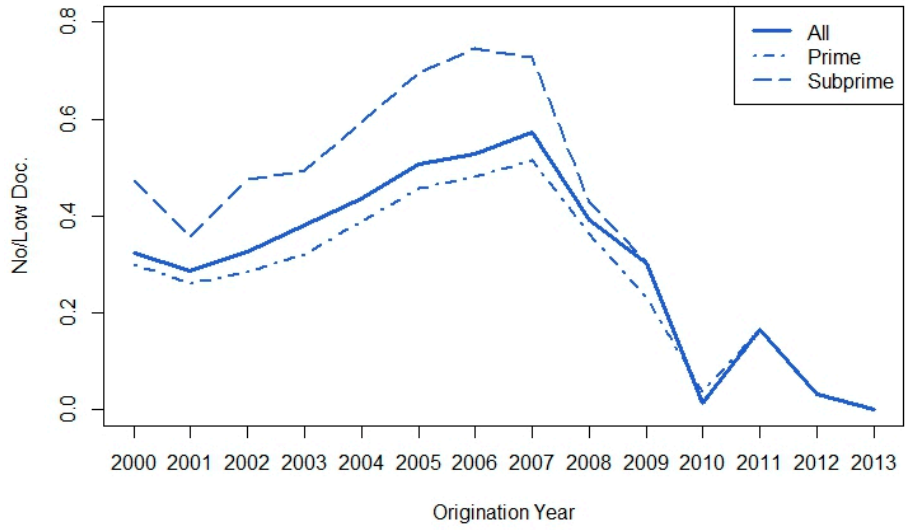

Figure A3. No/Low documentation at origination by payment type.

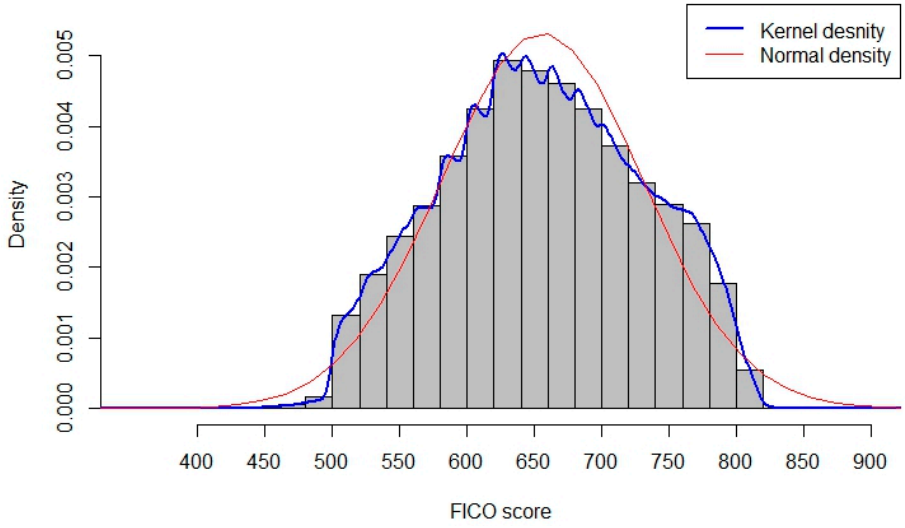

Figure A4. Kernel density fitting of the FICO score.

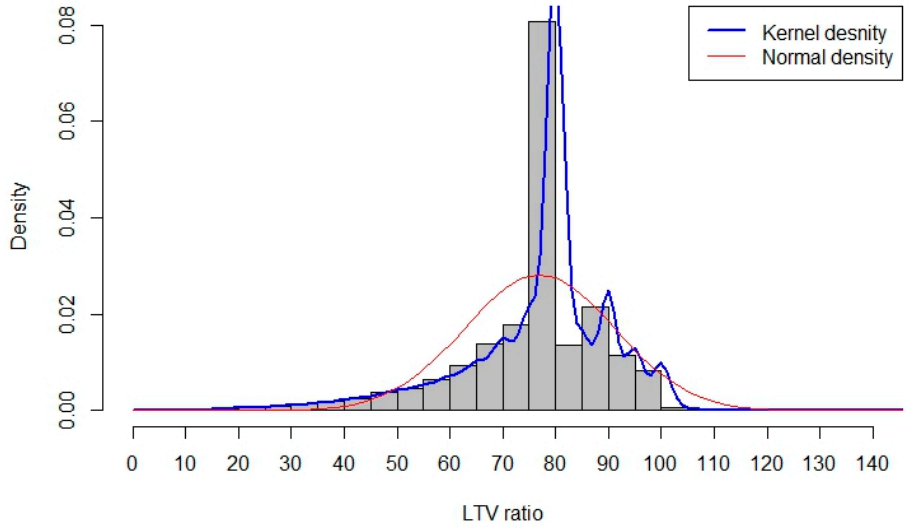

Figure A5. Kernel density fitting of the LTV ratio.

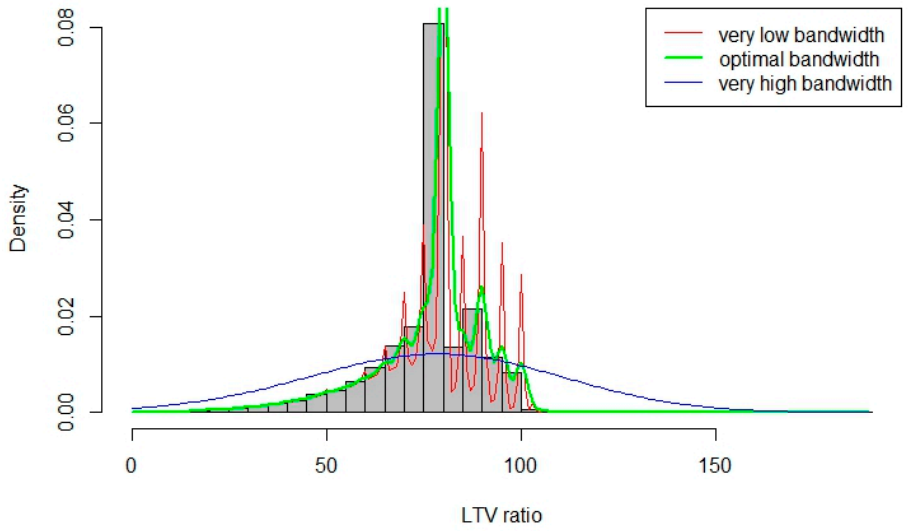

Figure A6. Fitting of the KDE with multiple bandwidths.

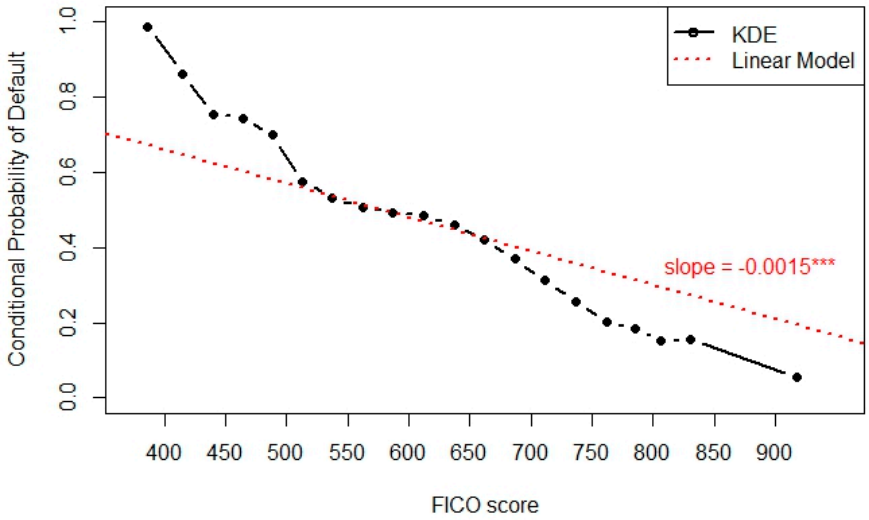

Figure A7. FICO score vs. conditional probability of default.

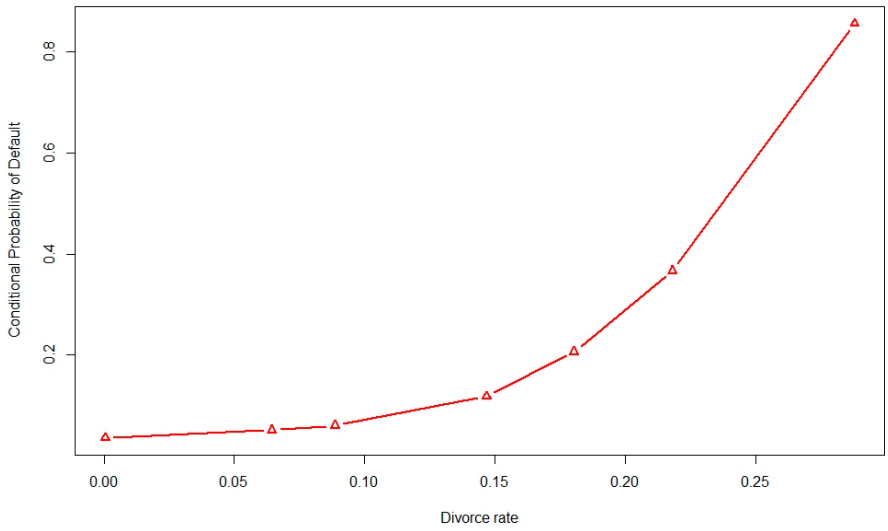

Figure A8. Divorce rate vs. expected probability of mortgage default.

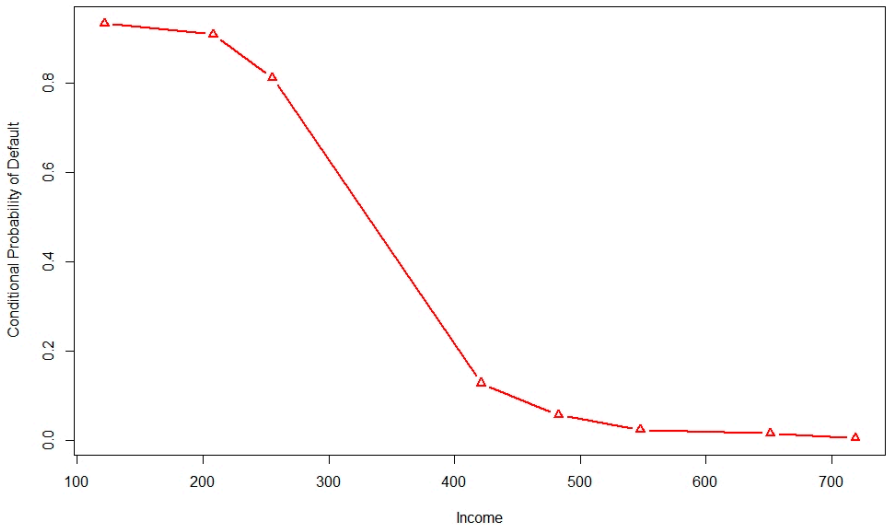

Figure A9. Income level vs. expected probability of mortgage default.

Note

[1] The contents of this section are based on the report of the Mortgage Bankers Association (MBA) and PwC US (PricewaterhouseCoopers) (2015), and the report to Congress by the Board of Governors of the Federal Reserve System (2016).

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The Role of Credit Consortia in the Financial Structure of Sardinian Companies During the SARS-CoV-2 Crisis

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Abstract: In this paper, we analyzed the role of credit consortia in supporting SMEs of the Italian region of Sardinia around and during the SARS-CoV-2 pandemic crisis. Credit consortia (or credit guarantee schemes) are financial companies whose institutional role is to support small firms needing bank lending who are individually weak in the bank–firm relationship. Credit consortia are particularly relevant in Italy, where they mitigate credit restrictions for SMEs by supplying guarantees to the bank, allowing for partial coverage of potential losses, providing peer-monitoring activity, and collectively negotiating more favorable interest rates and other conditions with banks. During the SARS-CoV-2 pandemic, credit consortia had a crucial role in supporting Sardinian SMEs with guarantees and obtaining government financial support. The evolution of Sardinian companies' financial structures during the SARS-CoV-2 pandemic shows that the confidi-supported firms have low capitalization and are financially fragile yet capable of good returns. The liquidity provided by the government during the pandemic loosened these constraints, boosting the available liquidity, which translated, in short, into higher investment and higher sales. The demographics of Sardinian companies in 2019–2022 and the volumes of loans and savings showed a strengthening of debt capital payments, increased collections, and a progressive improvement of the Sardinian companies' net financial positions.

Keywords: credit consortia; SARS-CoV-2 pandemic; bank–firm relationship; SMEs

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1. Introduction

Credit consortia (or credit guarantee schemes) are financial companies whose institutional role is to support small firms needing bank lending who are individually weak in the bank–firm relationship. According to Leone et al. (2013), credit consortia "offer mutualistic guarantees aimed at alleviating financial constraints on their small or medium-sized shareholding or syndicated enterprises". Credit consortia are particularly relevant in Italy, accounting for almost 40 percent of the total outstanding volume of guarantees to SMEs (Columba et al. 2010).

Technically, credit consortia mitigate credit restrictions for SMEs by supplying guarantees to the lending bank, allowing for partial coverage of potential losses, providing peer-monitoring activity, and acting like debtors' unions for collectively negotiating more favorable interest rates and other conditions with banks.

Usually, credit consortia are strictly linked with business associations, which helps with information sharing among firms within the business association and the credit consortia and allows for some lobbying activity.

Credit consortia played a significant role during the SARS-CoV-2 pandemic, supporting SMEs with guarantees and easing the bank–firm relationship in all credit processes.

In this paper, we analyzed the evolution of Sardinian SMEs' financial equilibrium and the role played by credit consortia in supporting it during and after the SARS-CoV-2 pandemic.

In 2020, Italy was one of the European countries most affected by the pandemic, which caused significant contractions in the business economy. According to the Centro Studi Confcommercio (CSC) (2024), Italy's Gross Domestic Product (GDP) lost EUR 139 billion, or over EUR 2600 per inhabitant. The supply and demand crisis impacted specific economic activity sectors and aggregate variables. Of the EUR 139 billion in lost product in 2020, approximately EUR 129 billion were attributed to the collapse of domestic consumption, including spending by non-residents in Italy.

Das (2020) highlights territorial differences in the forecasted and actual growth rates between countries, emphasizing how policies against the pandemic and vaccination campaigns affected trends and growth rates.

These territorial differences affected the incidence numbers and the level of government restrictions. According to the "Osservatorio Nazionale sulla Salute nelle Regioni Italiane (2021, November)" report, SARS-CoV-2 infections in Sardinia initially remained lower than in other Italian regions, particularly during the early stages of the pandemic in 2020. However, by late 2020 and early 2021, Sardinia saw a significant rise in cases, aligning with the national trend. Despite this, the region did not face the same level of healthcare strain as northern Italy. Throughout 2021, as vaccines were rolled out, the case numbers stabilized, although fluctuations remained due to new variants. Sardinia's trajectory generally mirrored national patterns, with some regional variations in infection rates and healthcare system pressure.

In 2021, thanks to the vaccination campaign and the subsequent reduction in the spread of infections and easing restrictions, Italy recovered about two-thirds of the GDP contraction seen in 2020, with a GDP growth of +6.6%.

In early 2021, Sardinia's regional economy remained weak, being influenced by the complex epidemiological situation and restrictions on social activities, which severely impacted the tourism sector. In Sardinia, the crisis primarily affected the services sector, which was highly sensitive to containment measures, particularly in tourism, transport, entertainment, and non-food retail. The industrial sector also faced contractions, with significant reductions in the chemical and oil industries. Corporate profitability decreased due to lower turnover, leading to an increased need for liquidity, which was met through expanded credit and public support measures, as will be discussed later.

During 2021, economic activity showed significant improvements from April to June, followed by more moderate growth in the second half of the year, as the Bank of Italy estimated in its quarterly regional economy report (Bank of Italy, 2021 and 2022). Increased consumption, a modest investment rebound, and growing foreign demand for key Sardinian products supported this recovery. However, estimates by Prometeia () indicated that by the end of 2021, Sardinia's GDP was still 4.5% lower than pre-pandemic levels.

In the manufacturing sector, economic conditions improved unevenly across different sectors. The global economic slowdown continued into the last quarter of 2021, being driven by the rise in infections linked to the Omicron variant, production input shortages, and geopolitical tensions that culminated with Russia's invasion of Ukraine. These tensions led to a significant increase in raw material prices, particularly energy, exacerbated by the Russia–Ukraine conflict in 2022. Despite these challenges, in 2021, the profitability of Sardinian companies strengthened, being primarily driven by increased sales but partially constrained by rising prices for energy, commodities, and other raw materials, especially in the manufacturing sector. Corporate liquidity remained high, supported by favorable access to credit, but investment activity remained limited, especially in the industrial sector.

At the national level in 2020, according to Banca d'Italia (2023a), Italian banks continued to meet companies' demands for financing. Supply conditions remained generally favorable, being supported by ongoing monetary policy measures and public guarantees. According to the Ufficio Studi ABI—Associazione Bancaria Italiana (2024), loans in Italy

grew by 4.1% in 2020 compared to the previous year, with Sardinia showing a slightly higher growth of 4.3%. This trend held even when focusing solely on production activities, with Sardinia recording an increase of 8.8%, close to the national figure of 8.4%. These data suggest that despite the economic challenges generated by the pandemic, Italian banks continued to support businesses through financing, being aided by monetary policies and government guarantees.

The financial structure of Sardinian companies and the role of regional credit consortia (confidi) during the SARS-CoV-2 pandemic revealed that firms supported by confidi were typically low-capitalized and financially fragile. However, these firms could generate good returns, and the liquidity provided by government measures during the pandemic alleviated these constraints. The government support led to higher available liquidity, translating into increased investment and sales in the short term. Evidently, this government spending had more macro-effects, but discussing these effects is beyond the scope of this paper.

The remainder of the paper is structured as follows: Section 2 presents the literature review, Section 3 outlines the Sardinian economic framework, Section 4 discusses the evolution of the pandemic, Section 5 compares the differential evolution of a general sample and confidi-supported firms, and Section 6 discusses the results and concludes.

2. Literature Review

Our study aims to examine the role of credit consortia (also known as credit guarantee schemes, CGSs, or mutual guarantee societies, MGSs) on Sardinian SMEs during and after the SARS-CoV-2 pandemic crisis. Numerous studies in the literature have investigated related questions, providing a foundation for understanding the financial challenges SMEs face during economic downturns and the role of credit consortia in supporting these businesses.

The literature review refers to three key areas: (1) studies examining credit consortia during the SARS-CoV-2 pandemic and other crises, (2) research analyzing SME behaviors in Italy during past economic crises, and (3) investigations into changes in financial structures influenced by the SARS-CoV-2 pandemic. This organization highlights how credit consortia have worked as financial stabilizers during crises, provides insights into SMEs' crisis responses in Italy, and examines the broader shifts in financial structures brought about by pandemic-related disruptions.

Several studies have focused on the Spanish credit market, specifically investigating the role of credit consortia, mainly called MGSs. In their paper, Corredera-Catalán et al. (2021) explore the Spanish guarantee model and how regional governments, in collaboration with MGSs, responded to the economic difficulties caused by the SARS-CoV-2 pandemic. Their study underscores the effectiveness of the guarantee schemes used by public administrations to improve SMEs' access to financing, helping stabilize the economy while minimizing the strain on public finances. Similar to our study, they evaluate the role of MGSs during crisis periods but focus solely on their effectiveness in supporting the lending capacity without analyzing the financial performances of the financed firms. Unlike our study, they do not incorporate balance sheet variables to assess firm performance during the crisis period.

De la Fuente-Cabrero et al. (2019) evaluated loan defaults in the portfolios of Spanish MGSs to understand their evolution between 2003 and 2012, covering both economic growth and recession periods. They highlight how MGS support influences the distribution of defaults based on the company size and sector of activity. However, this study investigated MGS lending using different risk factors. And it did not compare the financial performances of firms that used MGSs with those that obtained financing directly from banks or were not supported, as we do in our research.

Gómez et al. (2016) investigated SME access to financing through MGSs in Spain during the 2010 economic crisis. Their findings indicate that SMEs with MGS-backed financing generally had better access to bank loans than those without such guarantees.

However, the impact of reducing financing costs was less conclusive. Our results will show that for Sardinian firms, the cost of financing is higher when the funding source is an MGS.

Briozzo and Cardone-Riportella (2016) examine Spanish SMEs' access to credit and subsidies with credit guarantees during crisis periods compared to standard years. Similar to our study, they compare direct credit channels through official credit institutions with bank credit guaranteed by MGSs. They highlight that these guarantees can serve as countercyclical tools, noting that mutual guarantee schemes cover only a limited portion of the Spanish credit market, indicating a relatively reduced role in credit guarantee activities.

While other studies have investigated the behavior of Italian MGSs before the pandemic, research has yet to focus on their response to the recent economic crisis caused by SARS-CoV-2 in Italy. Considering less recent publications on the Italian credit market, Gai et al. (2016) analyzed the determinants of defaults among firms that received SME loans guaranteed by MGSs and counter-guaranteed by the Italian Central Guarantee Fund from 2010 to 2011. They found that the proportion of counter-guaranteed loans in MGS portfolios increases the default risk. This can be explained by the fact that SMEs financed through MGSs are smaller and more vulnerable during crises. In our study, we will demonstrate how support from MGSs enables these SMEs to access essential resources, fostering positive growth trends. This support is well invested in businesses that, without MGSs, would likely be unable to secure the resources needed to withstand economic downturns.

Caselli et al. (2021) examined the loan failure risk associated with public credit guarantees, distinguishing between banks and MGSs. Their study assessed the Italian SME credit market during the 2008 crisis, finding that banks provided better loan screening in the manufacturing sector than MGSs despite the challenges of evaluating smaller enterprises. Cusmano (2018) studied the relationship between credit guarantee schemes and MGSs across European countries, examining their role in supporting SME financing during the 2008 financial crisis. The findings suggest that guarantee schemes are most effective when they deeply understand the market and industry dynamics specific to the SMEs they support. These publications on the Italian market are relevant because they allow us to compare similar scenarios in which public intervention prevents financial difficulties for vulnerable businesses during times of crisis. Like these publications, our results highlight the resilience of SMEs due to public intervention.

Another area of research has extensively examined the impact of the SARS-CoV-2 pandemic on firms' financial structures, focusing on how shifts in economic conditions and increased uncertainty have affected capital allocation, debt management, and financial stability. Studies such as those of Halling et al. (2020), Acharya and Steffen (2020), Li et al. (2020), and Gopalakrishnan et al. (2022) indicate that during periods of heightened uncertainty, firms' capital structure decisions have led to an increase in debt financing. This greater reliance on debt can be linked to firms' precautionary needs and the financial challenges posed by crisis conditions. Additional studies by Prakash et al. (2023), Huang and Ye (2021), and Nguyen Kim (2023) investigate the pandemic's impact on the capital structure and debt levels of firms in India, China, and Vietnam, respectively. Additionally, D'Amato (2020) studied Italian SMEs before and after the global financial crisis, emphasizing that the short-term debt channel is more sensitive than the long-term one, supporting the findings of previously cited articles.

Similarly, Wang et al. (2024) demonstrates that extending debt maturity in response to SARS-CoV-2 shocks helps firms avoid potential maturity constraints, lowers debt financing costs, and alleviates liquidity pressures. In a crisis scenario, particularly during a pandemic shock, the uncertainty in the external environment amplifies risks from asset-liability maturity mismatches, leading to a decline in firm performance. Extending debt maturity can help alleviate these mismatches.

Considering the Italian credit market, SMEs' debt levels were supported by government intervention, which provided them with easier access to financial resources during the pandemic. Analyzing the performances of these financed firms will help determine whether, without public guarantees, these SMEs would have had sufficient internal resources to

achieve positive performance. Unlike the previously cited studies, which primarily focus on the financial structures of firms during the SARS-CoV-2 crisis, our research examines the performances of financed firms by tracking changes in financial indicators. We analyze shifts in debt and capitalization levels during the pandemic, highlighting that firms using MGSs exhibit higher debt exposure compared to the broader firm population that used direct bank financing. Typically smaller in size, these firms tend to prefer debt over equity due to the support provided by public credit guarantees.

Considering the three literature streams, financial support is one of the simpler and quicker responses for supporting the real economy during financial or economic crises. The experiences of the 2008–2012 crisis highlight that credit guarantees can effectively minimize the strain on public finances while helping SMEs overcome the crisis. In these cases, MGSs prove to be locally effective when they deeply understand the market and industry dynamics specific to the SMEs they support, and the intervention result most suited in these cases is the double support of immediate liquidity provision and debt maturity extension, so as to keep the firms' financial equilibrium.

Regarding methodology, the paper by Khurana et al. (2024) adopts a similar approach to ours. It analyzes the effects of SARS-CoV-2 on firm performance across various industries by examining liquidity and financial ratios, including the net working capital, quick ratio, debt–equity ratio, and financial autonomy rate. This study indicates a negative impact on specific sectors. It reveals a positive relationship between debt financing, working capital management, and firm performance while finding a negative correlation with financial autonomy. In our study, the average debt level is higher for MGS-supported firms due to their smaller size and reliance on government financial support, leading them to prefer external assistance over financial autonomy. While the study by Khurana et al. (2024) analyzes firms' responses to the crisis, our research distinguishes itself by comparing the performances of firms that are not supported with those supported through MGSs.

The SARS-CoV-2 pandemic has severely impacted SMEs, highlighting the need for effective financial support mechanisms. MGSs are crucial in providing credit guarantees to firms, particularly during economic crises. Our study aims to investigate the effects of SARS-CoV-2 on SME credit and explore the role of MGSs in supporting these businesses during this challenging time.

Additionally, our study differs from the cited works, as we use financial data both from firms financed through direct lending channels and those not and compare these with firms financed through the intermediary channel of MGSs. Only some studies in the literature have access to such detailed data for multiple years on firms supported by MGSs, as these entities are typically private, which adds value to our research.

Our methodology is based on a descriptive approach, focusing on the evolution of financial data before and after the pandemic. Despite extensive research on MGSs, significant gaps remain. Most studies focus on pre-pandemic periods or past economic crises, neglecting the recent challenges posed by SARS-CoV-2 in Italy. While many examine the lending capacity of MGSs, they often do not pay adequate attention to the financial performance of the firms they support. Moreover, the existing literature primarily examines MGSs in contexts outside of Italy, leading to a need for updated research specific to the Italian landscape during and after the pandemic.

Our study addresses these gaps by providing an analysis of MGSs during the SARS-CoV-2 pandemic and incorporating balance sheet variables to evaluate the financial performance of firms that receive MGS-backed financing compared to those utilizing direct lending channels. By leveraging comprehensive financial data over multiple years, our research will offer valuable insights into the effectiveness of MGS support, ultimately informing policymakers and financial institutions about enhancing SME resilience during crises.

3. The Sardinia Framework

During the SARS-CoV-2 crisis, the number of registered companies showed a slight increase compared to pre-pandemic years due to the effects of support measures in terms

of liquidity, credit, and fiscal and social security provisions, followed by a decline in 2022 (Figure 1). More in detail, a significant decline is observed in the number of companies in the trade sector, with a reduction of 931 units from December 2019 to December 2021 (reaching a decline of 1850 companies by the end of 2022). The manufacturing sector decreased by over 4.7%, the extractive sector declined by 11.1%, and transport and logistics contracted by approximately 3.1%. Sectors showing growth, as expected, include health services (+13.2%), real estate activities (+12.3%), electricity and gas supply (+12.0%), and business services (+6.8%).

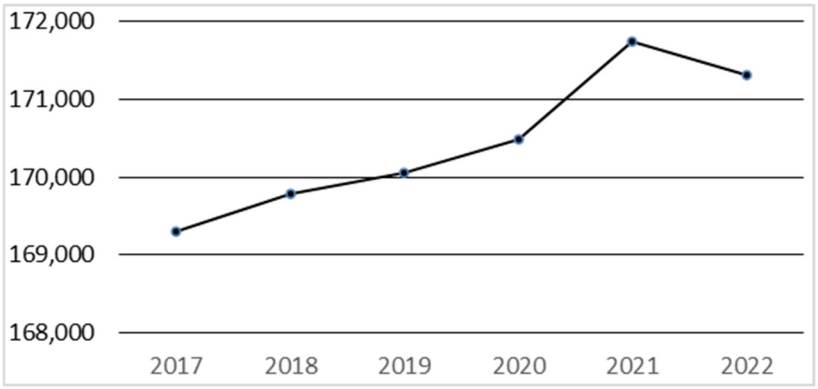

Figure 1. Total number of companies in Sardinia, years 2017–2022. Source: own elaborations on InfoCamere data.

3.1. Government Financial Support

To ensure resilience in the economic system during the SARS-CoV-2 emergency, it was crucial to preserve the levels of credit leverage, particularly in fragile or partially compromised economic scenarios. This included implementing guidelines set by the Italian government to maintain the effective functioning of the banking–business system. In response to the crisis, the Italian government focused on strengthening public guarantee funds rather than directly injecting liquidity into the production system or households. This strategy maintained the role of banks as financial intermediaries and encouraged a quantitative expansion of credit.

An essential role was also given to the "private" guarantees provided by credit consortia, which further reduced bank provisions and mitigated risks through increased counter-guarantees offered by the Central Guarantee Fund for SMEs (FCG). Legislative Decrees No. 18, 20, and 34 of 2020 (known as "Cura Italia", "Liquidità", and "Rilancio") primarily allocated resources toward direct public guarantees, with zero weighting on provisions and reinsurance for credit guarantee consortia. These measures helped to prevent an additional credit crunch, counteracting the decline in creditworthiness caused by the lockdown and averting potential crises in both the corporate and banking sectors.

While reducing credit leverage below a certain threshold may initially appear beneficial for banks due to lower provisions and reduced risk indicators, prolonged credit restriction threatens the stability of the production and entrepreneurial landscapes (Desogus and Casu 2020). Our analysis highlights the effectiveness of government measures and the significant role of credit consortia in preventing this adverse dynamic, supporting corporate liquidity and, ultimately, system stability.

3.2. Loans

During 2020, the Italian government implemented several actions to counteract the effects of the pandemic on the national economy and promote credit inclusion (Senato della Repubblica Italiana 2023). These actions, included in the aforementioned legislative decrees, were based on the extensive use of public guarantees and characterized by several key features:

- Free guarantee: the public guarantee was provided at no cost.
- Increase in the maximum guaranteed amount: the maximum guaranteed amount per company was raised from EUR 2.5 million to EUR 5 million.
- Increased coverage percentages of the FCG: coverage percentages from the Guarantee Fund for SMEs (FCG) were enhanced, with a direct guarantee of 80% and reinsurance of 90%.
- Granting guarantees without a credit assessment: guarantees were granted without a credit assessment, allowing companies across all rating ranges to be eligible.
- Suspension of mortgage payments: mortgage payments were suspended, with an automatic extension of any public guarantee.
- Consolidation/renegotiation operations: these operations were allowed within the same bank or banking group for loans not already covered by the FCG.
- Use of the Temporary Aid Framework: this framework provided a 100% guarantee for financing up to EUR 30,000 and increased FCG coverage to 90% for direct guarantees and 100% for reinsurance.

These measures increased public guarantees and, more broadly, helped to revitalize the role of credit consortia (confidi), which benefited from enhanced reinsurance coverage by the FCG, generating a more significant weighting effect. From the beginning of the SARS-CoV-2 emergency until the end of 2020, the largest number of operations benefiting from FCG guarantees were those of smaller size, with an average value of less than EUR 30,000 (100% covered), representing 63.56% of the accepted requests. These operations accounted for more than EUR 21 billion in guarantees (Fondo di Garanzia 2024a), with an average unit value of EUR 19,600. However, this category had a much lower impact (15.7%) on the total guaranteed values in the same period.

The interventions were designed specifically to reduce bureaucratic formalities, enabling near-automatic evaluations for immediate credit availability. These operations were primarily managed by banks, with credit consortia focusing on smaller-scale operations for micro-, small-, and medium-sized enterprises (mPMI). This shifted the role of confidi, which traditionally dealt with smaller-sized operations, as banks had previously expressed opposition due to the complexity of automating the investigation process, especially for sole proprietorships, partnerships, artisan businesses, start-ups, and companies with few years of activity. These businesses not only require guarantees but also support to access credit.

In practice, the banking sector's activity smoothed the potential growth of confidi-supported firms with the SARS-CoV-2 measures. However, a "carryover" effect bolstered the reinsurance activity of 2020 by confidi, with a national increase of 91.5% (from EUR 1596 to 3057 million) and a 30.8% rise at the regional level (from EUR 57 to 75 million). In 2021, FCG guarantees decreased from EUR 105.9 billion to EUR 67.6 billion (-36.1%), gradually returning to previous standards. In Sardinia, as illustrated by the tables and graphs below, the risk transfer to the state helped maintain a positive trend in corporate net liquidity.

The value of loans to businesses (Figure 2) stabilized the bank–business relationship, counteracting the shocks caused by the crisis and showing a slight increase. In Sardinia, aggregate data on business loans showed a +12.3% increase between 2020 and 2019, with a further +3.3% increase between 2021 and 2020 (end-of-year data). The overall intervention of the Central Fund (direct guarantees and counter-guarantees on confidi operations) increased from 2.6% in 2019 (pre-pandemic) to a peak of 18.95% in 2020, stabilizing at 12.7% in 2021. From 2020 to 2021, credit support for "Industrial Activities" grew by +29.3%, for "Services" by +13.9%, and for "Construction and Building" by +12.2%. In terms of firm size, which is influenced by the structure of the Italian and Sardinian economies, credit leverage for micro-enterprises grew by +10.2% between 2020 and 2022. Medium–large companies recorded a +6.1% increase, while small companies experienced a slight contraction of -0.5%.

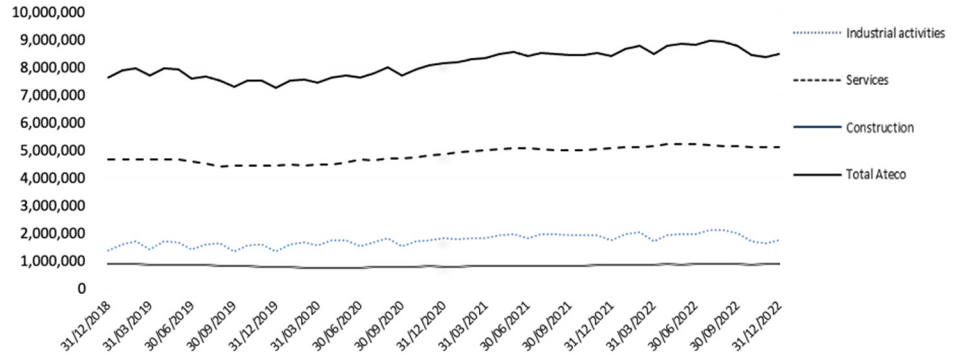

Figure 2. Loans in Sardinia by sector, years 2019–2022 (thousands of euros). Source: own computations on Bank of Italy data.

3.3. Non-Performing Loans

As reported by the Bank of Italy, during 2020–2021, despite the challenges posed by the pandemic, the stock of non-performing loans (NPLs) accumulated by Italian banks continued to decrease. This reduction affected both loans to households and loans to businesses. The trend in these indicators also continued to reflect the positive impact of government measures designed to support access to credit, such as moratoria (loan repayment deferrals) and guarantees on new loans.

Additionally, as directed by the supervisory authorities, the flexibility incorporated into the loan classification rules played a significant role, as previously mentioned. It is important to note that the reduction in NPLs was also facilitated by the sale of non-performing loans, continuing a trend that started in 2017. These sales improved the average quality of banks' assets, with a progressive decline in NPLs at the national and regional levels, as shown in Figure 3.

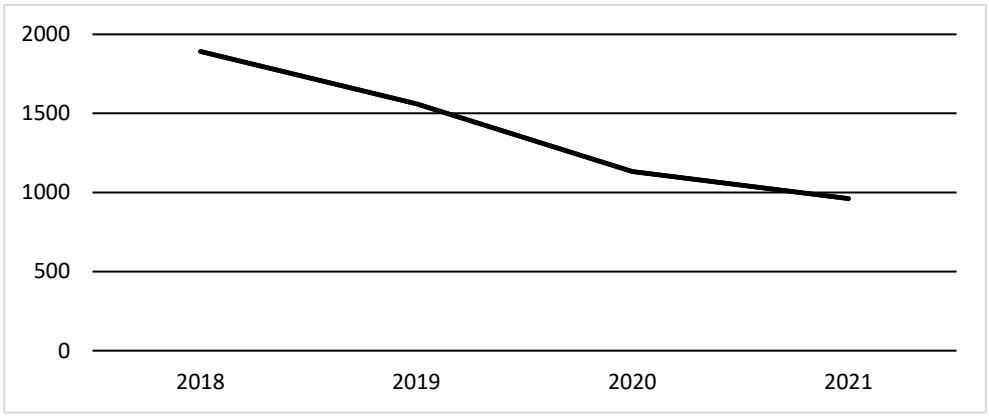

Figure 3. Bad loans in Sardinia, 2018–2021 (thousands of euros). Source: own computations on Bank of Italy data.

3.4. Deposits

Corporate liquidity showed a general increase during the period considered, as highlighted in Figure 4 below. Deposits from Sardinian companies grew by 36.3% between 2019 and 2020, followed by an additional increase of 17.2% in 2021. Overall, this two-year period saw a cumulative increase of 59.7%.

Figure 4 illustrates the increase in bank deposits during the pandemic period. Under normal circumstances, such deposits would decrease due to the financial distress that firms experience during economic uncertainty. However, this deposit growth can be attributed to government support measures implemented during the pandemic.

The graph shows that both producer households and private enterprises were able to increase their deposit levels despite the challenges posed to business activities. This

indicates that government support extended to firms of all sizes, benefiting smaller entities, such as producer households, and larger private enterprises across various categories.

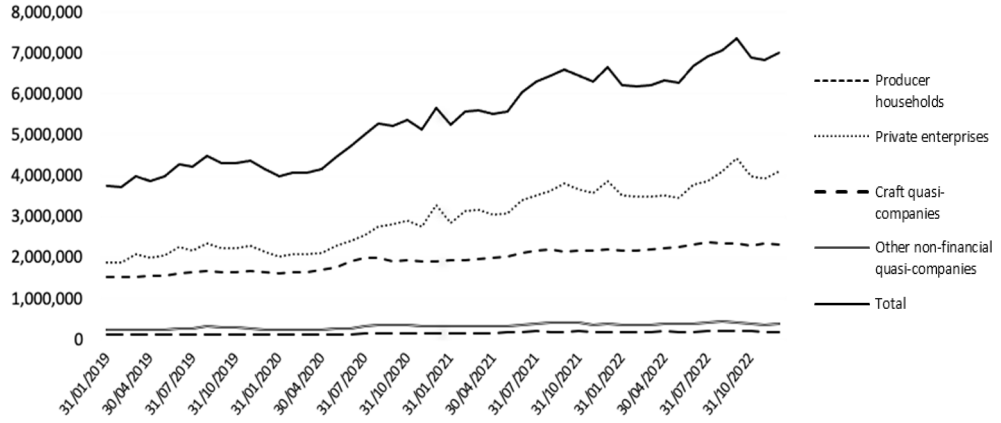

Figure 4. Deposits in Sardinia, years 2019–2022 (thousands of euros). Source: own computations on Bank of Italy data.

3.5. The Net Financial Position of Companies in Sardinia

The aggregate data of loans and deposits show a significant improvement in regional companies' overall net financial position: from EUR −3.1 billion at the end of 2019 to −2.5 billion at the end of 2020 to −1.8 billion at the end of 2021. The trend is also confirmed for December 2022, with an aggregate PFN of −1.5 billion.

A comprehensive analysis of the data presented in the previous paragraphs shows that the government measures effectively prevented the credit contraction that had been anticipated due to recession risks arising from the exogenous economic crisis caused by the SARS-CoV-2 pandemic. Although there is a slight decline in the business demographic balance in Sardinia between 2022 and 2021, the trends in loans extended to the production sector and the continued reduction in non-performing loans indicate stable systemic parametric trajectories. However, the evidence of deposit growth, alongside the reported improvement in the net financial position, reveals a conservative approach to resource management marked by limited investments. This further confirms the support's largely reactive and externally driven nature rather than a proactive one.

4. The Pandemic Crisis

To provide a more transparent contextual framework for the analysis of the impact of guarantee consortia (confidi) on mitigating the economic and financial effects of the SARS-CoV-2 containment measures, in the following paragraphs, we present trend data on the use of public guarantees and the extent of confidi interventions both at the national level and, in particular, within the Sardinian region for the years 2019–2022, splitting them into the pre-pandemic year (2019), the two pandemic years (2020 and 2021), and the post-pandemic year (2022).

4.1. Pre-Pandemic: The 2019 Scenario

In 2019, the world economy showed some positive signals: international trade began to grow again, and there was a reduction in tariff disputes between the United States and China. However, the outlook remained uncertain, with rising geopolitical tensions leading to weakly positive growth expectations. These expectations were supported by the accommodative policies of central banks, which provided a slight upward push to stock markets and facilitated a modest improvement in long-term yields. In the Euro area, economic activity was hindered by the vulnerability of the manufacturing sector, particularly in Germany, although an improving trend emerged toward the end of the year. This economic trend influenced inflation, which, while reinforced by monetary stimulus, remained below 2 percent. The ECB's

Governing Council maintained its accommodative policy throughout the year, signaling its continuation in the years ahead (Banca d'Italia 2020).

In Italy, economic activity showed slight growth in the third quarter but remained nearly stagnant in the fourth quarter, mainly due to the weak manufacturing sector. According to ISTAT—Istituto Nazionale di Statistica (2020) and the Banca d'Italia (2020), companies were slightly more optimistic about orders and foreign demand. However, uncertainty and trade tensions continued to pose obstacles. Despite this, companies planned to increase investments in 2020 at a more modest pace than the previous year. In the final months of 2019, foreign investors purchased significant amounts of Italian government bonds (over EUR 90 billion for the year), improving the Bank of Italy's debit balance on the European payment system TARGET2 (Drott et al. 2024; Glowka et al. 2022). This improvement was also supported by increased net foreign funding through the Repo market by Italian banks, facilitated by activating the new Eurosystem bank reserve remuneration system (Braun 2020).

During 2019, Italy's current account surplus remained substantial, and its net foreign position moved closer to equilibrium. Inflation remained contained, at 0.5% in December. Services contributed more to overall price dynamics, with modest growth observed in the industrial goods sector. Core inflation increased slightly in the autumn, reaching 0.7%. Starting mid-October, Italian government bond yields and stock markets rose, reflecting similar trends across the Euro area. However, yields on bonds issued by Italian banks and non-financial corporations remained more than 70 basis points below the average of the first half of 2019.

4.1.1. Financial Intermediation in 2019

The cost of credit decreased significantly for households. At the same time, lending to businesses continued to decline, primarily due to the weak demand for new financing. However, the measures adopted by the ECB in September were expected to improve credit conditions, according to commercial banks. The data from 2019 indicate a slight decrease in the net borrowing of public administrations relative to the GDP, but there was an overall increase in the debt-to-GDP ratio. The budget plan for 2020 to 2022, approved by parliament in December 2019, projected an average increase in the deficit of 0.7 percentage points of the GDP per year compared to trend values. According to the government's programs, the impact of net borrowing and debt on the economy was expected to decrease over the following two years (MEF—Ministero dell'Economia e delle Finanze 2020–2022).

4.1.2. The Confidi in Pre-Pandemic Periods

During 2019, the activity of national guarantee consortia showed a decrease in the number and volume of guarantees provided during the year and in the accumulated total.

From 2012 to 2019, the number of confidi steadily decreased, dropping from 642 to 298 (−53.6%), as shown in Table 1. This decline was observed across both supervised confidi (−48.3%) and the so-called "minor confidi" (−54.1%). In 2019, the reduction was 15.1%, with a more significant drop for supervised confidi (−16.7%) compared to minor confidi (−14.9%). The situation in Sardinia appeared slightly less critical, with 15 "minor" confidi registered and 8 canceled from the previous section. The supervised confidi registered under Art. 106 TUB numbered two (Unifidi Sardegna 2020). Many of the closures were the result of mergers between non-supervised confidi or incorporations into supervised and non-supervised confidi. However, this trend did not alleviate the worrying signals from the sector, as most mergers appeared to be responses to the crisis rather than proactive development strategies.

The volume of guarantees issued by confidi also followed a decreasing trend, with a 42.4% drop from 2012 to 2018, more pronounced for supervised confidi (−45.1%) than for "minor confidi" (−36.3%). The volume of guarantees almost halved over the same period, and the 2019 data confirmed this ongoing trend.

Several factors may explain this decline, including the rationing of credit to micro-, small-, and medium-sized enterprises (mSMEs), the disintermediation of credit guarantee

consortia by banks through the direct use of FCG guarantees, and the growing preference for automated credit assessment models based on algorithms rather than the traditional discretionary evaluations by analysts that involve soft information. Algorithm-based models tend to favor companies with large amounts of hard data, referred to as "digitally transparent", over disadvantaging companies with limited hard data, known as "digitally opaque". These latter companies are often the ones most in need of financial support and guarantees from credit guarantee consortia. In 2019, disintermediation by banks was particularly evident, with a significant increase in the direct use of FCG guarantees compared to counter-guarantees or co-guarantees, as confirmed by the Fund's data (Fondo di Garanzia 2024a; Fondo di Garanzia per le PMI 2020).

Table 1. Dynamics of confidi in Italy from 2012 to 2019 (number of intermediaries).

Year	Supervised *confidi*	"Minor" *confidi*	Total
2012	58	584	642
2013	60	557	617
2014	62	468	530
2015	56	452	508
2016	40	441	481
2017	38	401	439
2018	36	315	351
2019	30	268	298

Source: Bank of Italy.

The data analysis revealed a significant reduction in the incidence of counter-guarantees + co-guarantees on the total guarantees issued by the FCG (Table 2), which decreased from 31.5% to 14% over the last six years. In parallel, the share of direct guarantees provided by banks rose sharply, from 68.5% to 86%. A similar trend was observed at the regional level in Sardinia.

Table 2. Central Guarantee Fund's total amount of guarantees accepted in 2014–2019 in Italy (thousands of euros).

Year	Direct Guarantee Amount	Direct Guarantee %	Counter-Guarantee + Co-Guarantee Amount	Counter-Guarantee + Co-Guarantee %	Total
2014	9,794,161	68.5%	4,504,836	31.5%	14,298,996
2015	10,862,549	72.1%	4,202,344	27.9%	15,064,893
2016	12,918,729	77.3%	3,783,997	22.7%	16,702,727
2017	14,140,840	81.0%	3,320,734	19.0%	17,461,573
2018	16,057,493	83.1%	3,256,487	16.9%	19,313,980
2019	16,657,146	86.0%	2,718,550	14.0%	19,375,697

Source: own computations on FCG data.

The reform of the FCG introduced in March 2019 (Fondo di Garanzia 2024b), which was strongly supported by confidi and their associated systems, aimed to mitigate this trend. The reform introduced a graduated guarantee coverage based on the requesting company's risk profile, prioritizing the riskiest companies representing the majority of confidi members. Despite these more favorable conditions, disintermediation continued in 2019, with no signs of reversal.

This ongoing disintermediation can be attributed to banks' tendency to overlook the SME segment, viewing it as unprofitable and difficult to evaluate through digital systems due to the limited availability of reliable quantitative data (hard information). Additionally, the involvement of confidi often entails extra costs for companies and complicates banking procedures. A comparative analysis of the transparency documents published by the most relevant Sardinian confidi suggested a mitigating effect on average bank pricing of around 1.5%, based on conventional conditions, which was the net of an average annual

guarantee commission of approximately 1.2 percentage points on the nominal amount of the individual loan. However, it is essential to note that the disintermediation trend persisted throughout the year, as banks continued offering conditions equal to or even more favorable than those set by existing agreements with confidi.

4.2. The Pandemic Explosion: 2020

In 2020, based on macroeconomic data (Table 3) and the assessments by the Centro Studi Confcommercio (2024), the contraction in economic activity due to the SARS-CoV-2 pandemic was the worst since the Second World War despite the actions to combat the pandemic implemented by the government (De Vincenzo 2021).

Table 3. Some macroeconomic variables of Italy (average % variations).

Variables	2008–2018	2018–2019	2019–2020
GDP	−0.4	−0.3	−8.9
Consumption	−0.2	0.4	−11.7
Investments	−0.3	1.1	−9.1
Employed (ULA × 1000—var. ass.)	−981	28	−2.457
Debt as a % of the GDP		−1.6	−9.5
Public debt as a % of the GDP		134.8	155.6

Source: Confcommercio Research Centre.

4.2.1. Financial Intermediation in 2020

According to the Bank of Italy, Italian banks continued to respond to businesses' demands for financing in 2020 (Table 4a,b). Financing conditions remained generally favorable thanks to the continued support from monetary policies and public guarantees (Banca d'Italia 2021; Desogus and Venturi 2023).

Table 4. (**a**) Financing in Italy as of end 2019 (millions of euros). (**b**) Financing in Italy as of end 2020 (millions of euros).

(**a**)

Areas	Total Economy	Private Sector	Production Activities	Consumer Families
Italy	1,756,033	1,253,847	708,195	545,652
Mezzogiorno	250,349	225,376	100,435	124,941
Sardinia	24,573	20,289	8817	11,471
Cagliari	7938	7114	3099	4015
Nuoro	2252	2117	1075	1042
Oristano	1712	1623	749	873
Sassari	9539	6424	2818	3606
Sud Sardegna	3132	3012	1076	1935

(**b**)

Areas	Total Economy	Private Sector	Production Activities	Consumer Families
Italy	1,764,349	1,300,791	750,521	550,270
Mezzogiorno	253,025	228,329	103,964	124,365
Sardinia	25,292	20,871	9355	11,517
Cagliari	8400	7522	3476	4046
Nuoro	2258	2124	1073	1051
Oristano	1725	1639	763	876
Sassari	9771	6572	2948	3624
Sud Sardegna	3137	3015	1095	1920

Source: own computations on data from ABI Research Office and Bank of Italy.

According to the ABI Research Office (2023), in 2020, total loans grew by 4.1% in Italy and by +4.3% in Sardinia, a growth slightly higher than the national average for

production activities also, for which the Sardinian figure (+8.8%) was close to the national figure (+8.4%).

The Bank of Italy data reported in Tables 5 and 6 show that despite the pandemic, the reduction in Italian banks' NPLs continued in 2020. This reduction involved loans to households and businesses and was supported by the moratoriums and guarantees on new loans introduced by the government to ease access to credit, together with the long-term horizon in the risk weighting of loans allowed by the supervisory authorities.

Table 5. Gross impaired loans, Dec 2020 (millions of euros).

Areas	Sufferings	Probable Non-Fulfilments	Overdue/Impaired Loan Overdrafts	Total
Italy	46,502	47,365	3120	96,987
Mezzogiorno	11,505	8951	1148	21,605
Sardinia	1267	749	100	2116

Source: Unifidi Sardegna based on Bank of Italy data.

Table 6. Bad loans/loans ratio, Dec 2020.

Areas	Bad Debt/Loans (Production Activities)
Italy	5.09
Mezzogiorno	8.13
Sardinia	12.09
Cagliari	11.16
Nuoro	11.38
Oristano	5.63
Sassari	14.42
Sud Sardegna	13.99

Source: Unifidi Sardegna based on Bank of Italy data.

4.2.2. The Confidi in 2020

The government interventions significantly increased the importance of public guarantees. Initially, they favored more significant activity from *confidi*, whose guarantees could have benefited from greater coverage by the FCG than the direct guarantee, producing a more significant weighting effect for the banks. However, while these measures indeed increased the use of the fund, the results were more evident in the number and volume of transactions directly supported by the public guarantee. In contrast, the transactions intermediated by *confidi* recorded a more marginal increase.

As highlighted in Table 7, at a national level, the impact of the pandemic led to an increase in direct guarantees of approximately 8.8 times, while counter-guarantees were less than doubled (1.9 times) (Dell'Atti and Lopes 2020; Unifidi Sardegna 2021).

Table 7. Operations of the Central Guarantee Fund for 2019–2020 in Italy (thousands of euros).

Year	Direct Guarantee Amount	Direct Guarantee %	Counter-Guarantee + Co-Guarantee Amount	Counter-Guarantee + Co-Guarantee %	Total Amount
2019	11,745,677	88.00%	1,596,453	12.00%	13,342,131
2020	102,863,646	97.10%	3,057,069	2.90%	105,920,715

Source: own computations on FCG data.

At the Sardinian regional level, the trend mirrors the national one but with a more marked decrease (25.8%) in the last year.

Focusing on the two primary types of operations benefiting from the FCG guarantee in 2020 (Table 8), it was found that operations with a value of less than EUR 30 thousand, which received 100% coverage, accounted for 63.56% of the accepted requests, with an average value of EUR 19.6 thousand each (Fondo di Garanzia 2024a). Although they represented a significant portion of the accepted requests, they contributed to a lesser extent (15.7%) to the total financing guaranteed by the Fund during the same period (Fondo di Garanzia per le PMI 2021).

Table 8. Operations of the Central Guarantee Fund for 2015–2020, Sardinia (total amount of guarantees issued in thousands of euros).

Year	Direct Guarantee Amount	Direct Guarantee %	Counter-Guarantee + Co-Guarantee Amount	Counter-Guarantee + Co-Guarantee %	Total
2015	89,402	71.10%	36,290	28.90%	125,692
2016	107,723	70.30%	45,561	29.70%	153,284
2017	113,638	67.70%	54,300	32.30%	167,938
2018	119,867	67.70%	57,196	32.30%	177,063
2019	129,395	69.30%	57,430	30.70%	186,825
2020	1,468,782	95.10%	75,107	4.90%	1,543,889

Source: own computations on FCG data.

As previously mentioned, these interventions were specifically designed to minimize bureaucratic formalities and provide an almost automatic evaluation method for immediate credit availability.

These operations, primarily managed by banks, excluded confidi from an important target group, namely micro-, small-, and medium-sized enterprises (mPMI), which had often been neglected or excluded by banks due to the difficulties in automating credit assessment processes. These difficulties stemmed from the complexity of digital information for individual firms, partnerships, artisan businesses, start-ups, and companies with few years of activity (De Socio et al. 2020; Nadotti 2020). More than others, these businesses required both guarantees and additional support to access credit. As a result, the role of confidi was further weakened, limiting their growth compared to the potential offered by the SARS-CoV-2 measures.

However, in 2020, confidi increased their reinsurance activity, which grew by 91.5% at the national level and 30.8% at the regional level. The increase in guaranteed volumes is mainly due to the rise in the guarantee quota per individual loan rather than an increase in the number of guaranteed transactions over the year. The numerical distribution between major and minor consortiums shows that there were 32 major consortiums, representing 15.3% of the total providers of consortium guarantee services in the market, and 177 minor consortiums, representing 84.7%. Although the major consortiums are numerically a minority, as of the end of 2020, they held a stock of guarantees amounting to EUR 6.7 billion, representing approximately three-quarters of the total. In contrast, the minor consortiums, with a total stock of guarantees of just over EUR 2.4 billion, saw an 8% growth compared to the previous year.

4.3. The Second Pandemic Year: 2021

In 2021, the improvement of vaccination campaigns, which were remarkably rapid in advanced countries, led to significant progress in overcoming the global pandemic, as highlighted by the Banca d'Italia (2022b). This enabled a relaxation of mobility restrictions and a recovery in global demand (Armantier et al. 2021), supporting a global growth recovery of +6.1% and a rebound in international trade.

The slowdown in production during the pandemic led to global supply shortages (Reis 2022) and contributed to inflation due to rising commodity prices, especially for energy and food. In the Euro area, GDP grew significantly in 2021 after the severe contraction in 2020. However, toward the end of the year, economic activity was partially affected by

persistent supply difficulties in global distribution chains and rising energy prices, being exacerbated by the onset of tensions between Russia and Ukraine.

Italy, in 2021, saw the easing of restrictions, leading to a 6.6% growth in the national GDP, allowing for the recovery of two-thirds of the exceptional contraction in 2020 caused by the health crisis. This recovery was widespread across the country, with the northeast experiencing the highest growth (7.2%), followed by the northwest (6.8%), the center (6.1%), and the south (5.7%). Although the number of employed people and the total hours worked increased, both remained below pre-pandemic levels (ISTAT—Istituto Nazionale di Statistica 2024).

During 2021, inflation rose to 1.9%, being mainly driven by higher energy costs, after being nearly negligible in 2020. In contrast, due to moderate wage growth, core inflation remained under control (Unifidi Sardegna 2022). While consumption grew significantly, it only partially recovered from the sharp contraction in 2020, especially in tourism and leisure-related spending. Despite a decrease from the highs of 2020, the propensity to save remained high compared to the levels of the past twenty years (ISTAT—Istituto Nazionale di Statistica 2022, Rapporto annuale). Real estate wealth increased in 2021, in line with rising house prices.

Production activity resumed growth, particularly in industry and construction, while services grew more smoothly. However, only the construction sector fully recovered its pre-pandemic level, being boosted by tax incentives for housing redevelopment. The easing of containment measures supported the recovery but was also constrained by ongoing difficulties in supplying intermediate products and rising raw material costs, especially energy.

The birth rate of businesses in 2021 returned to pre-crisis levels, and the exit rate from the market decreased, especially in sectors that benefited most from public support measures (Centro Studi Confcommercio 2024). Overall, households' financial conditions improved due to growth in disposable income and increased asset value. Households' loans and consumer credit grew, although at slower rates compared to the pre-pandemic period. Corporate profitability improved, although still slightly below 2019 levels, thanks to abundant liquidity that reduced the need for new loans (Ufficio Studi ABI—Associazione Bancaria Italiana 2024).

4.3.1. Financial Intermediation in 2021

The improvement in macroeconomic conditions and government support measures in response to the pandemic positively impacted bank balance sheets in 2021. However, the gradual end of government support measures and the Russia–Ukraine war induced significant uncertainty for credit intermediaries' profitability and asset quality.

Bank lending slowed significantly due to lower demand for financing from businesses, while lending to households accelerated, being driven by the growth in mortgages for house purchases; consumer credit remained weak (Banca d'Italia 2021, 2022b).

The ratio of new non-performing loans to total performing loans remaining limited and the volume of disposals still being high made the share of non-performing loans in total financing fall to a lower level than before the global financial crisis and to stay in line with the average of major Euro area countries.

Overall, collections continued to grow, albeit slower than in 2020. Bank profitability increased, returning to pre-health emergency levels, mainly due to the reduction in loan write-downs, which had been very high in 2020, and the increase of non-interest income (notably commissions), while the interest margin slightly decreased (Ufficio Studi ABI—Associazione Bancaria Italiana 2024).

4.3.2. The Confidi in 2021

In 2021, the amount of accumulated guarantees held by the confidi under Art. 106 TUB slightly increased, reaching EUR 8 billion, with impaired loans accounting for 22% of the total. The sector's profitability was influenced by high fixed costs, which absorbed

85% of the intermediation margin, a 2.3% increase. The ratio between own funds and risk-weighted assets remained high at 33% (Camera di Commercio Industria Artigianato e Agricoltura di Torino 2022).

By the end of 2021, Italian confidi maintained a stock of approximately EUR 9.1 billion in accumulated guarantees, with significant geographical disparities. The northern regions of Italy exhibited a marked concentration of guarantees. During 2021, Italian confidi issued around EUR 2.85 billion in guarantees, with an even more pronounced polarization in the northern regions. Although confidi in northern Italy represented only a third of the total, they issued 57% of the overall guarantee flow, totaling EUR 1.6 billion out of EUR 2.8 billion. In contrast, the southern regions, which host more than half of the Italian confidi, issued only approximately 15% of the overall guarantees.

The confidi categorization revealed that the largest confidi provided 84.31% of the total guarantees, amounting to EUR 2.4 billion, while the smaller confidi contributed just 15.69% (Unifidi Sardegna 2022; Camera di Commercio Industria Artigianato e Agricoltura di Torino 2022).

As shown in Table 9, at the national level in 2021, guarantees issued by the FCG (Fondo di Garanzia) decreased by 36.1%, falling from EUR 105.9 billion to EUR 67.6 billion. Both direct guarantees and combined counter-guarantees and co-guarantees saw declines in absolute value and percentage terms, with direct guarantees experiencing a steeper decline of 36.6% compared to those intermediated by confidi. Notably, the share of guarantees intermediated by confidi showed a slight increase, rising from 2.9% to 3.6% of the total (Fondo di Garanzia 2024b; Fondo di Garanzia per le PMI 2022).

Table 9. Operations of the Central Guarantee Fund for 2020–2021 in Italy (thousands of euros).

Year	Direct Guarantee Amount	Direct Guarantee %	Counter-Guarantee + Co-Guarantee Amount	Counter-Guarantee + Co-Guarantee %	Total Amount
2020	102,863,646	97.10%	3,057,069	2.90%	105,920,715
2021	65,191,455	96.40%	2,450,385	3.60%	67,641,840

Source: own computations on FCG data.

In Sardinia, during 2021, the trend mirrored the national one (Table 10), with a 30.9% decrease in the total guarantees issued by the Fund, dropping from EUR 1.54 billion to EUR 1.07 billion. However, it is worth noting that the behavior of direct guarantees differed from the aggregate guarantees intermediated by the confidi: while direct guarantees saw a decrease of 33.6%, the aggregate of counter-guarantees and co-guarantees increased by EUR 16.5 million, rising from EUR 75.1 million to EUR 91.6 million, a 22% increase. Consequently, the share of the aggregate guarantees in the total guarantees issued by the Fund in Sardinia rose from 4.9% to 8.6% (Unifidi Sardegna 2022; Fondo di Garanzia per le PMI 2022).

Table 10. Operations of the Central Guarantee Fund for 2020–2021 in Sardinia (thousands of euros).

Year	Direct Guarantee Amount	Direct Guarantee%	Counter-Guarantee + Co-Guarantee Amount	Counter-Guarantee + Co-Guarantee %	Total Amount
2020	1,468,782	95.10%	75,107	4.90%	1,543,889
2021	975,787	91.40%	91,680	8.60%	1,067,467

Source: own computations on FCG data.

Although this figure represents only 1.5% of the Fund's total assets in Sardinia, it still demonstrates a notable increase in guarantees intermediated by Sardinian confidi, reflecting the dynamism of local economic activity.

4.3.3. Minor Confidi

The analysis of the segmentation by quartiles of the consortiums registered in the list maintained by the "Organismo Confidi Minori" (OCM), based on the guarantee flows issued in 2020 (Vescina 2021), reveals that the efficiency of the consortium guarantee instrument increases with the size of the consortium's assets (Table 11a–c).

Table 11. (**a**) Assets guaranteed in 2020, distribution by quartiles (EUR). (**b**) Flows of guarantee stock in 2020, distribution by quartiles (EUR). (**c**) Guarantee stock in 2020, distribution by quartiles (EUR).

(**a**)			
Quartiles	**Net Assets**	**% of Total**	**Average Net Assets**
1st quartile	32,239,841	3.10%	716,441
2nd quartile	89,684,847	8.50%	1,992,997
3rd quartile	211,059,395	20.00%	4,690,209
4th quartile	722,064,817	68.40%	16,045,885
Total	1,055,048,900	100.00%	5,861,383
(**b**)			
Quartiles	**Flows**	**% of Total**	**Average Flow**
1st quartile	1,924,587	0.20%	42,769
2nd quartile	19,343,801	2.30%	429,862
3rd quartile	82,984,646	10.00%	1,844,103
4th quartile	727,204,634	87.50%	16,160,103
Total	831,457,668	100.00%	4,619,209
(**c**)			
Quartiles	**Stock**	**% of Total**	**Average Stock**
1st quartile	33,572,623	1.30%	746,058
2nd quartile	152,925,702	6.10%	3,398,349
3rd quartile	372,846,045	15.00%	8,285,468
4th quartile	1,930,287,945	77.50%	42,895,288
Total	2,489,632,316	100.00%	13,831,291

Source: OCM.

The ratio between guarantee stock and net assets is approximately 1 to 1 in the first quartile, while it reaches 1 to 2.65 in the fourth quartile. This result signals the need for capital-strengthening measures of credit consortia.

4.4. The Post-Pandemic Recovery: 2022

As reported by the Bank of Italy (2023), 2022 economic activity in advanced countries slowed due to the persistent effects of high inflation and the ongoing conflict in Ukraine. In China, economic weakness became evident, particularly from autumn onwards, as measures were implemented to counter what appeared to be a new wave of the COVID-19 pandemic. International trade suffered from a significant global demand slowdown, contributing to a moderate decrease in oil prices. This trend was even more pronounced for natural gas prices in Europe, which, although still high, saw a notable decline.

In the Euro area, the GDP mainly remained stable in the final quarter of 2022, while consumer inflation remained elevated, reaching 9.2% in December. The European Central Bank raised its official rates by 75 basis points in October and by an additional 50 basis points in December, signaling that further significant and steady increases would be necessary in the following quarters to return inflation to its medium-term objective (Diebold et al. 2023).

In Italy, the Bank of Italy (Unifidi Sardegna 2023) reported a weakening of economic activity in the final months of 2022. This was driven by a slowdown in the recovery of services and a decrease in industrial production. Household spending also decelerated despite government measures aimed at mitigating the impact of high energy prices and

supporting disposable income, particularly for the more vulnerable population segments. The propensity to save declined, returning to pre-health-emergency levels.

In the October–December quarter, exports of goods remained stable, while imports fell, contributing to a widening of the current account deficit, mainly due to the worsening energy deficit. Industrial production contracted in the fourth quarter due to high energy costs and reduced demand. After expanding in the second and third quarters, activity in the tertiary sector slowed down.

Uncertainty surrounding the ongoing conflict in Ukraine and tighter financial conditions negatively impacted investment spending and the outlook for the real estate sector. Inflation reached new highs in the autumn months, driven mainly by energy prices, which continued to push up the cost of other goods and services. This contributed to a moderate rise in core inflation. Despite government interventions in the energy sector, consumer price inflation only eased at the end of the year (ISTAT—Istituto Nazionale di Statistica 2024).

The Confidi in 2022

As of 31 December 2022, there were 200 Italian confidi, consisting of 32 major confidi and 168 minor confidi. The major confidi were distributed across 15 Italian regions, with a concentration in the north (20 out of 32). At the same time, approximately one-third were located in the center and south (six confidi in each area). Regarding geographical distribution, the minor confidi were spread across the entire country, with at least one present in each region. The highest concentration of minor confidi was in the southern regions (94 out of 168), followed by the north (48 confidi) and the center (26 confidi) (Camera di Commercio Industria Artigianato e Agricoltura di Torino 2023).

At the end of 2022, Italian confidi held a total of EUR 8.4 billion in guarantees, reflecting a decrease of 7% compared to 2021, when the cumulative stock was EUR 9.1 billion. However, the distribution of outstanding guarantees differed from the geographical distribution of the confidi. During the year, Italian confidi issued approximately EUR 2.8 billion in new guarantees, most of which came from northern Italy. In contrast, the southern regions, where about half of the Italian confidi are located, accounted for only 14% of the guarantees issued.

The share of guarantees issued by the largest confidi was 85%, while the smaller confidi accounted for 15%. The data indicate a trend toward a greater concentration of guarantee stocks in the larger confidi and, consequently, the northern regions. Specifically, while the southern regions held 21% of the guarantee stocks at the end of 2022, they issued only 14% of the flows during the year. Meanwhile, northern regions, which held 51% of the stocks at the end of 2021, issued 57% of the flows in 2022. According to the Bank of Italy, in 2022, the amount of guarantees issued by the largest confidi decreased by 11%, reaching EUR 6.9 billion. The percentage of impaired guarantees to the total issued was 19.5%, compared to 22.2% in 2021.

The sector's profitability remained limited due to the high impact of fixed costs. However, the ratio of own funds to risk-weighted assets remained high at 36.4% (Banca d'Italia 2022a, 2023b; Camera di Commercio Industria Artigianato e Agricoltura di Torino 2023). This emerging picture suggests that the gradual reduction in the size of the smaller confidi may be partly due to the end of the extraordinary pandemic-related measures, which had directly affected confidi operations, increasing their activity in some areas. Meanwhile, the consolidation process among the larger confidi continued, strengthening certain players in terms of available resources.

At the same time, there was a growing diversification of commercial activities, with a significant shift toward "residual" activities. These were seen as the only sustainable economic and financial viability sources for the confidi. Consequently, the revenues of the larger confidi grew, driven by these activities, which did not require provisions like the issuing of guarantees. This option, however, was excluded for smaller confidi, whose operations remained focused solely on issuing collective guarantees.

In 2022, there was a further and significant contraction in the guarantees issued by the FCG, with a national decrease of 37.7%, from EUR 67.6 billion to EUR 42.1 billion (34.2% less than the change recorded in 2020–2021). Both direct guarantees and the aggregate of counter-guarantees and co-guarantees saw reductions in both absolute and percentage terms (Table 12). However, the decrease was more pronounced for direct guarantees (−38.6% compared to −36.6% in the previous two-year period), while the aggregate intermediated by confidi recorded a decrease of 13.1% (compared to −19.8% in the previous two-year period). As a result, the incidence of the guarantees intermediated by confidi increased from 3.6% to 5.1%.

Table 12. Operations of the Central Guarantee Fund for 2021–2022 in Italy (thousands of euros).

Year	Direct Guarantee Amount	Direct Guarantee %	Counter-Guarantee + Co-Guarantee Amount	Counter-Guarantee + Co-Guarantee %	Total Amount
2021	65,191,455	96.40%	2,450,385	3.60%	67,641,840
2022	40,006,760	94.90%	2,129,342	5.10%	42,136,102

Source: own computations on FCG data.

In Sardinia, the general trend in 2022 showed a more significant decrease than the national average, with a reduction of 40.7% in the total guarantees issued by the Fund, which fell from EUR 1.07 to 0.63 billion. As in the previous year, a decrease was observed in both components. However, while the direct guarantee recorded a decrease of −42.6% (Table 13), which was higher than the overall reduction, the aggregate of guarantees intermediated by the guarantee consortia decreased to a lesser extent (−20.6%). This led to an increase in the share of the aggregate guarantees from 8.6% to 11.5% of the total guarantees issued on the island by the Central Guarantee Fund between 2021 and 2022.

Table 13. Operations of the Central Guarantee Fund for 2021–2022 in Sardinia (thousands of euros).

Year	Direct Guarantee Amount	Direct Guarantee %	Counter-Guarantee + Co-Guarantee Amount	Counter-Guarantee + Co-Guarantee %	Total Amount
2021	975,787	91.40%	91,680	8.60%	1,067,467
2022	559,785	88.50%	72,757	11.50%	632,542

Source: own computations on FCG data.

Notably, the data regarding the reduction in the volume of counter-guarantees intermediated by Sardinian guarantee consortia in 2022 are significant, amounting to a decrease of EUR 18.9 million (Unifidi Sardegna 2023; Fondo di Garanzia per le PMI 2023).

5. Comparison Between General Averages and a Sample of Regional Confidi Supported Firms

5.1. Data

Our study examines the role of credit consortia in supporting SMEs during the SARS-CoV-2 crisis by comparing the financial performances of firms financed through credit consortia with those funded directly by banks. Using a descriptive methodology, we assess key financial indicators across three distinct periods—pre-crisis, during the crisis, and post-crisis—to determine which financing channel offered more effective support during economic uncertainty. This comparison of firms with and without credit consortium backing allows us to evaluate performance trends throughout the selected timeframe.

The dataset consists of companies registered in the Chambers of Commerce of the Sardinia region and operating in the business sectors listed in the following Table 14.

Table 14 presents data on firms supported by confidi credit consortia during the pandemic, which were selected based on the most frequent industry sectors as defined by the Italian ATECO classification, alongside a larger sample of firms from the AIDA database, which were selected using the same industry sector criteria.

Table 14. Data description (number of firms by sector and type).

Ateco Code	Description	Totals	Aida Firms	Confidi Supported
41.20.00	Construction of residential and non-residential buildings	660	652	8
47.77.00	Retail sale of watches, jewelry, and silverware	22	18	4
49.41.00	Road freight transport	178	175	3
56.10.11	Full-service restaurants	315	305	10

Source: own computations on data from ABI Research Office and Bank of Italy.

Of the total companies active in these selected sectors in Sardinia in 2022, a "rational" sampling approach was applied to the general database. This process was carried out through the AIDA—Analisi Informatizzata delle Aziende Italiane (2024) platform, focused on extracting limited liability companies to mitigate the digital opacity typically associated with sole proprietorships and partnerships.

Starting with an initial pool of 10,745 companies extracted from the AIDA database, only those that had filed their 2022 financial statements were considered. From this, 1150 companies were selected, including only those with complete data and no missing values. These firms were further filtered based on having total assets of less than EUR 5 million, creating a sample that closely mirrors the characteristics of confidi-supported companies, thereby enabling a more accurate comparison between the two groups.

The final sector breakdown of this sample consists of 652 firms under code 41.20.00, 18 under code 47.77.00, 175 under code 49.41.00, and 315 under code 56.10.11. In contrast, the confidi sample includes 25 companies distributed as follows: 8 under code 41.20.00, 4 under code 47.77.00, 3 under code 49.41.00, and 10 under code 56.10.11. The comparatively lower representation of credit consortium-assisted companies in the construction sector is attributed to significant fluctuations in financial liabilities tied to the "super bonus" for construction introduced by the Italian government in May 2020. This policy did not involve confidi intermediaries.

In particular, the data relating to 2017–2018–2019 (pre-pandemic), 2020–2021 (pandemic), and 2022 (post-pandemic) were identified. The balance sheet elements considered were the total assets, capitalization, liquidity, total debts, sales volume, ROI, and cost of debt. All these variables were extracted from the firms' year-end financial statements; consequently, the values are nominal and not adjusted for inflation.

The total assets per firm include current and non-current assets. The capitalization value is represented by the ratio of equity (the net worth attributable to the firm's shareholders or owners) on total assets. The liquidity ratio refers to the ratio of liquid assets—assets that can be quickly and easily converted into cash with little to no loss in value—over total assets. The total debts represent the total amount of money a firm owes, encompassing both short-term and long-term liabilities such as loans, bonds, and accounts payable. The sales volume indicates the total revenue a firm generates from its sales of goods or services during the year considered, reflecting business activity and market demand. The return on investment (ROI) measures the EBITDA over total assets, indicating how effectively the firm generates returns. Finally, the cost of debt represents the ratio of financial charges, including interest expenses and other associated borrowing costs, over the total debt, reflecting the firm's expense for financing through debt.

The AIDA sample values were first calculated by industry sector and then synthesized using a weighted average, with the same weighting as the confidi-supported sample. This process allows for an accurate proportional comparison of the values between the two samples, with the AIDA sample balanced against the confidi-supported one.

The financial indicators considered in this study are inter-related and reflect a firm's overall financial health, operational efficiency, and risk profile.

The evolution of total assets reflects the business's dimension and its expansion level. Growth in total assets indicates an increase in the scale of operations, which may be associated with higher investment in production capacity, strategic assets, or acquisitions. The capitalization ratio, on the other hand, captures financial autonomy. A higher capitalization ratio suggests that the firm is relying more on equity financing than on debt, which lowers financial risk. This makes the firm more resilient to economic shocks, as it has a greater cushion against financial distress.

Liquidity and total debts are inversely related. Liquidity measures a firm's ability to quickly meet its short-term obligations by converting assets into cash. Firms with high levels of debt, particularly short-term liabilities, may struggle to maintain liquidity because a significant portion of their resources is used for debt servicing rather than remaining available as cash or liquid assets. High debt levels can strain the firm's finances, especially if the sales volume decreases or operational challenges emerge, which is often the case during periods of economic uncertainty like the SARS-CoV-2 pandemic. In this context, government intervention plays a critical role in shaping debt levels, with public financial support for SMEs helping to ease debt burdens and improve liquidity.

The sales volume and ROI are closely connected, as they both reflect a firm's profitability and the efficiency of its resource utilization. A higher sales volume will likely produce higher returns on its invested assets, indicating greater operational efficiency and improved financial performance. Conversely, the ROI may also drop if sales volumes decline, signaling reduced profitability.

Liquidity is also tied to the cost of debt, specifically to the level of interest rates. High interest rates increase the cost of debt, making it harder for a firm to manage its liabilities and maintain liquidity. A firm with poor liquidity may struggle to secure financing, especially during economic distress.

In summary, these financial indicators are part of an interconnected cycle. Effective liquidity management, debt, asset utilization, and sales growth can improve profitability and the ROI, while the capitalization ratio determines a firm's financial risk profile. The SARS-CoV-2 pandemic likely disrupted these relationships, introducing business challenges and opportunities, particularly in managing liquidity, securing debt financing, and maintaining operational efficiency. The pandemic underscored the importance of strategic decision making and financial planning to navigate periods of financial distress.

5.2. Evolution of the Sardinian Companies During and After the SARS-CoV-2 Crisis

The following graphs show the evolution of the main financial indicators from 2017 to 2022. We use them to compare the two samples and understand how each group was influenced by the pandemic, based on whether they were supported by credit consortia or not.

In the following figures, the two samples show similar ongoing trends, as the framework is the same for the credit consortium-supported and non-supported firms. Nevertheless, some differences in the evolution are evident, and our focus is on these differences to evidence the role of credit consortia.

The total assets volume evolution, as reported in Figure 5, shows that the pre-pandemic level was similar for the general sample and the confidi-supported firms. In contrast, during and after the pandemic, the general sample registered growth, but the confidi-supported sample reported more significant growth, almost doubling the value of their total assets. This rapid growth suggests that the confidi-supported firms already had potential in the previous years, which was only expressed as they had the liquidity to finance it.

The capitalization level (Figure 6), measured by the equity/(total liabilities + equity ratio), shows an almost flat evolution in the pre-pandemic and pandemic years, staying in the 26% range from 2017 to 2021 for the general sample and in the range 15–16% for those that were confidi supported in the same years, followed by an irrelevant reduction in the post-pandemic, which reduced the ratio value from 26% in 2021 to 25% in 2022 for the general sample and from 15% to 13% for the confidi-supported sample. This evolution

evidenced the lower capitalization rates of the confidi-supported firms, confirming their patrimonial weakness and the need for external support in their bank–firm relationship. The evolution also shows the reduction in capitalization, mainly related to the availability of cheap debt (see Figures 7 and 8) and the government's financial support granted as a response to the pandemic problems.

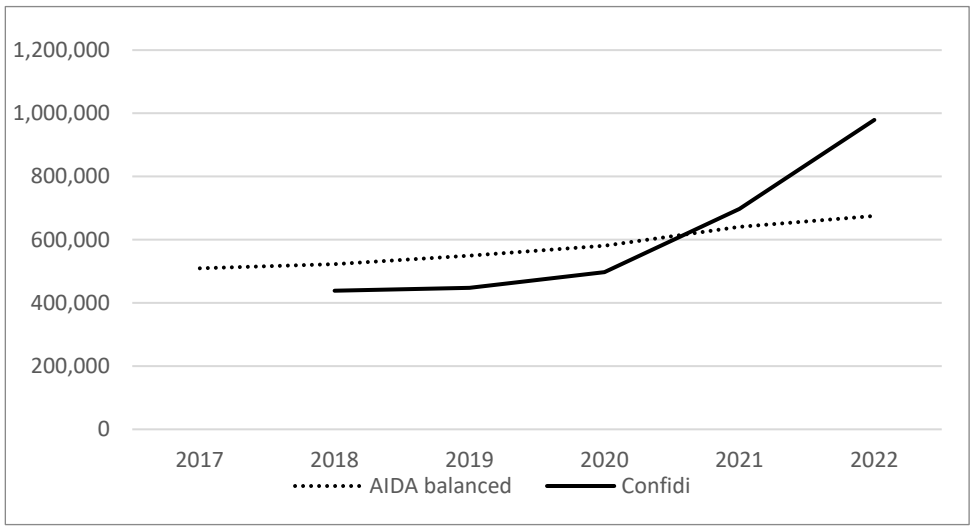

Figure 5. Average total assets per firm (EUR) for the years 2017–2022.

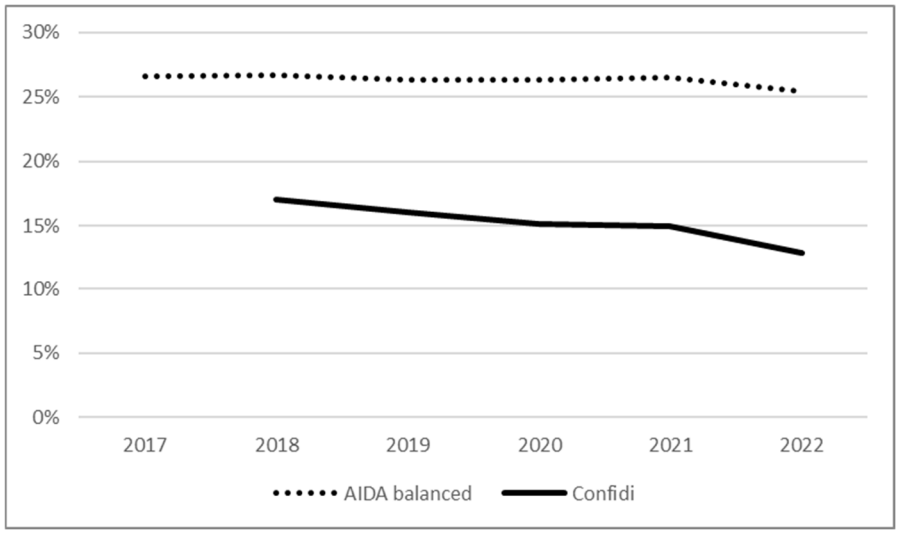

Figure 6. Capitalization: equity/(total liabilities + equity), years 2017–2022.

The liquidity rate evolution, as reported in Figure 7, shows even more clearly the impact of government policy interventions in support of firms. The liquidity ratio values, ranging from 12% to 14% in the pre-pandemic years for the general Aida sample, rose to 16% in 2021. Instead, the confidi-supported firms show a more significant liquidity improvement, starting from around 6% for the pre-pandemic period and almost reaching 12% in 2021, more than doubling the previous values. This graph also evidences the deficient liquidity levels of the confidi-supported firms, which greatly benefited from the government's pandemic support policies but, even in the moments of higher support availability, could not reach the pre-pandemic minimum liquidity levels of the general sample. This low liquidity confirms the financial weakness of the confidi-supported firms.

The debt incidence rates reported in Figure 8 show the total debt level evolution in the considered period. It is worth noting that the total debt level includes bank and

commercial debts. Thus, the high level of debt of the confidi-supported firms does not evidence the easy and more extensive credit availability of these firms but rather the low capitalization and high level of commercial debts. It is confirmed by the rising debt level in the post-pandemic, which is related to the need to restart the business activity at the previous (or higher) levels (see also Figure 9), so needing higher financial coverage but also allowing for more commercial debts.

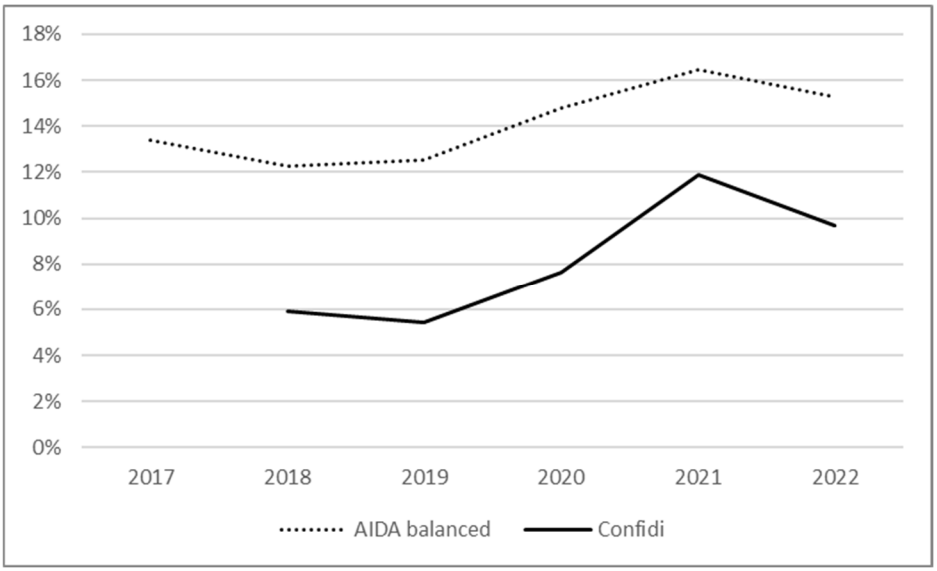

Figure 7. Liquidity ratio for the years 2017–2022.

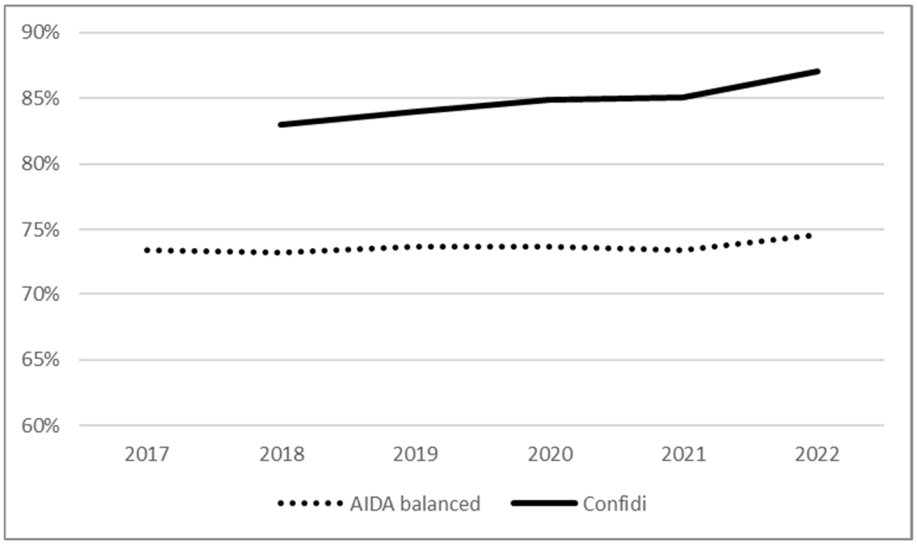

Figure 8. Debts/total assets, years 2017–2022.

The evolution of sales, as reported in Figure 9, shows a very interesting post-pandemic opportunity for the considered firms, with the general sample average ranging from EUR 330 to 400 thousand in the pre-pandemic years and reaching EUR 532 thousand in the post-pandemic, but even more for the confidi-supported sample, which ranged from EUR 600 to 700 th. in the pre-pandemic and almost doubled their sales volume in the post-pandemic period, around EUR 1200th in 2022.

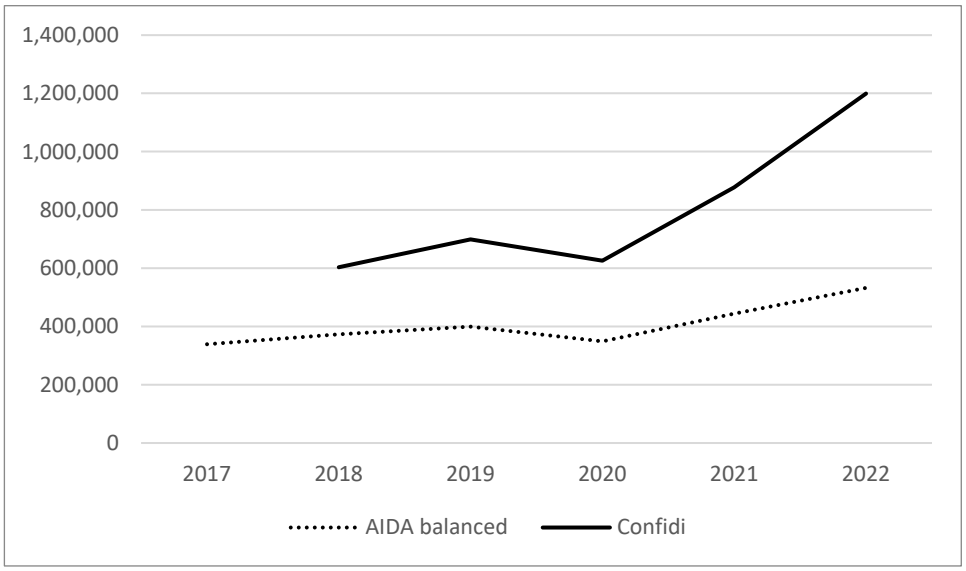

Figure 9. Average sales per firm, years 2017–2022 (EUR).

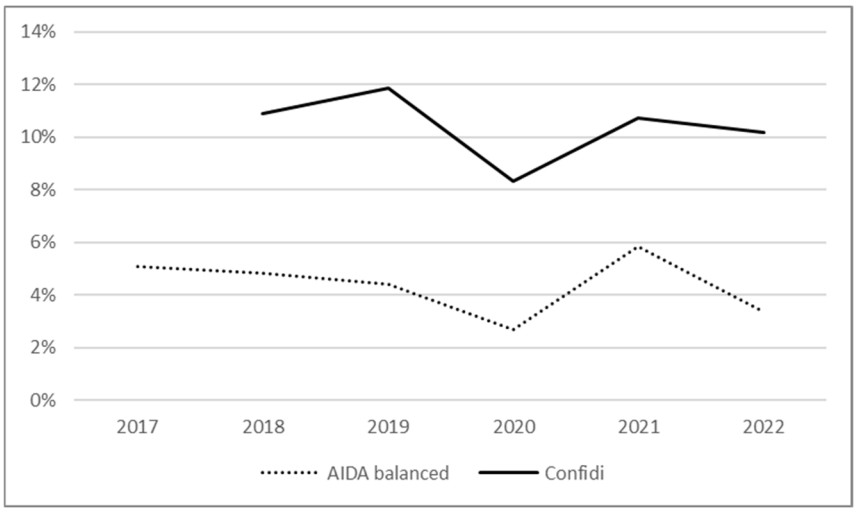

Figure 10. ROI, years 2017–2022.

The ROI evolution (Figure 10), computed as the EBITDA over the total assets, shows two sides of the considered phenomena. On the one side, the general evolution of the ROI is that of a significant reduction during the most dramatic pandemic year, 2020, reducing the return on investment from 5% in 2019 to 2.6% in 2020 considering the Aida sample, and even more for the confidi-supported sample, going from 11.9% to 8.3% in the same years, but bouncing up in 2021 for both groups nearly to the previous levels and suffering a new reduction in 2022. On the other hand, the confidi-supported firms reported higher ROI levels in all years, showing an interesting return and income capability, which contrasts with their weak financial situation, evidencing their weakness in the bank–firm relationship.

The average cost of debt (Figure 11), computed as the total financial charges over the total debt, confirms the confidi-supported firms' weakness in the bank–firm relationship, reporting higher costs than the general sample, while both samples evidence a significant reduction in debt costs related to the government's financial support during the pandemic years.

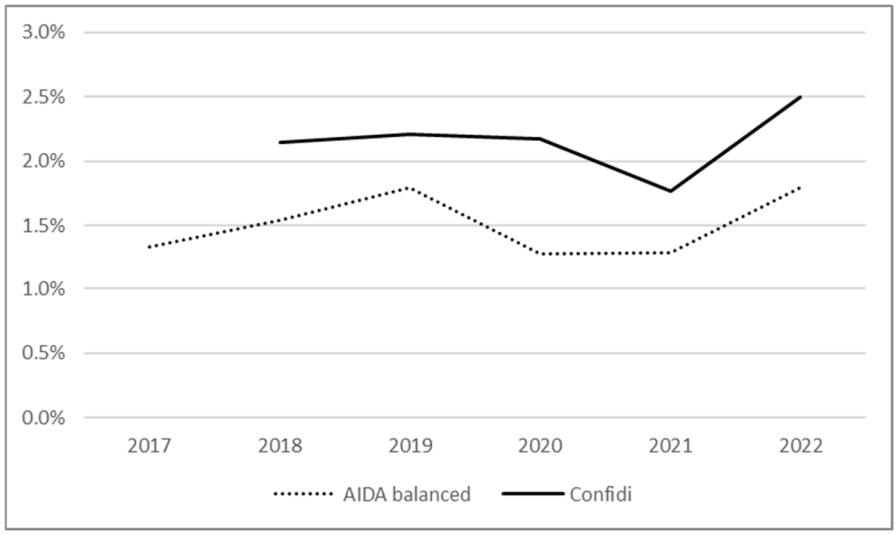

Figure 11. Average cost of debt, years 2017–2022.

5.3. Economic Significance: A Summary of the Analyses on the Role of Confidi

A comprehensive overview of the previous analyses' economic and financial significance provides a synthesis of the confidi's role and their combined effect with the counter-guarantee of the Central Guarantee Fund in supporting businesses during the pandemic period.

Such an overview highlights the general action of the government and private guarantee entities aimed at mitigating the risks of a credit crunch associated with the economic crisis brought about by the COVID-19 emergency and the lockdown measures.

Specifically, the analysis focused on comparing the resilience and performance of businesses supported by confidi versus those external or not associated with guarantee consortia revealed that businesses affiliated with confidi entered the pandemic period generally less liquid (Figure 7), weaker in their ability to generate cash flows, and less capitalized in absolute terms and relative to their liabilities (Figures 6 and 8). These characteristics depress creditworthiness, leading to adverse rating outcomes and, thus, reducing these businesses' independent abilities to secure financial leverage. The confidi's intervention proved essential to ensuring these businesses' survival in the market. Moreover, these companies demonstrated greater receptivity to fixed-asset investment strategies, enhancing their corporate structures (Figure 5).

From a strictly economic perspective, the confidi's support for these (financially fragile) businesses significantly contributed to revenue growth (even doubling in some cases, Figure 9) and achieved profitability. Although subject to para-physiological cyclical fluctuations, this profitability remained significantly higher than the external sample's (Figure 10).

In short, the confidi's role positively impacts businesses characterized by viable and scalable business models, albeit financially and patrimonially weak, less resilient to systemic crises, and more dependent on credit support. The confidi's guarantees enable these businesses to maintain their market position even during turbulent periods while facilitating their development in terms of assets, production value, and operational profitability.

6. Discussion and Conclusions

Credit consortia are essential in mitigating the asymmetry in the bank–firm relationship. Acting like a debtors' union, they help small and financially fragile firms find credit coverage for their investments and negotiate conditions. Our data confirm that the confidi-supported firms are smaller, less capitalized, and less liquid but capable of high returns. This is the typical profile of small firms needing support in the firm–bank relationship, allowing confidi to help them obtain more credit in better conditions.

During the SARS-CoV-2 pandemic crisis, credit consortia played a significant role, supporting Sardinian SMEs with guarantees and helping them obtain government financial support.

As highlighted by our study, debt financing has proven to be a critical resource for SMEs during challenging economic periods. Specifically, during the SARS-CoV-2 pandemic, we observed a decrease in equity levels alongside an increase in debt financing. This finding is supported by the studies of Halling et al. (2020), Acharya and Steffen (2020), Li et al. (2020), and Gopalakrishnan et al. (2022), which underscore the critical role of debt for firms during periods of uncertainty. Similarly, Khurana et al. (2024) note that SMEs often prefer debt over financial autonomy during crises, a conclusion confirmed by our research. This trend aligns with our findings that the availability of inexpensive debt, facilitated by public intervention, significantly encouraged its use as a financing mechanism during the pandemic. As our study highlights, government interventions aimed at enhancing credit access for firms played a critical role in reducing the cost of debt. Wang et al. (2024) similarly observed that such measures alleviated liquidity pressures and enabled businesses to sustain operations.

Our study further reveals that the level of debt increased during the crisis as borrowing costs declined due to government-supported credit initiatives. Additionally, we noted that firms utilizing credit consortia experienced higher debt costs than other firms. Gómez et al. (2016) also observed that credit consortium intermediaries were generally more expensive than direct bank financing due to additional layers of intermediation. However, public support programs promoting SME growth made credit consortia a vital financing channel for specific firms, particularly for those unable to access direct banking due to their small size and vulnerability. Our study also highlights the heightened vulnerability of firms supported by credit consortia, characterized by limited liquidity levels, higher average costs of debt, and significant debt exposure. This increased risk for firms relying on credit consortia was also noted by Gai et al. (2016).

In terms of performance, our analysis shows that SMEs benefiting from credit consortia exhibited more significant increases in sales and asset levels attributed to public intervention compared to the general sample. Additionally, these supported firms demonstrated higher and sustained ROI levels during the crisis than the general sample. Similar findings were reported by Khurana et al. (2024), Corredera-Catalán et al. (2021), and Briozzo and Cardone-Riportella (2016), who demonstrated a positive correlation between firm performance and the financial support received during crises. These studies collectively emphasize the untapped potential of SMEs, which can only be realized when they have access to essential financial resources to strengthen their operations and drive growth.

The pandemic was an exciting chance to study the effect of liquidity injections in small and nonliquid firms. The capability of higher investment and positive returns, which is expected by theoretical deduction, is confirmed by the evidence. The liquidity provided by the government support, filling the main gap in their financial structure, lighted a restart of the confidi-supported firms, firstly just providing higher liquidity, which, from the subsequent year, was transformed not only into higher investment but also resulting in a positive jump on sales.

The demographics of Sardinian companies in 2019–2022 and the volumes of loans and savings showed a strengthening of debt capital payments, increased collections, and a progressive improvement of the companies' aggregate net financial position in Sardinia. In short, the credit support provided by the government, banks, and credit consortia resulted in the overcoming of the crisis. It improved the real economy framework with respect to the pre-pandemic scenario.

The evolution described here suggests that the credit restrictions SMEs suffer from can be due to a market failure, such as the credit system's incapability and banks' ability to allocate credit resources properly.

This incapability to select good customers is often due to the need for more hard information from balance sheets and bank account records. The opacity of accounting

information is due to the small firms' possibility of a simplified accounting system and the significant use of cash, which reduces the information coming from the bank account. The lack of hard information is becoming more significant over time as the banks' progressive use of credit scoring quantitative models actually relies on hard information. Hence, the unavailability or mistrust of these information sources reduces the scoring model's capability to allow for firm financing.

In this sense, the role of credit consortia is very significant, as on the one side, their credit assessment mainly relies on the soft information provided by the close contact and specific knowledge of each firm, and, on the other side, backing the financing request by specific guarantees, which increase the firm scoring, allows the bank to finance the firm.

The guarantee support, which is fundamental in this framework, is the primary constraint for the credit consortium activity, as it must be covered with capital or counter-guarantees. The analysis of credit consortium activity in Sardinia shows instead a progressive reduction in their activity, partially substituted by direct public guarantees. It shows a higher efficiency of larger confidi, which are also the ones under stricter supervision by the Banca d'Italia, being monitored by quantitative risk measurement and management models.

The higher efficiency of larger confidi is critical in policy terms, as it shows that a smaller number of larger credit consortia can provide more substantial support to Sardinia's small and financially fragile firms. In operative terms, the opportunity to merge or acquire the smaller ones into one or a few larger ones is a possible way to improve their capability to help Sardinia's smaller firms and to support them in their investment and growth.

The main limit of this analysis is in the small number of cases of confidi-supported firms, which are not publicly available. Future studies based on more data could extend the analysis to encompass the entire Italian context, considering firms supported by MGSs across all regions, not just Sardinia. A broader examination would allow for an assessment of regional differences in Italy and offer a more comprehensive understanding of firms' responses on a national scale.

The role of confidi could be better understood outside the context of financial distress, focusing instead on a more typical economic setting. In such an environment, evaluating their effectiveness in supporting financially stable firms and comparing their performance with direct financing channels could provide more insights into their value proposition. Given the limited research on credit consortia within the Italian economy, new studies would help improve our understanding of their function and impact in the broader financial landscape.

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The Role of Personal Remittances in Economic Development: A Comparative Analysis with Foreign Direct Investment in Lebanon

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Abstract: Understanding the role of personal remittances in economic development is crucial, particularly for countries like Lebanon, where these inflows play a significant role in economic stability. This study investigates the impact of personal remittances on Lebanon's economic development over the period from 2002 to 2022, employing a mixed-methods approach that combines quantitative regression analyses and qualitative data from surveys. The research finds that personal remittances have a more substantial effect on Lebanon's GDP compared to foreign direct investment (FDI), with positive correlations observed between remittances and key economic indicators such as GDP, public debt, and unemployment rates. Additionally, qualitative findings reveal that remittances are vital for addressing basic living expenses, education, and healthcare needs, illustrating their multifaceted influence on household well-being. This study contributes to the existing literature by providing a nuanced understanding of how remittances impact economic development in Lebanon and highlights the need for policy interventions aimed at enhancing financial literacy and promoting productive investments. The findings offer valuable implications for policymakers and stakeholders, suggesting that improving the management and utilization of remittances could significantly bolster Lebanon's economic resilience and growth prospects.

Keywords: personal remittances; Lebanon; FDI; sustainability; development economics

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1. Introduction—Research Context and Aim

Worldwide, the volume of personal remittances has been expanding. Personal remittances increased from $420.07 billion in 2010 to $658.06 billion in 2020 (World Bank Group 2022a). In 2023, remittance flows to low- and middle-income nations amounted to approximately $669 billion (World Bank Group 2023). This surge was primarily driven by stable labor markets in developed economies and GCC nations, enabling migrants to continue sending money back home. The regions witnessing growth in remittance inflows included Latin America and the Caribbean (8%), South Asia (7.2%), East Asia and the Pacific (3%), and Sub-Saharan Africa (1.9%). Conversely, the Middle East and North Africa experienced a 5.3% decrease, mainly attributed to a sharp decline in Egypt. The United States maintained its position as the largest source of remittances (World Bank Group 2023).

This increase in remittances of formal transfers against a decrease in financial inflows after the COVID-19 pandemic (El Hamma 2019) in developing countries, especially labor-exporting countries, has gained the attention of researchers considering the impact of foreign currency inflows in those countries. Furthermore, the volume of money sent through informal channels is estimated to be as high as 10% to 50% of the personal remittances received through formal transfers (El Hamma 2019), making personal inflows (formal plus informal) even higher than disclosed inflows.

In 2020, Lebanon's remittances constituted 38% of its GDP, making it the second highest globally. By 2023, remittances made up 28% of Lebanon's GDP, highlighting their essential role in mitigating current account and fiscal deficits (World Bank Group 2022b). Meanwhile, even though the amount of inflow of those personal remittances remains constant and high, the economic indicators in Lebanon are deteriorating (refer to Figure 1).

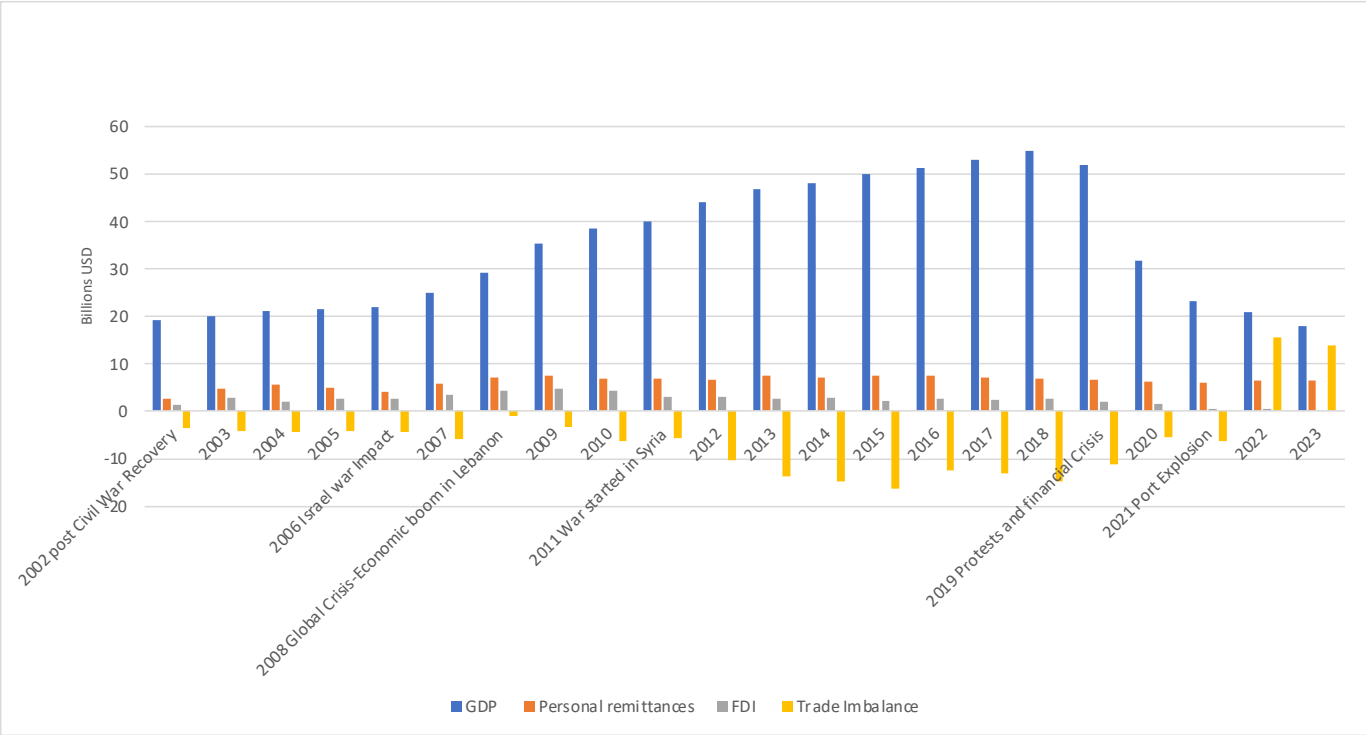

Figure 1. Lebanon economic indicators (2002–2023): A timeline of turning points and influencing factors, adapted by the authors (World Bank Group 2023; Mrad 2024).

Over the last two decades, Lebanon's economic journey has been punctuated by pivotal moments. The early 2000s saw a post–Civil War recovery, but the 2006 Israel–Hezbollah conflict slowed economic growth. During 2007–2008, the country benefited from an economic boom, although, in general, the world faced a global financial crisis. Lebanon exhibited resilience in the face of the 2008 global financial crisis, leveraging its robust banking sector and prudent financial measures. Despite global economic turmoil, Lebanon's GDP increased, and key indicators such as the fixed exchange rate, money supply, and foreign interest rates remained stable (BDL 2023).

The Syrian Civil War in 2011 and protests in 2019 heightened regional tensions and destabilized Lebanon's economy (Rijnoveanu and DemiR 2013; Abdo et al. 2020). By 2020, Lebanon faced a severe economic crisis, worsened by currency devaluation, banking sector collapse, and the Beirut Port explosion. Economic and political uncertainties persist as of 2024.

1.1. Previous Research and Findings on Remittances

Research has extensively examined the role of personal remittances in economic development. Studies emphasize that remittances provide crucial foreign currency, fostering consumption, reducing poverty, and stabilizing economies, particularly in labor-exporting countries like Lebanon (El Hamma 2019). However, the negative implications have also been highlighted, with some arguing that heavy reliance on remittances discourages local investment and can lead to complacency in addressing structural economic issues (Rijnoveanu and DemiR 2013).

In Lebanon, remittances have proven resilient in times of crisis, supporting the economy through events such as the 2008 global financial crisis and the 2020 economic collapse. However, despite their importance, limited research compares the impacts of personal remittances with other financial inflows like foreign direct investment (FDI), which also play a crucial role in the economy.

1.2. Identifying and Addressing the Research Gap

While remittances are widely acknowledged as vital to Lebanon's economy, there is a significant gap in understanding how they compare to other financial flows, such as foreign direct investment (FDI), in terms of their contributions to economic stability and growth. Moreover, the current literature often overlooks the strategic potential of remittances in fostering long-term development. Specifically, few studies analyze the strategic decisions that could help Lebanon harness remittances more effectively to promote sustainable economic growth, particularly in comparison to FDI. Understanding this gap is critical as Lebanon seeks solutions to its ongoing economic crisis.

Filling this gap is crucial for both theory and practice. By comparing the contributions of personal remittances and FDI, this study will provide insights into how Lebanon can leverage these financial flows for sustainable development. The findings will contribute to broader discussions on remittances, helping policymakers in Lebanon and similar labor-exporting countries better understand how to strategically maximize remittances' impact on long-term growth. Thus, addressing this gap will advance both academic research and practical policy recommendations, offering potential strategies to mitigate Lebanon's economic challenges.

1.3. Proposed Solution and Research Approach

This paper aims to explore the impact of personal remittances on Lebanon's economic development using a mixed-methods approach. It compares the significance of personal remittances to foreign direct investment (FDI) and identifies strategic decisions to leverage remittances for sustainable economic growth.

Using regression analysis, a questionnaire, and qualitative data, the research will provide empirical insights into how remittances and FDI contribute to Lebanon's economic stability.

Based on that, the research questions are as follows:

RQ1—How had personal remittances affected economic factors in Lebanon amid several shocks and events?

RQ2—What is the comparative significance of personal remittances (PR) versus foreign direct investment (FDI) in driving economic growth and development, particularly in the context of Lebanon's economy?

RQ3—What strategic decisions may be considered to support economic development, specifically by benefiting from the potential of personal remittances?

The paper starts with an introduction, highlighting the global rise in personal remittances and providing the context, aim, and contribution of the research. Subsequently, the literature review explores extant research, focusing on both the positive and the negative impacts, particularly in the context of Lebanon. The methodology section next explains how the study was conducted. Regression analyses of the empirical results then present the findings, and thereafter, insights are reached that are aligned with social capital theory. Thereafter, discussion interprets the results, leading to surmised conclusions to end industry recommendations and policy implications. Figure 2, below, schematically presents the comprehensive research framework.

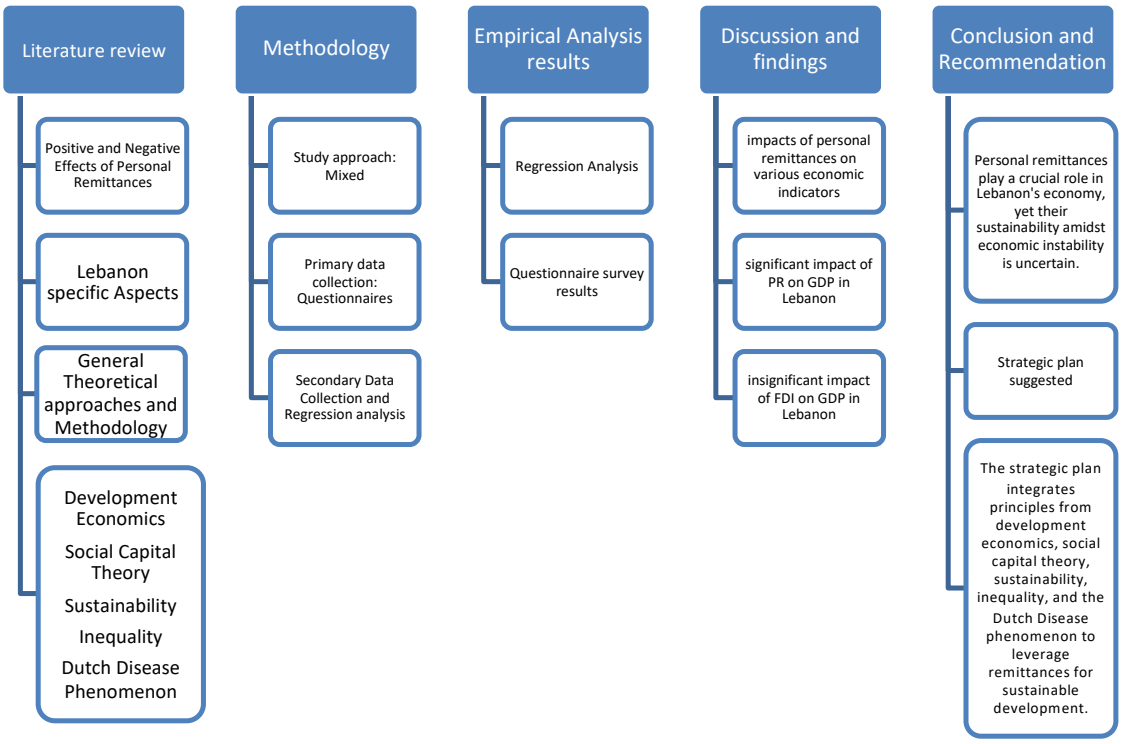

Figure 2. Comprehensive research framework, developed by the authors.

2. Literature Review

2.1. Theoretical Foundations: An Integrated Theory Approach

To conduct this study, a mixed research approach was employed, integrating insights from development economics and social capital theory to comprehensively analyze the impact of personal remittances on Lebanon's economy.

1. Development economics: Development economics focuses on improving economic, social, and political well-being in developing countries (Hayami and Godo 2005). Personal remittances' impact on Lebanon's developmental trajectory is analyzed, considering dimensions such as economic growth, income distribution, and poverty alleviation (UNDP 2023).
2. Social capital theory: Social capital theory provides insights into the societal effects of personal remittances, emphasizing the value embedded in social relationships and networks within communities (Palloni et al. 2001). This framework allows for an examination of how remittances influence wealth distribution and shape societal dynamics. Informed by social capital theory, studies explore the impact of remittance-related social networks on communities, and they emphasize the role of an efficient institutional environment in fostering positive outcomes (Kadozi 2019; UNCTAD 2013).
3. Sustainability: Sustainability considerations underscore the need to ensure long-term economic stability and development in Lebanon. While personal remittances contribute to short-term stability, sustainable development goals emphasize economic growth while protecting the environment and promoting social inclusivity (Aniche 2020). Diversification of revenue sources is essential for Lebanon's long-term sustainability (Chang and Lebdioui 2020).
4. Inequality: Inequality considerations suggest that personal remittances may alleviate poverty and reduce income inequality in recipient countries (Adenutsi 2011). However, remittances may also widen inequality gaps if not distributed equitably or if they primarily benefit certain segments of the population (Islam and Azad 2023).
5. Dutch disease phenomenon: The Dutch disease phenomenon is a crucial aspect to consider in highlighting the negative consequences of remittances. Scholars argue

that remittances may negatively impact productivity and growth, as funds are often directed toward consumption dominated by foreign goods rather than productive investments (Perez-Saiz et al. 2019). This phenomenon suggests that a surge in remittance inflows may lead to a real appreciation of the exchange rate, causing a shift away from tradable to non-tradable sectors (Fullenkamp et al. 2008b).

To provide a comprehensive theoretical framework, this study links key theories that explain the impact of personal remittances on economic development. Development economics emphasizes how remittances can stimulate growth by improving household consumption, education, and health, contributing to overall economic stability. Social capital theory further elaborates on the social dynamics of remittances, as they strengthen relationships between the diaspora and local communities, enhancing social cohesion and economic participation. At the same time, the Dutch disease phenomenon warns of the potential drawbacks of large remittance inflows, such as currency appreciation and reduced competitiveness in export sectors. These economic effects also intersect with concerns of inequality, where remittances may both reduce poverty and simultaneously widen income gaps if unequally distributed. Together, these theories highlight the multifaceted nature of remittances: while they offer vital economic support, especially in crises, their long-term impacts require careful management to promote sustainability and equitable growth.

The relevance of these theoretical frameworks to the context of Lebanon and personal remittances underscores the need for a nuanced understanding of the dynamics at play. Incorporating sustainability and inequality broadens the scope of the literature review, providing a comprehensive understanding of the multifaceted impacts of personal remittances on Lebanon's economy.

2.2. Positive and Negative Effects of Personal Remittances

Meyer and Shera (2015) provided a comprehensive overview of the impact of personal remittances on macroeconomic development. Their study highlighted the positive effects of remittances, such as increasing investment and productivity and improving market conditions to alleviate poverty. However, other research suggested potential negative consequences of remittances, such as moral hazard, reduced work effort, and inflation. El Hamma (2019) examined the impact of global economic changes and the COVID-19 pandemic on remittance flows, which significantly implicate macroeconomic stability. Jongwanich and Kohpaiboon (2019) examined this relationship in developing countries across Asia and the Pacific using data from 1993 to 2013. They discovered a significant negative impact when the ratio of remittances to GDP exceeded 10 percent, while the impact was insignificantly negative when the ratio remained below 10 percent. Furthermore, the Dutch disease phenomenon, as discussed by El Hamma (2019), suggests that spending might shift toward consumption rather than productive sectors, hindering growth. The study critically assessed this paradox, indicating that while remittances can boost consumption, they might also divert resources away from more productive uses.

The positive effects of personal remittances include their role in fostering economic growth through consumption, savings, and investment (Perez-Saiz et al. 2019). Studies in countries like Morocco, India, Pakistan, and Mediterranean nations have shown favorable impacts on investment acceleration (Sahoo 2006). Scholars like Zghidi et al. (2018) and the World Bank emphasized the positive contribution of remittances to developing countries' balance of payments, influencing economic growth directly through savings and investment in human and physical capital and indirectly through consumption. Research by Giuliano and Ruiz-Arranz (2009) highlighted the developmental effects of remittances on consumption multipliers, financial institution development, and foreign exchange utilization.

Conversely, Meyer and Shera (2015) cautioned against potential negative consequences of remittances, including real exchange rate appreciation and resource allocation shifts from tradable to non-tradable sectors. Rodrik's (2008) study suggested that real exchange rate overvaluation can hinder long-term economic growth, especially in developing countries with weak institutions. Sobiech (2019) found partial or negative impacts of remittances on growth in various countries, and Chowdhury et al. (2023) discovered a negative correlation between remittances and per capita income growth. Remittances may indirectly affect the real exchange rate, leading to the Dutch disease phenomenon and negatively impacting economic growth in countries heavily reliant on remittances (Acosta et al. 2009).

Overall, the literature indicates a mixed correlation between remittances and macroeconomic growth. El Hamma (2019) suggested that achieving a positive impact from remittances requires financial development and an efficient institutional environment.

3. Methodology

This study combines quantitative methods to investigate the impact of personal remittances and FDI on economic development in Lebanon. By employing a comprehensive approach, the research integrates both secondary and primary data sources to provide a robust analysis of the influence of this type of financial flow on GDP growth. Additionally, data collection via questionnaires offers contextual understanding (Maxwell 2012) and captures the nuanced perspectives of the Lebanese population regarding the impact of remittances.

Based on the literature review and theoretical approaches in this study, the hypotheses tested are as follows:

Hypothesis (H1). *The relationship between foreign direct investment (FDI) inflows and GDP growth in Lebanon is insignificant or weakly positive. This expectation is supported by literature suggesting that, in economies facing political instability and financial crises, such as Lebanon's post-2019 environment, FDI may have limited influence on economic growth due to lack of investor confidence, governance challenges, and declining business opportunities (Kadozi 2019).*

Hypothesis (H2). *Personal remittances have a positive and significant impact on GDP growth in Lebanon, suggesting their substantial impact on the country's economic development. This is justified by extensive literature indicating that remittances, especially in developing economies like Lebanon, serve as a vital source of income, boost household consumption, and support economic resilience in times of financial instability (UNDP 2023; Fullenkamp et al. 2008a). Given the surge in remittances post-2019, they are expected to significantly contribute to GDP growth.*

These hypotheses were subject to empirical testing using a regression analysis. The outcomes offered valuable insights into the dynamics of economic development driven by remittances and FDI in Lebanon.

The general form of the regression equation, applicable to each of the analyses conducted, is as follows:

$$Y = \beta 0 + \beta 1 \times X + \varepsilon$$

where

- Y represents the dependent variable (e.g., foreign direct investment, public debt, unemployment rate, GDP, or inflation rate)
- X represents the independent variable (personal remittances and FDI in this case)
- $\beta 0$ is the intercept term, representing the value of Y when X is zero
- $\beta 1$ is the coefficient, indicating the change in Y for a one-unit change in X
- ε represents the error term, capturing the difference between the observed and predicted values of Y.

3.1. Secondary Data Collection and Regression Analysis

In our research, we employed secondary data collection methods to tap into existing knowledge from academic papers, government reports, and statistical data, enhancing our understanding of the research topic. Academic papers offered scholarly perspectives, government reports provided insights into societal issues, and statistical data allowed for a quantitative analysis of various aspects.

Additionally, statistical data from reputable sources such as the International Monetary Fund (IMF), the World Bank, and Lebanon's Central Bank facilitated a quantitative analysis of various economic indicators. We specifically utilized yearly data spanning from 2002 to 2021. This time frame allowed for an in-depth examination of long-term trends related to personal remittances, foreign direct investment (FDI), and GDP growth in Lebanon.

The use of SPSS ensured rigorous data analysis, facilitating efficient management, organization, and visualization of the data. This secondary data were critical in testing the hypotheses regarding the relationships between personal remittances, FDI, and GDP growth in Lebanon. We considered the assumptions and limitations of statistical techniques, seeking expert guidance for accurate interpretation.

3.2. Primary Data Collection: Questionnaires

In tandem with our literature review and quantitative analysis, which utilized regression models to examine various variables, we conducted a questionnaire-based survey in December 2023, collecting 157 responses from Lebanese residents.

This methodological choice was driven by the need to delve deeper into the profound impact of personal remittances on a substantial segment of the Lebanese populace. The sampling method was non-probability, given the specific focus on individuals likely affected by remittances. The survey was conducted online due to logistical advantages, such as broader reach across different regions of Lebanon and abroad, as well as the ability to gather responses in a cost-effective and timely manner. Online surveys also offer flexibility, allowing participants to respond at their convenience, thus increasing response rates.

The decision to limit the sample size to 157 was purposeful, statistically reflecting Lebanon's modest population and allowing for a more detailed analysis of the open-ended responses. By integrating both quantitative and qualitative insights, the survey provided a nuanced understanding of personal remittances' role in the economy, complementing our regression analysis.

By incorporating firsthand perspectives through the survey, we aimed to capture the nuanced and pervasive influence of personal remittances, enriching our quantitative analysis with additional contextual data. The integration of quantitative insights from the survey supplements our regression analysis findings (Wang and Ji 2010) and amplifies the significance of personal remittances in shaping Lebanon's economic terrain. This process aligns with the principles of methodological triangulation (Creswell and Clark 2017). This approach ensures a holistic understanding of the subject matter, reinforcing the robustness and validity of our research outcomes.

The integration of these methods contributed to the quality and validity of our research, yielding a comprehensive understanding of the subject matter and supporting the recommendations and contribution of the research. Figure 3 summarizes the methodology framework followed.

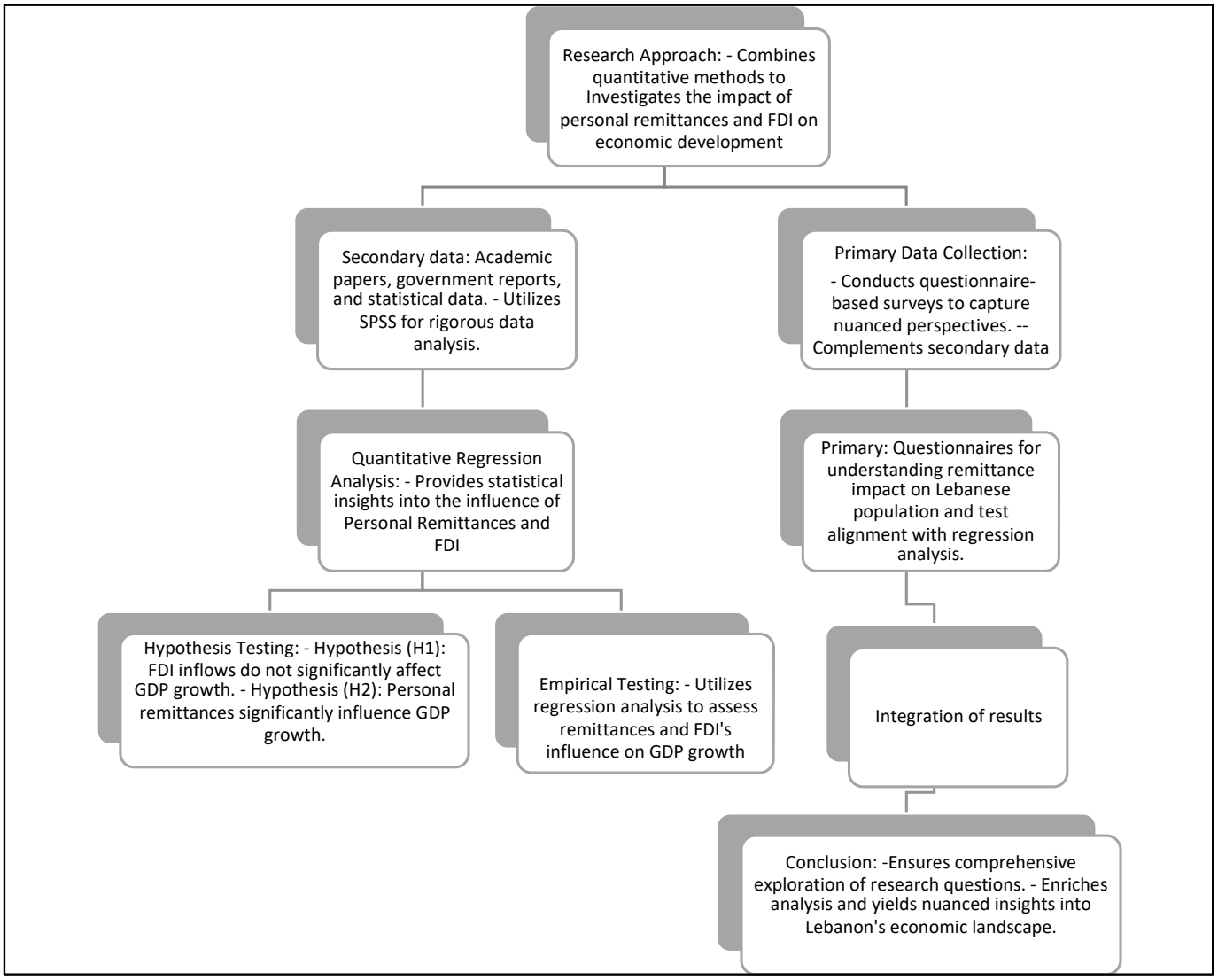

Figure 3. Methodology framework, adapted by the authors, based on Creswell (2013).

4. Empirical Analysis Results

4.1. Lebanon-Specific Aspects

Lebanon is currently facing a critical financial situation, particularly in its banking sector, where the ongoing crisis has led to a severe lack of trust in financial institutions. One potential solution in such crises is a bank bailout, as explored by Mihai Yiannaki (2011) in her study on lessons from recent bank bailouts. Bailouts could offer opportunities for financial recovery and strategic growth, but in Lebanon's case, the lack of public trust in banks and the broader financial system might render this approach unfeasible. Instead, innovative strategies must be explored, as emphasized in the work of Vrontis et al. (2023), which highlights the importance of sustainable and innovative business practices.

International remittances have always been a supporting factor for the financial system and economy of Lebanon. The remittances considered in our case, the Lebanese economy, are transferred by the Lebanese diaspora to their home country. Although there is an existing potential loss represented by brain drain, as well as by skilled employees' migration, we will focus in this study on the foreign currency that those labor forces provide Lebanon with.

The remittances received in Lebanon are high compared to other markets. For example, in 2016, as shown in Figure 4, Lebanon received $7.61 billion in personal remittances, while the Russian Federation received $6.69 billion, and the United States received $6.33 billion

(World Bank Group 2022a). That is despite the gap in GDP between these countries and the USA being the highest. In the same year, Lebanon's GDP stood at $51.15 billion, in comparison to Russia's $1.277 trillion and the United States' significantly larger $18.7 trillion (World Bank Group 2024).

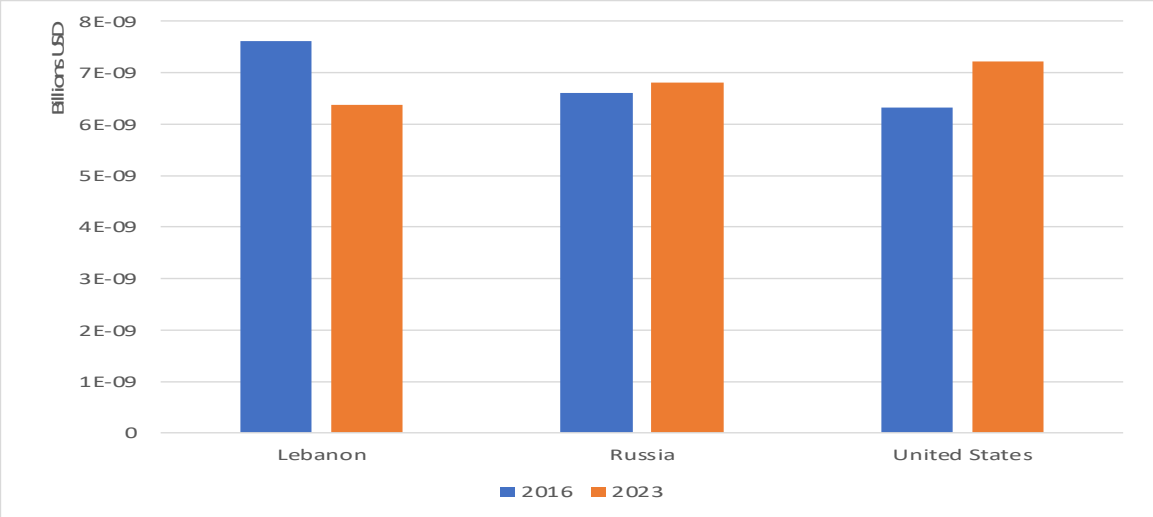

Figure 4. Personal remittances received in Lebanon, the Russian Federation, and the United States in 2016 and 2023. (World Bank Group 2024, adapted by the authors).

Following the financial and liquidity crisis in 2019, accompanied by a surge in unemployment and poverty rates, there has been a heightened reliance on international inflows in Lebanon. In the aftermath of the 2019 crisis, it is estimated that the proportion of Lebanese families depending on remittances has surged, reaching approximately 15% to 30% (Shehadi 2022). A recent study conducted by Mercy Corps Lebanon (2022) further highlighted that 32% of Lebanese individuals now rely on personal remittances to meet their essential expenses. According to World Bank Open Data (World Bank Group 2024), in 2023, Lebanon's remittances continued to be significant at $6.37 billion, reflecting its ongoing reliance on remittances compared to Russia and the United States, which saw increases to $6.80 billion and $7.22 billion, respectively. Our survey is elaborated on in Section 5 and supports this estimation.

Recent research provides additional insights into the broader economic implications of remittances in Lebanon. Kassab (2024) highlighted the inflationary pressures caused by remittance inflows, finding that remittance growth shocks led to significant short-run increases in inflation. This is particularly relevant to Lebanon's economy, where sudden inflows contribute to domestic liquidity but may exacerbate inflationary tendencies. Dauod and Ramirez (2024) explored remittances' positive effects on industrial production in Lebanon, using oil prices as an instrument due to the large share of remittances from Gulf States. Their study found that remittance-driven growth in industrial output is often underestimated, reinforcing the importance of these inflows to the productive sectors of the economy.

Additionally, Ayhan (2021) examined the role of remittances in the banking sector, finding that they positively affected return on equity (ROE) for Lebanese banks, indicating a strong relationship between remittances, banking profitability, and financial sector health. On a regional level, Kratou and Khlass (2022) examined how remittances reduce income inequality in the MENA region by targeting low-income households, which is particularly relevant in Lebanon, where remittances play a key role in poverty alleviation. These studies underline the multifaceted impact of remittances on Lebanon's economy beyond their role as a source of foreign currency.

The average cash inflow from remittances for the decade was about $7.15 billion. In 2022, Lebanon was ranked third in the MENA region after receiving an estimated $6.8 billion in remittances. This comes after Egypt, with a record $32.3 billion, and Morocco, registering $11.4 billion (Aoun 2022). As Figure 5 represents, personal remittances stand higher than FDI, which almost disappeared after the crisis of 2019 (Choueiri et al. 2023).

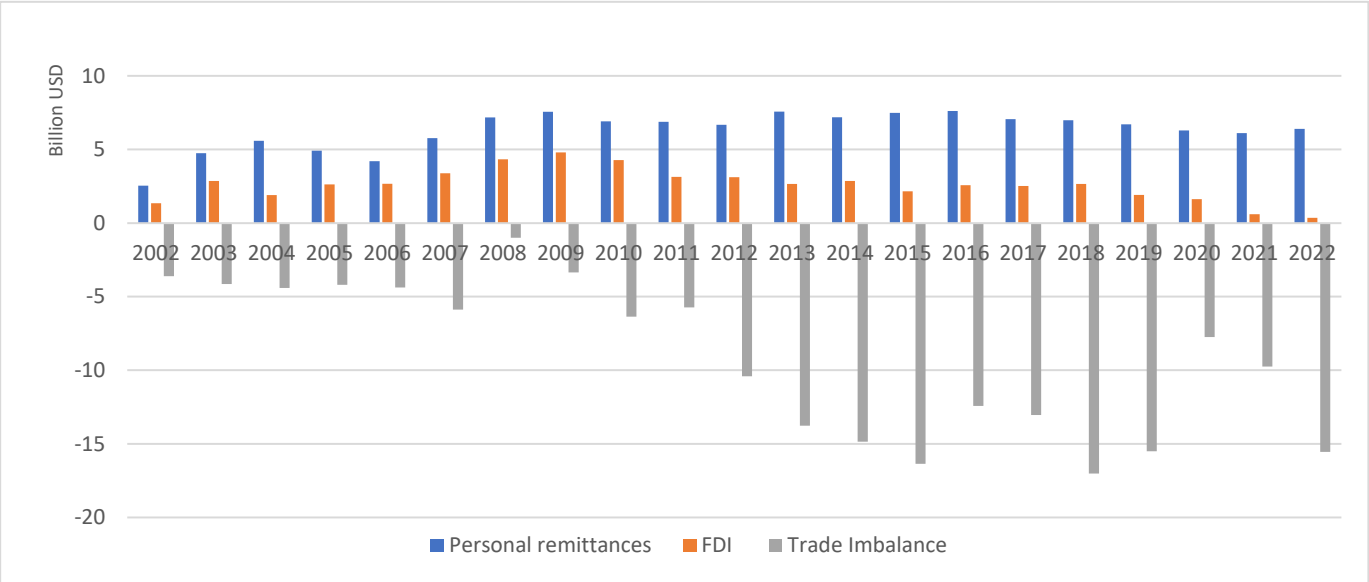

Figure 5. Personal remittances and FDI to Lebanon in billions of USD (World Bank Group 2022a).

Furthermore, Figure 5 illustrates the disparity between personal remittances and FDI, alongside the trade imbalance over the years:

- Personal remittances (PR) vs. FDI: The consistent trend of personal remittances surpassing FDI underscores the significant role of remittances in Lebanon's economy (Shahzad et al. 2014). Despite fluctuations, the overall dominance of PR implies a substantial inflow of funds from diaspora compared to direct investment. This raises questions about Lebanon's attractiveness to foreign investors and the factors driving the preference for remittances over FDI.
- Trade imbalance: The persistent negative values representing trade imbalances indicate Lebanon's reliance on imports, surpassing its export capacity (Azzi 2023). The fluctuating levels of trade deficits over time reflect dynamic economic conditions and external factors influencing trade dynamics. This imbalance poses challenges to Lebanon's economic sustainability and underscores the need for strategies to address trade disparities and promote export-driven growth.
- Impact as sources of foreign currency and economic implications: Personal remittances, crucial for Lebanon's financial stability and household support, dominate as stable sources of foreign currency (UNDP 2023). In contrast, FDI represents longer-term commitments subject to economic conditions. Heavy reliance on remittances to offset deficits raises sustainability concerns (Fullenkamp et al. 2008a). While providing short-term relief, remittances' long-term impact on development requires careful consideration. Lebanon must diversify foreign currencies sources and address structural issues for sustainable growth and resilience to shocks.

4.2. Regression Analysis

The first group of regression analyses was conducted on various dependent variables, each linked to personal remittances. Table 1 summarizes the contributions, implications, and further interpretations of each analysis.

Table 1. The impact of personal remittances on economic indicators.

Analysis	FDI (Foreign Direct Investment)	Public Debt	Unemployment Rate	GDP (Gross Domestic Product)	Inflation Rate
Contribution	A strong positive relationship exists between personal remittances and FDI, supported by a high R-squared value (0.9289) and low *p*-value (5.63×10^{12}).	There is a significant positive correlation between personal remittances and public debt, evidenced by the high R-squared value (0.8962) and low *p*-value (1.75×10^{10}).	The regression reveals a strong positive association between personal remittances and unemployment (R-squared = 0.9607, *p*-value = 1.18×1011).	A substantial positive relationship between personal remittances and GDP is evident, supported by a high R-squared value (0.9517) and low *p*-value (1.71×10^{13}).	The analysis indicates a weak positive correlation between personal remittances and the inflation rate (R-squared = 0.1291, *p*-value = 0.1106).
Implication	Higher personal remittances correlate with increased FDI, suggesting remittance-receiving countries may attract more foreign investment.	Increased personal remittances coincide with higher public debt, possibly indicating elevated government spending or borrowing influenced by remittance inflows.	Higher personal remittances are linked to increased unemployment rates, suggesting remittances may not effectively contribute to job creation or economic development.	Countries receiving higher personal remittances experience significant GDP growth, likely due to stimulation of consumption, investment, or other factors.	While there is a modest increase in the inflation rate with higher remittances, the result lacks statistical significance, suggesting a tenuous relationship between the two variables.

Based on the analysis in Table 1, we can interpret the observed relationships between personal remittances and key economic indicators.

Foreign Direct Investment (FDI): Although there is a strong positive correlation between personal remittances and FDI, further research is necessary to establish causality. Policymakers should investigate whether remittances directly attract FDI or if other factors contribute. Additionally, strategies should be explored to harness remittances for sustainable FDI and economic growth.

Public Debt: While the correlation suggests a relationship between remittances and public debt, it is crucial to assess the underlying factors driving this trend. Policymakers must consider whether increased public debt reflects productive investment or unsustainable fiscal practices. Strategies to manage public finances effectively and ensure transparency in government spending are essential for mitigating risks associated with rising debt levels.

Unemployment Rate: The observed correlation between remittances and unemployment underscores the complexity of labor market dynamics. Policymakers should investigate structural factors contributing to unemployment and explore targeted interventions to enhance job creation and workforce development. Additionally, assessing the quality of employment opportunities and addressing mismatches between labor supply and demand is critical for leveraging remittances to reduce unemployment effectively.

GDP (Gross Domestic Product): While remittances contribute positively to GDP growth, policymakers should consider the sustainability and inclusivity of economic expansion. Strategies to diversify the economy, promote innovation, and enhance productivity are essential for achieving resilient and inclusive growth beyond remittance-driven gains. Moreover, addressing structural constraints and investing in human capital development can amplify the long-term impact of remittances on economic prosperity.

Inflation Rate: The weak correlation between remittances and inflation underscores the importance of considering broader macroeconomic factors influencing price stability. Policymakers should monitor inflationary pressures and implement appropriate monetary policies to ensure price stability while harnessing the benefits of remittance inflows. Addi-

tionally, exploring the impact of remittances on income distribution and purchasing power can provide deeper insights into their implications for inflation dynamics.

In summary, these analyses provide valuable insights into the multifaceted impacts of personal remittances on various economic indicators, informing policymakers and researchers about the dynamics of these relationships. The implications highlight both positive and potentially challenging aspects of the influence of remittances on a country's economic landscape.

Thus, considering Table 2, a one-unit increase in personal remittances is associated with a substantial increase of 1.3718 units in FDI. For every one-unit increase in personal remittances, public debt is expected to increase by 0.4232 units. A one-unit increase in personal remittances corresponds to a significant 23.3070-unit increase in unemployment.An increase of one unit in personal remittances is linked to a 5.8345-unit increase in GDP. While a one-unit increase in personal remittances is associated with a 2.2184-unit increase in the inflation rate, the relationship lacks strong statistical support.

Table 2. Summary of results of regression analysis.

Dependent Variable (PR as Independent Variable)	FDI	Public Debt	Unemployment	GDP	Inflation Rate
R-squared	0.9289	0.8962	0.9607	0.9517	0.1291
Significance (*p*-value)	5.63×10^{12}	1.75×10^{10}	1.18×10^{11}	1.71×10^{13}	0.1106
Coefficient (PR)	1.3718	0.4232	23.307	5.8345	2.2184

Note: Personal remittances (PR) = independent variable. FDI, public debt, unemployment, GDP, and inflation rate = dependent variables.

The second concept of regression analysis was comparing the impact of Personal Remittances and FDI on GDP in Lebanon:

The comparison between the regression results for FDI and GDP, and personal remittances (PR) and GDP reveals stark differences in their impact on Lebanon's economic output:

Table 3 summarizes the regression statistics for both personal remittances to GDP and foreign direct investment to GDP, highlighting their respective coefficients, standard errors, t statistics, *p*-values, and confidence intervals.

Table 3. Comparing regression analysis.

	Personal Remittances (PR) to GDP	Foreign Direct Investment (FDI) to GDP
Multiple R	0.976	0.12
R-squared	0.952	0.014
Adjusted R-squared	0.899	−0.04
Coefficient	5.834	1.534
Standard error	0.302	2.996
t stat	19.347	0.512
p-value	5.82×10^{14}	0.615
Lower 95%	5.203	−4.761
Upper 95%	6.466	7.828

Note: Data sources: IMF, World Bank, Lebanese Central Bank.

The comparison between the regression results for FDI and GDP, as well as personal remittances and GDP, reveals stark differences in their impact on Lebanon's economic output. Regarding PR to GDP, the regression analysis demonstrates an exceptionally strong positive correlation, with a multiple R value of 0.976, indicating a robust relationship. The R-squared value of 0.952 suggests that approximately 95.2% of the variation in Lebanon's

GDP can be explained by variations in personal remittances, further supported by the adjusted R-squared value of 0.899, indicating statistical significance. The coefficient for personal remittances, standing at 5.834, signifies that for every unit increase in personal remittances, Lebanon's GDP increases by approximately 5.834 units. Conversely, the regression analysis for FDI and GDP reveals a weak positive correlation, with a multiple R value of 0.120. The R-squared value of 0.014 indicates that only about 1.4% of the variation in Lebanon's GDP can be explained by variations in FDI, and the adjusted R-squares value of -0.040 suggests a poor fit of the model to the data. The coefficient for FDI is 1.534, but it lacks statistical significance, with a p-value of 0.615. In summary, while personal remittances significantly impact Lebanon's GDP, FDI does not appear to be a significant driver of economic growth in the country. This underscores the necessity of understanding the varied sources of economic influence and implementing targeted policies to capitalize on the benefits of remittances for sustainable development in Lebanon.

In summary, while personal remittances have a substantial and statistically significant impact on Lebanon's GDP, FDI does not appear to be a significant driver of economic growth in the country. This highlights the importance of understanding the diverse sources of economic influence and the need for targeted policies to harness the benefits of remittances for sustainable development in Lebanon.

4.3. Hierarchical Multiple Regression Models

In order to strengthen the reliability of the regression analysis and the robustness of the pairwise estimates, a hierarchy of several multiple regression models was conducted. This approach involved the progressive addition of control variables to the baseline model, which initially focused on the relationship between foreign direct investment (FDI) and gross domestic product (GDP). The aim was to demonstrate the robustness of the regression estimates by exploring alternative models that control for other economic variables.

Hierarchical Regression Analysis Procedure:

Baseline Model 1: FDI to GDP

- Description: This baseline model examines the relationship between foreign direct investment (FDI) and gross domestic product (GDP). It seeks to establish whether FDI has a significant impact on economic growth in Lebanon when considered in isolation.
- Findings: The results show that FDI has a weak and statistically insignificant relationship with GDP. This indicates that FDI is not a major driver of economic growth in Lebanon, as expected by traditional economic theory. The low R-squared value (0.014) means that only 1.4% of the variation in GDP can be explained by FDI alone.

Model 2: Control Variables Added

- Description: In the second model, additional control variables—such as public debt, unemployment rate, and inflation rate—are introduced to account for other factors that may affect GDP. The aim is to isolate the specific effect of FDI on GDP while controlling for these economic variables.
- Findings: With the inclusion of control variables, the model fit improves significantly (R-squared increases to 0.819), explaining approximately 81.9% of the variation in GDP. However, even with the control variables, FDI remains a weak predictor of economic growth, reinforcing the findings from Model 1.

Model 3: Personal Remittances (PR) Added

- Description: This model adds personal remittances (PR) to the analysis as a new independent variable, given the strong correlation observed between PR and GDP in earlier pairwise analyses. The objective is to compare the relative contributions of FDI and PR to Lebanon's GDP.
- Findings: The inclusion of PR drastically improves the model, with R-squared rising to 0.899, meaning that 89.9% of the variation in GDP can now be explained by the model. The results show that PR has a much stronger and statistically significant impact on

GDP compared to FDI. This suggests that PR plays a more prominent role in driving Lebanon's economic growth.

Model 4: PR and FDI with Control Variables Removed

- Description: In this final model, control variables are removed to focus solely on the relationship between PR, FDI, and GDP. This step helps further evaluate the individual contributions of PR and FDI without the influence of other economic variables.
- Findings: The model fit decreases compared to Model 3 (R-squared drops to 0.616), but it still indicates that PR is a dominant predictor of GDP. The exclusion of control variables reinforces that FDI's impact on GDP remains minimal, while PR continues to explain a significant portion of the variation in GDP.

As summarized in Table 4, the hierarchical multiple regression results confirmed that personal remittances exhibited a much stronger and statistically significant impact on GDP than FDI, supporting earlier findings. These findings are crucial for policymakers aiming to harness remittances effectively for sustainable development, while also reconsidering the limited impact of FDI on Lebanon's economic trajectory.

Table 4. Model summary for hierarchical multiple regression.

Model	Variable	Coefficient (B)	Std. Error	t-Value	*p*-Value	R	R Square	Adjusted R Square
1. FDI	FDI	1.534	2.996	0.512	0.615	0.12	0.014	−0.04
2. Control Variables Added	FDI	0.819	0.77	1.063	0.262	0.905	0.819	0.77
	Public Debt	−0.547	0.092	−5.951	<0.001 ***			
	Unemployment Rate	6.855	1.295	5.29	<0.001 ***			
	Inflation Rate	−0.226	0.051	−4.431	<0.001 ***			
3. PR Added	FDI	−2.633	2.086	−1.263	0.207	0.948	0.899	0.863
	Public Debt	−0.309	0.1	−3.09	0.002 **			
	Unemployment Rate	4.302	1.256	3.429	<0.001 ***			
	Inflation Rate	−0.22	0.039	−5.641	<0.001 ***			
	Personal Remittances (PR)	8.197	1.588	5.159	<0.001 ***			
4. PR and FDI with Control Variables Removed	FDI	−2.633	2.086	−1.263	0.207	0.785	0.616	0.571
	Personal Remittances (PR)	8.197	1.588	5.159	<0.001 ***			

Notes: Significance levels: **: Significant at the 5 percent level; ***: Significant at the 1 percent level.

4.4. Questionnaire Results

Our investigation into the impact of personal remittances in Lebanon through the questionnaire has unveiled critical insights that align seamlessly with social capital theory. Rooted in Lebanon's intricate social fabric and close-knit communities, our findings provide a nuanced perspective on how personal remittances contribute to or disrupt social capital within the country. The unique societal structure of Lebanon, marked by diverse religious and cultural groups, underscores the paramount importance of social relationships and networks.

The questionnaire, with a focus on the role and impact of remittances, served as a lens through which we explored the intricate interplay between financial flows and social capital. Notably, a substantial portion of respondents (37.6%) receive remittances (Figure 6),

and about 60% of those receive transfers from family members or friends working abroad (Figure 7).

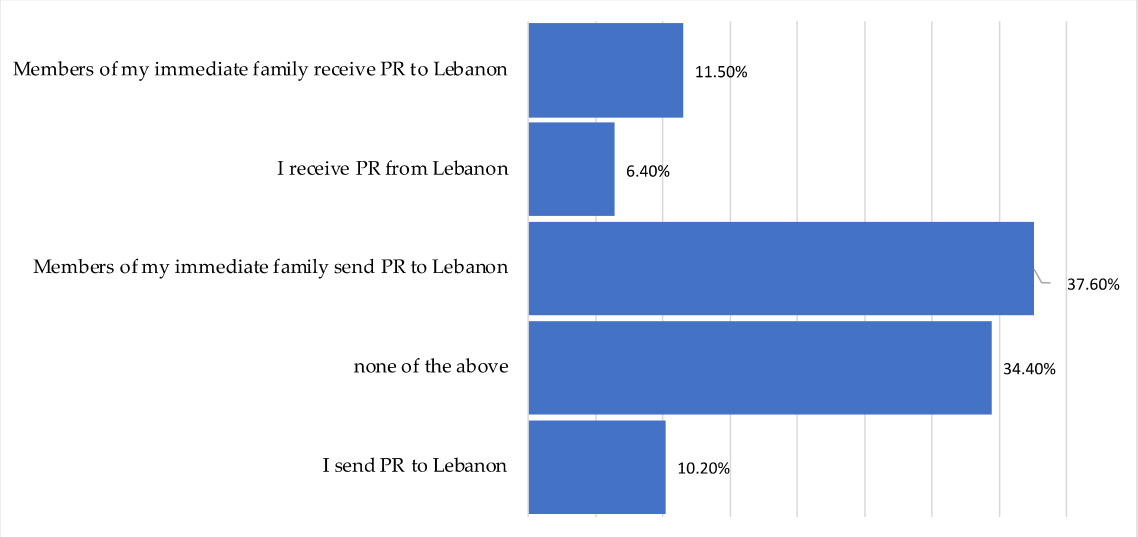

Figure 6. Percentage of receivers of personal remittances in Lebanon, based on survey responses (Question concerning if respondents, or their immediate family, sends or receive PR to/from Lebanon).

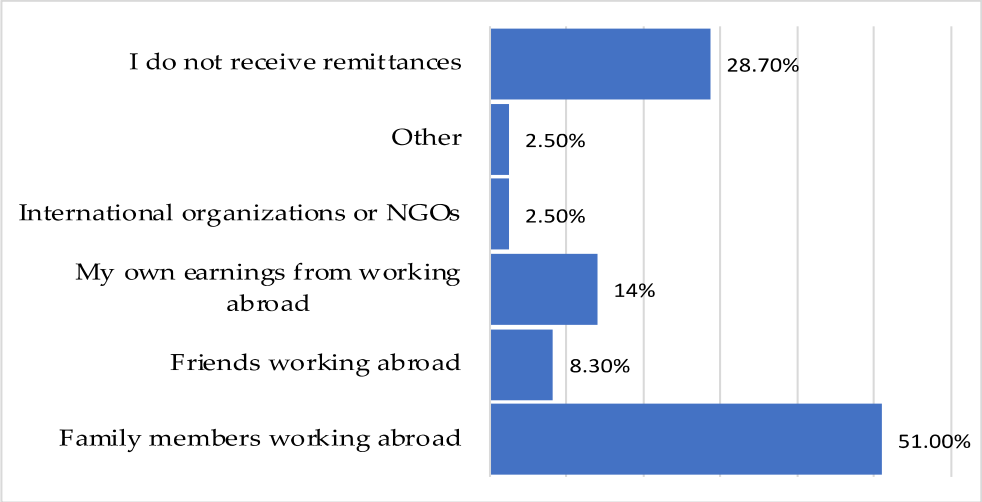

Figure 7. Primary source of remittances received, based on survey responses (If you or your immediate family receive remittance in Lebanon, please select the primary source(s) of these remittances. (You can select multiple options if applicable)).

Furthermore, the majority (about 52.4%) receive less than $1000 per month, and the respondents were asked to select the primary purpose or purposes for which these remittances are used (Figure 8).

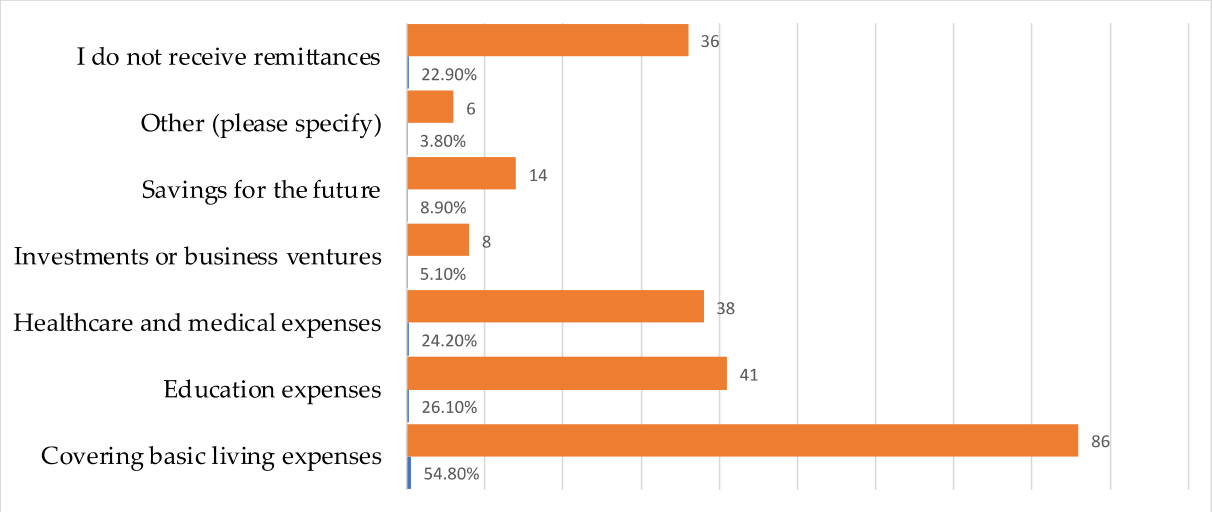

Figure 8. Primary purpose for remittances, based on survey responses (Purposes of remittances utilization among respondents).

The highest percentage of respondents (54.8%) reported that remittances primarily cover basic living expenses, indicating the crucial role of these funds in meeting day-to-day needs such as housing and food. Additionally, significant percentages allocate remittances to education expenses (26.1%) and healthcare (24.2%), reflecting priorities toward human capital development and well-being. The lower percentages directed toward investments or business ventures (5.1%) and savings for the future (8.9%) suggest a predominant focus on immediate needs rather than long-term financial planning or wealth accumulation.

The data related to inequality and sustainability of remittances in Lebanon suggests the following insights.

4.4.1. Inequality Impact

Perceptions regarding the impact of remittances on income inequality among respondents provide diverse insights into Lebanon's socioeconomic dynamics. Based on our survey, approximately 30.6% view remittances as a force for reducing income inequality, aligning with literature suggesting their positive contribution to poverty alleviation (Maimbo and Ratha 2005). Conversely, 16.6% believe remittances have no substantial effect on income inequality, reflecting a nuanced understanding of economic disparities. Concerns expressed by 18.5% about exacerbating income inequality highlight apprehensions about unequal access to remittance funds (Adenutsi 2011). Additionally, 34.4% expressed uncertainty, underscoring the need for further research and policy interventions. Engaging with existing literature can guide comprehensive evaluations of remittances' role in income distribution dynamics in Lebanon.

4.4.2. Sustainability

The analysis reveals diverse perceptions of remittance sustainability among respondents (Aniche 2020). While 25.5% expressed confidence in long-term sustainability, 42% harbored concerns about its continuity, reflecting apprehensions about potential disruptions. An additional 32.5% remain uncertain, highlighting the complexity of remittance dynamics. These findings align with literature discussing the resilience of remittance-based support systems amid economic challenges. However, they also underscore vulnerabilities to external shocks and the need for comprehensive research and policy initiatives to navigate the complexities of remittance flows and their impact (United Nations Department of Economic and Social Affairs 2020) on Lebanon's sustainable development.

4.4.3. Impact on Well-Being, Financial Stability, Development Economics

The analysis reveals varying perceptions of remittance impact on well-being and financial stability among respondents, reflecting the nuanced nature of these financial inflows (Arapi-Gjini 2022). While 50.3% acknowledged a positive or significant impact, 10.2% perceived no significant effect, and 2% noted negative outcomes. The sizable portion (38.2%) that claimed not to receive remittances highlights economic disparities. These findings underscore the need for tailored approaches to leverage remittances effectively and address diverse household needs, aligning with literature emphasizing context-specific strategies for sustainable development (United Nations Department of Economic and Social Affairs 2020).

In summary, the data reflect diverse perspectives on the impact of remittances on income inequality, with a range of opinions regarding whether remittances contribute to reducing or exacerbating disparities. Additionally, there are varying viewpoints on the sustainability of remittances, indicating a mix of optimism, concerns, and uncertainties among the respondents.

5. Discussion

The regression results (Table 1) imply that the analysis of the relationship between personal remittances and key economic indicators in Lebanon reveals nuanced dynamics with significant implications for economic policy and development strategies. While the positive correlation between remittances and FDI suggests potential benefits for attracting foreign investment, it necessitates further investigation into the underlying mechanisms driving this relationship. The association between remittances and increased public debt underscores the importance of fiscal prudence and sustainable debt management to mitigate risks to long-term economic stability. Unexpectedly, the positive link between remittances and unemployment challenges conventional assumptions, highlighting the need for targeted interventions to translate remittance inflows into sustainable job creation and economic opportunities. Despite the substantial contribution of remittances to GDP growth, concerns persist regarding the sustainability and inclusivity of economic expansion, necessitating efforts to address structural constraints and promote broad-based development. Lastly, while the modest correlation between remittances and inflation warrants monitoring, the lack of statistical significance underscores the complexity of inflation dynamics and the need for cautious interpretation in policymaking. In essence, the findings underscore the intricate interplay between remittances and economic variables, emphasizing the importance of evidence-based policymaking and proactive economic management to harness the potential of remittances for inclusive and sustainable development in Lebanon.

In the context of social capital theory, the data provide insights into how personal remittances influence social relationships and networks within the unique societal structure of Lebanon. The prevalence of remittances, with 37.6% of respondents receiving them, reflects the interconnectedness of families and friends working abroad. Most of these remittances come from family members or friends (60%), emphasizing the importance of close-knit relationships. This aligns with social capital theory, which highlights the value embedded in such social networks.

The breakdown of remittance purposes further illustrates how these financial flows contribute to societal dynamics. The primary use for covering basic living expenses (54.8%) indicates a direct impact on the day-to-day well-being of recipients, reinforcing social ties as a means of support. Education and healthcare expenses also feature prominently, emphasizing the role of remittances in facilitating access to essential services within the community.

However, the data also reveal variations in the use of remittances, with smaller percentages allocated to investments or business ventures, savings for the future, and other purposes. This diversity suggests that while remittances strengthen social ties, the economic choices made by recipients can vary, influencing the distribution of wealth within the community.

Upon examining the data considering the Dutch disease phenomenon, notable patterns emerge:

- Consumption focus: The majority (54.8%) said that directing remittances toward basic living expenses raised concerns about excessive consumption, aligning with the Dutch disease phenomenon. This pattern may divert funds from productive sectors necessary for sustained economic growth.
- Limited investment allocation: A small percentage (5.1%) said they allocated remittance to investments or business ventures, suggesting challenges in fostering entrepreneurship and productive capital formation. This limitation may hinder the development of sectors crucial for economic resilience.
- Sustainability concerns: A significant proportion (42%) expressed concerns about remittance sustainability, underscoring worries about the economy's overreliance on external inflows. This sentiment echoes Dutch disease caution against unsustainable dependence on remittance-driven support.

Moving to the data on inequality and sustainability, the insights align with the broader economic implications discussed regarding the Dutch disease phenomenon and social capital theory:

- Inequality impact: The data reflect respondents' diverse opinions on whether remittances contribute to reducing or exacerbating income inequality. While a significant portion (30.6%) believed in the reduction of income inequality, concerns were raised by 18.5% about the potential exacerbation of such disparities. This mirrors the nuanced nature of social relationships and economic choices within the community.
- Sustainability: Opinions on the sustainability of remittances are varied. While 25.5% believed in the long-term sustainability, a substantial percentage (42%) expressed concerns about continuity. This dichotomy echoes the potential drawbacks, such as the Dutch disease phenomenon, where the sustainability of remittance-driven support might face challenges.
- Impact on well-being and financial stability: The positive impact perceived by 50.3% aligns with the idea that, for a significant portion, remittances contribute positively to economic conditions. However, the diversity of opinions, including concerns about sustainability and uncertainty, underscores the complexity of assessing the overall effects of remittances on well-being and financial stability.

In conclusion, the data provide a rich tapestry of insights into the interplay between remittances, social capital, economic choices, and potential challenges. The findings align with the theoretical frameworks discussed and confirm hypotheses 1 and 2, emphasizing the need for a nuanced understanding of the societal and economic dynamics influenced by personal remittances in Lebanon.

The study findings suggest a potential need for careful consideration and policy planning to ensure that remittance inflows contribute to a balanced and sustainable economic development rather than inadvertently leading to challenges associated with the Dutch disease.

6. Conclusions and Recommendations

6.1. Theoretical Conclusions and Implications

This study highlights the complex landscape of Lebanon's economy, which is significantly influenced by personal remittances amid financial instability and political unrest. Remittances, a crucial source of foreign currency, have historically bolstered household incomes and consumption, showcasing their strong correlation with GDP. However, concerns about their long-term sustainability and their impact on productive sectors underline the challenges of economic resilience in Lebanon.

The observed disparity between the substantial impact of personal remittances and the relatively insignificant influence of FDI on GDP underscores Lebanon's struggle to

attract sustainable investments. This disparity points to the need for a diversified economic strategy that does not solely depend on remittances.

6.2. Industry and Policy Implications

To mitigate the risks associated with remittance dependency, it is essential to prioritize economic diversification, institutional reforms, and social inclusion. By leveraging remittances alongside targeted measures, Lebanon can navigate its economic challenges more effectively. Given the limited government capacity and the complexities of political instability, our strategic recommendations focus on engaging non-governmental actors like NGOs, private sector entities, and community-based organizations. These stakeholders are often more agile and responsive, fostering collaborative partnerships and promoting a sustainable approach to leveraging remittances for economic development.

Our proposed strategic plan encompasses actions like community needs assessment, partnership building, capacity program design, financial inclusion, entrepreneurship facilitation, and social enterprise promotion. These measures aim to empower local communities and enhance project sustainability without over-relying on government support.

6.3. Recommendations

Based on the results of this study, a strategic plan outlining the steps needed to implement the recommendations for leveraging personal remittances for economic development without relying heavily on direct government support is suggested (Table 5). The focus is on personal remittances, considering the significant correlation of remittances on economic variables and on FDI itself, while the impact of FDI on GDP is insignificant at such a low rate as it is now, and as per the study conducted.

Table 5. Strategic plan for leveraging personal remittances for economic development.

Steps	Recommended Actions
1. Assess community needs	Conduct comprehensive assessments to understand socioeconomic challenges, opportunities, and aspirations. Evaluate existing levels of financial literacy, entrepreneurial skills, access to services, and community assets.
2. Build partnerships	Forge strategic partnerships with local NGOs, microfinance institutions, academia, the private sector, and the diaspora. Collaborate to co-create and implement development programs, leveraging collective expertise and resources.
3. Design capacity programs	Develop tailored capacity-building programs focused on financial literacy, entrepreneurship, and digital skills. Customize learning materials and methodologies to cater to the specific needs and preferences of target groups.
4. Implement financial inclusion	Pilot innovative initiatives like mobile banking, digital payments, and community-based savings groups. Introduce user-friendly financial products and microcredit schemes designed for remittance beneficiaries.
5. Establish investment funds	Create social investment funds, impact platforms, or community development funds to mobilize remittances. Develop transparent governance structures and investment criteria to ensure accountability and sustainability.
6. Facilitate entrepreneurship	Launch entrepreneurship programs, business incubators, and startup accelerators to provide mentorship and funding. Foster innovation through hackathons, pitch competitions, and networking events connecting entrepreneurs.

Table 5. *Cont.*

Steps	Recommended Actions
7. Promote social enterprises	Encourage the formation of social enterprises, cooperatives, and community-owned businesses using remittance funds. Provide capacity-building support and technical assistance to help establish sustainable business models.
8. Monitor and evaluate	Establish robust monitoring and evaluation systems to track progress, outcomes, and impact of development initiatives. Collect quantitative and qualitative data for adaptive management and program refinement based on stakeholder feedback.
9. Advocate policy reforms	Lobby for policy reforms, regulatory incentives, and supportive environments to facilitate remittance flows. Engage policymakers, regulators, and development agencies in dialogues addressing barriers to financial inclusion.
10. Scale successful models	Identify scalable solutions demonstrating impact and sustainability in leveraging remittances for development. Document case studies and success stories to inspire replication and adaptation of effective interventions globally.

6.4. Limitations and Future Research Avenues

While this study provides valuable insights, it also has limitations. The small sample size, while reflective of Lebanon's population, might not capture the full spectrum of remittance impacts. Future research should explore larger samples or longitudinal studies to understand the evolving role of remittances and FDI in Lebanon's economy.

Moreover, this study primarily relied on pairwise regression results without incorporating control variables. This methodological choice, while simplifying the analysis, may compromise the reliability of the estimates. Future research should consider employing multiple regression models that include relevant control variables, enabling a more comprehensive understanding of the factors influencing the relationships examined.

Additionally, while our strategic plan for leveraging personal remittances for economic development provides a framework for future initiatives, further investigations into the specific barriers to attracting sustainable FDI are warranted. Identifying and addressing these barriers will empower researchers and policymakers to develop targeted strategies aimed at enhancing investment opportunities in Lebanon.

Furthermore, future research is encouraged to expand the survey questions to assess respondents' willingness to invest in Lebanon, particularly in initiatives aimed at supporting small and medium-sized enterprises (SMEs) or launching new businesses. Additionally, employing regression analysis on the survey data could yield valuable insights into the intricate dynamics of remittances and foreign direct investment, enriching our understanding of their impact on Lebanon's economic landscape.

In conclusion, this paper contributes to the literature by proposing an innovative strategic plan for leveraging personal remittances in economic development. Our comprehensive approach, involving diverse stakeholders and robust monitoring mechanisms, emphasizes collaboration and sustainability. By focusing on community empowerment and economic resilience, this study provides a fresh perspective on utilizing remittance flows to foster sustainable development. As highlighted by Bhatia et al. (2022), crises open doors for innovation, necessitating the formation of cross-functional teams to achieve transformative and revolutionary organizational change. This study emphasizes that amidst Lebanon's current economic challenges, such strategies can pave the way for meaningful transformation and growth.

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Effective Machine Learning Techniques for Dealing with Poor Credit Data

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Abstract: Credit risk is a crucial component of daily financial services operations; it measures the likelihood that a borrower will default on a loan, incurring an economic loss. By analysing historical data for assessment of the creditworthiness of a borrower, lenders can reduce credit risk. Data are vital at the core of the credit decision-making processes. Decision-making depends heavily on accurate, complete data, and failure to harness high-quality data would impact credit lenders when assessing the loan applicants' risk profiles. In this paper, an empirical comparison of the robustness of seven machine learning algorithms to credit risk, namely support vector machines (SVMs), naïve base, decision trees (DT), random forest (RF), gradient boosting (GB), K-nearest neighbour (K-NN), and logistic regression (LR), is carried out using the Lending Club credit data from Kaggle. This task uses seven performance measures, including the F1 Score (recall, accuracy, and precision), ROC-AUC, and HL and MCC metrics. Then, the harnessing of generative adversarial networks (GANs) simulation to enhance the robustness of the single machine learning classifiers for predicting credit risk is proposed. The results show that when GANs imputation is incorporated, the decision tree is the best-performing classifier with an accuracy rate of 93.01%, followed by random forest (92.92%), gradient boosting (92.33%), support vector machine (90.83%), logistic regression (90.76%), and naïve Bayes (89.29%), respectively. The classifier is the worst-performing method with a k-NN (88.68%) accuracy rate. Subsequently, when GANs are optimised, the accuracy rate of the naïve Bayes classifier improves significantly to (90%) accuracy rate. Additionally, the average error rate for these classifiers is over 9%, which implies that the estimates are not far from the actual values. In summary, most individual classifiers are more robust to missing data when GANs are used as an imputation technique. The differences in performance of all seven machine learning algorithms are significant at the 95% level.

Keywords: machine learning; credit risk modelling; missing data; generative adversarial networks

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1. Introduction

Additional risks emerge in the credit life cycle because of the spike in activities from the generation of credit to the awarding of loans. These difficulties have prompted the incorporation of technologies that can create reliable credit risk models and handle the underlying data quality problems. While data-driven tools significantly rely on the data to establish links between the inputs and outputs for an empirical framework, data quality is still crucial at every level of the model generation process. Biasness will result from failing to recognise and remove the noise from the data.

Many studies have investigated the effects of poor credit risk management procedures and excessive levels of credit risk in the banking system after the onset of the global financial crisis that caused economic downturns from 2007 to 2009. Banking organisations have now created sophisticated methods for measuring and controlling credit risk across various product lines. The advantages of credit risk management through the Internal Risk-Based

(IRB) approach, where banks use internal data to estimate risk components to quantify exposure to credit loss, have been noted by the Basel Committee (Häger and Andersen 2010).

Due to the missing data utilised to create these models, data quality becomes a fundamental difficulty in the new method. To make strategic decisions that will lead to business success, data are crucial to organisational operations, according to (Madnick and Lee 2009). Given the evolution of big data and its impact on business productivity, data scarcity or abnormalities in data management systems will have a significant adverse effect. According to (Haug et al. 2011), numerous studies have found that inadequate data continues to be an issue in most businesses despite adequate data within the organisation.

Unfortunately, the study on credit risk modelling, which addresses poor data problems, is limited, and reliable imputation strategies are used to reduce the missingness of the data using modern AI approaches. This study will eventually determine if credit risk models reduce the underlying financial loss in banks, which serves as a foundation for predicted credit loss.

By learning from data, artificial intelligence enables machines to replicate human intelligence. These programs will produce biased findings if their underlying data does not fully represent the population, eventually influencing their decision-making. This brings us to the research's main goal: address the significance of data quality, find ways to deal with missing data methodically, and propose effective machine-learning techniques for poor credit data.

The remainder of the paper is outlined as follows: Section 2 presents a literature review of the methods used in the paper. Section 3 related work for poor data phenomena, imputation strategies, mechanisms, and common statistical and machine learning approaches leveraged to tackle the problem; Section 4 presents the experimental set-up for the proposed use of the generative adversarial network strategy and the experimental results. We close with remarks and conclusions in Section 5.

2. Background Review

"Credit" is a derivative of the Greek word "Credere", which means reliable. According to the Greek interpretation, the fundamental principle of credit is the mutual trust between the creditor, which can be either an individual or an entity, and the debtors (the credit applicants). Credit risk is one of the most significant risks associated with banks' operations. Credit risk modelling aims to segregate the customers, identify borrowers likely to default, and eventually calculate the expected credit loss of the loan portfolio. It also assigns customers the proper cost based on their credit score, for instance, charging high rates to high-risk clients and cheap rates to low-risk clients.

As the granting of credit is essential to carrying out normal banking operations, it is safe to argue that this is where the majority of the risks the banks are exposed to originate (Andersen et al. 2001). To adequately manage credit risk exposures, banks need to understand credit risk, according to (Kim and Wu 2008). Furthermore, (Ljubić et al. 2015) assert that this calls for a system of credit risk management that offers accurate and adequate credit risk rating and exact segmentations of credits among priorities that should be closely overseen. A good credit risk policy should lead to the adoption of a system that encourages controlled risk, resulting in the development of a strong credit rating.

2.1. Machine Learning Classification Techniques

2.1.1. Support Vector Machines

Machine learning describes a system that can automatically learn information from experience and other sources. Various machine learning algorithms have been used to solve diverse classification issues. The approach taken to the learning process in each method differs significantly from one another (Danso et al. 2014). As opposed to modelling continuous valued functions, classification predicts categorical labels. In contrast to classification, which focuses on extending known structures to new data, clustering is the problem of

identifying groups and structures in the data that are in some other way without using known structures (David and Balakrishnan 2010).

One of the supervised machine learning approaches found in the literature is called support vector machine (SVM), a classification tool. SVM is based on the structural risk minimisation principle and was first introduced by Vapnik in 1999 to address classification issues. SVM's operating principles can be characterised as a hybrid of linear and non-linear. For regression, classification, and other learning tasks the kernel mapping technique can be used with separate and combined data, and it performs well across various learning tasks. Data storage kernels, (Cömert and Kocamaz 2017), are used to determine how similar or dissimilar data objects are.

In the analytical study of the service quality of Indian railways under soft computing, (Majumder et al. 2024), used support vector machines, extra trees, and multinomial naive Bayes as the three machine learning classification methods they utilised. They conducted a comparative analysis based on seven performance metrics and predicted the overall train rating. According to their findings, the support vector machine is the best estimator out of the three classifiers due to its improved capacity for making predictions on the train and railway data.

2.1.2. Logistic Regression

A form of regression model called a logistic regression is used to forecast the outcome of a categorical dependent variable using one or more predictor variables. Several axes can be related to a dichotomous dependent variable, such as D, using the mathematical modelling technique known as logistic regression. When the illness measure is dichotomous, logistic regression is the most frequent modelling technique used to analyse epidemiologic data. However, other modelling approaches are also viable. In other words, logistic regression computes probability scores for the dependent variable. It uses them to calculate the association between a continuous independent variable (or numerous continuous independent variables) and a categorical dependent variable (Chaudhary et al. 2013).

Like ordinary least squares (OLS) regression, logistic regression is a prediction method. The prediction outcome in logistic regression, however, is dichotomous. Logistic regression is one of the most used tools for applied statistics and discrete data analysis. Since linear interpolation is used in logistic regression (Osisanwo et al. 2017). The approach of choice for credit risk modelling over time has been logistic regression. For instance, (Kutty 1990) provided a logistic regression model for estimating the likelihood that debt owed by developing nations will default. The analysis included the debts of 79 nations over 19 years. The model anticipated the country's debt default two years in advance for Mexico, Brazil, and Argentina.

To forecast the likelihood of default based on financial data, (Hol et al. 2002) used a logistic regression model. Current estimates of the PD of US banks were made (Gurný and Gurný 2013) utilising various statistical techniques, including linear discriminate analysis, probit model, and logistic regression (LDA). For a model estimation in his study, the author examined a sample of 298 American commercial banks gathered from 2007 to 2010 during the financial crisis. Logit and probit models were also subjected to stepwise selection. Despite the probit model having one more indicator, the logit model and the probit model exhibited remarkably similar explanatory powers based on the fit in the training data (96.30% for the logit model and 95.85% for the probit model in terms of pseudo-R-square) (Zhang 2015).

2.1.3. Naïve Bayes

The Naive Bayes variation, known as Gaussian naïve Bayes, assumes that each class is normally distributed and supports continuous values. Based on Bayes' Theorem, Gaussian naïve Bayes strongly assumes that predictors should be independent of one another. For instance, whether we should grant a loan depends on the applicant's income, age, history of prior loans, geography, and transaction history. It is implausible that data points in a

real-world setting won't interact with one another, but unexpectedly, Gaussian naïve Bayes works well in that circumstance.

Despite oversimplified presumptions, it frequently performs better in various challenging real-world scenarios. The naïve Bayes theorem has the significant benefit of requiring less training data to estimate the parameters (Alam and Pachauri 2017). In agriculture, medicine, and biometrics, NB has been applied and proven successful. Nevertheless, nothing is performed with credit scoring to improve banks' and other financial institutions' assessments of a customer's creditworthiness. Finding the likelihood of a label given some observable features is our goal in Bayesian classification. Gaussian, multinomial, and Bernoulli are the three categories of Naive Bayes models.

2.1.4. Decision Trees

Decision trees (DTs) are supervised algorithms that repeatedly divide the data into subsets according to its properties until a stopping requirement is satisfied; a tree-like structure results from this iterative partitioning. DTs are white boxes because it is simple to follow the path from the root node to each leaf node in the tree and deduce the classification rules they learned. Even with the massive quantities of data, DTs are quite effective. This is owing to the algorithm's partitioning nature, which works on ever-smaller portions of the dataset. It typically only works with straightforward attribute–value data that is simple to alter.

$$\text{info}\,(S) = -\sum_{i=1}^{n} \frac{|t_i|}{|t|} \times \log_2\left(\frac{|t_i|}{|t|}\right) \tag{1}$$

Multistage decision-making can be approached in several ways, including the decision tree classifier (DTC). The capacity of DTCs to break down a complex decision-making process into a set of more straightforward options is its most crucial attribute since it results in a solution that is frequently simpler to understand (David and Balakrishnan 2010).

$$(x,\ Y\ ) = (x1,\ x2,\ x3,\ \ldots,\ xk,\ Y\ ) \tag{2}$$

Many conventional applications in numerous domains have successfully used decision trees. Although it can be said that DT is an older strategy, it has proven effective. For instance, DT has recently been used as a machine-learning technique to create automatic classification models for data related to pancreatic cancer. By classifying cases and arranging them based on feature values, DT-based algorithms "learn" from training examples. Each node in a DT stands for a characteristic of an instance that needs to be classified, and each branch stands for a value that the node might consider when planning. The image in the following figure shows how DT operates in the feature space (Danso et al. 2014).

Due to the replication problem, decision trees can represent some concepts substantially more sophisticatedly. One approach is to create intricate characteristics at nodes using an algorithm to prevent replication. The FICUS building technique was first introduced by (Markovitch and Rosenstein 2002). It employs the typical input of supervised learning and a feature representation specification to create a set of generated features. While FICUS shares certain similarities with other feature-creation algorithms, its key advantages are its flexibility and generality. FICUS was made to generate features from any feature representation specification that complies with its general-purpose language.

2.1.5. Random Forest

A random forest is a group of unpruned classification or regression trees inferred from bootstrap samples of the training data using random feature selection. Classifier trees don't require exploratory variables to be multicollinear or to have a functional form. Since they use non-parametric techniques, no distributional presumptions are necessary. Decision

trees can be constructed using a variety of algorithms. Classification trees, first famous by Breiman et al. (1984). These are the most common solutions for binary problems.

$$\hat{f}_{\text{bag}}(x) = \frac{1}{B}\sum_{b=1}^{B}\hat{f}^{b}(x) \tag{3}$$

Splitting rules, which we may use to divide the variable space into more manageable chunks, are the foundation of classification trees. Classification trees have the advantage of being easily understood and easy to understand. Overfitting is a problem that arises when developing an entire tree. Due to its intricacy, the tree's predictive capability may not be good. The pruning strategy, which is outlined, for instance, is the typical approach to address this problem; (Ortl 2016).

The ensemble's predictions are combined (by majority vote for classification or by average for regression) to produce the prediction. Random forest typically shows a significant performance gain compared to single tree classifiers like CART and C4.5 (Yadav and Tiwari 2015). In ensemble learning, RF is a classifier that improves generalisation and classification accuracy for big databases by growing over many classification trees. To use numerous prediction models, RF combines a set of base classifiers that operate independently of one another.

2.1.6. Gradient Boosting

The ensemble model, known as gradient boosting (GB) or stochastic gradient boosting, consists of several elementary decision trees. By merging the predictions of various base models and iteratively reducing the error term, ensemble models seek to increase accuracy. After the initial base model (tree) is set up, each succeeding base model is fitted to the residuals of the previous model to minimise the error term and avoid errors in the current ensemble. Since it is a homogeneous ensemble classifier, more randomness is introduced through bootstrap sampling (Andrić et al. 2019).

Gradient boosting results from Leo Breiman's discovery that boosting may be seen as an optimisation technique for an appropriate cost function. Later, Jerome H. Friedman created explicit regression gradient boosting techniques in parallel with Llew Mason's more comprehensive functional gradient boosting viewpoint (Mason et al. 2000).

The two later studies provide an abstract interpretation of boosting techniques as iterative functional gradient descent algorithms. This refers to algorithms that select a function (weak hypothesis) that points toward the negative gradient iteratively to optimise a cost function across function space. In many fields of machine learning and statistics outside of regression and classification, boosting techniques have been developed due to this functional gradient interpretation of boosting.

2.2. Poor Data Overview

In reality, the data's qualities frequently vary across its many dimensions. The default coverage, for instance, may be less extensive in the early period of the data than in the latter time. Also, smaller firms' financial statements may not be as accurate or consistent compared to larger organisations. For example, sample selection biases, data collection difficulties, and default definition variations are just a few of the data factors that (Dwyer 2007) offer an overview of when validating private enterprises' default risk models.

Most analysts know that these data issues exist in their validation and development samples. Still, they cannot quantify their exact scope, according to (Tang et al. 2011). A standard statistical issue in many application areas is missing values in datasets. Internal records may be lacking in credit analysis for various reasons, including improper registration, clients who refuse to respond to enquiries, and database or recording system errors. One possible approach is to drop the missing values from the original dataset, as performed by (Adams et al. 2002) and (Berger et al. 2005), or perform a preprocessing to replace the missing values, as performed by Banasik et al. (2003) and Paleologo et al. (2010). These procedures are missing data imputations (Louzada et al. 2016).

2.2.1. Listwise Deletion Approach

Listwise deletion, also known as complete-case analysis, is a generally used approach in data analysis. It involves removing any case with one or more missing values from the dataset. The simplest option for dealing with missing data is to use deletion techniques, in which the dataset's rows or columns having missing values are just eliminated. Even though deletion techniques are simple to comprehend and apply, they could yield biased results, particularly when handling missing data that adheres to a unique missingness mechanism. Randomly deleting data might result in the loss of essential information and deliver biases into the analysis that comes afterwards (Zhou et al. 2024).

If a single value is absent from a record, the entire record is removed from the analysis, known as listwise deletion. However, if there are a lot of incomplete records, this strategy could be wasteful and drastically impair statistical power. This happens when the likelihood of missing data is the same across all cases and the process is unrelated to the data (MCAR). As such, there won't be any bias additions to the dataset. Instead, there will only be a loss of data and diminished statistical power (Woods et al. 2021).

A complete-case analysis will provide unbiased estimates in this situation, but standard errors and confidence intervals will reflect the smaller data group containing complete records. Removing any subject with an incomplete set of measurements is comparable to having a lower sampling fraction and a smaller sample size and does not introduce bias. Thus, listwise deletion decreases efficiency even when appropriate, sometimes leading to a dramatically smaller sample size.

2.2.2. Imputation Techniques

Various imputation strategies might be used to keep records of incomplete data in the analysis. Maximum likelihood and multiple imputation techniques can generate accurate estimates for MCAR and MAR without sacrificing statistical power. Observations that are missing are replaced by values that are in some way projected, frequently from a model, using imputation techniques. In a single imputation, the missing observation may be replaced with the sample mean or median, with a predicted value of the variable (for example, from a regression model, bootstrap, or a random dataset from multiple imputation), or with the value from a study patient who matches the patient with the missing data on a set of chosen covariates.

2.2.3. Single Imputation (Median/Mean) and Mode Imputation

Machine learning algorithms can learn from incomplete data with the support of missing value imputation. The three basic missing value imputation strategies are mean, median, and mode. The mean of a set is its average value, the median is its middle value when the numbers are arranged by size, and the mode is the value that appears most frequently in two or more sets. They are only conjectures; it is reasonable to assume that the missing values are most likely very close to the value of the mean or the median of the distribution since these represent the most frequent/average observation when data are missing completely at random. The missing observations most likely look like the majority of the observations in the variable.

2.2.4. Multiple Imputation

Various imputation strategies that accommodate records with missing value data have been used to deal with the incomplete data problem. Maximum likelihood and multiple imputation techniques can generate accurate estimates for MCAR and MAR without sacrificing statistical power. Observations that are missing are replaced by values that are in some way projected, frequently from a model, using imputation techniques. In a single imputation, the missing observation may be replaced with the sample mean or median, with a predicted value of the variable (for example, from a regression model, bootstrap, or a random dataset from multiple imputation), or with the value from a study patient who matches the patient with the missing data on a set of chosen covariates.

2.2.5. K-Nearest Neighbour

A supervised technique called *k*-nearest neighbours (KNNs) categorises new cases based on a similarity metric after storing all the existing data (e.g., distance functions). KNN has been employed in statistical estimation and pattern identification based on their nearest neighbours and an odd number. Its resemblance is quantified by a distance function, like the Euclidean one (Payrovnaziri et al. 2020). K is typically treated as a bizarre number exclusively when making decisions. If K = 1, it will be automatically placed in the class of its closest neighbour. The class with the most votes from its closest neighbour is assigned if K is an odd number; (Reddy and Babu 2018).

$$\text{dist}(X_1, X_2) = \sqrt{\sum_{i=1}^{n} (x_{1i} - x_{2i})^2}, \tag{4}$$

where $X_1 = (x_{11}, x_{12}, \ldots, x_{1n})$ and $X_2 = (x_{21}, x_{22}, \ldots, x_{2n})$.

The two types of nearest neighbour algorithms are structure-based KNN and structure-less KNN. The structure-based approach deals with the data's fundamental structure, with fewer mechanisms connected to training data samples. The data are divided into training and sample points using a structure-less technique. The distance between each training and sample point is determined, and the training point with the least distance is referred to as the nearest neighbour. The KNN technique's effectiveness for big training datasets and robustness against noisy training sets are among its primary features.

Rather than using all available instances in the data, the KNN imputation algorithm uses only similar cases with incomplete patterns. Given an incomplete pattern x, this method selects the K closest cases that are not missing values in the attributes to be imputed (i.e., features with missing values in x), such that they minimise some distance measures.

KNN's benefits include its simplicity, transparency, robustness against noisy training data, ease of understanding, and ease of implementation, while its drawbacks include its computational complexity, memory constraints, poor runtime performance for large training sets, and the potential for issues caused by irrelevant attributes (Soofi and Awan 2017).

The goal is to commit the training set to memory and then predict the label of any new instance based on the labels of its close training set neighbours. This method's justification is predicated on the idea that the characteristics utilised to characterise the domain points are pertinent to their labelling in a way that makes nearby points likely to share the same label (Shalev-Shwartz and Ben-David 2014).

2.2.6. Generative Adversarial Networks (GANs)

A technique called generative adversarial networks (GANs) imputation uses GANs to fill in the missing values in a dataset. A generator network plus a discriminator network makes up GANs, a subtype of deep neural network. The discriminator network attempts to differentiate between the generated samples and the genuine data, while the generator network creates samples similar to the input data. The GAN network is trained to develop data samples identical to the actual data using the available data, including the features and the target variable.

The generator network is taught to produce samples that the discriminator network cannot differentiate from actual data. The GAN network can fill in the missing values once trained by providing the available data along with the missing values and utilising the generator to create the imputed data.

The goal of generative modelling, an unsupervised learning task in machine learning, is to automatically identify and learn the patterns in input data so that the model can produce new examples that could have been reasonably drawn from the original dataset. Figure 1 below shows the GAN architecture for image complexion, where G denotes a generative network trained to produce fake images and the discriminator that learns to categorise them. The discriminator learns to distinguish the counterfeit images made by the generator from the actual images from the dataset.

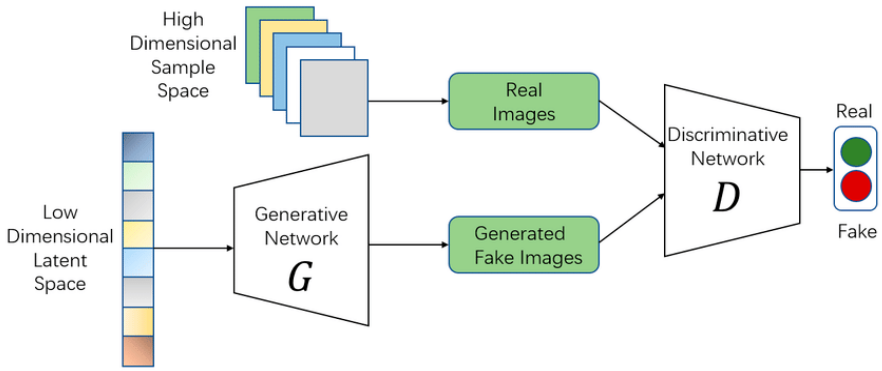

Figure 1. Generative adversarial networks architecture.

It takes two networks to train a GAN: a discriminator network and a generator network. Real data from a dataset is used in the process, along with fake data continuously produced by the generator throughout training. The discriminator receives instructions similarly to any other deep neural network-defined classifier. Data from the training set is presented to the discriminator. The discriminator has been trained to classify the data into the "real" class, and the training process also uses fake data. First, a random vector z is sampled from a previous distribution over the model's latent variables to create the bogus data.

Consequently, the generator generates a sample x = G(z). The function G serves as a neural network model of the random, unstructured z vector meant to be statistically undetectable from the training data. The discriminator subsequently categorises this fake material. Training the discriminator assigns this data to the "fake" class. The generator can be trained using the discriminator's output derivatives concerning its input due to the backpropagation process.

The generator is trained to fool the discriminator into identifying its input with the "real" class. Except for using data from a parameter distribution for the "fake" class, which is updated dynamically as the generator learns, the discriminator's training process resembles that of any other binary classifier. The generator is rewarded by generating outcomes that fool its opponent rather than being given explicit output targets, and its learning process is somewhat different; (Goodfellow et al. 2020).

Motivated by the generative adversarial networks in the previous studies, this paper aims to simulate GAN architecture in the incomplete case context to stimulate the classification accuracy of machine learning models for credit risk modelling. The credit data are mainly classified under a missing at-random mechanism, and the analysis will simulate the GANs architecture to build a robust strategy to improve the data quality.

3. Related Work

First, the nature of the missingness in this paper must be explained to align the methods and assumptions that will handle the dataset used in the experiment. There are three missing data categories: MAR, MCAR, and NMCAR. The data variable is missing completely at random (MCAR) if the probability that the feature is missing is independent of the feature's value and any other features' values. This is often the best-case missingness scenario, with no relation to observed or unobserved values and data equally likely to be missing.

In the medical field, (Jerez et al. 2010) applied machine learning techniques, such as the multi-layer perceptron (MLP), self-organising maps (SOM), and k-nearest neighbour (KNN), to data collected through the "El lamo-I" project. The results were compared to those obtained from the listwise deletion (LD) imputation method. The prediction of patient outcomes was improved by imputation techniques based on machine learning algorithms over imputation statistical techniques.

Templ et al. (2011) mentioned that the imputation method can be used for multiple imputation, producing more than one option for a missing cell if it can handle the inherent

randomness in the data. The use of multiple imputations to reflect sampling variability should only be performed after carefully examining the distributional assumptions and underlying models.

In datasets gathered through the delivery of psychological and educational assessments, missing data are a prevalent issue. It is well known that missing data can cause significant problems like skewed parameter estimates and inflated standard errors. An empirical comparison of the effectiveness of the missing data imputation techniques IRT model-based imputation (MBI), expectation–maximization (EM), multiple imputation (MI), and regression imputation (RI) was conducted in this study. Results demonstrated that MBI performed better than other imputation approaches, particularly with larger sample sizes, in retrieving item difficulty and the mean of the ability characteristics. However, when recovering item discrimination parameters, MI delivered the most significant results (Kalkan et al. 2018).

In practical machine learning tasks, incompleteness is one of the primary data quality concerns. Numerous studies have been carried out to address this problem. Although there is little research on symbolic regression with missing data, most concentrate on the classification task. In this study, a brand-new imputation technique for symbolic regression using unfinished data is presented. The method seeks to enhance the effectiveness and efficiency of symbolic regression using imputed missing data.

Genetic programming (GP) and weighted k-nearest neighbours (KNN.) are the foundations of this approach. To forecast the missing values of partial features, it builds GP-based models utilising other already available features. Such models are built using weighted KNN to choose the instances. The experimental results on actual datasets demonstrate that the suggested method exceeds a number of state-of-the-art methods in terms of imputation accuracy, symbolic regression performance, and imputation time (Al-Helali et al. 2021).

Banks and other lending institutions can build credit risk control models for lending businesses by harnessing machine learning algorithms. The result helps to mitigate the negative aspects of conventional evaluation techniques, such as low efficiency and an overreliance on subjective matter assessment. Nonetheless, data with missing credit features will always be encountered during the practical evaluation of the process. For those machine learning algorithms to be trained appropriately, the missing attributes must be filled in, especially when applying the algorithms to small banks that have little credit data. In this study, we introduced an autoencoder-based approach that can recover the missing data items in the features by leveraging the correlation between the data (Yan 2023).

Thin-file borrowers are consumers whose creditworthiness assessment is uncertain because they do not have a credit history. Many researchers have utilised borrowers' social interactions as an alternative data source to address missing credit information. Traditionally, manual feature engineering has been used to exploit social networking data; however, in recent times, graph neural networks have emerged as a promising alternative. Muñoz-Cancino et al. (2023) introduced an information-processing framework to improve credit scoring models using several methods of graph-based learning: feature engineering graph embeddings.

In several areas of medical research, missing data frequently occurs, especially in questionnaires. In addition to the widely used complete case analysis, this article aims to describe and compare six conceptually distinct multiple imputation methods. It also examines whether the methodology for handling missing data may affect the clinical conclusions drawn from a regression model when the data are categorical.

The missing handling methods selected significantly influence the clinical interpretation of the supplementary statistical analysis. The decision to impute missing data and the imputation method can affect the clinical conclusions made from a regression model and should, therefore, be given adequate consideration (Stavseth et al. 2019).

According to (Wu et al. 2021), they have to categorise a sizable amount of data in the study of mining software repositories to build a predictive model. How accurate the labels are will significantly impact a model's performance. However, the effect of

incorrectly labelled occurrences on a predictive model has only been the subject of a few small studies. The case study was on the prediction of the security bug report (SBR) to close the gap. They discovered that five publicly accessible datasets for SBR prediction contain many occurrences that have been incorrectly classified, which has negatively impacted the accuracy of SBR prediction models used in recent studies.

Although the concept of a decision tree is not recent, decision tree algorithms have been gaining popularity with the growth of machine learning. This technique uses mathematical formulas like the Gini index to find an attribute of the data and a threshold value of that attribute to make splits of the input space (Patil et al. 2016; Amaro 2020). (Namvar et al. 2018) presented an empirical comparison of various combinations of classifiers and resampling methods within a novel risk assessment methodology that integrates unbalanced data to solve these problems. The credit projections from each combination are assessed using a G-mean measure to prevent bias toward the majority class, which has not been considered in previous studies. As a result of their findings, combining random forest and undersampling may be a valuable method for determining the credit risk of loan applications in social lending markets.

(Sharma et al. 2022), in the study titled "A Study on Decision-Making of the Indian Railways Reservation System during COVID-19" and under machine learning application, used a random forest classifier and an extra trees classifier. They also examined the classifiers' predictive power to the cross-validation score and six performance metrics, which include accuracy, precision, recall, F1-score, Hamming loss, and Matthew's correlation coefficient. Their findings indicated no differences in the confusion matrices or values of any performance measures between the two classifiers. However, ETC performs better than RFC in terms of cross-validation score when measured using 10-fold stratified cross-validation.

By adapting the popular generative adversarial networks (GANs) paradigm, we provide a novel approach to imputing missing data. Because of this, they refer to our technique as generative adversarial imputation networks (GAIN). After observing a portion of an actual data vector, the generator (G) imputes the missing data based on the observed data and returns a completed vector. Next, given a finished vector, the discriminator (D) tries to identify which components were imputed and which were genuinely observed. We give D some extra data in the form of a hint vector to make sure D makes G learn the intended distribution. D uses the partial information about the original sample's missingness that the hint provides to concentrate on the imputation quality of specific components. With this edge, G is guaranteed to learn how to generate based on the actual data distribution. We conducted tests of our method on multiple datasets and observed that GAIN performed much better than the state-of-the-art imputation methods (Yoon et al. 2018).

The possibility of missing credit risk data might significantly diminish the assessment model's effectiveness. Therefore, building a data imputation technique is highly beneficial for accurate missing data prediction. Due to the complicated random missing patterns and high missing rate of credit risk assessment datasets, creating an efficient imputation model is typically exceedingly tricky. Multiple generative adversarial imputation networks (MGAINs), a novel imputation technique, is proposed in this research, and this was the first time missing credit risk assessment data were imputed using GANs (Zhao et al. 2022).

The studies above provide various methods for coping with incomplete data in credit risk and other industries. The studies presented one solution in a particular area instead of many solutions to different issues in the credit risk environment. Although robust methods were identified and acknowledged from the studies above, a gap exists in integrating effective strategies to handle poor data extensively. Given the current fourth industrial revolution age and the complexity of its systems and technology component, the paper aims to illustrate the integration of various techniques holistically to underline the necessity to remediate faulty data from end to end but not from its totality.

4. Experiments

4.1. Experimental Set-Up

This section will propose using generative adversarial network unsupervised learning to deal with poor credit data. The aim is to test the robustness of machine learning classification algorithms, namely SVM, naïve base, decision trees, random forest, gradient boosting, K-NN, and logistic regression, when GANs are harnessed as an imputation strategy for the incomplete case scenario. In addition, the empirical comparison of the classification algorithms when the complete case approach, single imputation (mean/median), mode, multiple imputation, and K-NN machine learning are employed is also explored to determine the effectiveness of the machine learning strategies when handling poor data. Furthermore, the complete case approach involves the instance where records with missing values are eliminated from the dataset. While the complete case approach is more effective for the MCAR missingness mechanism, depending on how outcomes and missingness are related, the validity of this strategy may hold in scenarios where data are missing at random.

4.1.1. Data Source

The loan application data are sourced from the Lending Club website in Kaggle. Lending Club is a US peer-to-peer lending company headquartered in San Francisco, California. It was the first peer-to-peer lender to register its securities with the Securities and Exchange Commission (SEC) and offer loan trading on a secondary market. The Lending Club is the world's largest peer-to-peer lending platform.

In terms of missing values, there are a total of 74 identified variables with missing factor ratios, and it is composed of 57 features of numeric data types and 17 categorical data types. The missingness rate percentage ranges from (0.01%) to (100%). Out of the 57 numeric variables, only 16 features have a missingness rate percentage below (50%), 18 features have a missingness rate between +50% and 90% and the remaining 23 features have above a 90% missingness rate.

4.1.2. Data Processing

We applied Z-Score with the threshold method and isolation forest approaches as outlier detection methods to identify potential outliers for the numeric features. The results of the two outlier detectors were compared to see which method was more stable when categorising the outlier instances. The identified outlier's values were treated using median imputation, Winsorize to with (5% and 10%), and different transformations (logarithms, square root, Yeo, and quantiles) were tested. Additionally, this transformation was experimented with to deal with highly skewed data. This attempt was intended to complement the Z-score approach to enhance the technique's performance. Finally, the outliers that impacted the model performance results were discarded.

The missing rate percentage assessed was observed since we are dealing with an incomplete case scenario. The features with over 50% missingness rates were all dropped. Features with missing values were treated using mean/median, mode, multiple imputation, K-NN, and GANs imputation techniques. One-hot encoding was applied to convert categorical variables to numerical data format, and the data were normalised using the min–max scaler.

Correlation metrics for feature relationships were conducted to understand the variables' relationships better. A SelectKBest approach based on a scoring function was used to select the best features and leveraged to train the classifiers. The model performance results were compared with the case where variable selection was not used. The outcome shows almost identical results.

4.1.3. Missing Data

The credit data are mainly classified under a missing at-random mechanism, and the analysis will simulate the GANs architecture to build a robust strategy to solve the data

quality issue. Nicoletti and Peracchi (2006) summarise missing at random (MAR) for the default loan data and state the missing values depend on the observed data, can be fully described by other variables in the dataset, and are not dependent on the missing data.

This assumption underlies most imputation procedures. For example, even though respondents at the lower and upper end of the income distribution are less likely to provide survey responses than those in the middle, these missing data points are related to demographics and other socioeconomic variables, which can be observed in the data (Pedersen et al. 2017).

4.1.4. Data Partition

According to (Siddiqi 2006), there are various ways to split the development (sample on which the scorecard is developed) and validation ("hold") datasets. Typically, 70% to 80% of the sample is used to create each scorecard; the remaining 20% to 30% is set aside and then used to test or validate the scorecard independently. Where sample sizes are small, the scorecard can be developed using 100% of the sample and validated using several randomly selected samples of 50% to 80% each. In this paper, we propose to use a 70% split of the data from the population sample since the primary purpose is to assess the robustness of the classification algorithm to manage poor data.

4.1.5. Model Evaluation

According to (Castermans et al. 2010), the primary aim of back-testing PD discrimination is to verify whether the model still correctly distinguishes or separates between defaulters and non-defaulters or provides a correct ordinal ranking of default risk such that defaults are assigned low ratings and non-defaulters high ratings. Consequently, discriminatory power aims to discriminate the difference between good default events and good non-default events. Therefore, the model can make wrong forecasts for the event.

With that setting in mind, (Wójcicka 2012) stated that in times of economic crises, banks (financial institutions) first and foremost need to minimise their losses by limiting the probability of default of the companies they finance. Of course, on the other hand, they would also want to optimise the profit that comes from funding "good" companies, and lowering the number of "good" companies by classifying too many of them into the group of "bad" firms will result in decreasing their income.

There are two scenarios in which default models can produce misleading results. First, if the model shows a low risk when the risk is high, it points to a type 1 error. This error issues customers with no chance of defaulting with high credit quality. Type 2 error is when the model indicates a high risk when, in fact, the risk is low. The illustration explains the Table 1 below scenarios further on the contingency table.

Table 1. The classification report (Type I and Type II errors).

		ESTIMATED	
		NO DEFAULT	DEFAULT
OBSERVED	NON-DEFAULT	True	(1-Sensitivity) = TYPE II Error
	DEFAULT	(1-Specificity) = TYPE I Error	Hit

4.1.6. Model Performance Analysis

The KS statistic and Gini coefficient are the two most frequently used metrics in an industry context, and the Basel Committee recommends that the Gini coefficient or accuracy ratio (AR) be used in banks to measure models of discriminants. The KS statistic measures the maximum vertical separation (deviations) between two cumulative distributions (good and bad) in scorecard modelling.

To know how to order the attributes from best to worst risk, one must know whether the variable is positively or negatively correlated with the outcome variable. If there is a positive correlation, the higher the variable values, the higher their levels of risk, and vice versa (Bjornsdottir et al. 2009).

(Guo et al. 2017) state that receiver operating characteristic (ROC) curves display the discrimination potential of fitted logistic models by evaluating the tradeoffs between actual positive rate (sensitivity) and false positive rate (1—specificity). If you have a cutoff value, you can classify the subjects as positive or negative according to their predicted probabilities. Hence, a 2×2 classification table can be constructed to show the relationship between the expected and actual outcomes. Sensitivity is the fraction of positive subjects predicted as positive, and specificity is the fraction of negative subjects correctly predicted as unfavourable.

A hamming loss (HL) is the ratio of incorrect labels to total labels. In multiclass classification, the hamming distance between y_true and y_pred is used to compute hamming loss. Consequently, HL considers the prediction and missing errors normalised across the whole number of samples and classes.

The Matthews coefficient is a machine learning performance statistic for binary classifiers, commonly known as the Matthews correlation coefficient (MCC). It evaluates the relationship between the actual and expected binary outcomes, considering each of the confusion matrix's four components.

The randomised search from the sklearn Python library was leveraged to select the best set of hyperparameters so that the classifiers could achieve improved model classification accuracy. The following are the hyperparameters per classifier. The random state for all the classifiers was set to 42. The following are the hyperparameters selected using the randomised search criteria for the seven machine learning classifiers.

- Support vector machines: C = 1.3, gamma = 0.7, kernel = 'linear';
- Random forest: n_estimators = 50, min_samples_split = 5, min_samples_leaf = 2, max_features = 'sqrt', max_depth = None, bootstrap = False;
- Logistic regression: C = 0.2, penalty = 'l1', solver = 'liblinear';
- Gradient boosting: learning_rate = 0.01, max_depth = 4, min_samples_leaf = 2, min_samples_split = 2, n_estimators = 117;
- K-nearest neighbourhood: metric = 'euclidean', n_neighbors = 20, weights = 'uniform';
- Naïve Bayes: var_smoothing = 0.12 and GausianNB;
- Decision trees: max_depth = 5, max_features = None, min_samples_leaf = 2, min_samples_split = 5.

4.2. Experimental Results

A comparative analysis of five imputation strategies and a complete case scenario are conducted. The results of this experiment show the effectiveness of machine learning methods when blended with different missing data approaches. The random state is set to 42, and the classification accuracy for each model is produced to measure the performance.

When GANs imputation is harnessed, the decision tree is the best-performing classifier with an accuracy rate of 93.01%, followed by random forest (92.92%), gradient boosting (92.33%), support vector machine (90.83%), logistic regression (90.76%), and naïve Bayes k-NN (89.29%), respectively. The K-nearest neighbours classifier is the worst-performing method, with an 88.68% accuracy.

For the complete-case approach, the best-performing machine learning algorithms in terms of their robustness when dealing with missing values are the random forest (93.01%), followed by gradient boosting (92.67%), naïve Bayes (90.01%), logistic regression (88.43%), k-NN (87.34%), and SVM (86.84%), respectively. The worst performance is by decision tree with an accuracy rate of 85.01%. The differences in performance of all seven machine learning algorithms are significant at the 95% significance level.

The above table shows the performance report concerning six performance metrics when cross-validation is employed. These models are developed under the GANs im-

putation for incomplete data since the simulation results of GANs from Table 2 revealed improved classification accuracy for algorithms compared to traditional methods. It can be noted that decision trees outperform all six other classifiers in all six performance metrics; gradient boosting, SVM, logistic regression, decision trees, and naïve Bayes follow this. The least-performing classifier is K-NN. The random forest and gradient boosting have almost identical performances, which could be attributed to the fact that both classifiers belong to the ensemble family.

Table 2. Single classifiers using GANs imputation strategy vs. others.

Classifier	Complete Case	GANS	Median/Mean	Mode	MI	KNN
Logistic regression	0.8843	0.9076	0.9126	0.9108	0.9126	0.9114
Naive Bayes	0.9001	0.8929	0.8780	0.8780	0.8745	0.8780
Random forest	0.9301	0.9292	0.9244	0.9244	0.9250	0.9239
Decision trees	0.8526	0.9301	0.8566	0.8560	0.8519	0.8584
Gradient boosting	0.9267	0.9233	0.9233	0.9262	0.9239	0.9239
K-nearest neighbours	0.8734	0.8868	0.8662	0.8673	0.8662	0.8667
Support vector machine	0.8684	0.9083	0.9096	0.9096	0.8745	0.9096

The recall rate of 93% implies the decision tree classifier correctly generalises the data well as shown from the Table 3 below. The GANs strategy has been optimised, and the epochs and batch size have been adjusted to improve the results. The accuracy rate of Naive Bayes was significantly enhanced by over 5% when the GANs strategy was optimised. The results suggest that most algorithms are more robust to incomplete data when GANs are leveraged as an imputation method.

Table 3. Cross validation scores for the performance metrics per seven classifiers.

Classifiers	Accuracy	Precision	Recall	F1 Score	HL	MCC
Logistics regression	0.9076	0.9004	0.9083	0.8926	0.0916	0.4983
Naïve Bayes	0.8929	0.8791	0.8929	0.8811	0.1071	0.4482
Random forest	0.9292	0.9330	0.9292	0.9153	0.0708	0.5955
Decision trees	0.9301	0.9352	0.9301	0.9161	0.0699	0.6022
Gradient boosting	0.9233	0.9209	0.9218	0.9088	0.0781	0.5865
K-nearest neighbours	0.8868	0.8532	0.8868	0.8462	0.1132	0.1704
Support vector machine	0.9083	0.9101	0.9083	0.8881	0.0917	0.5146

The Figure 2 below shows the learning curves of different classifiers to evaluate the performance of the classifiers in the training and cross-validation. The intention is to visually diagnose if the model overfits, underfits, or performs well over time during the learning experience. Additionally, the cross-validation ensures that classifiers' performance is robust and the learning curves are reliable. The learning curve for the training error is higher than that of cross-validation, with most classification models around 90% average accuracy in the train scores, which indicates that the models do not overfit and thus can generalise well in the test data. The lift curve performs well for all the classifiers because the training score and validation score accuracy are close to each other. Even though K-NN is the least performing classifier compared to others, the classifier shows a consistent trend and performs as observed in Figure 2.

The Figure 3 below shows the ROC curve for a comparative analysis of the performance of six different classifiers. The classifiers with the highest AUC scores are as follows:

decision trees (82%) AUC and gradient boosting (82%) AUC, followed by random forest (81%) AUC, logistic regression (79%) AUC, support vector machine (74%) AUC, and naïve Bayes (73%). The K-NN has the lowest (60%) AUC score. Compared to other algorithms, the 82% AUC score for the two classifiers indicates that algorithms perform better for discriminatory power when distinguishing between positive and negative cases. For support vector machine (74%) AUC and naïve Bayes (73%) AUC, this implies a good discriminatory power and offers room to improve the classifiers, which can be achieved through further hyperparameter tuning. Furthermore, though decision trees and gradient boosting have completed (82%) higher AUC scores, decision trees stood out as having a better classification when taking into account all the other evaluation metrics, such as accuracy, precision, F1 score, recall, HL, and MCC. K-NN has the least discriminatory power compared to the six other algorithms and has shown consistent sensitivity to poor data across other evaluation metrics.

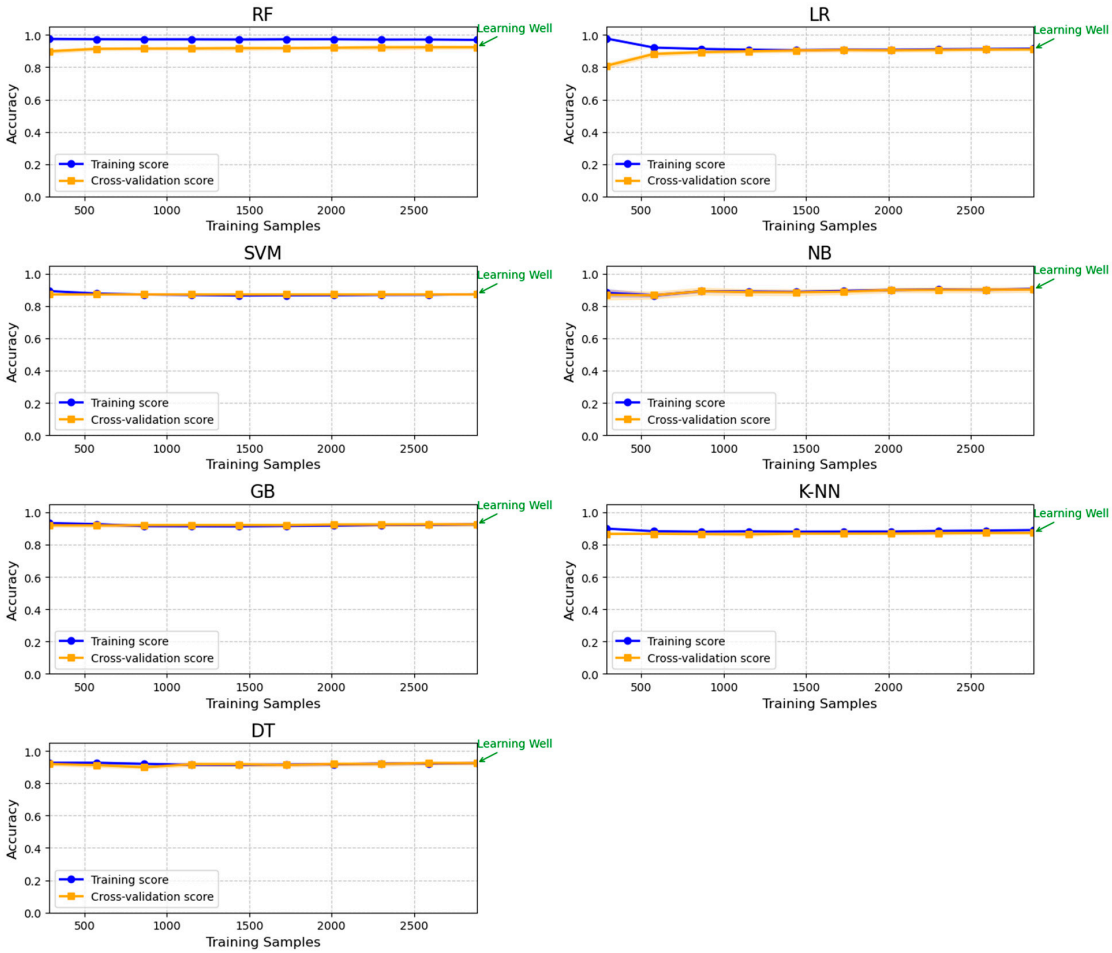

Figure 2. Learning curves for classification models.

The Figure 4 below shows that the decision tree algorithm has the lowest error rate, followed by random forest, gradient boosting, and logistic regression. This low error rate implies that these four algorithms are performing well in classification and generalising well in the validation dataset, as it reveals what percentage of the class predictions are invalid. Though naïve Bayes achieved the highest accuracy from the classification report table refer to Table 2, naïve Bayes have a somewhat lower error rate, above the average 9% error rate compared to SVM and K-NN. This error rate assessment is supplemented with ROC—AUC curve metrics for comprehensive model evaluation to limit the cases of bias in the event of class imbalance. Overall, the performance of DT, RF, GB, and LR consistently show more robustness towards poor data than NB, SVM, and K-NN classifiers.

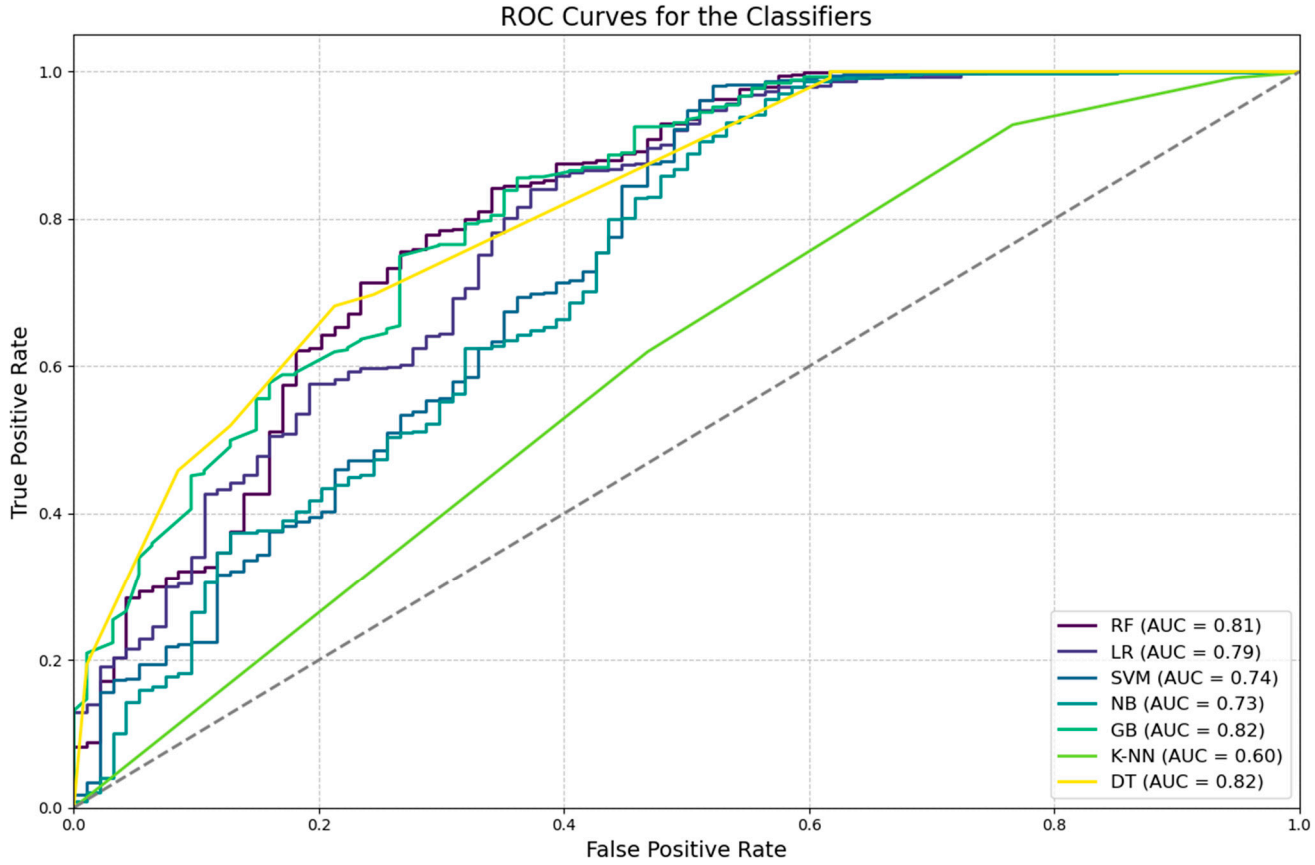

Figure 3. Classifiers ROC curves and AUC.

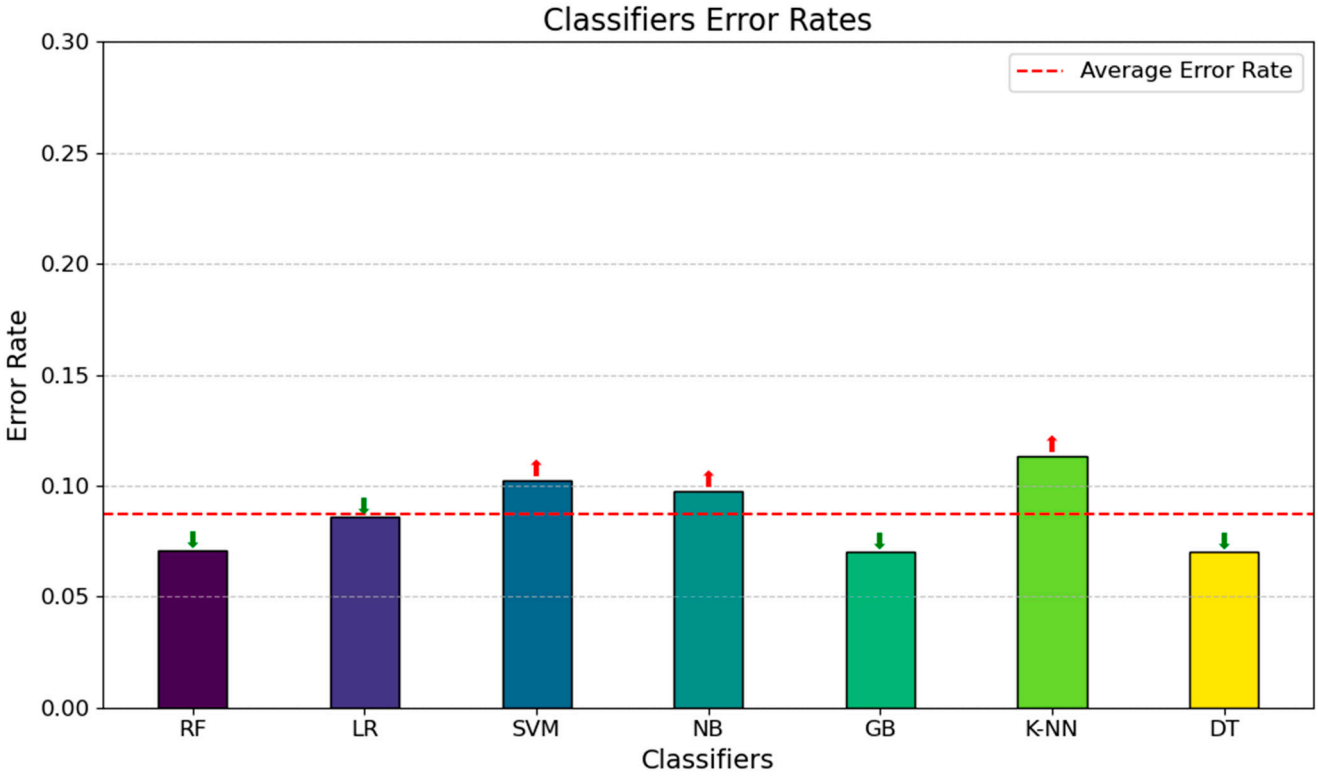

Figure 4. Classification error rates.

5. Remarks and Conclusions

Overall, the results suggest that the GANs unsupervised learning strategy is effective for handling incomplete credit data. When this unsupervised method is harnessed, the results show that most single classifiers displayed robustness towards missing data problems due to their improved model performance. Additionally, though the sample size impacts the model performance, this strategy can overcome the complexity challenge. The accuracy of the classifier experimented with under old methods deteriorated compared to the GANs strategy.

The decision tree classifier is the best-performing algorithm concerning the six performance evaluation metrics. DT outperforms all the other five classifiers and has consistent outputs across all performance metrics. Random Forest showed consistent classification accuracy compared to other algorithms, regardless of which imputation technique is leveraged. Though random forest is the second-best performing algorithm, its AUC value is slightly lower than that of gradient boosting. This dynamic reveals the tradeoff between random forest and gradient boosting algorithms, and this is ideal because these two belong to the ensemble learning family. The other key finding is the efficiency of K-nearest neighbourhood imputation; the method is faster than the GANs and multiple imputation techniques. Although K-NN is not better than GANs for handling poor data, it works better than traditional statistical methods such as median and mode. By leveraging optimisation, the naïve Bayes classifier accuracy rate significantly improved. Hyperparameter optimisation is a progressive practice that is essential for any modelling process to achieve better performance.

In conclusion, this paper offers the first steps toward a clearer understanding of the relative benefits and drawbacks of methods for estimating credit risk from potentially incomplete information. We hope that future empirical and theoretical research into the significance of data quality in the credit risk sector and cutting-edge deep learning techniques as robust methods are expected to be motivated by this work.

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Risk Management in Product Diversification: The Role of Managerial Overconfidence in Cost Stickiness—Evidence from Iran

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Abstract: Purpose: This study investigates the relationship between product diversification strategy and cost stickiness, focusing on managerial overconfidence as a moderating factor. It aims to address a critical gap in the literature by providing empirical insights grounded in the Resource-Based View (RBV) theory, specifically examining firms listed on the Tehran Stock Exchange. Methodology: Utilizing a sample of 149 companies from the Tehran Stock Exchange in Iran spanning from 2015 to 2021, this study tests two hypotheses: (1) a positive relationship between product diversification and cost stickiness and (2) the amplification of this relationship by managerial overconfidence. Product diversification is quantified using the Herfindahl Index, while managerial overconfidence is measured through an investment-based index derived from capital expenditures. Cost stickiness is assessed by analysing the asymmetric behaviour of costs in response to changes in sales, focusing on how costs tend to remain high even when sales decrease. Findings: The empirical results substantiate both hypotheses, demonstrating a significant positive relationship between product diversification strategy and cost stickiness. Furthermore, managerial overconfidence amplifies this relationship, highlighting the role of internal resources and managerial perceptions in shaping cost behaviour. Originality: This study contributes substantially to the literature by being among the first to empirically examine the interplay between product diversification strategy, cost stickiness, and managerial overconfidence. Extending the RBV theory to cost behaviour and strategic management provides novel insights for scholars and practitioners in entrepreneurship, corporate strategy, and organizational behaviour. The findings underscore the importance of strategic choices and managerial traits in determining cost stickiness, offering valuable implications for financial analysts, auditors, and stakeholders.

Keywords: product diversification strategy; organizational flexibility; cost behaviour; decision making; cost stickiness; managerial overconfidence; risk

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1. Introduction

In an increasingly competitive and volatile business environment, understanding the dynamics of cost behaviour and strategic management is crucial for organizations striving for long-term success (Hitt et al. 2020). Organizations encounter many strategic challenges, among the most critical of which is the need to effectively align their growth strategies with rigorous cost management practices (Grant 2016). Product diversification strategy has received considerable attention in the literature (Bengtsson 2000; Garrido-Prada et al. 2019; Tang et al. 2019; Wang et al. 2014). It represents organizational flexibility by enabling companies to adapt to changing market conditions through an expanded range of products and services. It improves stability by allowing the firm to spread its business risks across different product lines and reduce its vulnerability to market fluctuations while maximising

the efficiency of its resource allocation (Dinh et al. 2019; Friberg 2021; Hautz et al. 2014; Mammen et al. 2021; Smeritschnig et al. 2021; Sohl et al. 2022; Solano et al. 2019). The literature supports this notion that product diversification can be considered as one of the competitive strategies (Zúñiga-Vicente et al. 2019). However, given the organisational changes and costs that a product diversification strategy entails, we are unsure if there would be less cost reduction during declining sales, leading to increased cost stickiness. This is the primary question that this study attempts to address.

To examine the relationship between business strategy, product diversification, and cost behaviour, it is crucial to emphasize the importance of cost management in organizations. Cost is one of the most critical factors for any enterprise, and effective cost management is essential for achieving an optimal internal structure, earning a profit, and maintaining continuous development (Cai et al. 2019; Ding et al. 2021; Dormady et al. 2022; Stadtherr and Wouters 2021). Lee et al. (2020) consider cost management a core component of internal structure optimization, risk control, and profitability. Hence, understanding cost behaviour is fundamental to management and cost accounting (Anderson et al. 2003). Managerial overconfidence, a behavioural bias where managers overestimate their abilities and underestimate risks, plays a pivotal role in strategic decision-making (Gurdgiev and Ni 2023). Overconfident managers are more likely to retain resources during sales declines, anticipating future rebounds, which can intensify cost stickiness (Chen et al. 2022). This study explores the relationship between product diversification and cost stickiness, specifically focusing on how managerial overconfidence influences this dynamic.

The theoretical foundation of this study is grounded in the Resource-Based View (RBV) theory, which posits that firms can gain a competitive advantage through unique resources and capabilities (Barney et al. 2011). In this context, product diversification represents a unique resource, while cost stickiness is viewed as resource management and risk mitigation capabilities. This study formulates two hypotheses for testing: First, it proposes a positive relationship between product diversification strategy and cost stickiness. This proposition aligns with RBV, as diversification often involves significant investments, resulting in elevated resource adjustment costs and delayed reduction of underutilized resources during sales declines. Second, this study suggests that managerial overconfidence strengthens the direct link between product diversification and cost stickiness. This hypothesis is consistent with RBV, as overconfident managers are more likely to retain underutilized resources, anticipating future sales rebounds, thus intensifying cost stickiness.

Evolving regulations in Iran's environment can influence managerial decisions, often leading to cautious resource management during sales declines. This careful approach, driven by overconfidence and regulatory considerations, can contribute to increased cost stickiness, particularly in firms with diversified product portfolios (Nili and Rastad 2007). In addition, external economic conditions have affected the business environment by reducing access to some international markets and capital, leading to challenges in operational stability. In response, managers may adopt more optimistic behaviours as a strategic adjustment, contributing to cost stickiness as they retain resources in anticipation of future opportunities (Katzman 2014). Moreover, the inflation rates add complexity to cost management, as the real value of costs can be distorted. Overconfident managers may underestimate the risks of inflation, leading to increased resource commitments despite declining sales, which heightens cost stickiness (Pesaran 2012). Finally, cultural context influences how risk is perceived and handled. Iranian cultures where risk-taking is en-couraged, managerial overconfidence may be more prevalent, as leaders may feel empow-ered to make bold decisions. This cultural dynamic can lead to decisions favouring maintaining resources during downturns, thereby increasing cost stickiness (Nazarian and Atkinson 2013).

Despite the extensive literature on cost stickiness and its influencing factors in various contexts (Chen et al. 2022; Costa and Habib 2021), the role of managerial overconfidence in moderating the relationship between product diversification and cost stickiness has not been extensively studied, particularly in the context of the Iranian market. This study investigates the intricate relationship between product diversification strategy and cost

stickiness, focusing on the moderating influence of managerial overconfidence on decision-making. It aims to fill a notable gap in the existing literature by providing empirical insights into this underexplored area, particularly within the risk management framework in corporate finance.

Using a sample of 149 companies listed on the Tehran Stock Exchange in Iran from 2015 to 2021, this study employs rigorous statistical analysis to assess these hypotheses. The results empirically substantiate both hypotheses, shedding light on the positive relationship between product diversification and cost stickiness and the amplifying effect of managerial overconfidence.

This study makes a significant theoretical contribution by anchoring its research questions in the RBV theory, providing robust empirical evidence, and delivering valuable insights for scholars and practitioners of entrepreneurship, corporate strategy, and organizational behaviour worldwide. By focusing on the intersection of product diversification, cost behaviour, and managerial traits, this study offers new insights into risk management frameworks and financial strategies, contributing to the broader discourse on corporate finance and strategic decision-making in high-risk environments. The remainder of this study is structured as follows. Section 2 reviews the research literature and develops the hypotheses. Section 3 discusses the research method. Section 4 reports the results, and Sections 5 and 6 provide the discussion and conclusion.

2. Literature Review and Hypotheses Development

Traditional models of cost behaviour divide costs into fixed and variable based on some conventional drivers, such as the sale or production volumes (Bugeja et al. 2015). However, recent research indicates that the relationship between costs and cost drivers is more complex than traditionally assumed, involving multiple factors influencing cost behaviour (Banker and Byzalov 2014; Costa and Habib 2021). Cooper and Kaplan (1998) show that costs increase more when activity rises than they decrease with a proportional decrease in activity. This asymmetric cost behaviour is referred to as cost stickiness (Cooper and Kaplan 1998).

Recent research in cost management adds two crucial concepts to traditional cost analysis. First, cost behaviour is driven by managerial decisions, which depend on managers' expectations of future demand and their incentives (Jin and Wu 2021). Second, when sales decline, managers' ability to reduce unutilised resources becomes limited due to resource adjustment costs, such as the cost of employee layoffs (Banker et al. 2018). Managers' optimism about future demand, managerial incentives driven by self-interest (e.g., empire-building), and adjustment costs are the key factors that motivate managers to retain unutilised resources during declining sales. Managers' unwillingness to cut resources in such conditions will lead to cost stickiness (Banker et al. 2013; Hartlieb et al. 2020; Xue and Hong 2016).

Asymmetric cost behaviour and cost management have broad implications for owners, investors, creditors, employees (concerning job security), and other stakeholders (Costa and Habib 2021). Cost stickiness affects the authenticity of a firm's costs and reduces the effectiveness of its resource allocation (Li et al. 2020). Recent studies have investigated the relationship between cost stickiness and various factors (Chen and Xu 2023; Costa and Habib 2021; Haga et al. 2019; Li et al. 2020). However, the relationship between business strategies, particularly growth strategies and cost stickiness, has not been explored. Anderson et al. (2003) argue that a firm's strategy choice shapes its cost structure. Porter's generic business-level strategy, namely, cost leadership, differentiation, and focus, have become a central paradigm in the business policy literature (Porter 1980). Each represents a different approach to creating and maintaining a competitive advantage. For example, companies that adopt a cost leadership strategy have a more flexible cost structure. When sales decline, they have to reduce the price of products to maintain their competitive advantage. As a result, they cut costs and experience lower cost stickiness. On the other hand, companies that adopt a differentiation strategy will face high adjustment costs when

sales decline. As a result, they retain unutilised resources and experience higher cost stickiness (Zhong et al. 2020).

Diversification is one of the four growth strategies outlined in Ansoff's product-market matrix (Ansoff 1957). Diversification is a strategy where the company expands its products and services. Diversification has been a common competitive strategy for decades (Jha et al. 2021). A diversification strategy targets new markets with new products. It assumes that a company can adopt and require new resources and capabilities and make necessary changes in organisational structure and processes (Zúñiga-Vicente et al. 2019). So, we can expect that companies adopting a diversification strategy must restructure their business units and change current practices and existing contracts. This strategy requires comprehensive planning to implement diversification processes using internal and external resources and expertise. As a result, recruiting specialists, hiring and training new employees, and new equipment might be needed, which can be very costly (Lin et al. 2020).

As the business environment becomes more competitive, effective cost management has become an essential element of business operations (Chen et al. 2022). As an intuitionistic reflection of the cost decisions made in the accounting information system, cost behaviour shows the current conditions and tendencies of the company's resource investment. It reflects the executives' strategies in response to changes in economic conditions (Lee et al. 2020). Resource adjustment decisions are one of these responses that significantly impact firm performance (Chen et al. 2022).

Another factor that may affect organisational strategy and product diversification is managerial behaviour biases (Kak 2004). One of these biases is managerial overconfidence, which refers to managers' tendency to overestimate their abilities and/or overinvest (Hyun and Seung 2019). Overconfidence is one of the essential concepts in modern behavioural finance. Overconfidence causes people to overestimate their knowledge and skills and underestimate risks, feeling that they have control over events, which may not be the case (Weinstein 1980). Anderson et al. (2003) argue that one reason for asymmetric cost behaviour is the CEO's optimistic expectations about future sales improvement (Hur et al. 2019; Schrand and Zechman 2012). Hribar and Yang (2016) found that overconfidence increases the degree of optimism in management forecasts. As a result, managers will be more willing to retain slack resources when sales decline to reduce adjustment costs (Hribar and Yang 2016; Lee et al. 2020). Overconfidence can manifest itself by adding more resources when demand increases or retaining unutilised resources when demand decreases, leading to greater cost stickiness (Chen et al. 2022). On the other hand, Chu et al. (2021) found that companies with overconfident managers will have greater cost stickiness if they adopt a differentiation strategy than a cost leadership strategy (Chu et al. 2021).

Companies may adopt different strategies in a competitive market, leading to asymmetric cost behaviour. For example, as noted earlier, cost stickiness can increase with a differentiation strategy increase but decrease with a cost leadership strategy (Zhong et al. 2020). On the other hand, a product diversification strategy aimed at higher profitability and growth can increase sales volume and lead to better financial performance (Dinh et al. 2019; Omosa et al. 2022). Given that companies with a product diversification strategy require new investments, skills, equipment, practices, and changes in organisational structure and processes, it is possible that, when future sales are uncertain, overconfident managers will maintain the business scale and avoid adjusting unutilised resources in the hope of obtaining higher returns in the future, which will lead to more sticky cost behaviour (Chen et al. 2022). Therefore, we expect managerial overconfidence to moderate the relationship between product diversification strategy and cost stickiness. The present research seeks to answer the following questions: Is there a relationship between product diversification strategy and cost stickiness? Does managerial overconfidence moderate the relationship between diversification and cost stickiness?

Following prior research (Lin et al. 2020; Tang et al. 2022; Zúñiga-Vicente et al. 2019), product diversification is measured using the Herfindahl Index. Following Killins et al. (2021), managerial overconfidence is measured using an investment-based index, which

is calculated based on the median of capital expenditures. Cost stickiness is measured according to the model proposed by Banker et al. (2013). Our results show a significant positive relationship between product diversification strategy and cost stickiness. In other words, cost stickiness is higher in companies with higher product diversification. In addition, managerial overconfidence increases asymmetric cost behaviour in companies with a product diversification strategy.

In the literature, various methodologies such as scenario analysis, econometric modelling, and stress testing are commonly used to assess the impact of global risks on firms (Schwartz 1997; Wooldridge 2010; Borio et al. 2014). Scenario analysis and stress testing often rely on hypothetical scenarios to predict outcomes, while econometric models analyse historical data to quantify these risks. Our study diverges from these approaches by using empirical data from the Tehran Stock Exchange to examine how economic conditions in Iran affect cost stickiness and managerial decisions. This empirical approach provides a more accurate reflection of real-world impacts, offering specific insights into the Iranian context that might differ from global risk assessments based on hypothetical scenarios.

Product diversification can mitigate risks by spreading them across different markets, which is beneficial in stable or growing economies. However, during economic downturns, the high costs associated with maintaining diverse product lines may outweigh the benefits. The economic environment, including inflation, currency fluctuations, sanctions, and evolving regulations, can further complicate diversification efforts, making them more costly and less effective (Zúñiga-Vicente et al. 2019; Katzman 2014). Cost stickiness, while strategic in some cases, can become a liability during economic downturns, as maintaining unutilized resources can strain a firm's financial health. Proposed strategies, like cautious resource allocation, may work in stable conditions but could face challenges in volatile economies (Banker et al. 2013). Managerial overconfidence can exacerbate cost stickiness, particularly in volatile economic environments where cost-cutting is essential but may be overlooked (Chen et al. 2022).

The present research will contribute to the literature in two significant ways. First, it sheds light on the relationship between product diversification strategy and cost stickiness, while prior research (Chu et al. 2021; Zhong et al. 2020) has focused on other business strategies. Therefore, the findings of this study can expand the literature on cost behaviour and product diversification strategy. Secondly, by investigating the effect of managerial overconfidence, the present research contributes to the literature on the psychological factors affecting decision-making.

There is an accumulated body of literature on diversification, yet the results are ambiguous and inconclusive (Askarany and Spraakman 2020; Blavatskyy 2023; Denuit et al. 2015; Galavotti et al. 2017; Guidolin and Rinaldi 2013; Wang et al. 2020). Askarany and Spraakman (2020) have investigated the relationship between diversification and financial performance through an excess-capacity theory lens. They found a positive and significant association between diversification and financial performance due to spare capacity (a kind of cost stickiness). In other words, they found that firms with higher excess capacity need to pay less for diversification than those with less or no spare capacity. Therefore, they are more likely to achieve better financial performance than those with less or no excess capacity. This study suggests the possibility of a relationship between diversification and cost behaviour (including cost stickiness).

Other studies explain the diversification through the lens of the Resource-Based View theory (Khurana and Farhat 2021; Situm 2019). The Resource-Based View theory (RBV) posits that a firm's unique resources and capabilities are the primary drivers of its competitive advantage and performance (Barney et al. 2021). Adopting RBV in this study, we suggest the resource of interest is the diversification strategy, and the capability is the ability to manage cost stickiness.

2.1. Product Diversification Strategy and Cost Stickiness

Traditional models of cost behaviour view cost changes as a direct result of changes in the volume of activity (Noreen 1991). Costs are traditionally classified into fixed and variable costs. A fixed cost remains constant as a company's sales or production volume changes, while a variable cost changes in proportion to sales and production volume (Anderson et al. 2003). Recent cost stickiness research suggests that the traditional assumption of symmetric cost behaviour does not always hold in practice (Calleja et al. 2006; Lee et al. 2020). A critical review of the findings of Cooper and Kaplan (1998) and Noreen and Soderstrom (1997) introduces a new perspective to cost accounting research. They provided empirical evidence that, in some cases, cost behaviour is asymmetric (Cooper and Kaplan 1998; Noreen and Soderstrom 1997). Later, Anderson et al. (2003) showed that selling, general, and administrative (SG&A) costs decrease less when sales decrease than when sales increase. In other words, these studies state that cost changes are determined by the shift in volume and the direction of activities. This asymmetric cost behaviour is referred to as cost stickiness. The results of Anderson and Lanen (2007) show that SG&A costs increase by an average of 0.55% for a 1% increase in sales but only decrease by 0.35% for a 1% decrease in sales (Anderson and Lanen 2007).

Banker and Byzalov (2014) discussed three factors that cause cost stickiness: agency problems, optimistic managerial expectations, and adjustment costs. Agency problems, where managers prioritize their interests over those of shareholders, can lead to sticky cost behaviour, particularly when managers with empire-building tendencies fail to reduce resources during sales declines (Chen et al. 2012; Zhong et al. 2020). Managerial optimism further intensifies cost stickiness, as optimistic managers are more likely to retain resources even when sales decrease, unlike pessimistic managers who reduce committed resources in response to declining sales. Finally, decisions about resource adjustment are made mainly by the management and significantly impact firm performance (Chen et al. 2022). Hiring/layoff of employees and installation/deployment costs for equipment are examples of adjustment costs. As sales decline, managers tend to retain a certain amount of slack capacity instead of reducing SG&A costs (Banker and Byzalov 2014). Pamplona et al. (2016) found evidence of asymmetric cost behaviour in large South American companies. By analysing the effects of inflation and GDP growth, they also showed that macroeconomic factors explain differences in companies' cost behaviour. Inflation was negatively associated with cost behaviour, while GDP growth was positively associated with cost behaviour. Zhong et al. (2020) showed that cost stickiness is higher in companies with a differentiation strategy than those with a cost leadership strategy.

Large companies need to make strategic decisions to improve their long-term performance. One of these decisions is product diversification (Azman et al. 2020). The reasons why firms diversify into new businesses and their implications for competitive advantage have been at the core of research on corporate strategy (Becerra et al. 2020). Park and Jang (2013) define diversification as the entry of the company into new markets (sectors, industries) where they previously had no presence (Park and Jang 2013). Zúñiga-Vicente et al. (2019) showed that managers who pursue moderate levels of diversification achieve better profitability during a boom period than those who adopt high or low levels of diversification.

In contrast, moderate and high levels of diversification are equally adequate during an economic downturn. They also found that internationalisation negatively affects profitability, independent of the economic cycle. The effect of product diversification on a firm's productivity depends on market structure, among other factors. For example, companies operating in a market with little opportunity for growth should diversify by entering different markets. Conversely, diversifying products can be a good strategy for companies operating in a competitive industry. By exploiting and leveraging their resources across multiple markets, companies can gain more competitive advantages and opportunities for further development (Hautz et al. 2013)

The effect of diversification on firm performance has been extensively investigated (Arte and Larimo 2022; Azman et al. 2020). Some studies have reported a positive effect (Kuppuswamy and Villalonga 2016), while others have found a negative impact (Arte and Larimo 2022; Rugman 1976). Lin et al. (2020) examined the effect of operational stickiness on product quality and the moderating effect of product diversification in Chinese exporting firms. The results show an inverted U-shaped relationship between operational stickiness and product quality and that product diversification strategy significantly moderates this relationship. Meanwhile, several studies have reported both positive and negative effects of diversification on performance (Garrido-Prada et al. 2019). For example, Azman et al. (2020) examined the impact of different types of product diversification on firm performance. They found that unrelated diversification reduced company performance in 2003–2016, while related diversification positively affected firm performance during 2010–2016. Similarly, Arte and Larimo (2022) show that the relationship between international diversification and firm performance follows an inverted U-shape and that a firm's performance is higher with low/related product diversity than with high/unrelated product diversity.

Li and Zheng (2017) show that product market competition increases cost stickiness. They argue that product market competition encourages companies to invest frequently to exploit new investment opportunities under uncertainty (Li and Zheng 2017). Product diversification is also a strategy that requires significant investment in human resources, new machinery and equipment, research and development (R&D), and advertising (Lin et al. 2020). Additionally, this strategy may stem from the agency problem; the top management may try to reduce their employment and reputation risk by diversifying products (Lin et al. 2020). A decrease in sales indicates that the company is losing its competitive position in the market. This can encourage managers to commit more resources to R&D, quality control, marketing, or customer satisfaction to regain the company's market share and maintain its competitive position in the industry (Li and Zheng 2017).

Moreover, under economic crisis and declining sales, companies may invest less in the related segment and more in unrelated segments to maintain some of their business lines, increasing their internal control, governance, and coordination costs (Chang and Wang 2007). In addition, resource adjustment costs should also be considered. Generally, the cost of increasing resources is lower than the adjustment cost of decreasing resources (Subramaniam and Watson 2016). Due to high adjustment costs, managers are more likely to retain slack resources (Anderson et al. 2003). As a result, costs will not change in proportion to the volume of business activity, leading to cost stickiness (Anderson et al. 2003). Balakrishnan et al. (2004) found that sticky costs are associated with the level of capacity utilisation.

On the other hand, Anderson et al. (2003) showed that companies with more human and physical resources exhibit higher levels of cost stickiness. As Lin et al. (2020) noted, the product diversification strategy requires high human resources and equipment levels. Employment growth increases in the years before diversification, while asset and sales growth increases during and after diversification (Coad and Guenther 2014). Therefore, it can be concluded that resource adjustment costs are higher in companies that adopt a product diversification strategy.

According to Anderson et al. (2003), choosing a business strategy affects cost behaviour. Zhong et al. (2020) documented differences in cost stickiness between companies using differentiation and cost leadership strategies. According to Chen et al. (2022), when sales decline, there is a significant adjustment cost for companies with a product diversification strategy since implementing this strategy requires substantial investment in the company's structure. Therefore, it can be argued that the product diversification strategy, one of the growth strategies in Ansoff's matrix (Dawes 2018; Hussain et al. 2013), is associated with cost stickiness. Given the above, we propose our first hypothesis as follows:

H1. *There is a significant relationship between product diversification strategy and cost stickiness.*

2.2. Managerial Overconfidence, Product Diversification and Cost Stickiness

Managerial overconfidence is a behavioural bias that overestimates one's abilities and underestimates potential risks (Weinstein 1980). Psychological evidence shows that people overestimate the outcomes related to their abilities and underestimate the likelihood of adverse events. This behavioural tendency is called overconfidence (Hyun and Seung 2019). Furthermore, although overconfidence does not equal greater risk-taking, overconfident managers make less conservative decisions by relying too much on positive information (Gervais et al. 2011). Hilary and Hsu (2011) found that managers who accurately forecast earnings in the previous four quarters are less accurate in their subsequent forecasts, suggesting that overconfidence leads managers to be more optimistic. Managers' cognitive biases affect their decision-making since overconfident managers are optimistic and tend to overestimate returns while underestimating their investment risk (Hilary and Hsu 2011; Killins et al. 2021). As managers become more overconfident, the risk of making wrong decisions increases. This can lead to crises, scandals, and poor performance (Johnson and Fowler 2011; Kunz and Sonnenholzner 2023).

However, some studies have highlighted the benefits of overconfidence. For example, overconfidence motivates managers to pursue promising but risky projects. Overconfident managers tend to pursue innovation and exploit innovative growth opportunities with investment, achieving tremendous innovative success (Hirshleifer et al. 2012). Similarly, Hyun and Seung (2019) found that companies with overconfident managers have higher returns on net operating assets and can better forecast changes in future earnings.

Executives and their personal traits significantly impact organisational capabilities, decision-making, and operations (Kunz and Sonnenholzner 2023). Overconfidence is one of these traits. Previous research shows that managerial overconfidence affects a company's investment, financing, and financial reporting decisions (Gervais et al. 2011). Overconfident managers are more likely to overestimate returns on investment and underestimate the associated risks (Aabo et al. 2021; Hirshleifer et al. 2012). Empirical studies have provided evidence about the impact of managerial overconfidence on different strategies. Companies with a diversification strategy and overconfident managers experience a decline in value compared to those run by their rational counterparts (Schumacher et al. 2020). Chen et al. (2022) found that managerial overconfidence as an essential factor in resource adjustment decisions is positively associated with cost stickiness.

Similarly, Chu et al. (2021) showed that companies with a differentiation strategy and overconfident managers face higher cost stickiness than those with a cost leadership strategy. Overconfident managers are generally more optimistic and overestimate their abilities to rebound during periods of declining sales (Chen et al. 2022). Therefore, managers' overconfidence can cause them to ignore cost adjustment, thus increasing cost stickiness (Kuang et al. 2015). Given the above, we propose our second hypothesis as follows:

H2. *Managerial overconfidence moderates the relationship between product diversification strategy and cost stickiness.*

3. Methodology

3.1. Models and Variables

In the cost stickiness literature, the model developed by Anderson et al. (2003) and Banker et al. (2013) is often used to determine the presence or absence of cost stickiness (Haga et al. 2019; Lee et al. 2020). This model is shown in Equation (1).

$$\Delta lnCOGS_{it} = \beta_0 + \beta_1 \Delta lnsales_{it} + \beta_2 D_{it} * \Delta lnsales_{it} + \varepsilon_{it} \quad (1)$$

where $\Delta \ln COGS_{it}$ is the dependent variable, equal to the log change in the cost of goods sold for firm i in year t; $\Delta \ln Sales_{it}$ is the log change in the sales revenue for firm i in year t; D_{it} is a dummy variable that equals one if sales decrease in year t, and zero otherwise.

Banker's model is based on Anderson's model, which considers resource adjustment decisions under sales increases as a function of managerial discretion and theoretically allows for differences in these decisions under different conditions. In contrast, the traditional model of cost stickiness considers managerial discretion only under declining sales and assumes a mechanical relationship between resource expansion (increase in cost) and increases in sales, which does not account for managerial discretion in decisions to expand resources. Given that our hypothesis considers the possibility of different reactions by managers in various situations (either increase or decrease in sales), our proposed model is adopted from Banker et al. (2013), as shown in Equation (2). Incorporating interaction terms allows us to examine the conditional effects of product diversification based on changes in sales ($\Delta\ln$ *Sales*) and the occurrence of sales decrease (D). In this model, the coefficient β_1 denotes the percentage increase in total cost per 1% increase in sales revenue. The coefficient β_2 captures the degree of asymmetry in cost responses to decreases versus increases in sales. Therefore, $\beta_1 + \beta_2$ show the percentage decrease in total cost per 1% decrease in sales revenue. Cost stickiness is present in a company if β_1 is significant and positive and β_2 is significant and negative. Moreover, if the coefficient of the independent variable (β_4) is negative and significant, it suggests that the product diversification strategy reduces the variability of costs concerning changes in revenue and, as a result, increases cost stickiness. Thus, the proposed model is as follows:

$$\begin{aligned}\Delta\ln COGS_{it} = {} & \beta_0 + \beta_1 \Delta\ln Sales_{it} + \beta_2 D_{it} * \Delta\ln Sales_{it} + \beta_3 PD_{it} * \Delta\ln Sales_{it} + \beta_4 D_{it} * PD_{it} * \Delta\ln Sales_{it} \\ & + \beta_5 ASINT_{it} * \Delta\ln Sales_{it} + \beta_6 D_{it} * ASINT_{it} * \Delta\ln Sales_{it} + \beta_7 EMPINT_{it} * \Delta\ln Sales_{it} \\ & + \beta_8 D_{it} * EMPINT_{it} * \Delta\ln Sales_{it} + \beta_9 GDP_t * \Delta\ln Sales_{it} + \beta_{10} D_{it} * GDP_t * \Delta\ln Sales_{it} \\ & + \beta_{11} \sum T_j \; Industry + \beta_{12} \sum \theta_j \; Year + \varepsilon_{it}\end{aligned} \tag{2}$$

where $\Delta\ln COGS_{it}$ is the dependent variable, equal to the log change in the cost of goods sold for firm i in year t; $\Delta\ln Sales_{it}$ is the log change in the sales revenue for firm i in year t; D_{it} is a dummy variable that equals one if sales decrease in year t, and zero otherwise; and PD_{it} is product diversification as the independent variable, measured by the Herfindahl index (Tang et al. 2022; Zúñiga-Vicente et al. 2019). The Herfindahl index is calculated as shown in Equation (3):

$$\text{Herfindahl} = 1 - \sum_{i=1}^{n} p_i^2 \tag{3}$$

where p_i^2 is the ratio of the sales of each segment to the total sales of the company, and n is the number of segments. In Iran, the categorization of industries has been implemented following the standards outlined in the Fourth Edition of the International Standard Industrial Classification (ISIC). The lower the index (i.e., the closer it is to zero), the lower the product diversification.

Following Zhong et al. (2020), Cai et al. (2019), and Anderson et al. (2003), the following control variables are included in the model:

- $ASINT_{it}$: Asset intensity, calculated as the ratio of total assets to sales revenue at the end of the fiscal year.
- $EMPINT_{it}$: Employee intensity is calculated as the ratio of the number of employees to sales revenue at the end of the fiscal year.
- GDP_t: Growth rate of gross domestic product.

We expect β_6 and β_8 to be negative since asset- and employee-intensive firms tend to have high-cost stickiness. GDP growth is included to control macroeconomic conditions that might affect the firms' operations. We expect β_{10} to be negative since the GDP growth rate increases managers' optimism regarding future sales, encouraging them to retain slack resources, which could lead to greater cost stickiness (Costa and Habib 2021).

Due to Iran's inflationary economy, the model is estimated after deflating the primary variables, i.e., sales revenue and costs, based on the inflation rate reported by the Central Bank. Deflation for each year is performed by dividing the sales and expenses of a given year by one plus the inflation rate of that year (MohammadRezaei and Mohd-Saleh 2017). The rationale is to remove the effects of inflation since the proposed cost stickiness model uses sales as a measure of activity level. Therefore, deflated values do not include the increase in sales/costs caused by inflation. In addition, year and industry dummies are included in the model to control for year and industry-fixed effects. The block diagram is presented in Figure 1.

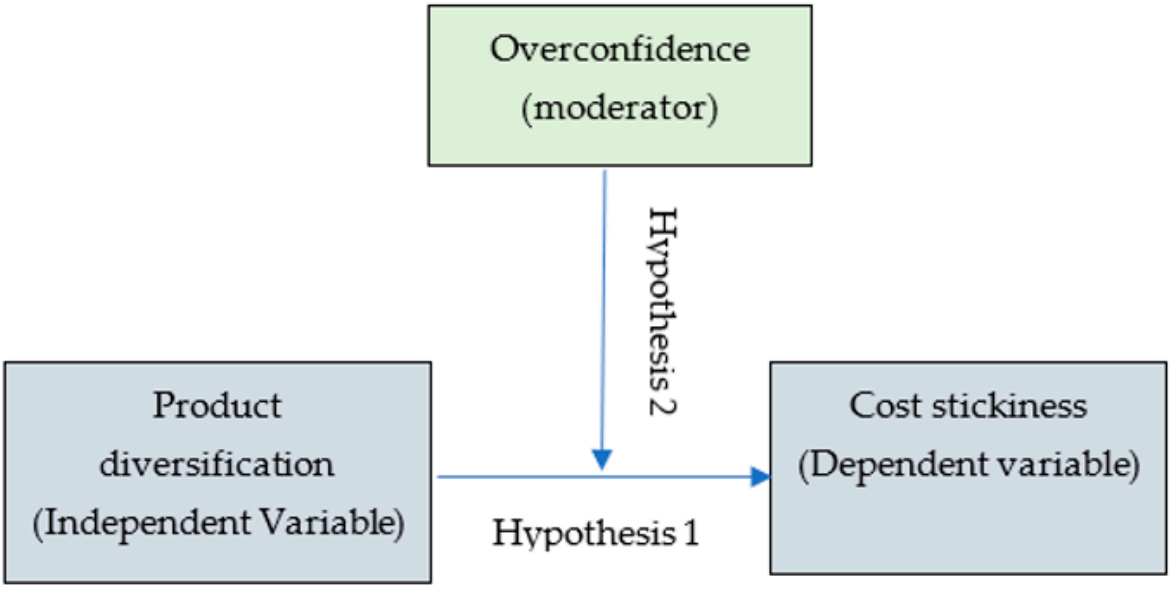

Figure 1. Block diagram. Source: authors' own work.

The second hypothesis examines the moderating effect of managerial overconfidence (OCD) on the relationship between product diversification strategy and cost stickiness, as shown in Figure 1. We employ a split-sample method to test this hypothesis, following a similar approach to Costa and Habib (2021). This method divides our statistical sample into companies exhibiting managerial overconfidence and those without. Subsequently, distinct regression models are estimated for each subgroup to examine the differential impact of product diversification on cost stickiness based on the presence or absence of managerial overconfidence. Overconfidence is measured using the index proposed by Killins et al. (2021). This index is a dummy variable equal to one if the capital expenditures scaled by total assets in a given year are greater than the industry median and zero otherwise (Ahmed and Duellman 2013). In the proposed model, a statistically significant difference in coefficients on β_4 indicates the moderating effect of managerial overconfidence.

3.2. Population and Sample

Our statistical population consists of all the companies listed on the Tehran Stock Exchange (TSE) for seven years from 2015 to the end of 2021. Each firm had to meet the following criteria to be included in our sample:

1. Financial institutions and intermediaries (e.g., banks, investment companies, etc.) are excluded.
2. They were listed on the TSE at the beginning of 2015.
3. They had available data and no fiscal year changes during 2015–2021.

TSE is the largest stock exchange in Iran and a reliable source of information (Daryaei et al. 2022; Nassirzadeh et al. 2022; Shandiz et al. 2022).

There were 380 firms listed on TSE by the end of 2021, but only 149 companies met the above criteria that we selected and analysed.

3.3. Descriptive Statistics

The descriptive statistics of the variables are reported in Tables 1 and 2. According to the data, the dispersion of log-change in sales is 0.32. This value is close to the dispersion of log-change in sales revenue (0.33) and indicates low-cost stickiness in the sample companies. According to Herfindahl's product diversification index (Tang et al. 2022; Zúñiga-Vicente et al. 2019), the findings suggest that manufacturing companies have an average product diversification of 47%. The highest product diversification is 90% (a company with 16 product lines), and some companies have only one product and have not used a diversification strategy. The decrease in the dummy variable for sales shows that 23% of the sample had a reduction in sales, which is close to the result of Zhong et al. (2020). As for the control variables, our results show that the average ratio of assets to sales revenue is more than 1.4, indicating the high asset intensity of the sample companies.

Table 1. Descriptive statistics of the continuous variables.

Variable	Proxy	Mean	Median	SD	Min.	Max.
Log-change in cost of goods sold.	Δln COGS	0.012	0.013	0.323	−3.298	2.096
Log-change in sales revenue	Δln SALES	0.025	0.022	0.332	−2.709	1.750
Product diversification	PD	0.471	0.521	0.268	0.000	0.904
Asset intensity	ASINT	1.453	1.211	1.084	0.133	9.746
Employee intensity	EMPINT	0.0003	0.0002	0.0003	0.0001	0.003
GDP growth rate	GDP	0.018	0.018	0.037	−0.023	0.088

Source: authors' own work.

Table 2. Descriptive statistics of the discreet variables.

Variable	Proxy	Categories	Frequency	Relative Frequency
Sales decrease	D	Decrease	242	0.232
Managerial overconfidence 1	OCD1	High OCD	542	0.519
		Low OCD	501	0.481

Source: authors' own work.

Following Killins et al. (2021), managerial overconfidence is measured using an investment-based index, which is calculated based on the median of capital expenditures. Nearly half of the companies have overconfident managers, similar to Killins et al. (2021) results with the same index. It must be noted that the data are winsorised at the 99% level to reduce the effect of outliers. Also, regression assumptions are tested before estimating the regression models.

4. Results

4.1. Testing the First Hypothesis

The first hypothesis examines the relationship between product diversification strategy and cost stickiness. This hypothesis is tested using panel data after controlling for year and industry-fixed effects. The *p*-value of the F-statistic is less than 0.01, indicating the significance of the model. This research uses ordinary least squares (OLS) with robust standard errors to solve the problem of autocorrelation of residuals and heteroskedasticity (Petersen 2009). Finally, the variance inflation factor (VIF) is calculated to check for multicollinearity. The VIF values obtained are smaller than ten and indicate the absence of multicollinearity between the independent variables. These results are reported in Table 3.

According to these results, the coefficient of $\Delta \ln$ SALES (β_1) is 0.99, which is positive and significant, and the coefficient of D$*\Delta \ln$ SALES (β_2) in the model is -0.21, which is negative and significant. This indicates the presence of cost stickiness as per the model adopted by Banker et al. (2013). The economic implication is that costs increase by 0.99% per 1% increase in sales but decrease by 0.78% (0.99% − 0.21%) per 1% decrease in sales. Moreover, given that the coefficient of D$*$PD$*\Delta \ln$ SALES (β_4) is negative and significant, the first hypothesis is accepted, indicating that cost stickiness increases with product diversification. Regarding the control variables, the coefficients of D$*$ASINT$*\Delta \ln$ SALES (β_6) and D$*$GDP$*\Delta \ln$ SALES (β_{10}) are negative and significant. This suggests that firms with higher asset intensity and GDP growth rates have greater cost stickiness.

Table 3. Estimation results for the first hypothesis.

	Beta	**t-Statistic**	***p*-Value**	**VIF**
C	0.06	−2.02	0.045 **	-
(β_1) : $\Delta \ln$ SALES	0.99	85.56	0.000 ***	1.86
(β_2) : D$*\Delta \ln$ SALES	−0.21	−2.66	0.009 ***	2.59
(β_3) : PD$*\Delta \ln$ SALES	−0.01	−1.07	0.287	1.29
(β_4) : D$*$PD$*\Delta \ln$ SALES	−0.07	−3.00	0.003 ***	1.35
(β_5) : ASINT$*\Delta \ln$ SALES	−0.01	0.20	0.840	9.00
(β_6) : D$*$ASINT$*\Delta \ln$ SALES	−0.01	−4.50	0.000 ***	8.84
(β_7) : EMPINT$*\Delta \ln$ SALES	−22.97	−1.36	0.177	2.42
(β_8) : D$*$EMPINT$*\Delta \ln$ SALES	−2.28	−0.73	0.467	7.66
(β_9) : GDP$*\Delta \ln$ SALES	−0.03	−2.96	0.004 ***	1.26
(β_{10}) : D$*$GDP$*\Delta \ln$ SALES	−0.23	−3.03	0.003 ***	7.62
Year	Controlled			
Industry	Controlled			
Adjusted R^2	0.873			
F-statistic	210.84			
Sig.	0.000			

Source: authors' own work (**: $p < 0.05$; ***: $p < 0.01$).

4.2. Testing the Second Hypothesis

The second hypothesis examines the moderating effect of managerial overconfidence on the relationship between product diversification strategy and cost stickiness. The estimation results for the two models related to this hypothesis (two overconfidence states) are reported in Table 4. The z-test is used to investigate the effect of the moderator variable. This test compares the difference in β_4 between companies with high and low managerial overconfidence. The significant difference in β_4 confirms the moderating effect of managerial overconfidence on the relationship between product diversification and cost stickiness. The z-statistic is obtained using Equation (4):

$$Z = \frac{\hat{\beta}_{4(1)} - \hat{\beta}_{4(2)}}{\sqrt{se\left(\hat{\beta}_{4(1)}\right)^2 + se\left(\hat{\beta}_{4(2)}\right)^2}} \tag{4}$$

where $\hat{\beta}_{4(1)}$ and $\hat{\beta}_{4(2)}$ are the estimated coefficients for high and low overconfidence groups, respectively.

$se\hat{\beta}_{4(1)}$ and $se\hat{\beta}_{4(2)}$ are the standard errors associated with each coefficient.

The result of the z-test for this measure of managerial overconfidence shows a statistically significant difference in β_4 between companies with high and low managerial overconfidence at the 90% confidence level ($p < 0.1$). In other words, managerial overconfidence moderates the relationship between product diversification and cost stickiness.

This coefficient is more prominent in companies with high managerial overconfidence. Therefore, the second hypothesis is supported.

Table 4. Estimation results for the second hypothesis.

	Managerial Overconfidence (OCD1)							
	High OCD				**Low OCD**			
Variable	**Beta**	**t-Statistic**	***p*-Value**	**VIF**	**Beta**	**t-Statistic**	***p*-Value**	**VIF**
C	0.001	0.04	0.968	-	0.00	0.00	0.998	-
(β_1) : ΔlnSALES	1.02	8.05	0.000 ***	1.81	0.84	21.87	0.000 ***	1.72
(β_2) : D∗ΔlnSALES	−0.32	−2.51	0.013 **	2.34	−0.16	−1.99	0.049 **	2.12
(β_3) : PD∗ΔlnSALES	−0.14	−0.85	0.398	1.20	0.002	0.37	0.714	1.32
(β_4) : D∗PD∗ΔlnSALES	−0.35	−1.89	0.037 **	1.24	−0.04	−2.74	0.007 ***	1.39
(β_5) : ASINT∗ΔlnSALES	−0.02	−0.71	0.481	2.09	−0.00	−0.18	0.856	9.85
(β_6) : D∗ASINT∗ΔlnSALES	−0.05	−1.94	0.054 *	1.23	−0.00	−0.47	0.640	5.86
(β_7) : EMPINT∗ΔlnSALES	36.26	0.14	0.885	2.65	−15.80	−0.95	0.346	8.61
(β_8) : D∗EMPINT∗ΔlnSALES	72.24	0.29	0.770	2.19	−53.86	−2.82	0.006 ***	9.64
(β_9) : GDP∗ΔlnSALES	0.25	2.24	0.026 **	1.14	−0.02	−2.09	0.038 **	1.33
(β_{10}) : D∗GDP∗ΔlnSALES	−0.53	−1.99	0.048 **	1.64	−0.22	−2.12	0.036 **	1.07
Year	Controlled				Controlled			
Industry	Controlled				Controlled			
Adjusted R^2	0.868				0.858			
F-statistic	919.28				631.46			
Sig.	0.000				0.000			
z-statistic	−1.904							

Source: authors' own work (*: $p < 0.1$; **: $p < 0.05$; ***: $p < 0.01$).

4.3. Robustness Tests

4.3.1. An Alternative Measure of Managerial Overconfidence

In addition to the indicator variable proposed by Killins et al. (2021), we use the index proposed by Schrand and Zechman (2012) to measure managerial overconfidence. This index is based on excess investment and is the residual from a regression of total asset growth on sales growth, as shown in Equation (5):

$$ASSETGR_{i,t} = \beta_0 + \beta_1 SALEGR_{i,t} + \varepsilon_{i,t} \quad (5)$$

This index takes the value of one if $\varepsilon > 0$ (i.e., if assets grow at a higher rate than sales, indicating overinvestment due to managerial overconfidence) and zero otherwise. According to the data, about 43% of companies have overconfident managers, nearly similar to the first index. In this alternative model, the magnitude of the difference in β_4 indicates the significant moderating effect of managerial overconfidence. The results are reported in Table 5.

The result of the z-test for the second measure of managerial overconfidence indicates a significant difference in β_4 between companies with high and low managerial overconfidence at the 90% confidence level ($p < 0.1$). Again, this coefficient is more prominent in companies with high managerial overconfidence. Therefore, these results support our baseline findings.

Table 5. Estimation results using an alternative measure of managerial overconfidence.

	Managerial Overconfidence (OCD2)							
	High OCD				**Low OCD**			
Variable	**Beta**	**t-Statistic**	***p*-Value**	**VIF**	**Beta**	**t-Statistic**	***p*-Value**	**VIF**
C	−0.05	−1.09	0.278	-	−0.03	−1.81	0.073 *	-
(β_1) : ΔlnSALES	0.97	45.15	0.000 ***	1.81	0.88	23.34	0.000 ***	2.29
(β_2) : D∗ΔlnSALES	−0.20	−2.21	0.028 **	1.51	−0.10	−1.80	0.074 *	1.14
(β_3) : PD∗ΔlnSALES	0.01	0.71	0.476	1.43	−0.01	−0.71	0.477	1.24
(β_4) : D∗PD∗ΔlnSALES	−0.07	−2.90	0.004 ***	1.08	−0.04	−2.38	0.018 **	1.08
(β_5) : ASINT∗ΔlnSALES	−0.00	−0.38	0.705	2.06	−0.00	−1.21	0.229	8.97
(β_6) : D∗ASINT∗ΔlnSALES	−0.02	−2.04	0.043 **	1.51	−0.01	−3.59	0.000 ***	7.58
(β_7) : EMPINT∗ΔlnSALES	−38.21	−1.79	0.076 *	1.82	6.54	0.41	0.680	4.55
(β_8) : D∗EMPINT∗ΔlnSALES	−131.95	−8.56	0.000 ***	1.06	−26.54	1.95	0.053 *	1.57
(β_9) : GDP∗ΔlnSALES	−0.03	−2.31	0.022 **	1.27	−0.02	−2.99	0.003 ***	1.15
(β_{10}) : D∗GDP∗ΔlnSALES	−0.06	−0.30	0.768	1.08	−0.01	−0.54	0.592	1.89
Year	Controlled				Controlled			
Industry	Controlled				Controlled			
Adjusted R^2	0.723				0.863			
F-statistic	607.27				658.94			
Sig.	0.000				0.000			
z-statistic	−1.788							

Source: authors' own work (*: $p < 0.1$; **: $p < 0.05$; ***: $p < 0.01$).

4.3.2. An Alternative Measure of Costs

As another sensitivity test, we used SG&A costs instead of the cost of goods sold, as shown in Equation (6). According to the data, log-change dispersion in SG&A costs is 0.37. This value is close to the dispersion of log-change in sales revenue (0.33) and indicates low-cost stickiness in the sample companies. The results are reported in Table 6.

$$\begin{aligned}\Delta\ln SG\&A_{it} = {} & \beta_0 + \beta_1\Delta\ln Sales_{it} + \beta_2 D_{it} * \Delta\ln Sales_{it} + \beta_3 PD_{it} * \Delta\ln Sales_{it} + \beta_4 D_{it} * PD_{it} * \Delta\ln Sales_{it} \\ & + \beta_5 ASINT_{it} * \Delta\ln Sales_{it} + \beta_6 D_{it} * ASINT_{it} * \Delta\ln Sales_{it} + \beta_7 EMPINT_{it} * \Delta\ln Sales_{it} \\ & + \beta_8 D_{it} * EMPINT_{it} * \Delta\ln Sales_{it} + \beta_9 GDP_t * \Delta\ln Sales_{it} + \beta_{10} D_{it} * GDP_t * \Delta\ln Sales_{it} \\ & + \beta_{11}\sum T_j\ Industry + \beta_{12}\sum\theta_j\ Year + \varepsilon_{it}\end{aligned} \quad (6)$$

According to these results, the coefficient of ΔlnSALES (β_1) is 0.92, which is positive and significant, and the coefficient of D∗ΔlnSALES (β_2) in the model is −0.11, which is negative and significant. Consistent with the baseline findings, these results indicate the presence of cost stickiness. Moreover, given that the coefficient of D∗PD∗ΔlnSALES (β_4) is negative and significant, and the first hypothesis is accepted, this suggests meaningful positive relationship between product diversification and cost stickiness. Similarly, the coefficients of the control variables D∗ASINT∗ΔlnSALES (β_6) and D∗GDP∗ΔlnSALES (β_{10}) are negative and significant, suggesting that firms with higher asset intensity and GDP growth rates have greater cost stickiness.

Table 6. Estimation results using an alternative measure of costs (SG&A costs).

Variable	Beta	t-Statistic	*p*-Value	VIF
C	0.35	−4.58	0.000 ***	-
(β_1) : ΔlnSALES	0.92	31.60	0.000 ***	1.60
(β_2) : D∗ΔlnSALES	−0.11	−5.39	0.000 ***	7.34
(β_3) : PD∗ΔlnSALES	−0.03	−2.03	0.044 **	1.67
(β_4) : D∗PD∗ΔlnSALES	−0.05	−1.78	0.077 *	5.26
(β_5) : ASINT∗ΔlnSALES	0.01	1.01	0.316	9.28
(β_6) : D∗ASINT∗ΔlnSALES	−0.01	−1.68	0.066 *	9.75
(β_7) : EMPINT∗ΔlnSALES	−66.32	−3.29	0.001 ***	7.04
(β_8) : D∗EMPINT∗ΔlnSALES	34.96	1.40	0.163	9.53
(β_9) : GDP∗ΔlnSALES	−0.07	−3.86	0.000 ***	1.41
(β_{10}) : D∗GDP∗ΔlnSALES	−0.14	−2.86	0.005 ***	1.56
Year	Controlled			
Industry	Controlled			
Adjusted R^2	0.690			
F-statistic	111.79			
Sig.	0.000			

Source: authors' own work (*: $p < 0.1$; **: $p < 0.05$; ***: $p < 0.01$).

4.3.3. Incorporating COVID-19 as a Moderator

To address the unique contextual factors stemming from the COVID-19 pandemic, we included a COVID-19 variable as a moderator in our analysis. The results are reported in Table 7. This additional analysis allowed us to explore how the pandemic may have influenced the relationship between our critical variables between 2020 and 2023.

Table 7. COVID-19 and the relationship between product diversification strategy and cost stickiness.

	COVID 19							
	Pre COVID 19				COVID 19 Period			
Variable	Beta	t-Statistic	*p*-Value	VIF	Beta	t-Statistic	*p*-Value	VIF
C	−0.48	−1.98	0.05 *	-	0.003	0.22	0.83	-
(β_1) : ΔlnSALES	0.88	12.23	0.000 ***	1.92	0.87	25.91	0.000 ***	1.12
(β_2) : D∗ΔlnSALES	−0.25	−2.69	0.008 ***	2.52	−0.05	−1.96	0.052 *	2.82
(β_3) : PD∗ΔlnSALES	−0.01	−1.58	0.117	1.31	−0.001	−0.25	0.802	1.72
(β_4) : D∗PD∗ΔlnSALES	−0.03	−1.74	0.084 *	1.1	−0.04	−3.22	0.002 ***	1.91
(β_5) : ASINT∗ΔlnSALES	−0.003	−1.26	0.209	8.23	−0.001	−0.64	0.525	8.13
(β_6) : D∗ASINT∗ΔlnSALES	−0.05	−2.32	0.022 **	6.01	−0.02	−2.19	0.03 **	5.81
(β_7) : EMPINT∗ΔlnSALES	−11.66	−0.31	0.757	8.99	12.11	1.4	0.163	8.01
(β_8) : D∗EMPINT∗ΔlnSALES	−51.57	−1.22	0.226	7.28	−3.77	−1.89	0.061 *	8.14
(β_9) : GDP∗ΔlnSALES	−0.02	−2.25	0.026 **	1.38	−0.02	−3.61	0.000 ***	1.18
(β_{10}) : D∗GDP∗ΔlnSALES	−0.048	−1.97	0.051 *	1.92	−0.11	−2.26	0.025 **	2.07
Year	Controlled				Controlled			
Industry	Controlled				Controlled			
Adjusted R^2	0.781				0.855			
F-statistic	508.17				680.84			
Sig.	0.000				0.000			
z-statistic	0.55							

Source: authors' own work (*: $p < 0.1$; **: $p < 0.05$; ***: $p < 0.01$).

The result of the z-test indicates that there is no significant difference in (β_4) between companies affected by the COVID-19 pandemic and those unaffected by it. Our analysis suggests that the COVID-19 pandemic did not significantly impact the relationship between product diversification and cost stickiness.

5. Discussion

This study significantly enhances the understanding of the relationship between product diversification strategy, cost stickiness, and the moderating role of managerial overconfidence, particularly within the context of the Resource-Based View (RBV) theory. The existing literature on diversification and its implications has often yielded inconclusive results, failing to capture this complex relationship comprehensively. Some studies suggest that diversification enhances firm performance by creating synergies and spreading risk (Krivokapić et al. 2017; Bhatia and Thakur 2018), while others argue that diversification can lead to inefficiencies (Dawid and Reimann 2011). These mixed findings highlight the complexity of the relationship between diversification and firm performance, mainly when cost behaviour is considered. Our study addresses this gap by exploring the interplay between diversification and cost stickiness, offering a new perspective and valuable insights.

Our findings reveal a substantial and previously uncharted link between product diversification strategy and cost stickiness, particularly in manufacturing companies. This connection aligns with the RBV theory, which emphasizes the significance of unique resources and capabilities in achieving a competitive advantage (Barney et al. 2011). In this case, product diversification represents a unique resource, while cost stickiness reflects a capacity related to resource management and risk mitigation. Thus, this study underscores the theoretical underpinnings of RBV by empirically validating its principles in the context of corporate strategies. This finding is consistent with Banker and Byzalov (2014), who suggest that firms with greater resource commitments are more likely to exhibit cost stickiness due to the perceived value of maintaining resources in anticipation of future opportunities.

Moreover, this study uncovers the moderating influence of managerial overconfidence on the relationship between diversification and cost stickiness. This aspect further substantiates RBV, emphasizing the role of managerial decisions and perceptions in resource allocation and risk management. Our findings are consistent with those of Chen et al. (2022) as well as Keke (2021), showing that managers' overconfidence impacts their investment decisions and costs (leading to a more pronounced cost stickiness in companies with product diversification strategies). This empirical validation of managerial overconfidence as a moderating factor reinforces the RBV's emphasis on the role of internal resources and managerial decisions in shaping firm performance.

6. Conclusions

This study aimed to investigate the relationship between product diversification and cost stickiness, focusing on the moderating role of managerial overconfidence within the context of Iranian manufacturing companies. Through our analysis, we found that product diversification is significantly associated with increased cost stickiness, and this relationship is further amplified by managerial overconfidence. These findings suggest that strategic diversification and resource management decisions are critical in shaping a company's cost behaviour, especially under economic uncertainty.

This study's implications are far-reaching. It highlights the critical role of strategic choices in determining cost stickiness, providing valuable insights for shareholders, creditors, and stakeholders in assessing a company's financial behaviour and risk exposure. Additionally, this study offers auditors a deeper understanding of cost behaviour and its determinants, enhancing their analytical procedures.

For analysts and users of financial statements, this study underscores the importance of considering managerial overconfidence and cost stickiness when evaluating a company's financial performance and risk profile. Managers are urged to understand external changes and cost control better to improve their strategic positioning and management

efficiency. Lastly, this study raises intriguing questions about the optimal level of product diversification, prompting further exploration in this area.

While this research contributes significantly to the literature, it has some limitations. The reliance on financial statements and the absence of face-to-face interactions with respondents pose constraints. Additionally, this study's focus on Iranian companies may limit its generalizability to other contexts. Iran's economic and regulatory environment might have influenced the findings, meaning that they should be interpreted with care when considering their applicability to different contexts. Furthermore, the data were modified through deflation to adjust for inflation. This may have influenced the results by providing a more precise reflection of real economic values rather than nominal figures. This adjustment could potentially affect the observed relationships, as it eliminates the distorting effects of inflation, allowing for a more accurate analysis. However, this adjustment assumes a uniform impact of inflation across all firms, potentially overlooking sector-specific differences. Future research can extend these findings by examining different types of product diversification, exploring internationalization strategies, and delving into moderating variables, including other managerial factors, market competition, and intensity of technological innovation, that influence cost stickiness and risk management, thus further enriching the RBV theory's application in diverse contexts.

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A Financial Stability Model for Iraqi Companies

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Abstract: The current study aims to develop a financial stability model in Iraq; after reviewing the relevant literature and sources related to financial stability and considering Iraq's social, economic, political, and cultural conditions, a conceptual model and a research questionnaire have been developed. Based on the developed conceptual model, macro variables at the level of the economy, micro variables at the level of companies, the environmental variables of companies, and corporate governance have been selected as model dimensions. Each dimension has several components, including several indicators; 39 indicators were measured through questions in 2024. The research questionnaire was subjected to the opinion of 21 experts with sufficient experimental and academic records on this subject, and by using the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods, the results were analyzed, and the final model was extracted. In this model, the scientific method used to analyze the results determines the weight of each dimension, component, and indicator. The results of this research show that the dimensions of corporate governance, the variables of the company environment, micro variables at the company level, and macro variables at the economic level with coefficients of 0.345, 0.251, 0.236, and 0.168, respectively, have the most significant impact on the ranking of the company's financial stability. So far, research has yet to be conducted to present the financial stability model of Iraqi companies. Therefore, the present research is one of the first studies in this respect, which presents a model both qualitatively (by designing a questionnaire and conceptual model) and quantitatively (through a mathematical model) to measure financial stability that can help the development of science and knowledge in this field.

Keywords: financial stability; political factors

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1. Introduction

Unlike price stability, defining or measuring financial stability is not a simple and easy task due to the interdependence and complex interactions of the various financial system elements of companies with each other and the economy, which is more complicated due to the time and cross-border dimensions of such interactions (Kukushina et al. 2021). Financial stability is when the financial system resists economic shocks and can perform its financial tasks correctly (Taranova et al. 2021). The need for financial stability analysis was first recognized since the establishment of stock markets suggesting organized training in the 17th century; after that, by the industrial revolution in the 19th century, credit rating agencies emerged to evaluate the financial stability of organizations to provide a basis for the investors in decision-making processes (Antonov 2022). More recently, in the 20th century, as a result of the massive development of financial markets, metrics such as earnings per share (EPS) and price-to-earnings (P/E) ratios were formulated to assess the financial stability of corporates (Goswami et al. 2014). In addition to the general need for an assessment of the financial stability of companies, the financial crises positioned in the late 1990s, after financial liberalization, have highlighted the importance of financial stability, and its importance was strengthened by the occurrence of financial and economic crises in

2007–2008 (Yusgiantoro et al. 2019). Before the crisis, corporate indebtedness had reached unprecedented levels, forcing companies to repay their loans and putting further pressure on their financial stability. High leverage levels increased firms' sensitivities to economic shocks and credit tightening during the crisis (Mayasari and Wulandari 2022). During the crisis, as was evident in the volatility of equity markets worldwide, the systemic nature of risks threatened corporate financial stability. Also, declining commodity prices and the fading of the commodity boom cycle had adverse effects on foreign direct investment in natural resources and changed the fate of businesses operating in the mining and energy sectors. Therefore, the economic slowdown and recession that the crisis triggered reduced the attractiveness of stock markets as an investment destination, reduced foreign investment flows, and reduced companies' growth prospects (Fingleton et al. 2008). High corporate indebtedness, contagious financial markets, unfavorable economic conditions, and regulatory changes finally caused the financial crisis of 2007–2008, which profoundly impacted companies' financial stability worldwide. Therefore, financial stability is essential for economic prosperity at the firm and macro levels.

Indebtedness and debt management are critical for improving financial stability in corporate entities, municipalities, and national economies. The following are the major points provided by the existing literature: (1) Efficient public debt management minimizes the vulnerability of an economy to financial shocks and supports a stable financial environment. For example, in Poland, it follows that effective public debt management reduces financial threats and enhances the stability of economics (Misztal 2021). (2) Public debt management is crucial for the broad economic stability of any country. It touches on public finances, monetary turnover, the investment climate, and international cooperation. For example, in Kazakhstan, the improvement in the system of public debt management plays a significant role in increasing financial stability, especially with regard to economic transformation and growing economic risks (Mataibayeva et al. 2019). (3) In the corporate sector, financial stability is conditioned by the balance between companies' own resources and external debts. Companies with a higher share of their own resources tend to be more stable. Also, excessive reliance on external debt can seriously threaten the firm's financial health if the economy becomes hostile (Chiladze 2018). Therefore, efficient debt management uses long-term debt financing tools to increase the return on equity and improve overall financial stability.

During the last two decades, researchers of central banks and entities have tried to depict financial stability conditions through various indicators of financial system vulnerabilities (Nadri et al. 2018). Several central banks try to assess financial stability risks by focusing on a few critical indicators through Financial Stability Reports (FSR) (Kalsie et al. 2020). In addition, there are ongoing efforts to develop a unit-wide measure indicating business fragility or financial stress (Akosah et al. 2018). The composite quantitative measures of financial stability are intuitively appealing for their ability to, first, present policymakers and participants with a system of more effective monitoring of the level of stability within the system; second, to foresee the sources and causes of financial stress; and third, to understand their implications better. The methodology for constructing these measures has been changing over the years, shifting the focus from micro-prudential to macro-prudential aspects of financial stability. It shifted focus from looking into the early warning indicators to assessing the condition of the banking system, specifically the default risk of individual institutions, to a comprehensive assessment of risks across financial markets, institutions, and infrastructure of the whole system. Recently, increasing analytical focus has been placed on behavioral dynamics, the eventual emergence of unstable conditions, and the shock transmission mechanisms (Stona et al. 2018). In examining financial stability and providing the necessary model to measure it, we must also analyze the banking and financial systems of the companies listed on the Iraqi Stock Exchange. Therefore, in this research, in addition to the listed companies on the Iraqi Stock Exchange, we also consider banks listed on the Iraqi Stock Exchange. The factors affecting financial instability are diverse and can differ according to the period and the countries included in the analysis.

One of the critical issues underlying these analytical developments is the need to fill data gaps in several fields, such as the financial departments of companies listed on the Iraqi Stock Exchange. The current research can help to review the work carried out in the direction of developing quantitative financial stability criteria, presenting the financial stability model for Iraqi companies in both qualitative and quantitative ways: qualitative through a questionnaire and quantitative through a mathematical model used in the published financial reports of business units. Therefore, in this research, we seek to present a model of financial stability in Iraqi companies. The reason for choosing Iraq is because this country has faced several crises in recent years, including the US military attack, the occupation of this country by the ISIS terrorist group, internal riots in the country, and finally, the global crisis of COVID-19. It is known that each of these crises has dramatically impacted the economy and financial performance of businesses and the financial system of Iraq (Abdullah 2018). Also, by reviewing the subject literature, it has been determined that, so far, most of the studies carried out in the field of financial stability have often identified factors affecting financial stability and ranked various factors affecting it. So far, no research has provided a model for stability. Therefore, the current study, considering the importance of financial stability for the financial systems of banks and business units of countries, seeks to investigate this issue in the developing and crisis-stricken country of Iraq to eliminate the research gap in this field. It will also help the development of science and knowledge in this field.

2. Theoretical Principles

Financial stability is a feature of a financial system that eliminates financial imbalances that arise endogenously in financial markets or result from significant adverse and unpredictable events (Icaza 2017). When the system is stable, it absorbs economic shocks, mainly through self-correcting mechanisms, and prevents adverse events from disrupting the real economy or contaminating other financial systems (Elsayed et al. 2023). Financial stability is crucial for economic growth, as most transactions in the real economy are conducted through the financial system (Hadian and Dargahi 2018).

Without financial stability, businesses and banks will be reluctant to finance profitable projects, the price of assets may deviate significantly from their intrinsic values, and the payments settlement program may be derailed (Habib et al. 2020). Therefore, financial stability is essential to maintain the confidence of businesses and financial institutions (Dai and Zhou 2022). The potential consequences of excessive volatility can include financial crises, bankruptcies of business units and banks, severe inflation, and stock market crashes (Akins et al. 2016). In other words, financial stability is the goal of central bank policy for price stability and the healthy development of countries' economies and business units (Mamipour and Godarzi 2020). Because financial instability imposes high costs on the economy and businesses, as the volatility of price variables in financial markets increases, financial institutions or companies may go bankrupt (Enaiati et al. 2022).

Moreover, economic development can be limited at such a time, as economic agents need help making rational decisions and the efficiency of resource allocation decreases. Since the 1980s, several countries have achieved the positive effects of the rapid growth of the financial industry due to the progress of financial liberalization (Dai and Zhou 2022). At the same time, they have also experienced a dramatic slowdown in economic growth due to heavy economic costs caused by financial instability or financial crises (Martinez-Miera and Repullo 2020). In the face of this, countries have greatly emphasized this issue when implementing their policies. Attention to financial stability among all countries is currently increasing, as new factors with the potential to create financial instability, including strengthening financial sector linkages between companies and the uncontrolled development of complex financial instruments, have emerged that make it difficult for businesses to help financial institutions have financial stability against crises (Xie et al. 2022). Therefore, given the importance of financial stability for the economy and the financial system of businesses and banks, it is necessary to provide a model that can correctly depict

the various factors affecting financial stability. Especially in Iraq, due to the crises it has gone through in recent years, such a model can be used to assess the financial stability of the financial system of its banks while measuring the financial stability of the listed companies on the Iraqi Stock Exchange.

2.1. Financial Stability

Over the past decade, financial stability has become one of the important goals of economic policy. Many central banks and financial authorities, such as the International Monetary Fund, the World Bank, and the Bank for International Settlements, publish periodic financial stability reports to embed analysis and the pursuit of financial stability into their mainstream activities. Financial stability goes way beyond the absence of crises. A stable financial system is one that, through the conduct of other processes and financial and economic functions such as savings and investments, lending and borrowing, and liquidity creation and distribution, among others, effectively conducts the geographical and temporal allocation of economic resources, evaluating, pricing, and allocating financial risks. It must also manage the risks and have the ability to maintain the performance of those key functions despite adverse external shocks or imbalances.

The system is composed of infrastructures such as legal, payment, settlement, and accounting systems; institutions such as banks, security firms, and institutional investors; and markets for stock, bonds, money, and derivatives. In case of trouble with one component, there is a potential to affect the whole stability of the system itself (Barra and Zotti 2019). However, given that the system is strong enough to hold on to its core functionalities, problems in one component of the system might not necessarily threaten overall stability (Dai and Zhou 2022). The need for financial stability does not pre-assume that all areas within the financial system need to work optimally all the time. It allows for the self-correction of mechanisms to reduce and eliminate these imbalances before they grow to become full-blown crises, such that the national currency performs its roles as a medium of exchange, unit of account, and store of value functions. This, therefore, means that financial and monetary stability are interconnected. According to Barra and Ruggiero (2021), overall, a financial system would be termed stable if disturbances and crises are improbable to hurt economic activity. Increased competition or the assimilation of new information may lead to the closure of a financial institution, growing volatility, or significant market corrections, which indicate good health in the financial system (Bazzazan 2020).

Because the financial system is continuously changing, the concept of financial stability does not pertain to any one stable state or trajectory that the system would revert to post-shock; rather, it alludes to a spectrum or continuum. This multidimensional continuum reveals itself in different observable and measurable variables that are of help in providing for the quantification of the effectuality of a financial system in fulfilling its facilitative roles (Xie et al. 2022). Financial stability is a broad concept and difficult to reduce to be measured by a single metric. The contagion effects and non-linear interactions among the different segments of the financial system cause problems in predicting financial crises. Therefore, a systemic and comprehensive perspective on the stability of the financial system is needed (Ayam 2021).

At the same time, crisis prevention has to be based on a realistic understanding of the degree to which developments in financial stability can be controlled. Many of the policy instruments available for ensuring financial stability pursue other primary objectives, like the protection of depositors in their dealings with banks (prudential policies), price stability (monetary policy), or the efficient settlement of payment transactions (payment policies). The impact of such policy tools on financial stability is most often indirect and occurs after some lag, which may be in contravention of the original purpose of using those tools (Zargarkoche and SoroushRad 2019). Although financial stability is advisable to be identified and quantitatively assessed, in this paper, an approach toward the identification of the most important dimensions and indicators that are relevant for the effect on financial stability is pursued so that this variable can be calculated and forecasted accurately.

2.2. Financial Stability Dimensions and Indicators

Financial stability is multidimensional, so it takes work to measure. Financial stability is measured and evaluated based on the performance of financial markets, institutions, and infrastructures and the interaction between the financial sector and the macroeconomic environment. Therefore, financial stability cannot be analyzed as a single variable or a financial indicator per business, such as macro-level liquidity ratios, with an indicator such as the inflation rate (Dai and Zhou 2022).

Financial market stability refers to the ability of financial markets to absorb a shock and not destabilize their fundamental functions with regard to price discovery and liquidity. Financial market stability is a situation in which companies listed in the financial markets can meet obligations without foreign interference or aid, prices do not change in the short term, and there is a change in fundamental indicators (Ghassan and Krichene 2017). This stability should alleviate the systemic risks to preclude broad contagion or market failure, especially during serious market constraints (Baur and Schulze 2009). Markets in developed countries show more stable characteristics compared to their counterparts in emerging markets, where the impact of systematic shocks can be very high during periods of crisis (Chirilă and Chirilă 2015). Shi et al. (2011) believe that to achieve financial market stability, a sound regulatory framework must be implemented, which compels finance institutions to carry out their business transparently and accountably with the proper practice of risk management. Moreover, monitoring crises can enforce capital adequacy so that the listed institutions might be more resilient under economic shocks. Using advanced analytics, market practitioners can continuously monitor market activities, which is necessary for the early detection of potential risks to prevent systemic risks (Chen et al. 2013). Interventionist monetary and fiscal policies by governments and central banks during times of crisis—for example, the adoption of quantitative easing or the provision of liquidity support—can help stabilize the financial markets. Policymakers may also help stabilize financial markets by proposing clear crisis management protocols so that markets can respond well during sudden shocks. This includes designing contingency plans and emergency liquidity provisions. Therefore, financial market stability is a prerequisite for successful economic development. Financial markets can be stabilized by comprehensive regulatory measures, improved market surveillance, and investor education to ensure sustained economic growth.

In terms of company financial stability, several studies have been conducted, and some indicators of financial stability have been provided. For companies, financial stability refers to the ability to maintain the overall balance in a company's financial structure and to fulfill all financial obligations uninterruptedly over time, whether affected by economic difficulties or market fluctuations. It indicates a company's ability to generate sufficient cash, keep adequate liquidity, manage debt effectively, and ensure profitability and growth. In particular, an optimally balanced capital structure, including internal resources with outside debt, may allow a firm to conduct business efficiently without having too great of a financial burden. Therefore, debt management and efficient capital structure are among the paramount factors determining the financial stability of corporates (Chiladze 2018). Liquidity and profitability, referring to a company's ability to meet short-term obligations and have consistent profitability, are other factors increasing the financial stability of corporates through generating continuous positive cash flows. Other financial stability perspectives address financial risks and market uncertainties by implementing risk management approaches and enhancing adaptability to modify the changing economic conditions (Oleynik and Borisova 2019).

Existing literature also explores some aspects of the financial stability of companies. For example, Allen and Wood (2006) have taken asset price volatility as a measure of financial stability. Financial stability avoids disruptions in the financial system that are likely to cause significant production costs, financial problems in institutions, or disruptions in capital markets. They also defined financial stability as the stability of the value of money, the stability of prices, the favorable level of employment, trust in monetary and financial

institutions, and the absence of fluctuations in the liquidity and profitability of companies. Virolainen (2004) introduced macro-level indicators such as interest rates, GDP growth, and credit expansion as companies' financial stability indicators.

However, at the micro level, financial stability criteria are mainly based on liquidity risk, financial solvency, systematic and non-systematic risk, and the Altman Z criterion for predicting financial crises. The review of research (e.g., Beck et al. 2014; Virolainen 2004; Ghassan and Krichene 2017) shows that in the research of Beck et al. (2014), the return on equity basis is used as an indicator of financial stability.

Also, for the purpose of conducting an objective analysis of the value and structure of the company's assets and liabilities and determining the degree of financial stability and independence, comparing the objectives of financial and economic activities with the regulations of the company, the debt and interest coverage ratios are used as criteria. The financial security and trust of the company are leveraged in external financing (Dai and Zhou 2022).

On the other hand, the literature review also suggests that fundamental accounting variables, financial ratios, or a combination of them are generally considered factors affecting financial stability (Pinčák and Bartoš 2015).

Blank (2013) used indicators such as liquidity ratios and debt repayment, such as the current ratio and debt repayment period, to assess financial stability. Thus, if liquidity indicators are greater than normative values, it can be a sign of the improper use of available financial resources. Therefore, indicators of business activity such as asset turnover, inventory, claims receipt period, and working capital can be used to assess financial stability. Because these ratios indicate the management of assets in production and sales and the employment of working and total capital, it is essential in strengthening companies' liquidity.

Table 1 summarizes the research on financial stability and the indicators used to measure financial instability as follows.

Table 1. Indicators employed for financial instability.

Authors	The Index Used for Financial Instability
Altman (1968)	Altman's Z-score index is a measure to predict the probability of financial instability or helplessness based on financial ratios, including working capital to assets, residual profit to assets, profit before interest and tax to assets, the market value of stocks, and sales to assets.
Ohlson (1980)	Score index 9-factor linear combination of coefficients to evaluate the business probability of failure or financial instability. In this regard, the exponential power of this score is divided by 1 plus this exponential power. In this index, the forecasting factors are the sum of assets, the price index in national income, the sum of liabilities, working capital, current liabilities, and current assets; if the sum of liabilities is greater than the sum of assets, it takes 1; otherwise, 0. Net profit, operating cash flows; if the company has made losses in the last 2 years, it takes 1; otherwise, 0.
Zmijewski (1984)	It uses a model based on net profit to assets, total liabilities to assets, and current assets to current liabilities to predict financial instability.
Hillegeist et al. (2004)	They have used famous indicators based on accounting and market variables called BSM-Prob, which indicates the probability of financial helplessness and instability. The variables used include the current market value of assets, the objective value of debt, the expected return on assets, and the expected interest rate of stocks.
Campbell et al. (2008)	To measure financial stability and instability, the following model is developed by the authors: $CHS = -20.26NIMTAAVG + 1.42TLMAT - 2.13EXRETAVG + 1.41SIGMA - 0.045RSIZE - 2.13CASHMTA + 0.075MB - 0.58PRICE - 9.1$ In this model, NIMTAAVG is the measure of profitability, TLMTA is the measure of financial leverage, EXRETAVG is the average past excess return, SIGMA is the volatility of stock returns, RSIZE is the relative size of the company based on market value, CASHMTA is liquidity and short-term investment. In addition, MB is the market's ratio to the stock's book value and PRICE is the stock price based on decimals. CHS uses quarterly accounting data, lack of success, or instability for reasons related to performance and receiving points from rating agencies. The probability of failure and financial instability for a few years is based on logistic regression estimation.
Sudarsanam and Lai (2001)	The Toffler Z Index consists of components such as profit before tax, current liabilities to current assets, total liabilities to current liabilities, and total assets to the non-credit interval.
Zhang et al. (2018)	Crisis and non-crisis model. This index classifies companies into two categories, crisis and non-crisis, in terms of financial stability.

Note: The term financial instability represents bankruptcy, financial distress, and financial crisis to increase the understandability of Table 1.

According to Table 2, by reviewing the literature, the factors affecting companies' financial helplessness or financial instability are categorized into three categories: company-level characteristics or performance micro variables, macroeconomic-level variables, and corporate governance determining factors. The research conducted on the factors of financial instability (Beaver et al. 2011) in companies is shown as follows:

Table 2. Studies based on company-level characteristics (micro variables).

Authors	Research Question	Sample Studied	Method Used	Findings	Economic Significance
Al-Hadi et al. (2017)	The relationship between CSR and the probability of occurrence of financial instability in the economic cycle	651 Australian companies, years 2007–2013, randomly selected	Altman's Z-index: Lower values indicate less financial instability.	CSR reduces the possibility of financial instability at the maturity stage.	One deviation of the CSR benchmark reduces the probability of financial instability by 46%.
Zhang et al. (2018)	The impact of R&D spending on financial volatility	55652 American companies, years 1980–2011	Linear regression	R&D positively impacts financial volatility, especially in a recession, and intangible assets negatively impact future financial volatility.	One standard deviation of R&D reduces financial volatility by 1.3 percentage points.
Beck et al. (2014)	The relationship between CSR and the likelihood of financial instability	58 Taiwanese companies in 2007–2010	The structural equation model can predict financial volatility.	CSR reduces the possibility of financial instability in the global recession crisis.	-
Tinoco and Wilson (2013)	Accounting variables, capital market, and financial volatility	23218 English companies, years 1980–2011	Binary logistic regression	The full model has the same power to explain volatility changes as Altman.	No
Magee (2013)	Foreign exchange backing and financial instability	401 American companies, 1996–2000	Merton's instability probability (1974)	Foreign exchange backing has a negative impact on financial instability.	One deviation of the foreign exchange backing benchmark reduces the probability of financial instability by 0.785%.
Kane et al. (2005)	Employee relations and the possibility of financial instability	2228 American companies, 1991–2001	Altman's Z-index	Good relationships with employees have a negative impact on financial instability.	No
Tennyson et al. (2008)	Usefulness of financial information and financial instability	Two examples of 23 successful and unsuccessful English companies		The level of relevance of financial information has a negative impact on financial instability.	No

Also, according to Table 3, the factors affecting the occurrence of financial instability based on corporate governance are described as follows:

Table 3. Studies based on the components of corporate governance.

Authors	Research Question	Sample Studied	Method Used	Findings
Gottardo and Moisello (2017)	Family ownership and financial instability	1137 views of Italy in 2004–2013	Binary logistic regression	Family ownership, the number of family members in management, and female CEOs negatively affect financial instability.
Schulze (2022)	Characteristics of the board of directors and financial instability	962 Australian companies, years 2000–2007	Probability of financial instability, Merton (1974)	Management ownership reduces financial instability, and the percentage of non-executive directors increases financial instability.
Darrat et al. (2016)	Characteristics of corporate governance and financial instability	217 successful and 9100 unsuccessful American companies, 1996–2006	Logistic regression	Obligator, personal knowledge and experience, percentage of female managers, length of CEO tenure, CEO succession, reduced financial volatility, and CEO power increases financial volatility.
Hsu and Wu (2023)	Board composition and financial instability	Two samples of 234 English companies in 1997–2000	Binary variable for financial instability and financial stability of the company	A company with more non-obligatory grey managers has more financial stability.
Kallunki and Pyykkö (2013)	Managing Director, Executive Director, and financial instability	48716 Finnish companies, years 2001–2008	Z-adjusted salary or benchmark CEO pay	A CEO or executive with a history of self-interest increases financial instability.
Tinoco and Wilson (2013)	Private ownership and financial instability	1852 acquired companies from 15 European countries in 2008–2000	Altman's Z index and Olson's index	Experienced private acquisition syndication managements have a negative effect on financial instability.

2.3. Research Background

Al-Rjoub (2021) examined financial stability indicators for Jordan. He divides financial health indicators into four categories: 1. have announced capital adequacy; 2. earnings and solvency; 3. liquidity; 4. based on these variables, asset quality constructed by the composite financial stability index with equal weighting using the principal component method from 2003 to 2015. He showed that financial stability in the banking sector in Jordan is consciously resilient to shocks and adverse economic conditions.

Ilesanmi and Tewari (2020) investigated the issue of financial stress indicators and economic activities in South Africa. The financial stress index is a single aggregate index constructed to reflect finance's volatile systemic nature and measure the financial system's vulnerability to internal and external shocks. They have identified the financial stress index for South Africa between 2006 and 2017 using principal component analysis. The results show that the financial stress index is handy for measuring the effectiveness of government measures to reduce the impact of financial stress.

Kalsie et al. (2020) also examined the measurement of financial stability and its impact on foreign direct investment with evidence from BRIC countries. Economic stability has

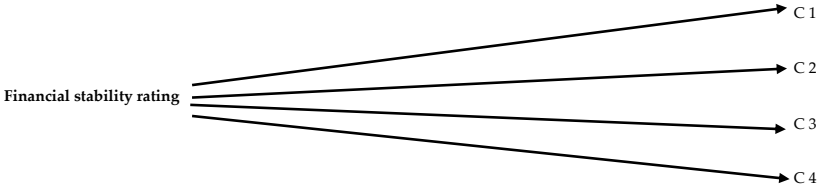
become a key fiscal, economic, and monetary policy objective. They pursued two objectives, one to create four indicators of financial stability and the second to use four indicators of financial stability constructed in a two-stage least squares regression framework to determine the impact of financial stability indicators on foreign direct investment for the period 2000 to 2017 in four countries, Brazil, Russia, India, and China. The results showed that all four indicators of financial stability in Brazil are significant. In the case of Russia, the government's financial management needs to be carried out correctly. In the case of China, the large flow of foreign direct investment could be more effective in attracting foreign capital. The openness of the economy in all countries except India is conducive to foreign direct investment; of the four, Brazil is on the right track.

Ozili (2018) examined the impact of financial instability on sustainable development. The findings of the sustainable development index analysis show that financial stability significantly impacts sustainable development, and its impact is negative in Asian countries. European and Asian countries have a higher sustainable development index than African countries.

Orazalin et al. (2024) investigated whether CSR contributes to the financial sector's financial stability. Their research suggests that CSR initiatives contribute to the financial stability of the financial sector and three subsectors.

2.4. Conceptual Model

After conducting exploratory studies and reviewing the research conducted, the analytical model of the present research, which is the basis for formulating the research question, is as follows, illustrated in Figure 1. Moreover, the conceptual model of the study is displayed in Figure 2.



What are the dimensions of companies' financial stability models?				Corporate governance variables	Company environment variables	Micro variables at the level of companies				Macro variables at the level of the economy	Dimensions
What are the components of companies' financial stability models?				Shareholders' rights transparency Effectiveness of the board of directors Effects of ownership	Features of the company Profitability variables	Performance	Financial structure	Resource management	Liquidity	Characteristics of the economy Instability Political factors	Components
What is the value of the components of the financial stability model of companies?	Institutional ownership property management size of the company Independence of the board of directors Disclosure of remuneration of board members Disclosure of contract details The duality of management	Industry dummy variable Growth opportunities Return on equity	Return on investment Earnings per share Return on capital Net profit margin Fluctuation of profitability Stock beta	Long-term liabilities to capital Covering financial costs Total debt ratio	Periodicals Collection Working capital Circulation of assets Circulation of goods	Debt repayment period Quick ratio current ratio			Oil prices swelling Isis Political instability Boycott Changes in exchange rates		Indicators

Figure 1. Analytical model of the research.

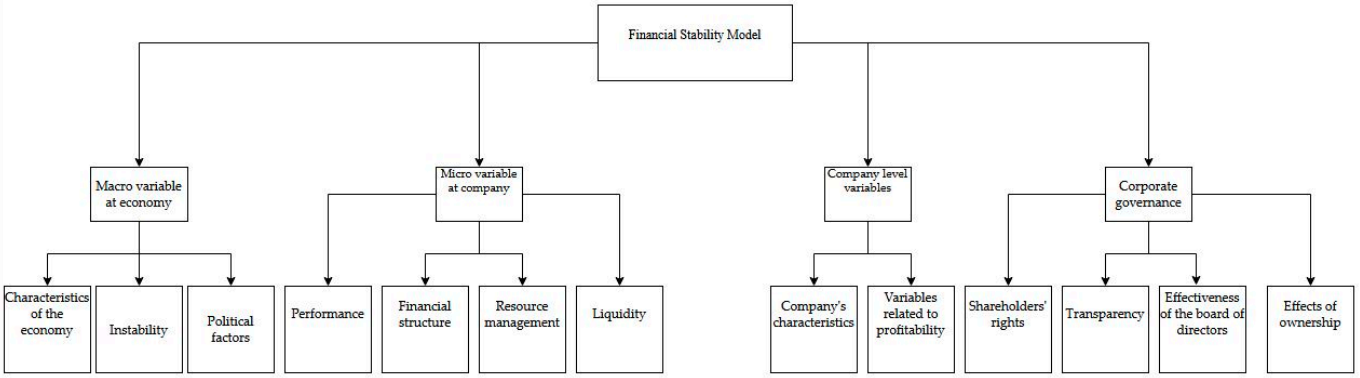


Figure 2. Conceptual model of the study.

3. Research Method

The philosophy of the current research is that the upcoming research is one of quantitative–qualitative study in the form of interpretations and positivism, and it is a mixture of different approaches such as exploratory, descriptive, quantitative, and qualitative. Therefore, it is also part of the philosophy of pragmatism. In the current research, the study conducts a survey and collects secondary data numerically by using interviews and then preparing a questionnaire. Therefore, the current research is quantitative–qualitative. Also, this research collects data for the variables and prepares essential indicators of financial stability in the world and Iraq by using experts' opinions (including board members, financial managers, university professors, auditors, and other stakeholders) and studying previous research. Therefore, it is descriptive, and in the end, since there has yet to be research on financial stability modeling in Iraq, future research will gain new insight into the calculation of financial stability in Iraq and explain a model in this regard through an exploratory strategy.

3.1. Statistical Sample and Research Period

The statistical population of this research is divided into two parts:

The first part comprises research experts' opinions about the leading stability indicators. The experts must have related occupational experience and knowledge about the current study's topic. For example, they must be board members, financial managers, university professors, auditors, and other stakeholders.

The second part will include all the managers (including the CEO, financial manager, and managers of other departments) of the companies listed on the Iraqi Stock Exchange, which is used to measure the validity and reliability of the questionnaire extracted from the expert interviews at the beginning of 2024.

3.2. Sampling

The philosophical stance of the current study is a mixed-methods approach that includes quantitative and qualitative methodologies. This study applies exploratory and descriptive strategies to understand the financial stability indicators of Iraq. The research might be in the form of surveys and secondary data by interviewing experts, and it could be followed up by developing a structured questionnaire. It aims to obtain the essential indicators of financial stability by collecting insights from board members, financial managers, university professors, auditors, and other related experts from a wide circle of respondents. Since no previous study has been conducted with respect to modeling the financial stability of Iraq, this research may provide new insights for developing a model to assess financial stability in such a context.

Our purposive sampling technique may ensure the selection of at least 100 experts based on a pre-compiled list of academic and professional individuals in the field of finance. The selection criterion is guaranteed to be one that allows only participating respondents who have some form of educational background in the area under study and related

practical experience. It is justified on the basis that in statistical advice, a sample size of 100 is sufficient for qualitative studies, given that this number can ensure data saturation to give out a robust analysis of expert opinions.

3.3. Necessary Features for Experts

To ensure the reliability of this study's findings, selected experts have to be experienced and knowledgeable and may provide high-quality and reliable information. Therefore, some criteria shall be developed to identify the participants that best fit this role. Such factors will be in direct relation to the studied topic and the model for financial stability being examined. In the selection of experts to be included in this study, the following factors shall be taken into account. (1) Experts require a relevant educational background in finance, economics, accounting, or management areas. A minimum requirement will be a bachelor's degree in one of the disciplines mentioned above. (2) Experts should have good professional experience with the research subject. This may include a minimum of 5 years of work experience holding a senior financial or managerial position, such as Chief Financial Officer, Financial Controller, Treasurer, etc.; a minimum of 5 years of work experience as a financial analyst/investment banker/portfolio manager working in the financial services industry; at least 5 years of work experience as a financial regulator, policymaker, or central bank official; or at least 5 years of working experience as an academic researcher or professor in finance, economics, or some other related area. (3) Experts must be able to show publications of research articles, books, or reports relating to financial stability, risk management, or corporate finance in reputable journals or other publications. This would serve to demonstrate the individual's expertise and contribution to the field. (4) Professional certification as a Chartered Financial Analyst, Certified Public Accountant, or Certified Treasury Professional will be considered an added qualification to the aforementioned. (5) Experts shall have an absolute reputation and recognition in the Iraqi financial sector. Evidence may be in the form of awards, honors, or leadership positions held within professional associations or industry organizations. Considering these criteria, we may ensure that the collected data in the study are of high quality and represent insights and experiences from people with an in-depth understanding of financial stability within the Iraqi context.

3.4. Data Collection Methods and Instruments

The purpose is to present a model of financial stability in Iraqi companies, identify and explain its constituent factors and elements, and determine the value and importance of each of them in the model of financial stability. To carry out this research, the methods of study and exploratory search in relevant texts are used, and on the other hand, the opinions of academic publishers and the capital market are used.

A questionnaire approach is used to measure the determinants of financial stability in Iraq, as this approach can easily be adaptable to the situation and population of this country to which one applies, thus making it easy to cover most of the drivers of variables relevant to the research topic and demographic group. Moreover, it is administrable in various formats, such as online, face-to-face, or by telephone, making it the most effective instrument for collecting experts' viewpoints. Also, the respondents may provide detailed and qualitative answers, as the questionnaires contain open-ended questions, reaching beyond simple answers to provide further distinctions of ideas, emotions, and experiences. Finally, the employed survey can yield data for a vast number of concepts, from social attitudes/behavior to individual-level health outcomes and environmental factors (Wang et al. 2022).

In particular, several reasons motivated the authors to use a non-parametric approach, while there are several parametric measurements for financial stability proposed by the existing literature. The study entails developing a conceptual model that considers the different dimensions affecting financial stability, such as macroeconomic and microeconomic variables at both the company and environmental levels and corporate governance. Therefore, such an approach gives insight into the realistic scenario of the elements influ-

encing financial stability within the particular case of Iraq. In addition, a panel of 21 experts in related fields of study, validating the questionnaire to meet the objective of the study, may significantly increase the credibility of the data collected through the questionnaire. Thus, the employed methodology provides a robust analysis of financial stability by combining qualitative insights proposed through a questionnaire analysis and quantitative analysis using methods such as AHP and TOPSIS. In essence, this mixed-method approach provides a deeper understanding of the data with accommodation for statistical rigor, anchored in context-appropriate insights. By the employed approach, the weights for the various dimensions and components are determined clearly to bring out which factor most impacts financial stability, which seems impossible to obtain by employing parametric measurements of financial stability. This quantitative aspect is very important in assisting policymakers and practitioners in prioritizing interventions. More importantly, non-parametric methods require a few assumptions to be made about the distribution of the data. This is highly useful when the data may not be normally distributed, usually in the case of finance data exposed to sources of variability. Financial data always contain at least a certain number of outliers—extreme values that make a biased result. Meanwhile, the employed approach in this study is free from outliers and data abnormality, suggesting more robust and accurate insight into the central tendency and relationships within the data. The mixed method used in this study may serve as a necessary complement to any parametric analysis, adding insight or confirming the purpose of the findings. It leads to enhanced robustness of the research outcomes, which helps in producing an exhaustive understanding of the dynamics of financial stability. Finally, this approach is employed because of the special social, economic, and political context that Iraq possesses. The employed method may permit a much more tailored analysis, which catches hold of the generalities of this local environment.

Relevant to the theoretical framework of this investigation, there are several merits of AHP and TOPSIS approaches in the measurement of financial stability as follows. (1) Flexibility and adaptability: AHP and TOPSIS are flexible techniques that can be used in any environment of decision-making. They can deal with qualitative and quantitative criteria; therefore, they will be appropriate for the problem of financial stability, which is complex and involves objective data and subjective expert judgments. (2) Hierarchical structure: AHP decomposes the decision problem into a hierarchy, whereby the relationships among the goal, criteria, and alternatives can be better understood. This structured approach brings clarity to the relative importance of factors impacting financial stability. (3) Consistency check: AHP has a consistency check built into the process for measuring the logical consistency of the pairwise comparisons. This enables the detection of inconsistencies in expert judgments and hence gives an idea about where to correct them for reliable results. (4) Sensitivity analysis: AHP and TOPSIS allow for sensitivity analysis, which means that the former can check variations in the weights of the criteria for the final ranking of the alternative. This will also add weight to the results on the robustness and point out critical factors. (5) Dealing with uncertainty: AHP and TOPSIS are non-parametric methods, hence applicable in situations with uncertainty and ambiguity of choice in decision-making. No assumption about the underlying probability distribution is required; hence, the methods are quite appropriate for analysis with financial data that may not be normally distributed. (6) Ranking interventions: AHP and TOPSIS could, thus, be of great help in giving policymakers at different levels clear weights of the various dimensions impacting financial stability, thereby allowing them to prioritize their interventions. Quantification is thus hugely important in optimizing resource allocation and targeting only key factors with the most effect. These advantages are further enhanced by the combination of the two methods: that of eliciting qualitative insight and that of quantitative analysis, making AHP and TOPSIS very strong tools for the attainment of a holistic understanding of financial stability in the context of Iraq. Collectively, there are several advantages proposed by the mixed method employed in this study.

The employed questionnaire is disclosed in Appendix A. There are several reasons to employ this questionnaire, including (1) comprehensive coverage: the survey covers a wide range of drivers in promoting financial stability. The drivers are at the firm level, corporate governance level, macroeconomic, and environmental levels. In general, the presented questions may cover most of the potentially critical views of the topic. (2) Clear and concise questioning: the majority of the questions are solidly clear and concise; thus, they are easily understood by the respondents, which improves the credibility of the findings. (3) Using the Likert scale: the data responses are on a 5-point Likert scale, hence allowing the data to be analyzed numerically for computation and comparison; it also allows for statistical analysis and credible comparison. (4) Structured format: the contained questions are structured and separate the different categories of factors, making them easier to read and suiting the experience of the respondents. (5) Focusing on key areas: this questionnaire is guided by key thematic areas such as corporate governance, macroeconomic conditions, and firm-specific and environmental factors that play critical roles in ascertaining the overall financial health of a firm. The controlled thematic areas provide a thorough foundation on which valuable cues can be picked regarding what drives financial stability. This questionnaire may enhance the credibility and applicability of our results significantly.

4. Data Analysis

The study aims to examine the financial stability ratings in the capital market, identify and describe its constituent factors and elements, and determine their value and importance in the company's financial stability rating model. To conduct this research, in the first stage, an exploratory study and search are conducted in the relevant literature, and on the other hand, the opinions of academic and capital market experts are used. The theoretical framework of the topic and relevant sources will also be determined, and by studying English and Arabic articles, research questions are designed to formulate the model.

In the next stage, after designing the initial framework of the research to validate it, we identify the model's dimensions and determine whether the predicted financial stability model and its elements and constituent factors are compatible with the situation and reality of the Iraqi capital market. For this purpose, based on Table 4, financial stability indicators were prepared and compiled as a questionnaire with 39 questions. In other words, an initial questionnaire was provided by preparing an initial list of 100 academic and professional experts and examining scientific and experimental records regarding the research topic. To ensure the research selection and final questionnaire met rigorous standards, the work was reviewed by a panel of 21 highly qualified researchers with expertise in the field. Table 4 shows the descriptive statistics of the respondents by education, service history, gender, position in the department, level of education, and field of study.

According to the final goal of the research, which is to provide a financial stability model for Iraqi companies, experts' opinions should be analyzed to determine the statistical significance of the coefficient of each model's dimensions, components, and indicators. The hierarchical analysis process method will be used to analyze dimensions and components, and the TOPSIS method will be used to analyze indicators. The reason for using the TOPSIS method in the analysis of indicators is that the number of indicators exceeds the limit of other applicable methods, such as AHP. The AHP is a structured technique to organize and analyze a complex decision based on qualitative and quantitative factors. It involves breaking down a decision into a hierarchy of objectives, criteria, and alternatives. The TOPSIS approach, as a statistical technique, is used to provide the order of preference by similarity to the ideal solution in our multi-criteria decision analyses, which considers evaluation and ranking against multiple criteria. We employed the TOPSIS due to its simplicity and rationality. TOPSIS gives an apparent and rational view of how to make decisions; it is easy to understand and implement, increasing our findings' credibility. It suggests a quantifiable process featured with flexibility for various kinds of data as necessary for our settings. It can accommodate a high number of criteria and alternatives, so it is suitable for the analysis of the complicated situation of this study. TOPSIS also

provides a simple computational process that can easily be automated by the authors, thus enabling efficient analysis of the data sets used for this study. Therefore, the authors have used TOPSIS to ensure the credibility of the findings. In addition, employed method for determining model's coefficient is displayed in Figure 3.

Table 4. Descriptive statistics of respondents to the research questionnaire.

Variable	Respondent Opinion	Frequency	Percentage
Gender	Male	19	90%
	Female	2	10%
Age	Less than 40	11	53%
	40–45	4	19%
	45–50	2	09%
	50–55	4	19%
Position	University professor	2	10%
	Accountants	5	24%
	Auditor	4	19%
	Financial manager	6	28%
	Other	4	19%
Work experience	Less than 10	11	52%
	10–15	3	14%
	15–20	1	06%
	20–25	3	14%
	25 and up	3	14%
Education	Bachelor's degree	12	57%
	Master's degree	4	19%
	PhD	5	24%
Field of study	Economics	6	28%
	Accounting	11	53%
	Management	4	19%

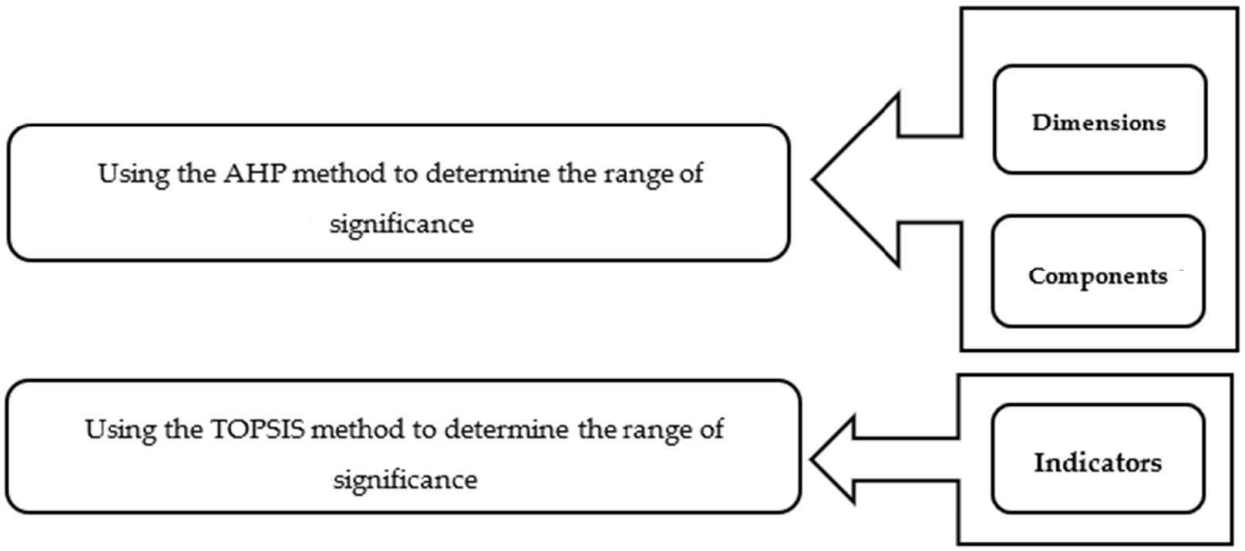


Figure 3. Methods used to determine model coefficients.

4.1. The Results

The AHP provides a framework for thinking about complex issues. This process helps us to make appropriate and correct decisions for complex issues by simplifying the decision-making process. AHP is a method in which a complex situation is decomposed into smaller parts, and these parts are in a hierarchical structure. In this method, according to the importance of each variable and the numerical values assigned to it, the most critical variables are identified through mental judgments. In other words, the priority order of the variables is determined.

AHP creates an effective structure for group decision-making by streamlining the group thinking process. Assigning numerical values to the variables helps the decision-makers have the appropriate thinking pattern to reach the result. Also, the nature of consensus in group decision-making (its consultative nature) improves the consistency of judgments and increases the reliability of AHP as a decision-making instrument. In this way, with the help of AHP, very complex problems that include many factors can be understood and simplified. Table 5 shows the coefficients of each dimension and component obtained using AHP.

Table 5. Dimension coefficients and model components.

Dimensions											
Macro Variable at Economy Level (C1) 0.168			**Micro Variable at Company Level (C2) 0.236**			**Company Level Variables (C3) 0.251**			**Corporate Governance Variables (C4) 0.345**		
Code	**Title**	**Coefficient**	**Code**	**Title**	**Coefficient**	**Code**	**Title**	**Coefficient**	**Code**	**Title**	**Coefficient**
C11	Characteristics of the economy	0.304	C21	Performance	0.201	C31	Company's characteristics	0.401	C41	Shareholders' rights	0.225
C12	Instability	0.265	C22	Financial structure	0.331	C32	Variables related to profitability	0.590	C42	Transparency	0.312
C13	Political factors	0.431	C23	Resource management	0.163				C43	Effectiveness of the board of directors	0.129
			C24	Liquidity	0.305				C44	Effects of ownership	0.334

As is known, the dimension of corporate governance with a coefficient of 0.345 significantly impacts corporate governance. According to prior investigations, improved corporate governance may lead to financial stability for several reasons. In this regard, Susanto and Walyoto (2023) indicate that enhanced corporate governance may assist companies in improving their stability through risk management. Effective corporate governance structures, through the board of commissioners and audit committees, enhance a company's ability to identify, assess, and mitigate financial risks. This ensures companies' resilience in facing emerging financial shocks. Moreover, independent decision-making can be guaranteed through effective corporate governance mechanisms, which include frequent board meetings and a balanced board structure. Consequently, a strong corporate governance structure can support the organization's adaptation to changing markets, including insurance innovations to maintain financial stability and business dynamism (Nwogugu 2015). It helps a company avoid suboptimal financial decisions that may endanger its financial stability. Effective corporate governance can also lead to more transparency in financial reporting and operations (Mabvira 2018). This is important in discovering or averting financial misreporting, critical to maintaining financial stability and investor trust in the market.

The dimensions of company environment variables, micro variables at the company level, and macro variables at the economic level are also critical, with coefficients of 0.251, 0.236, and 0.168, respectively. According to the results, the financial stability score (FSS) can be obtained at the dimension level through model (1):

Model (1):

$$\text{FSS} = 0.168\ \text{C1} + 0.236\ \text{C2} + 0.251\ \text{C3} + 0.345\ \text{C4}$$

Also, according to the obtained coefficients for the components, the related equations at the level of the components are described as follows:

Model (2):

$$C1 = 0.304\ C11 + 0.265\ C12 + 0.431\ C13$$

Model (3):

$$C2 = 0.201\ C21 + 0.331\ C22 + 0.163\ C23 + 0.305\ C24$$

Model (4):

$$C3 = 0.410\ C31 + 0.590\ C32$$

Model (5):

$$C4 = 0.225\ C41 + 0.312\ C42 + 0.129\ C43 + 0.334\ C44$$

By combining model (1) with models (2), (3), (4), and (5), the financial stability score equation can be obtained based on the components as follows:

Model (6):

$$\begin{aligned} FC = 0.051\ C11 \quad & +0.044\ C12 + 0.072\ C13 + 0.047\ C21 + 0.078\ C22 + 0.038\ C23 \\ & +0.072\ C24 + 0.102\ C31 + 0.148\ C32 + 0.069\ C41 + 0.107\ C42 \\ & +0.044\ C43 + 0.115\ C44 \end{aligned}$$

4.2. Prioritization of Indicators by TOPSIS Method

TOPSIS is one of the multi-criteria decision-making methods based on the distance size based on the Euclidean model for the negative and positive ideal solutions. The research conceptual model shows that each component includes one or more indicators. Due to the high number of indicators, the TOPSIS has prioritized the indicators. After performing the various steps of this method, the priority of the indicators regarding each of the components is in Table 6.

As seen in the above table, the value of two of the indices' coefficients for each column is equal to one, indicating that these two components consist of only one variable, respectively, sanctions and the industry dummy variable, instead of a composite of multiple indicators. The coefficient of each index in the final model can be calculated through the following relationship:

$$W_m = W_d + W_c + W_i$$

W_m is the result of the index coefficient, W_i is the index coefficient in the component, W_c is the component coefficient, and W_d is the dimension coefficient. The values of W_c and W_d are reported in Table 6. For example, the index coefficient of C441 in the final model is calculated as follows:

$$W_m = 0.345 * 0.334 * 0.467 = 0.0538$$

The sum of index coefficients in the final model for all indices (39) will equal one. By comparing the coefficients of the indicators in the final model, their importance in assessing each company's financial stability is determined. For example, the index has the highest coefficient among the 39 indicators of the model. As mentioned in the last part of the introduction, none of the countries, the rating institutes, or the research conducted have mentioned the coefficients of dimensions, components, and indicators, and only the titles of dimensions, components, and indicators have been mentioned. Therefore, comparing the results with those of previous studies is impossible. However, the cultural, political, economic, and social differences between the countries make it impossible to use them in other countries.

Table 6. Coefficients of each index in the model.

Index Code	Definition	Index Coefficient in Component	Index Coefficient in the Final Model
The priority of component indicators of macro variables at the economic level			
The priority of component indicators of economic characteristics			
C111	Oil price	0.428	0.021
C112	Inflation	0.572	0.029
The priority of volatility component indicators			
C121	Isis	0.331	0.014
C121	Changes in exchange rates	0.273	0.012
C123	Economic and political instability	0.369	0.016
C131	Sanctions	1	0.07241
According to the definition of only one index for this component, its coefficient is one.			
The priority of micro variable component indicators at the level of companies			
The priority of liquidity component indicators			
C211	Debt repayment period	0.278	0.013
C212	Quick ratio	0.457	0.021
C213	Current ratio	0.265	0.012
The priority of resource management component indicators			
C221	Periodicals Collection	0.196	0.015
C222	Working capital	0.350	0.027
C223	Turnover of assets	0.258	0.020
C224	Turnover of goods	0.196	0.015
The priority of financial structure component indicators			
C231		0.225	0.008
C232		0.312	0.012
C233		0.463	0.017
The priority of performance component indicators			
C241	Return on investment	0.116	0.008
C242	Earnings per share	0.237	0.016
C243	Return on capital	0.145	0.010
C244	Net profit margin	0.119	0.008
C245	Fluctuation of profitability	0.215	0.015
C246	Stock beta	0.168	0.012
The priority of the component indicators of the variables of the company's environment			
The priority of the component indicators of the company's characteristics			
C11	Industry dummy variable	1	0.10291
According to the definition of only one index for this component, its coefficient is one			
The priority of profitability component indicators			
C321	Growth opportunities	0.362	0.053
C322	Return on equity	0.638	0.094
Prioritization of component indicators of corporate governance variables			
Priority of shareholder rights component indicators			
C411	Announcement of dividend policy	0.183	0.014
C412	Providing financial reports	0.298	0.023
C413	Future management and performance forecasting	0.193	0.014
C414	Presenting the report of the board in meeting	0.326	0.025
The priority of transparency component indicators			
C421	Disclosure of remuneration of board members	0.421	0.045
C422	Disclosure of contract details	0.351	0.037
C423	Disclosure of shares of board members	0.228	0.024
The priority of indicators of the effectiveness of corporate governance			
C431	Independence of the board of directors	0.250	0.011
C432	Financial expertise of the board of directors	0.319	0.014
C433	Expertise in the board industry	0.103	0.004
C434	The duality of management	0.119	0.005
C435	The existence of an audit committee	0.209	0.009
The priority of ownership affects component indicators			
C441	Institutional ownership	0.467	0.053
C442	Property management	0.533	0.061

5. Discussion

The current study, considering the importance of the financial stability of the financial systems of the banks and business units of emerging countries such as Iraq, seeks to highlight critical aspects affecting the financial stability of companies and banks.

Generally, the statistical significance of the coefficient of the dimensions in the final model is, respectively, 0.342 for the corporate governance dimension, 0.312 for the corporate variables dimension at the micro level, 0.251 for the corporate environment variables, and 0.166 for the macro variable at the economic level, which indicates the increasing impact of corporate governance in developing the financial stability of Iraqi companies.

Primarily, the findings suggest that enhanced corporate governance may assist companies in improving their stability through risk management (Susanto and Walyoto 2023). Effective corporate governance structures, through the board of commissioners and audit committees, enhance a company's ability to identify, assess, and mitigate financial risks. This ensures companies' resilience in facing emerging financial shocks. Moreover, independent decision-making can be guaranteed through effective corporate governance mechanisms, which include frequent board meetings and a balanced board structure. Consequently, a strong corporate governance structure can support the organization's adaptation to changing markets, including innovations in the insurance market. For example, insurance maintains financial stability and business dynamism (Nwogugu 2015). It helps a company to preclude from suboptimal financial decisions that may endanger its financial stability. Effective corporate governance can also lead to more transparency in financial reporting and operations (Mabvira 2018). Additively, related to corporate governance, ownership structure effects have the highest coefficient of importance, with a coefficient of 0.334. It refers to the structure of a firm's distribution of ownership rights among all stakeholders, including individual shareholders, institutional investors, governmental owners, and management. The ownership structure can exert a great influence on the financial stability of a firm. Moudud-Ul-Huq et al. (2022) indicate that ownership structures can affect the financial stability of a company through efficient risk management. They document that Islamic banks are less risky than other forms of ownership, adding to their financial stability. They also suggest that ownership structure can affect a firm's market power and competitive position. Firms with solid ownership structures may be better positioned to cope with competitive pressures, thus enhancing their financial stability. Rubio-Misas (2020) indicates that companies with a more concentrated ownership structure tend to show lower levels of financial stability, consistent with the view that in closely held firms, the owner and manager incentives are more aligned. Therefore, different ownership structures may increase or decrease companies' risk-taking ability and risk-management strategies, eventually determining their stability.

Similarly, among the components related to macro variables at the economic level, political factors have the highest coefficient of importance, with a coefficient of 0.431. In essence, a predictable business environment requires political stability. Political instability, which includes violence and unrest, is likely to affect business operations, chase away investment, and increase operational risks (Zaiane and Moussa 2021). For instance, the political instability resulting from the Arab Spring impacted the performance of banks in the MENA region, an aspect that depicts the deteriorating impact of political turmoil on financial stability.

Additionally, among the components of micro variables at the company level, the financial structure with a coefficient of 0.331 has the highest coefficient of importance. The financial structure is vital to ensuring the financial stability of a company. The financial structure of a given company determines its flexibility toward change in the market. High debt levels limit a firm's flexibility during economic downturns, making them very vulnerable to financial distress (Abbas et al. 2021). For instance, the case of the Asia Cell Communications Company has highlighted that overdependency on debt adversely affects financial flexibility, which restrains a firm's ability to pay off short-term liabilities and, consequently, its financial stability. Moreover, the financial structure directly affects

the liquidity position of a firm. A firm with a much more balanced financial structure including sufficient cash and manageable debt can better cope with unexpected expenses or economic downturns (Aslam et al. 2016). Low liquidity can trigger inadequate cash flow, threatening a firm's financial stability. Finally, the financial structure indicates how a company efficiently runs its assets. A company with a reasonable balance between debt and equity typically has better asset and investment management skills (Eisdorfer et al. 2013). Therefore, effective asset and investment management can contribute to financial stability by ensuring that a company generates sufficient returns on assets to compensate for its liabilities.

Finally, among the components of the variables of the company's environment, variables related to profitability with a coefficient of 0.590 have the highest statistical significance. One major aspect that can have a telling effect on the financial stability of any firm is profitability. It directly determines the ability of a firm to generate cash flows and manage its liquidity. Higher profitability secures more funds for meeting short-term obligations, ensuring financial stability. Studies show that reduced liquidity due to low profitability can lead to a cash flow crisis, thus threatening the firm's financial stability (Abbas et al. 2021). Furthermore, profitability determines a firm's ability to service its interest and other debt-related obligations. High profitability ensures that firms can service interest and principal payments on time and are less likely to default on loans, thus ensuring financial stability (Aslam et al. 2016). In other words, reduced profitability will limit the ability of a company to service its debt, which is likely to increase financial risks. Finally, profitability may assist companies in improving their financial stability by providing a competitive advantage. The more profits a company obtains, the more it can invest in innovation, technology, and marketing, hence maintaining a market and financial position (Halim et al. 2023).

Model (6) shows the financial stability score equation based on research components. In this equation, C32 (profitability variables) has a coefficient of 0.148, C44 (ownership effects) has a coefficient of 0.115, C42 (Transparency) has a coefficient of 0.107, and C31 (company characteristics) has a coefficient of 0.102, with the most significant impact in the final model. Table 7 presents the research components in the order of statistical significance of their coefficients in the final model.

Table 7. Index coefficients in the final model.

No.	Code	Title	Coefficient in the Final Model	No.	Code	Title	Coefficient in the Final Model
1	C32	Variables related to profitability	0.148	8	C41	Shareholders' rights	0.069
2	C44	Effects of ownership	0.115	9	C11	Characteristics of the economy	0.051
3	C42	Transparency	0.107	10	C21	Function	0.047
4	C31	Features of the company	0.102	11	C12	Instability	0.044
5	C22	Financial structure	0.078	12	C43	Effectiveness of the board of directors	0.044
6	C24	Liquidity	0.072	13	C23	Resource management	0.038
7	C13	Political factors	0.072				

At the index level, in the final model, the index coefficients are presented in Table 7. Dummy variable indicators of industry, return on equity, sanctions, managerial ownership, institutional ownership, growth opportunities, disclosure of board members' remuneration, contract details, inflation, and working capital have the highest coefficients in the final model. Table 8 shows the indicators with higher importance coefficients (top 10 indicators).

Table 8. Top ten research indicators in terms of importance factor in the final model.

Code	Index Title	Coefficient in the Final Model
C311	Industry dummy variable	0.102
C322	Return on equity	0.094
C131	Sanctions	0.072
C442	Managerial ownership	0.061
C441	Institutional ownership	0.053
C321	Growth opportunities	0.053
C421	Disclosure of remuneration of board members	0.045
C422	Disclosure of contract details	0.037
C112	Inflation	0.029
C222	Working capital	0.027

6. Implications

The results suggest that Iraqi companies should pay enough attention to the company environment, corporate governance, and macroeconomic-level variables because these factors can affect their financial stability. Correspondingly, the following implications are proposed to companies, management, policymakers, and stockholders.

Based on the results of corporate governance enhancements, companies are required to enhance corporate governance structures to support improved risk management that is resilient against financial shocks and instability. Companies are supposed to implement proper mechanisms of governance, where effective board meetings are needed, with balanced board structures that guarantee independent decision-making. Increasing transparency in financial reporting and operations will reduce financial misreporting and sustain investor trust, which is necessary for risk management. Moreover, the ownership structure of firms should be considered and shaped very carefully since it influences their positioning with respect to financial stability via efficient risk management and competitive positioning.

To achieve political stability, which is necessary for a predictable business environment, governments must reduce political instability since its related shocks are among the biggest threats to organizational success. Companies must be prepared to handle the risks associated with political instability, positively impacting business operations and investments. According to the findings on the capital structure, firms should manage their level of indebtedness to be in a better position to deal with an economic downturn by reducing their vulnerability to financial distress. Those companies possessing a balanced financial structure are more resilient to financial shocks. For example, sufficient cash to keep the business running and bearable levels of debt that ensure sustainability during irregular periods or economic downturns are among the effective factors ensuring superior performance. The efficient management of assets and investments may also help companies keep the apt returns that will cover all liabilities.

Finally, the companies notice that high profitability is vital for generating cash flows and liquidity management, and securing sufficient funds is critical to meet short-term obligations. Therefore, a firm's profitability determines its ability to service interest and debt obligations, reducing the risk of default. Accordingly, it is recommended that profits should be reinvested in innovation, technology, and marketing to maintain a competitive and financial position in the market.

7. Conclusions

To conclude, the research provides a general model supporting the relationship between corporate governance, financial structure, political stability, and profitability in achieving company financial stability in Iraq. These findings have positive insightful implications for company management, policymakers, and investors, who have to worry about these dimensions to create a more stable and resilient financial environment in Iraq. By understanding these critical variables, the companies in Iraq may also achieve their financial stability, which contributes to the economic development of the nation.

Although this research depicted the financial stability model for the companies in Iraq, there are a few limitations, and further investigations can be performed based on our results about the complex nature of financial stability.

While the results might well apply to other similar emerging economies, they cannot be generalized to other cultural or economic settings. Indeed, the study is based on a relatively modest number of companies and experts, and while more widespread, diversified, and larger, the sample is the stronger foundation for establishing more decisive general conclusions. The research method used was cross-sectional, collecting data at one point in time. This methodology imposes limitations to find out changes in the status of financial stability over the long run or to establish a causal relationship between the variables.

Future research can adopt a longitudinal research design to trace the changes in the level of financial stability. This may help in understanding the dynamics of financial stability and the impact of various factors in different economic cycles during a long period. Comparative studies across different emerging markets might help to explain the way contexts impact financial stability. This can help identify best practices that can be transferable across different settings. Researchers can step ahead and investigate further dimensions or variables that are likely to affect financial stability; this includes technological changes, market competition, or regulatory changes.

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Appendix A. Employed Questionnaires to Assess the Financial Stability

	No.	Questionnaire Items	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Financial Stability						
Firm-level factors	1						
	2	The Z-score serves as a suitable indicator of financial stability.					
	3	A model based on net profit margin, total debt-to-assets ratio, and current ratio can predict financial instability.					
	4	Social responsibility is related to financial stability.					
	5	Research and development expense is a significant factor in financial stability.					
	6	Accounting variables play a major role in companies' financial stability.					
	7	Employee relations affect financial stability.					
	8	Foreign exchange backing of companies affects financial stability.					
Corporate governance factors	9	Family ownership affect financial stability					
	10	Family ownership in companies affects their financial stability.					
	11	The characteristics of the board of directors play a significant role in companies' financial stability.					
	12	Corporate governance characteristics affect financial stability.					
	13	The independence of the board of directors plays a very important role in companies' financial stability.					
	14	The size of the board of directors is one of the determining factors of a company's financial stability.					
	15	The composition of the board of directors affects companies' financial stability.					
	16	The CEO and executive managers play a determining role in the financial stability of companies.					

	No.	Questionnaire Items	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Financial Stability						
Corporate governance factors	17	Private ownership can lead to improved financial stability in companies.					
	18	The disclosure of contract details affects the financial stability of companies.					
	19	The disclosure of board members' compensation affects companies' financial stability.					
	20	Managerial ownership affects the financial stability of companies.					
	21	Management duality affects the financial stability of companies.					
	22	The industry in which companies operate affects their financial stability.					
	23	Growth opportunities in the industry affect companies' financial stability.					
	24	The price of oil affects the financial stability of companies.					
	25	Inflation can affect the financial stability of companies.					
	26	Economic and political sanctions can affect companies' financial stability.					
	27	Changes in exchange rates play a determining role in financial stability.					
	28	Attacks by the ISIS terrorist group and the occupation of the country by this group have affected the financial stability of companies.					
	29	The quick ratio and current ratio have affected the financial stability of companies.					
	30	The debt repayment period has affected companies' financial stability.					
	31	Growth opportunities have affected the financial stability of companies.					
	32	Return on equity has affected the financial stability of companies.					
	33	Accounts receivable turnover has affected the financial stability of companies.					
	34	Working capital turnover has affected the financial stability of companies.					
	35	The debt-to-equity ratio has affected the financial stability of companies.					
	36	Interest coverage has affected the financial stability of companies.					

- What do you consider to be the most important indicators of financial stability at the company level?
- What are the most important corporate governance indicators that affect corporate financial stability?
- What do you consider to be the most important macroeconomic indicators that affect corporate financial stability?
- What are the most important environmental indicators that affect companies' financial stability?

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Mapping the Landscape of Key Performance and Key Risk Indicators in Business: A Comprehensive Bibliometric Analysis

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Abstract: Our study investigates the relevance and application of key performance indicators (KPIs) and key risk indicators (KRIs) in business management from 1992 to 2023 through a comprehensive bibliometric analysis performed in RStudio using the Bibliometrix platform and in VOSviewer. Utilizing data from the Web of Science database, we identify trends, key themes, and influential research in this domain, observing an annual growth rate of 17.76%. Our analyses include the top 10 most globally cited documents, word clouds based on authors' keywords and Keywords Plus, clustering by coupling, co-occurrence networks, and factorial analysis. Our findings reveal a significant increase in research interest post-2004, with sustainability and corporate social responsibility emerging as central themes. We confirm positive correlations between KPIs, improved organizational performance, and effective risk management via KRIs. This research underscores the importance of international collaboration and diverse thematic exploration in advancing the field.

Keywords: key risk indicators; key performance indicators; performance management

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1. Introduction

The ability to successfully manage risks and monitor performance is essential for organizational success in today's dynamic business climate. The usage of key performance indicators (KPIs) and key risk indicators (KRIs) has grown in importance as enterprises attempt sustainable growth while navigating through uncertainty (Frederico et al. 2020). These indicators support strategic choices that lead to long-term success in addition to assisting with performance evaluation and threat identification.

Performance management is a crucial concept for any economic system, whether we are discussing the microeconomic, mesoeconomic, or macroeconomic levels. While its core function is to measure and manage the performance of an entity such as a business, organization, or industry, the most challenging aspect of performance management is defining it from the perspective of each entity. In other words, the way we measure performance can vary depending on the goals we set and the strategic, tactical, or operational decisions we make. In fact, we can say that performance management aims to build and develop an organization capable of achieving its goals, making good choices, ensuring that the various objectives of the company align with performance indicators.

The recent literature indicates a lack of comprehensive studies exploring the interdependent relationships between KPIs and KRIs in the context of performance and risk management. This study aims to fill this gap by providing a detailed bibliometric analysis of the existing research.

Performance management can also be described and understood from the perspective of three essential characteristics or components. The first person to describe performance management was Anthony (1965), where in his study, he defined management control as "the process by which managers ensure that resources are obtained and used efficiently

and effectively in the accomplishment of the organization's objectives". This definition practically affirms that performance management is a process, not an isolated act, explicitly referring to the concept of objectives, highlighting the behavioral aspect of performance management. Armstrong (2006), also states that performance management is a systematic process for improving organizational performance by developing the performance of individuals and teams.

Thus, performance management can be seen as a process, a loop that involves iterative learning based on setting core objectives. This approach is similar to a cybernetics approach to business processes, according to Nica and Ionescu (2021). Another perception of performance management is that it can only be understood and applied within an enterprise that has a defined purpose and clear objectives. Another perspective relies on applying incentives to increase the motivation of managers and employees. Mainly, performance management control systems have a monitoring dimension that should implement performance measures based on learning processes or cybernetics control loops and the implementation of strategic objectives and an incentive system.

This iterative approach is essential for developing an organization capable of achieving its objectives and adapting to changes in the business environment. In this context, the role of KPIs and KRIs becomes crucial.

KPIs are essential tools for measuring an organization's efficiency and effectiveness in achieving its strategic goals. These indicators provide a clear picture of organizational performance and help identify areas needing improvement. For example, KPIs may include metrics such as sales revenue (Van De Ven et al. 2023), customer satisfaction levels (Setijono and Dahlgaard 2007), or product delivery times (Munmun et al. 2023). By monitoring these indicators, organizations can make informed decisions and implement strategies to enhance performance.

On the other hand, KRIs are used to identify and monitor risks that could negatively impact organizational performance. These indicators provide early warning signals, allowing for organizations to take preventive measures to manage risks before they become major issues. Risk can be encountered in any type of business and in any type of environment—e.g., affected or not by different economic, social, or pandemic crises (Santos et al. 2022; Tavares et al. 2023, 2024). For instance, KRIs may include the incidence of cybersecurity breaches (Melançon et al. 2021; Giudici et al. 2024) or rate of attrition of high-value customers (Salamah et al. 2022). Constant monitoring of these risks helps organizations prioritize resources and implement effective mitigation measures.

KRIs and KPIs should not be confused, as both are essential tools for evaluating the performance of the economic system. To successfully use them in business management and decision-making, it is crucial to understand the differences and similarities between KPIs and KRIs. For example, the customer retention rate can be considered a performance indicator (KPIs) aimed at evaluating customer satisfaction and measuring success in maintaining customer loyalty (Valenzuela-Fernández et al. 2016). From a KRI perspective, the rate of losing high-value customers can serve as a risk indicator for identifying and managing the risk of losing valuable customers.

The use of KPIs and KRIs can significantly improve the strategic decision-making process within organizations. By continuously monitoring performance and identifying risks early, managers can make informed decisions that reduce uncertainty and optimize resources to achieve organizational objectives. Additionally, implementing a robust system of KPIs and KRIs allows for organizations to optimize resource utilization and improve operational efficiency. This can lead to reduced operational costs and increased profitability while ensuring a rapid response to potential threats. Continuous monitoring of KPIs and KRIs enables organizations to become more agile and capable of quickly adapting to changes in the business environment. This ability to promptly respond to new challenges and opportunities is essential for maintaining competitiveness in the market.

In this context, integrating KPIs and KRIs is essential for ensuring long-term organizational success. These indicators not only support performance evaluation and risk

identification but also facilitate strategic choices that lead to sustainable growth. This research fills a gap in the specialized literature by providing a comprehensive and systematic analysis of key performance and risk indicators in the business context. The use of a bibliometric approach is justified by the need to understand the current research landscape and identify future directions. Given the importance of KPIs and KRIs in performance and risk management, it is essential to understand how these tools are utilized and what their impact on organizations is. Previous studies have highlighted various aspects of these indicators, but there are still gaps in our knowledge. For example, it is not clear whether the use of KPIs is consistently correlated with the improvement in organizational performance or how the implementation of KRIs contributes to reducing operational risks.

To develop our research, we propose the following hypotheses:

H_1. *The specialized literature frequently highlights a correlation between the use of KPIs and the improvement in organizational performance.*

H_2. *Existing studies suggest that the implementation of KRIs is associated with a reduction in operational risks in companies.*

H_3. *International collaboration in KPIs and KRIs research is correlated with the production of more influential and highly cited studies.*

H_4. *The specialized literature indicates that the effective management of a variety of KPIs and KRIs is essential for organizational success and value growth.*

To answer this question, we conducted a bibliometric analysis to identify existing studies on business model KPIs and KRIs. The bibliometric approach allows for the analysis of a large volume of specialized literature, identification of research trends, determination of the influence of specific works and researchers, and highlighting of international collaborations. By using bibliometric techniques, we can provide a clear and detailed picture of the evolution of research and identify gaps and future opportunities. Hypothesis H_1 explores the impact of KPIs on the overall performance of companies, evaluating whether their use leads to measurable increases in efficiency and effectiveness. The second research hypothesis, H_2, analyzes whether the use of KRIs helps companies anticipate and manage risks more efficiently, thereby preventing major issues. Hypothesis H_3 examines the impact of international collaboration on the quality and influence of research, suggesting that global partnerships can lead to more robust and recognized results. The final proposed hypothesis, H_4, aims to identify the types of KPIs and KRIs most frequently mentioned in the literature and to evaluate their impact on organizational performance and value.

Thus, the primary aim of this study is to map the research landscape of KPIs and KRIs in the business context through a bibliometric analysis. This study aims to identify and evaluate the correlations between the use of KPIs and the improvement of organizational performance, the impact of implementing KRIs on reducing operational risks, the influence of international collaboration on research quality, and the diversity in KPIs and KRIs frequently mentioned in the academic literature, as well as their effective management for organizational success and value growth.

This study primarily focuses on performance and risk indicators at the micro- and mesoeconomic levels. We concentrated on these economic levels, considering that the concept of business is central to the selection of keywords used for database extraction. Thus, our analysis aims to enhance the understanding of how KPIs and KRIs are applied at the organizational and industry levels, without directly focusing on macroeconomic indicators. This approach allows for us to provide more precise and relevant recommendations for performance and risk management in specific business contexts.

2. Literature Review

Organizational success and strategic decision-making in the context of the dynamic and evolving business world make the measurement and analysis of economic system performances a critical component influencing these objectives (Asiaei and Bontis 2019; Tasheva and Nielsen 2022).

The study of KPIs and KRIs has gained significant attention in the field of business management and performance analysis. The main objectives of performance management systems are the identification and monitoring of KPIs (Cruz Villazón et al. 2020). These indicators are critical for organizations to monitor and manage their performance and risk effectively. KPIs are metrics that help organizations understand how well they are achieving their strategic and operational goals, while KRIs provide early warning signals about potential risks that could impact these objectives.

Research in this domain has evolved over the years, with a growing body of literature exploring various aspects of KPIs and KRIs. Early studies focused on defining and categorizing these indicators, establishing their importance in performance management frameworks. As the field increased in maturity, researchers began to investigate the application of KPIs and KRIs in different industries and contexts, examining their impact on organizational performance and risk management.

Recent advancements in technology and data analytics have further expanded the scope of KPI and KRI research. The integration of big data, artificial intelligence, and machine learning techniques has enabled more sophisticated and real-time monitoring of performance and risk. This has led to a more nuanced understanding of how organizations can leverage these indicators to drive decision-making and strategic planning.

Burlea-Schiopoiu and Ferhati (2020) aim to identify specific KPIs for the healthcare system to help propose recommendations for managers and employees in this sector. These recommendations will contribute to the evaluation and monitoring of critical factors that can influence the performance of this sector in Algeria. Khalifa and Khalid (2015), in their study, classify key performance indicators into three levels: operational, tactical, and strategic. Another study conducted by (Braglia et al. 2022) proposes investigating how to design and implement KPIs that can be used to monitor the evolution of core processes that will benefit from Industry 4.0 technologies. Additionally, Gackowiec et al. (2020) consider it essential to identify the most relevant KPIs for the analyzed processes within an organization. Their study emphasizes efficiency indicators adjusted to the needs of the mining industry specific to Industry 4.0.

In the study conducted by (Tseng et al. 2011), the authors develop an integrated approach that includes key risk factors along with management strategy risk. The aim is to facilitate the periodic evaluation of these risk factors and their involvement in the dynamics of business-to-business international internet banking.

Dahal et al. (2024) conducted a bibliometric analysis to address and respond to the gaps observed in the characteristics proposed by performance management systems. Based on their analysis, they concluded that (i) there is a notable increase in the collaborative nature of KPI research; (ii) there is a significant shift towards integrating sustainability and technological advancements into performance parameters; organizations can better understand performance by combining multiple performance perspectives such as internal regulatory frameworks, social effects, and customer satisfaction.

Another study conducted by (Van De Ven et al. 2023) aimed to systematically review the specialized literature to analyze and consolidate the current state of KPIs used in business models. The main findings focused on synthesizing business model-specific KPIs into a catalog structured around the dimensions of the business model. Additionally, Li et al. (2023) reviewed energy flexibility KPIs and open datasets that can be used for testing these KPIs. They concluded that incorporating occupant comfort and the acceptance of reduced comfort in the development of KPIs can provide valuable insights and improve the performance of B2G services.

Regarding the importance of KRIs, Niță et al. (2023) analyzed the impact of preventive measures against cyber fraud, focusing on the implementation of risk indicators and the use of protection mechanisms based on artificial intelligence. They addressed economic and legal perspectives and proposed a method for evaluating the compliance of artificial intelligence tools for cyber fraud prevention and monitoring, and adjusting them based on the evolution of key risk indicators over time. Additionally, F. Liu (2023) presents in his study that the increasing uncertainty in the operations and development of many enterprises due to the new global economic recession leads to the emergence of new risks. Enterprises urgently need more effective methods and approaches for risk management to improve the sensitivity in identifying and responding to risks. Establishing a risk early warning mechanism, especially the construction of a key risk indicator system, can become one of the effective methods to help enterprises respond rapidly to risks.

Lihachev (2024), through his study, emphasizes that the selection of a system of indicators can aid in evaluating the economic efficiency of production industries and in choosing the most efficient investment projects.

The literature review highlights the importance of performance and risk management systems, particularly using KPIs and KRIs, in the context of organizational success and strategic decision-making. The analyzed studies emphasize that the identification and monitoring of these indicators are essential for the effective evaluation and management of organizational performance and risks.

3. Results

3.1. Preliminary Data Analysis

In this section, we provide an initial analysis of the most significant data collected from our bibliometric study on KPIs and KRIs in business. This analysis offers insights into the research landscape, highlighting the active and extensive community of researchers involved in this field. We explore the dynamics and impact of the research, underscoring a clear trend towards collaboration and internationalization. These findings offer a comprehensive view of the current state and future directions of research in KPIs and KRIs, emphasizing the importance of global cooperation in advancing knowledge and practices.

Table 1 provides an overview of the data analyzed in our bibliometric study. Thus, our analysis covers the years 1992–2023, reflecting over three decades of research. The total number of sources used, including journals, books, and other documents, is 760. The total number of documents analyzed is 1395. Additionally, we observe that the annual average growth rate of the number of documents is 17.67% and the average age of the documents is 7.41 years. Furthermore, each document has an average of 18.16 citations, and the total number of references cited in all documents is 58,511. These data indicate growing interest and robust academic production in the analyzed field, with a significant growth rate and a considerable number of citations, suggesting the relevance and influence of research on KPIs and KRIs in business.

Table 1. Main information.

Main Information about Data	Results WoS
Timespan	1992:2023
Sources (journals, books, etc.)	760
Documents	1395
Annual growth rate (%)	17.67
Document average age	7.41
Average citations per doc	18.16
References	58,511

Table 2 provides key information about the content of the documents analyzed in our bibliometric study. We observe that the total number of Keywords Plus used in the analyzed articles is 1789. These keywords are generated by databases to enhance searches

and better reflect the content of the articles. Additionally, the total number of author's keywords is 4317. These keywords reflect the main themes and subjects addressed in the articles, offering insight into the points of interest in KPI and KRI research. The large number of Keywords Plus and author's keywords indicates significant thematic diversity in the studied literature. This suggests a comprehensive approach to topics related to KPIs and KRIs, highlighting the complexity and multidimensionality of research in this field.

Table 2. Document contents.

Main Information about Documents	Results WoS
Keywords Plus	1789
Author's keywords	4317

Important details regarding the writers of the examined articles are shown in Table 3, as can be seen. There are 4094 authors in all who have contributed to the materials under analysis. This figure indicates the size of the community of active researchers in the subject of business KPIs and KRIs. Only 179 authors can claim to have authored articles. This implies that while there are a lot of collaborations in this sector, there is also a lot of interest in solitary study. The total number of authors as well as the number of single authors in the papers signal a vibrant and varied research community. The existence of both individual and collaborative efforts highlights the complexity and diversity of techniques in the study of KPIs and KRIs and advises a balance between cooperative and independent research.

Table 3. Authors.

Main Information about Authors	Results WoS
Authors	4094
Authors of single-authored docs	179

The data from Table 4 reflect a balance between individual and collaborative research, with a strong emphasis on international collaborations. There are 182 single-authored documents, indicating that while collaboration is prevalent, individual research holds significant importance in the field. On average, each document has 3.15 co-authors, highlighting a high level of collaboration among researchers. Additionally, 23.87% of the documents involve international collaborations. This high percentage underscores the importance of international cooperation in KPI and KRI research. This suggests that the field benefits from a global network of researchers working together to advance knowledge and practices.

Table 4. Authors collaboration.

Main Information about Authors	Results WoS
Single-authored docs	182
Co-authors per doc	3.15
International co-authorships (%)	23.87

Thus, regarding the preliminary analysis of the most important data, we observe that research on KPIs and KRIs in business is characterized by a vast and active community of researchers. All this information provides a complex picture of the dynamics and impact of research in the analyzed field, highlighting a clear trend towards collaboration and internationalization.

3.2. Research Output and Impact Analysis

In this section, we analyze key visualizations to better understand the research landscape for KPIs and KRIs in business. Specifically, we examine the annual scientific production, the average citation per year, and a three-field plot. These analyses provide insights into the evolution, impact, and interconnectedness of research in this domain.

The scientific output for the considered time-period is highlighted with the help of Figure 1. With regard to the number of articles that have been published annually, a slight fluctuation can be observed between 1992 and 2003, but this period contains only a few articles, ranging from 1 in 1992 to 8 in 2002. However, starting from 2004 onwards, significant interest in the subject's matter took place, making the number of published articles range between 9 in 2004 and 159 in 2023, leading the trend to gradually increase over the years, most notably for the recent ones, registering a growth rate higher than the one in the late 2000s. This exponential growth for the recent years reflects that the researchers are more engaged and interested in the subject.

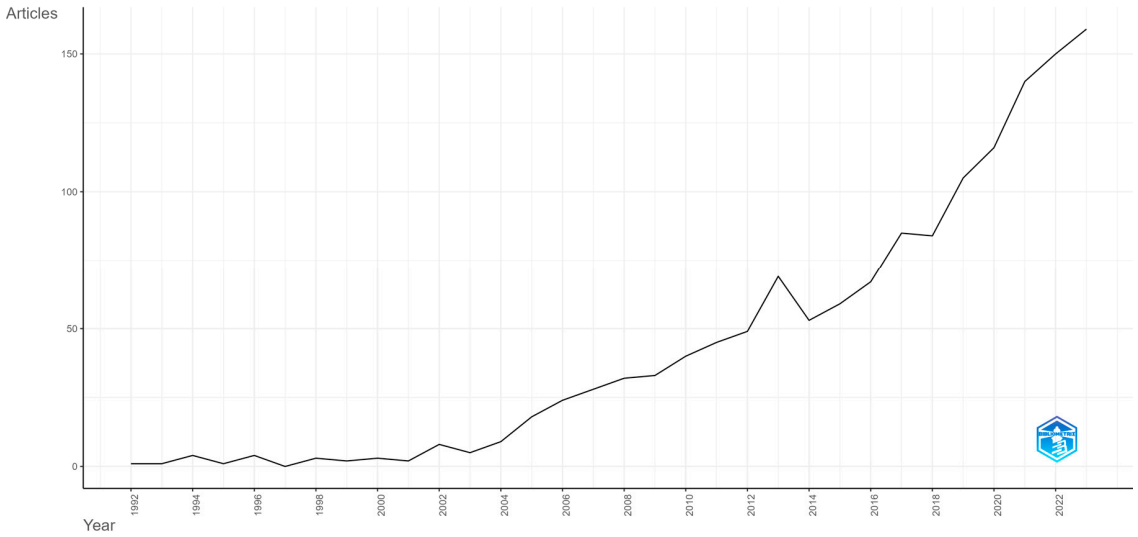

Figure 1. Annual scientific production.

It can be observed in Figure 2 that, throughout the considered period, there was very high fluctuation in the average citations, ranging from 0.1 to 3.9. From 1992 to 1998, the fluctuation was relatively small. Yet, 1999 registered a first peak in the trend with 3.5 citations, as companies began to think about risk indicators, considering the fact that specialists in the area of economics predicted the recession that was to come in the next year. However, in the following years, from 2000 to 2006, it is evident that interest in key performance indicators and key risk indicators decreased, compared to 1999, but still with fluctuations in this timeframe. Despite that, the year 2007 registered the trend's second and highest peak, with 3.9 citations, as everyone was expecting the next year's global economic crisis. For the remaining period, between 2008 and 2023, the number of citations still fluctuated, particularly for year 2011, when the global stock market crashed, and the year 2019, considering the start of the COVID-19 pandemic. Considering the dynamic of the average citations over the years, it is notable that the researchers' interest in the analyzed field is strongly linked with expected major world events that may impact the global economy.

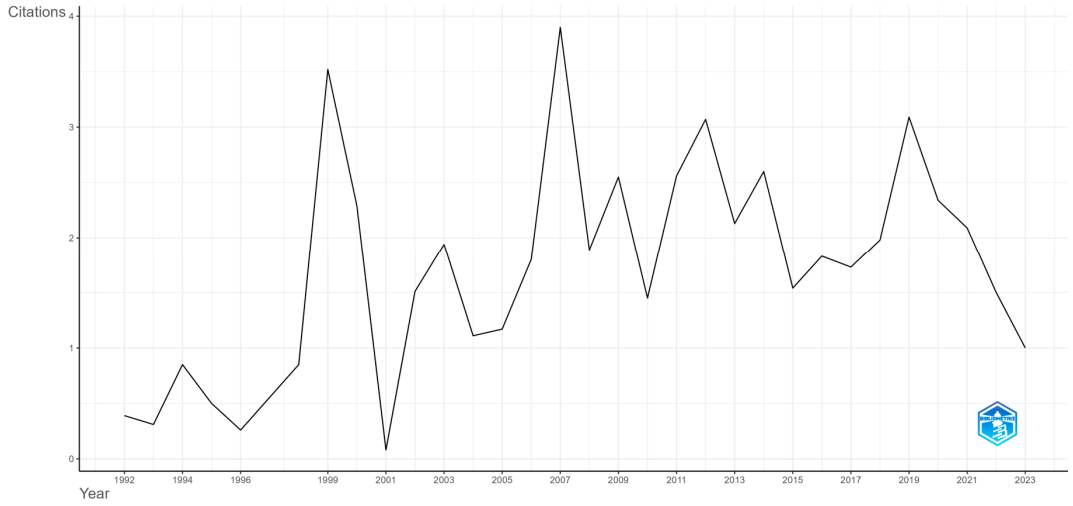

Figure 2. Average citations per year.

In Figure 3, we created a three-field plot describing the keywords, countries and Keywords Plus. The plot's first column shows how the considered keywords are linked to the countries, allowing for us to examine if a balanced distribution exists or if there are certain countries that dominate in a specific field. The second column orients our focus to the countries that are involved in the research, providing information about how each of them is related to the used keywords and Keywords Plus. The third and last column showcases, similarly to the first one, the association between Keywords Plus and the countries of origin, offering insights on how they are distributed.

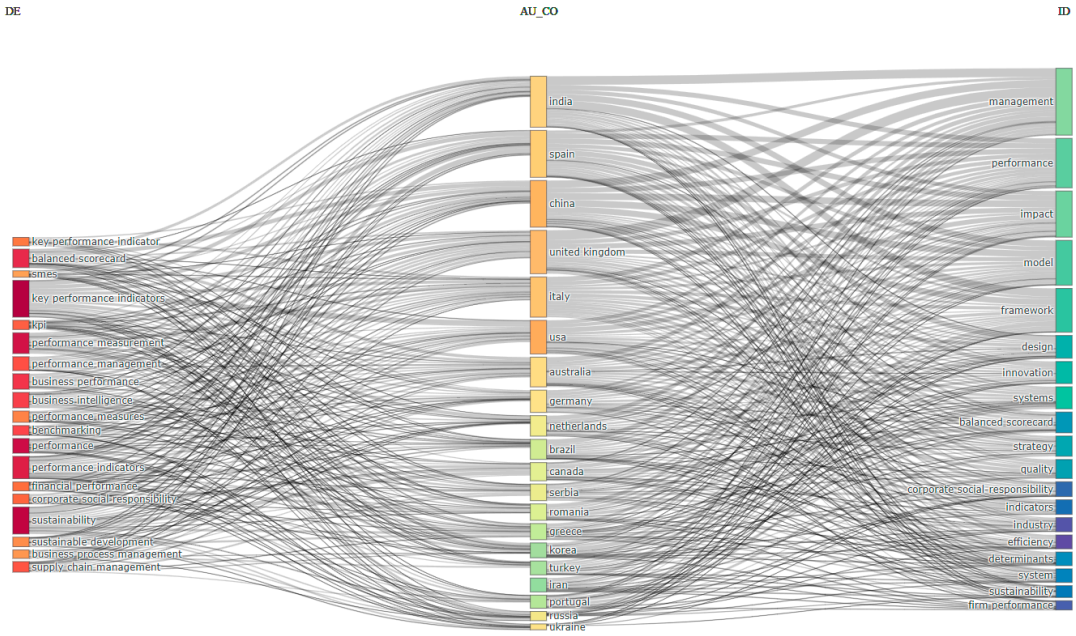

Figure 3. Three-field plot.

3.3. Author's Analysis

According to Figure 4, it is certain that Resinas M. is the most relevant author from the top 20, having the most contributions, with six articles, closely followed by Del-Rio-Ortega A. and Mate A., both of them having published five scientific papers. Among other authors that stand out, with four publications each, there are Loizia P., Ruiz-Cortes A., Singh S., Skouloudis A., Tadic D., Voukkali I., and Zorpas AA.

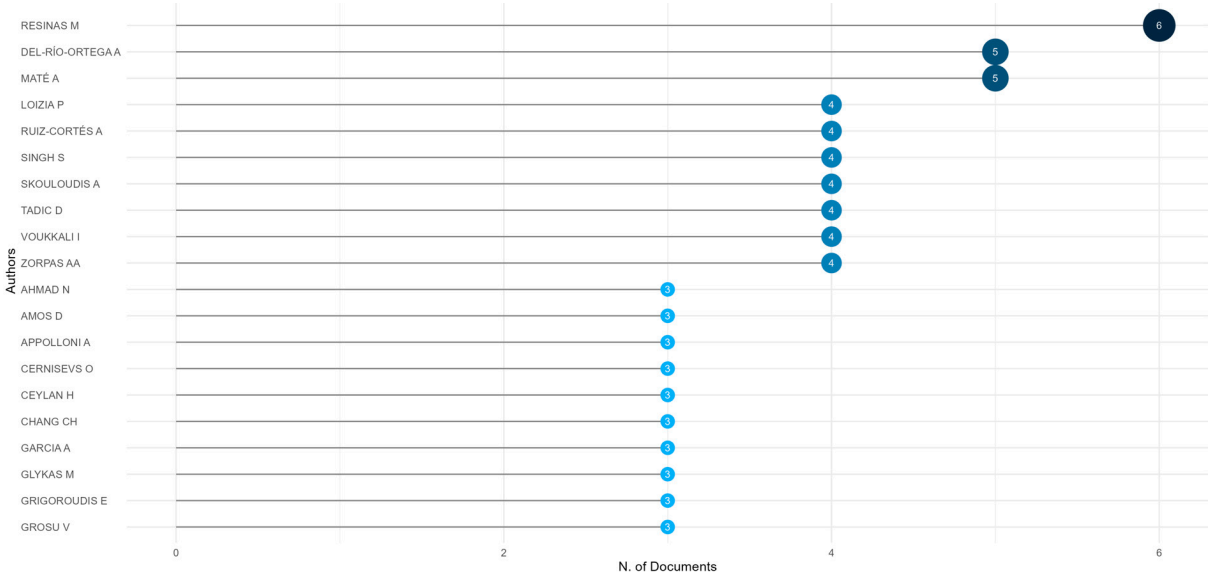

Figure 4. The most relevant 20 authors according to the total number of scientific publications.

With regard to the publication date of the scientific papers considered for the analyzed topic, in which only the first 20 most productive authors are taken into consideration, there is no doubt that there is a notable emerging trend, according to Figure 5. More explicitly, this trend is described by the fact that most of the articles were published from the year 2013 onwards.

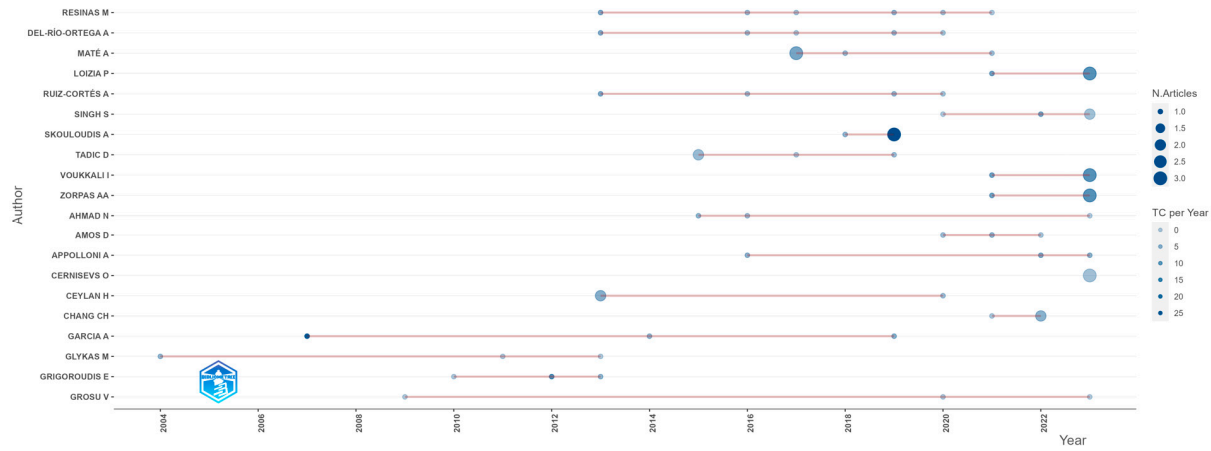

Figure 5. Top 20 authors' production over time.

Figure 6 illustrates the distribution of authors' productivity based on Lotka's Law, which states that the number of authors publishing n papers is inversely proportional to n^2. We observe that 94% of the authors have written only one paper (3857 authors), indicating that the majority of contributors are occasional authors. Then, the vast majority of authors contribute infrequently, writing only one paper. A very small proportion of authors produce multiple papers, reflecting higher effort, specialization, or sustained research activity in the field. This distribution supports Lotka's Law, demonstrating that prolific authors are rare, while most authors have limited publications.

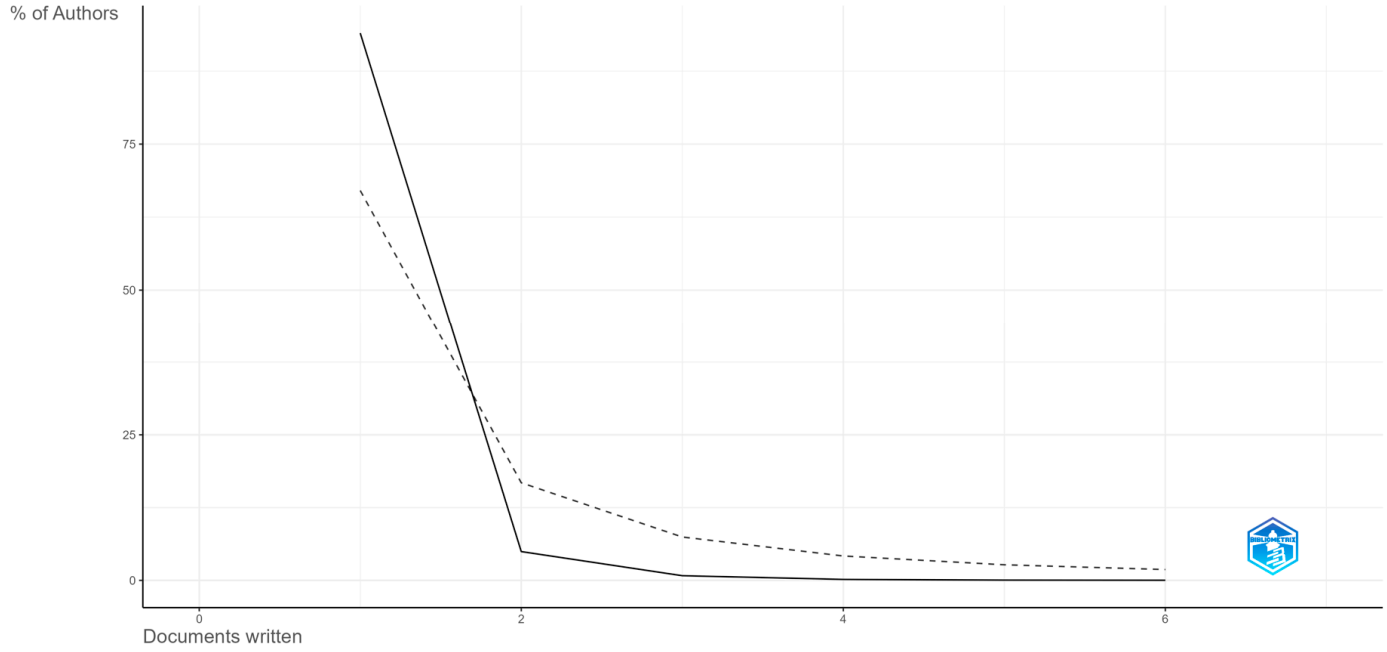

Figure 6. Author productivity through Lotka's Law.

3.4. Affiliations and Funding Agencies

In this subsection, we analyze the top 20 most relevant affiliations of authors. This analysis puts an emphasis on the institutions and countries that contribute the most to research on KPIs and KRIs. It can help recognize centers of excellence in this field. Additionally, the analysis can show how collaborations are distributed among different countries and institutions, suggesting trends in international collaboration and academic partnerships. Furthermore, identifying institutions that frequently publish in this field can help in assessing the impact and relevance of their research, providing a broader context for the quality and influence of these works. Funding agencies and academic institutions can use these data to direct resources to the areas and institutions with the highest activity and research potential. We also conduct an analysis from a funding perspective.

Table 5 highlights the most relevant affiliations of authors, showing the number of published articles and the countries of origin. We observe that the most prolific contributor is the Ministry of Education and Science of Ukraine with 63 articles, indicating substantial academic interest in Ukraine. Additionally, with 25 articles, the Indian Institute of Technology System (IIT System) ranks second, reflecting significant involvement in KPI and KRI research. Another important contributor is the University of Belgrade in Serbia with 22 articles, demonstrating a strong academic base in Serbia. Furthermore, the Bucharest University of Economic Studies in Romania, with 17 articles, indicates increased interest and notable academic activity in Romania. Other institutions, including universities from Croatia, Spain, Slovakia, Italy, the USA, Australia, Greece, and others, also contribute to this field, underscoring the global and collaborative nature of research on KPIs and KRIs.

Figure 7 highlights the top 20 funding agencies that support research on KPIs and KRIs, showing the number of funded projects. We observe that with 43 funded projects, the European Union is the main supporter of research, reflecting a strong commitment to advancing knowledge in this field. Additionally, the Spanish government has funded 16 projects, indicating significant involvement in KPI and KRI research. The Ministry of Science and Technology Taiwan has supported 11 projects, underscoring the importance of research in Taiwan. Other funding agencies, including those from Australia, Canada, Korea, and others, underscore the global nature of financial support for research. This suggests a vast international commitment to advancing knowledge and practices in the field of KPIs and KRIs.

Table 5. Top 20 most relevant affiliations according to the number of articles published.

Affiliation	No. of Articles	Country
Ministry of Education and Science of Ukraine	63	Ukraine
Indian Institute of Technology System (IIT System)	25	India
University of Belgrade	22	Republic of Serbia
Bucharest University of Economic Studies	17	Romania
National Institute of Technology (NIT System)	15	India
Egyptian Knowledge Bank	15	Egypt
University of Zagreb	14	Croatia
University of Sevilla	13	Spain
Technical University Kosice	13	Slovakia
Indian Institute of Technology (IIT)—Delhi	12	India
Sapienza University Rome	12	Italy
State University System of Florida	12	United States of America
Melbourne Genomics Health Alliance	11	Australia
University of Aegean	11	Greece
Indian Institute of Management (IIM System)	10	India
Loughborough University	10	United Kingdom
Delft University of Technology	9	Netherlands
Monash University	9	Australia
Sakarya University	9	Turkey
Universidade Federal De Santa Catarina (UFSC)	9	Brazil

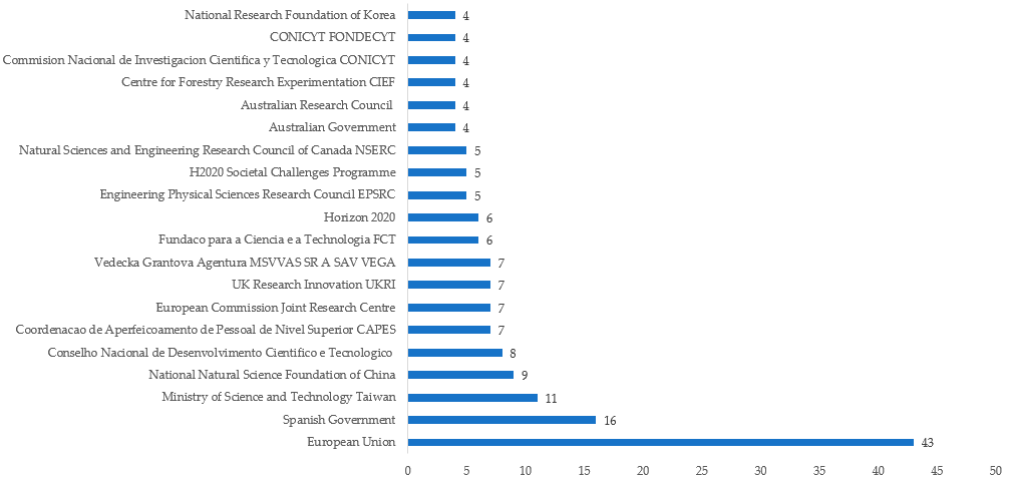

Figure 7. Top 20 funding agencies.

3.5. Countries Analysis

The first 20 countries with the most remarkable corresponding authors can be seen in Figure 8, which showcases the global distribution with regards to the scientific papers that have been written for the analyzed matter. Based on the below figure, it can be seen that the United States of America is the country with the most corresponding authors, having 112 articles, whereas China and United Kingdom follow closely, with 96 and 93 scientific papers each. This suggests that the aforementioned countries are able to produce a very high level of research output, emphasizing the strong engagement in the academic activities that are linked to the analyzed subject. Yet, countries such as India, Australia, Spain, and Italy are also among the top contributors, considering their number of articles, along with Germany, Russia, and Ukraine. It is worth mentioning that for Canada, even if the number of scientific papers is relatively low when compared to other countries, the rate between main corresponding publications and the total number of articles is rather high, implying that the country is more focused on research that is impactful. The distribution of the corresponding author countries emphasizes the global nature and importance of academic

collaboration, highlighting the fact that these are the main catalysts related to the overall expertise in the subject's matter.

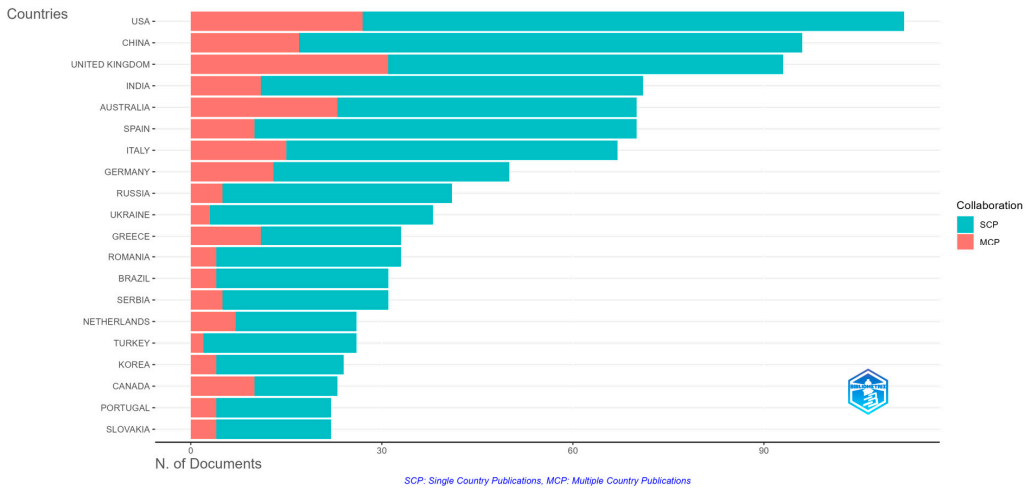

Figure 8. Global distribution of corresponding authors' countries.

With the help of a visualization map covering all the world's countries, according to Figure 9, we can easily see the states that have had the highest scientific contribution. In addition to this, the colors follow a certain pattern, ranging from dark blue to gray, basically underscoring the scientific production of each country. Due to a darker color used, the countries with the most contributions can be observed rather easily—countries such as the United States of America, with 241 articles; China, having 203 scientific papers; the United Kingdom, with 189 articles; and Italy and Spain, with a combined 156 publications. Yet, there are also countries that had a low contribution, implicitly a lighter blue or gray color on the visual map, for instance, Argentina, with two scientific papers, or Peru, with three articles.

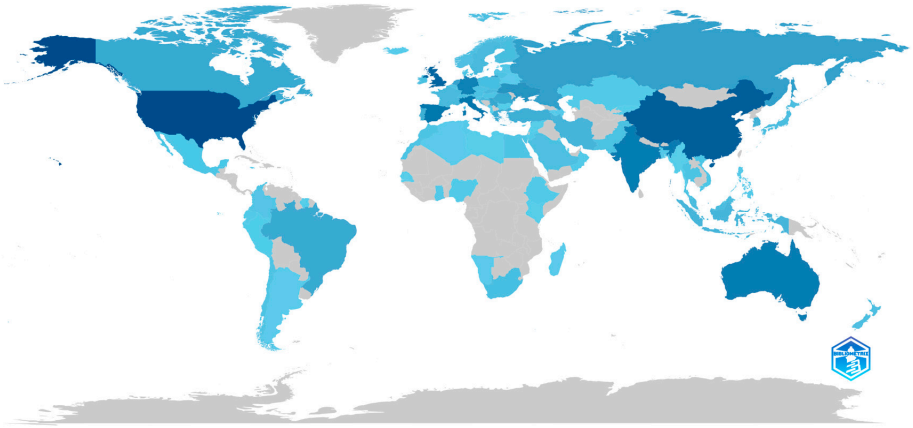

Figure 9. Corresponding authors' countries.

By examining the global trend with regard to the scientific research, it is visible in Figure 10 that the United States of America and China are the countries with the most citations, being cited 3331 and 3149 times, respectively.

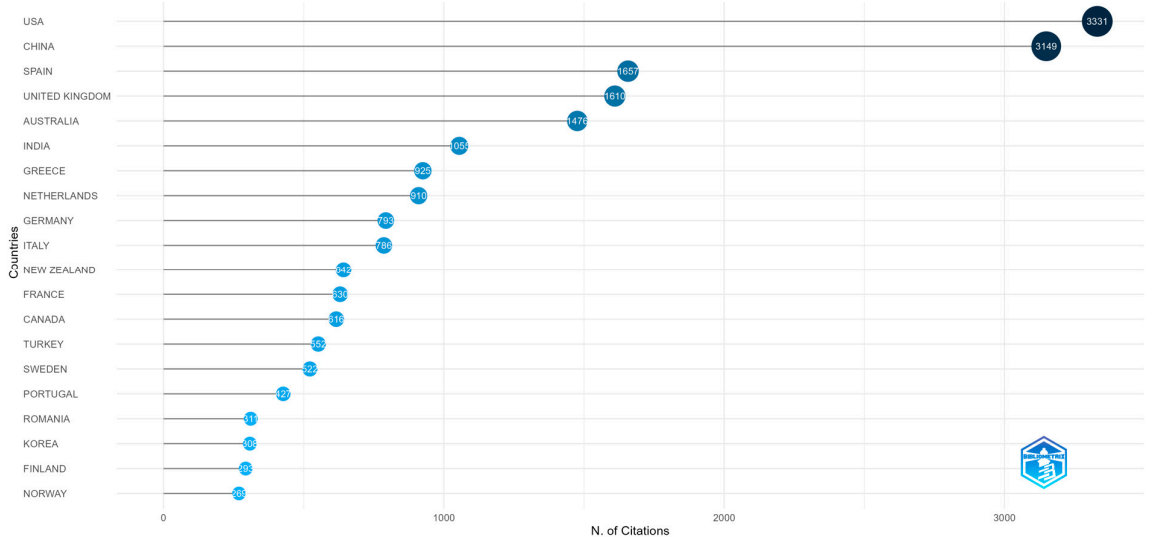

Figure 10. Top 20 most cited countries.

3.6. Sources Analysis

The conducted analysis on the top 20 journals most relevant to the subject matter illustrates the diversification and importance of research among various journals, as can be observed in Figure 11.

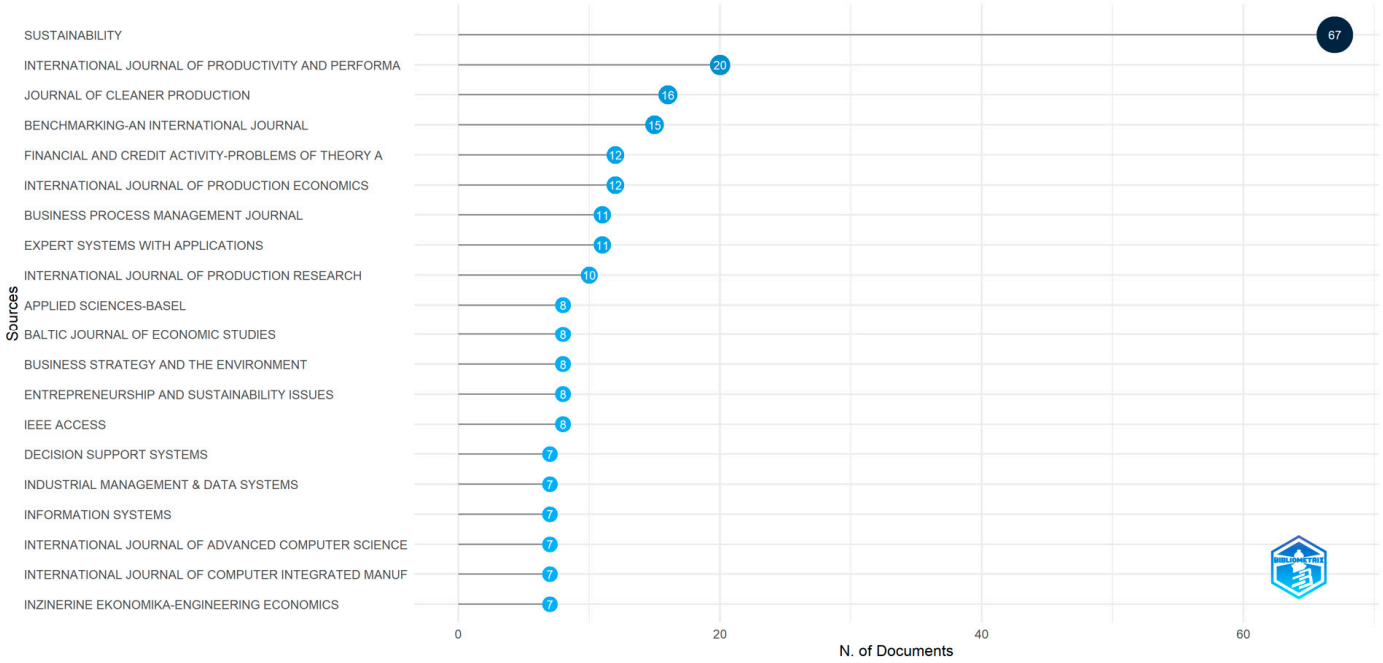

Figure 11. Top 20 most relevant sources.

The most significant one is *Sustainability*, with 67 articles, highlighting the significance of KPIs and KRIs in businesses, organizations, and companies with regard to the overall economic state of the countries. Among other noteworthy journals, we find the *International Journal of Productivity and Performance Management*, with 20 scientific papers; *Journal of Cleaner Production*, taking into account 16 articles; *Benchmarking: An International Journal*, with 15 articles; *Financial and Credit Activity: Problems of Theory and Practice* and the *International Journal of Production Economics*, each of them having 12 publications; and the *Business Process Management Journal* and *Expert Systems with Applications*, each account-

ing for 11 articles. Therefore, this journal variation indicates that the analyzed topic is a comprehensive one, covering not only the impact that the studied indicators may have on the general economic context within the countries, but also the performance of companies themselves, thus opening the door to more strategic decision-making for implementation within organizations, but only after the business itself chooses the right KPIs and KRIs as measurement units for its performance.

3.7. Document Analysis

In this section, we delve into various analytical methods to understand the research landscape regarding key performance indicators (KPIs) and key risk indicators (KRIs). We present the top 10 most globally cited documents, providing insights into the foundational works in this field. Additionally, we utilize word clouds based on authors' keywords and Keywords Plus to identify the most frequent terms. Our analysis extends to clustering by coupling, co-occurrence networks, and factorial analysis, revealing the structural relationships and thematic clusters within the research. These comprehensive analyses offer a multifaceted view of the key trends and priorities in the literature on KPIs and KRIs.

Table 6 lists the top 10 most globally cited documents. The analysis of these highly cited documents highlights significant contributions to the specialized literature on KPIs and KRIs. The first document, published by Sun et al. (2007) in the *Academy of Management Journal*, has the highest total number of citations, indicating major influence. Hanna et al. (2011) in *Business Horizons* presents the highest annual and normalized citations, reflecting a continuous and robust impact. Overall, the analyzed articles come from renowned journals and cover diverse themes, ranging from financial performance and sustainability to supply chain management and corporate governance. This diversity underscores the relevance and complexity of research on KPIs and KRIs, as well as their importance for various aspects of organizational management. We continue with a qualitative analysis of these articles to observe how performance and risk metrics and indicators are utilized.

Table 6. Top 10 most cited documents globally.

First Author, Year, Journal, References	Total Citations	Total Citation (TC) per Year	Normalized TC
Sun LY., 2007, *Academy of Management Journal*, (Sun et al. 2007)	956	53.11	13.42
Hanna R., 2011, *Business Horizons*, (Hanna et al. 2011)	783	55.93	21.67
Milne M.J., 2013, *Journal of Business Ethics*, (Milne and Gray 2013)	608	50.67	23.22
Ceccagnoli M., 2012, *MIS Quarterly*, (Ceccagnoli et al. 2012)	445	34.23	10.88
López M.V., 2007, *Journal of Business Ethics*, (López et al. 2007)	440	24.22	6.18
Lee A.H.I., 2008, *Expert Systems with Applications*, (Lee et al. 2008)	366	21.53	11.32
Hermann B.G., 2007, *Journal of Cleaner Production*, (Hermann et al. 2007)	237	13.17	3.33
Franking-Johnson E., 2016, *Journal of Cleaner Production*, (Franklin-Johnson et al. 2016)	225	25.00	13.27
Varsei M., 2014, *Supply Chain Management*, (Varsei et al. 2014)	220	20.00	7.57
Turner R., 2012, *Project Management Journal*, (Turner and Zolin 2012)	219	16.85	5.35

With regard to the article published by Sun et al. (2007), service-oriented organizational citizenship behavior was studied in order to reveal how much it can impact the linkage between performant human resource policies and KPIs, the latter taking into account only turnover and productivity. The authors conducted their analysis on hotels in the People's Republic of China.

For the second research article (Hanna et al. 2011), the authors gave insights about the importance of setting and the right KPIs and how to measure these with regard to the online social media world, for platforms such as YouTube, Twitter, or Facebook, in order for them to reach their target audience—that of young consumers. More than this, the researchers treated this matter by approaching the social media context as a mix of both traditional and digital media, suggesting some best practices for these aforementioned online social platforms to increase the potential range of strategic marketing decisions that can be made with the help of KPIs.

From a critical point of view, Milne and Gray (2013) emphasized in their research the fact that an analysis of life-supporting ecological systems should also be considered when practices of sustainability reporting are being tackled. Therefore, the authors consider that the corporate or organizational level of sustainability may also be described by the level of environmental, social, and economic performance indicators. Yet, nowadays, from their perspective, even if there are diverse benchmarking approaches that should reinforce the sustainability of a business, it seems that these are not enough to also cover the ecological part that seems to be somehow disregarded in this process, thus arguing about the fact that the benchmarking tools should give more credit to the ecological area.

Ceccagnoli et al. (2012) studied how partnerships between enterprise software companies and relatively small companies that act as software vendors (ISVs) impact the latter, with the help of KPIs proving that these kinds of partnerships are beneficial for ISVs. The software vendors' sales rose considerably, and the partnership offers they received from software enterprises did as well.

López et al. (2007) analyzed how corporate social responsibility (CSR) accounting practices impact business performance, if adopted. The researchers did this by comparing the differences between the KPIs of European organizations that had already adopted some of the CSR practices to those who did not. The authors proved that there was a slight negative impact on the KPIs of companies that adopted CSR practices in comparison to businesses that had not implemented any CSR norms.

Lee et al. (2008) highlighted how important information technology (IT) is in the context of any business, underscoring the way that IT departments can contribute to the strategic goals of organizations. The scientists highlighted the fact that these kinds of technical departments cannot apply their performance measurement from a monetary unit perspective, but rather from four major ones: financial, internal business process, customer, and growth. Therefore, the authors implied that each perspective should have its own set of KPIs, as all these perspectives are different from a performance point of view. Furthermore, the results that the scientists obtained after constructing a model in which any of the abovementioned perspectives was considered separately in order to rightly evaluate the overall performance of the IT departments proved to offer very valuable insights within the department. Therefore, a detailed productivity tree of the department via performance evaluation should provide enough data for the business to consider the right strategy for further development of the department.

By their study, Hermann et al. (2007) provided a tool that can be used by businesses to find out essential information on the environmental impact they have. The authors mentioned that parts of diverse tools, such as environmental performance indicators, multi-criteria analysis, and life cycle assessment were integrated with their solution and environmental performance indicators.

The study published by Franklin-Johnson et al. (2016) proposes a new indicator in order to assess the environmental performance with regard to the circular economy, mentioning that the current methodology is quite cumbersome. This new suggested indicator considers the earned recycled lifetime, initial lifetime, and earned refurbished lifetime, and its management is crucial for the decision-making process, but also for making the right KPI assessment with regard to the circular economy, as per the authors' mentioning. The researchers also state that the indicator should play a major role on a managerial level

as well, not only on an organizational one, thus helping in the measurement that a business decision has against the longevity of materials.

The article published by Varsei et al. (2014) proposes a framework that can be used by the focal companies to assist them in developing supply chains that are sustainable. Therefore, the authors' framework excels in detecting and assessing a specter of various key performance, economic, and environmental indicators, thus helping the companies achieve a sustainable supply chain. Certainly, this is of utmost need nowadays, as the researchers believe that there is an increasingly tendency for these focal companies to incorporate the assessment and advancement of sustainability with regard to supply chains in the supply chain's management, pointing out that the companies may otherwise miss out on an overall better estimation of the supply chain's sustainability.

The aim that Turner and Zolin (2012) had in their paper was to propose a set of critical KPIs in order to help managers who handle big projects give a better prognosis about stakeholder perceptions of success while projects are still ongoing. The researchers mentioned with certainty that some of these projects may be very long-living within an organization, basically increasing the chance that the project's stakeholders' definitions of success change over time. Thus, the authors suggested a model that should achieve stakeholder success at any point in the future. The advised model extends the traditional triple constraint that is described by scope, cost, and time, each of them with their own specific KPIs, to also include two KPIs related to the projects' success and seven KPIs linked to the stakeholders' satisfaction about the projects. Therefore, the usage of this tool by project managers should provide them with better control over the projects they lead.

Figure 12 presents the word cloud analysis created based on the authors' keywords, revealing frequently used terms in the specialized literature on KPIs and KRIs, providing valuable insights into the dominant themes and their alignment with our research hypotheses. The central term "key performance indicators" reflects the focus on KPIs as essential tools for measuring and improving organizational performance. Additionally, the appearance of the keyword "sustainability" highlights the importance of sustainability in organizational performance and the alignment of KPIs with sustainable development goals. The keywords "performance", "performance measurement", and "performance indicators" reflect major interest in measuring and evaluating performance in various organizational contexts. Furthermore, "business performance", "business intelligence", and "benchmarking" emphasize the link between KPIs and business performance, the use of business intelligence, and benchmarking practices for performance evaluation.

Figure 12. Word cloud based on authors' keywords.

Regarding the authors' keywords relevant to KRIs, we observe "risk management" and "risk". These terms highlight the importance of identifying and managing risks within organizations. Risk management is essential for protecting and optimizing business operations and emphasizing the role of KRIs in anticipating and mitigating risks. Additionally,

the appearance of the keyword "supply chain management" may indicate that managing risks in supply chains is a major concern. KRIs are used to identify risks in the supply chain and implement mitigation measures to ensure continuity and efficiency in operations. Additionally, the concept of "financial performance" is highly relevant to KRIs because financial risks are a crucial part of KRI assessment. These terms underscore the central role of KRIs in identifying, monitoring, and managing risks from various aspects of business, from supply chains to financial performance and corporate governance. These perspectives provide a deeper understanding of how KRIs are integrated into risk management strategies and highlight their relevance in ensuring organizational success.

The word cloud in Figure 13, created based on Keywords Plus, provides valuable insights into the dominant themes and their frequency in the literature related to KPIs and KRIs in business. The most frequent term is "management", indicating that management is a central topic in discussions about KPIs and KRIs. Additionally, key concepts such as "impact" and "performance" highlight the importance of evaluating effects and performance in the context of using KPIs and KRIs. Keywords like "model" and "framework" reflect the extensive use of models and conceptual frameworks in analyzing and applying KPIs and KRIs. More than this, we observe a high frequency of keywords such as "innovation" and "strategy". This demonstrates the connection between innovation, strategy, and organizational performance. Significant concern is also highlighted for "sustainability" and "corporate social responsibility".

Figure 13. Word cloud based on Keywords Plus.

Additionally, other keywords found in this word cloud include "decision-making", "quality", "satisfaction", "risk", and "balanced scorecard". The keyword "decision-making" is highly relevant to our analysis, as the ability to make informed decisions is essential for organizational success, emphasizing the importance of KPIs and KRIs in the decision-making process. KPIs and KRIs provide data and information that support strategic and tactical decision-making. The keyword "quality" highlights that it is a vital aspect of organizational performance, and the use of KPIs is essential for monitoring and improving the quality of products and services. The keyword "satisfaction" indicates the importance of customer and employee satisfaction in evaluating organizational success through KPIs. Satisfaction KPIs help measure satisfaction levels and identify areas needing improvement. The concept of "risk" is crucial in KRI analysis, underscoring the importance of identifying and managing risks to protect and optimize business operations. The appearance of this keyword in the word cloud reflects the focus on risk evaluation and reduction using specific indicators. Finally, "balanced scorecard" is also a keyword observed in our word cloud. The

balanced scorecard is a frequently used strategic methodology to align business activities with the organization's vision and strategy, and its integration into KPI research indicates a structured and holistic approach to performance management.

The clustering by coupling graph in Figure 14 provides a visualization of clusters based on centrality and impact. On the vertical axis, we have impact, and on the horizontal axis, we have centrality. Each cluster is colored differently and represented by a specific set of dominant keywords. Table 7 presents the values of centrality and impact for each label and formed cluster.

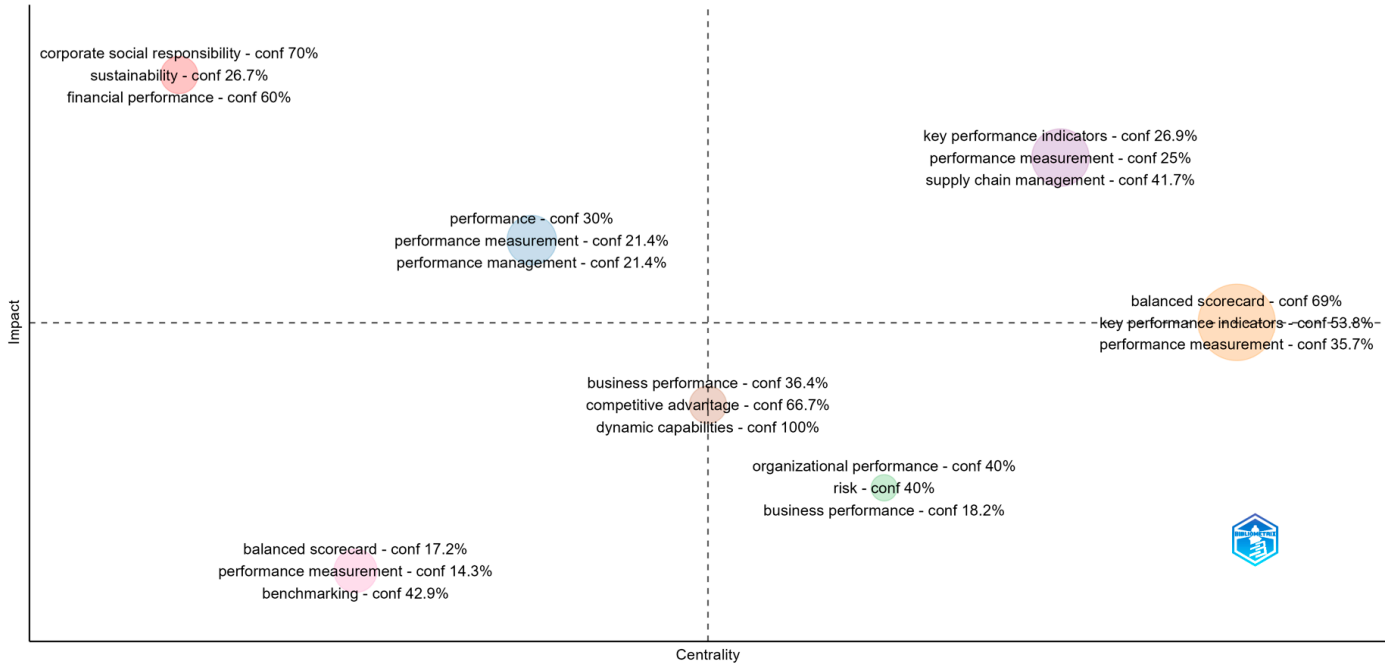

Figure 14. Clusterization by document coupling (coupling by references, global impact, cluster labels, and author keywords).

Table 7. Clusters based on coupling map analysis.

Label	Cluster	Freq	Centrality	Impact
corporate social responsibility—conf 70% sustainability—conf 26.7% financial performance—conf 60%	1—red	21	0.307	4.290
performance—conf 30% performance measurement—conf 21.4% performance management—conf 21.4%	2—blue	33	0.311	2.725
organizational performance—conf 40% risk—conf 40% business performance—conf 18.2%	3—green	14	0.373	2.201
key performance indicators—conf 26.9% performance measurement—conf 25% supply chain management—conf 41.7%	4—purple	44	0.439	3.305
balanced scorecard—conf 69% key performance indicators—conf 53.8% performance measurement—conf 35.7%	5—orange	91	0.475	2.575
business performance—conf 36.4% competitive advantage—conf 66.7% dynamic capabilities—conf 100%	6—brown	21	0.357	2.519
balanced scorecard—conf 17.2% performance measurement—conf 14.3% benchmarking—conf 42.9%	7—pink	26	0.308	2.044

Thus, Cluster 1 (red) focuses on corporate social responsibility and sustainability, with very high impact and moderate centrality, suggesting these themes are essential for KPI and KRI research. Cluster 2 (blue), with a centrality of 0.311 and an impact of 2.725, indicates moderate values, reflecting the importance of performance evaluation and management in the analyzed research. Cluster 3 (green) combines organizational performance with

risk and business performance, having relatively high centrality and moderate impact. Cluster 4 (purple) has a high centrality level of 0.439 and high impact, indicating the importance of KPIs and supply chain management. Cluster 5 (orange) has the highest centrality, but a more moderate impact compared to Cluster 4, highlighting the strategic use of these tools. Regarding Cluster 6 (brown), this cluster reflects the importance of business performance and competitive advantage, with moderate centrality and impact. Finally, Cluster 7 (pink) focuses on performance evaluation and benchmarking, with moderate impact and centrality.

Thus, the information in Figure 14 and Table 7 shows how various themes are grouped in KPI and KRI research. The most central and impactful themes are KPIs, balanced scorecard, and supply chain management, highlighting their importance in the organizational context. The clusters illustrate the distribution and relevance of different subjects in the specialized literature, providing a clear picture of research priorities.

The co-occurrence network created in Figure 15 is based on the authors' keywords reveals the structure and relationships among central themes in KPI and KRI research. Each node represents a keyword, and the clusters indicate thematic groups. The values of centrality and impact provide additional information about the importance and interconnectedness of these terms. We observe that seven clusters were formed, which can be interpreted as follows:

- Cluster 1 (red): Key concepts include "performance measurement", "balanced scorecard", "benchmarking", "performance management", and "supply chain management". This cluster has medium centrality and high impact and focuses on performance measurement and management methods, including balanced scorecard and supply chain management, emphasizing the importance of these tools in evaluating organizational performance.
- Cluster 2 (blue): Includes terms such as "process mining" and "machine learning". This cluster, with low centrality and moderate impact, reflects the use of advanced technologies such as process mining and machine learning in performance analysis.
- Cluster 3 (green): Key concepts such as "key performance indicators", "performance", "business performance", and "business intelligence" are identified in this cluster, which has high centrality and impact. The cluster has a clear focus on KPIs and business intelligence, highlighting the role of KPIs in improving business performance and decision-making.
- Cluster 4 (purple): Terms such as "sustainability", "performance indicators", "corporate social responsibility", and "innovation" are present in this cluster. It is centered on sustainability and corporate social responsibility, indicating concern for the social and environmental impact of organizations, having medium centrality but high impact.
- Cluster 5 (orange): With medium centrality and low impact, this classification includes terms such as "big data" and "data mining", reflecting their use in performance analysis and risk management.
- Cluster 6 (brown): Includes terms such as "COVID-19" and "risk". It has both low centrality and impact, highlighting the recent concern for risk management in the context of the COVID-19 pandemic (Munmun et al. 2023).
- Cluster 7 (pink): Includes the concept of "business process management" and has medium centrality and moderate impact. The cluster emphasizes the importance of managing business processes for improving organizational performance.

The co-occurrence network shows how various themes are interconnected in KPI and KRI research. The most central and impactful themes include performance measurement, balanced scorecard, KPIs, and sustainability, highlighting the importance of these aspects in the organizational context. The clusters show the distribution and relevance of different subjects in the specialized literature, providing a clear picture of research priorities.

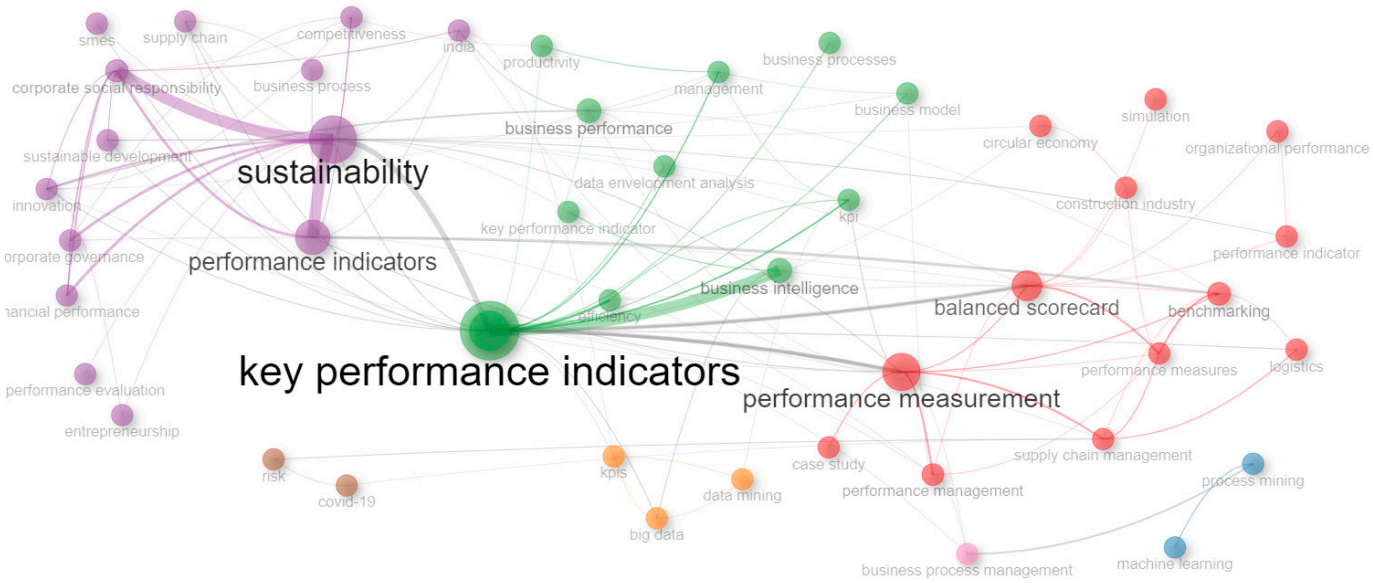

Figure 15. Co-occurrence network by authors' keywords.

The factorial analysis in Figure 16 shows how various themes are interconnected and grouped in the research on KPIs and KRIs. Additionally, the factorial analysis of the authors' keywords highlights the structure and relationships among the different research themes regarding KPIs and KRIs. In this case, using the multiple correspondence analysis (MCA) method, five clusters were formed as follows:

- Cluster 1 (red) includes keywords such as "key performance indicators", "performance", "performance measurement", "business process management", "business performance", "firm performance", "business intelligence", etc. This cluster comprises essential terms for performance measurement and management. The positioning of the terms in Dim1 and Dim2 shows that they are closely related to organizational performance evaluation and the use of management tools.
- Cluster 2 (blue) groups keywords such as "financial performance", "sustainability", and "performance indicator". This cluster is focused on sustainability and financial performance, highlighting the importance of integrating sustainable development goals into organizational performance.
- Cluster 3 (green) groups keywords like "benchmarking", "supply chain management", "environmental management", etc. This cluster concentrates on supply chain management and benchmarking, indicating performance comparison practices and efficient supply chain management.
- Cluster 4 (purple) includes keywords such as "corporate social responsibility", "competitiveness", and "corporate governance". This cluster focuses on corporate social responsibility and corporate governance, reflecting concerns about social impact and business competitiveness.
- Cluster 5 (orange) groups key terms such as "innovation", "management", "productivity", and "entrepreneurship", highlighting innovation, management, and productivity, and emphasizing the importance of innovation and entrepreneurship in organizational performance.

Thus, we observe that the most prominent themes include performance measurement, sustainability, supply chain management, and corporate social responsibility, underscoring the importance of these aspects in the organizational context.

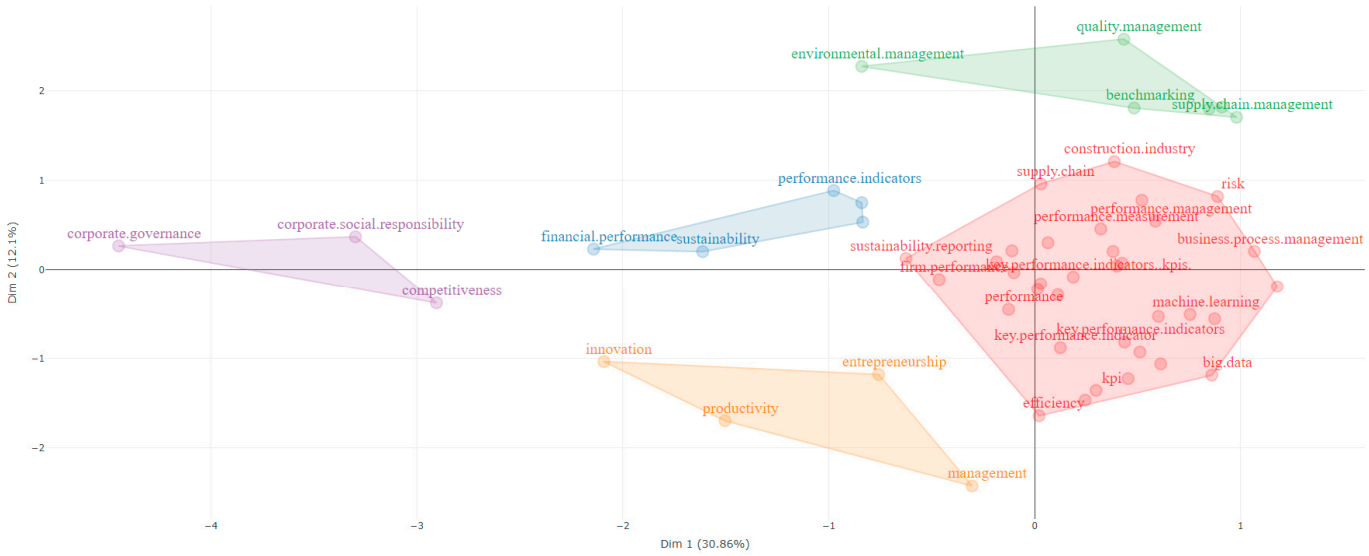

Figure 16. Factorial analysis.

Figure 17 is a map created in VOSviewer that highlights the most relevant key concepts.

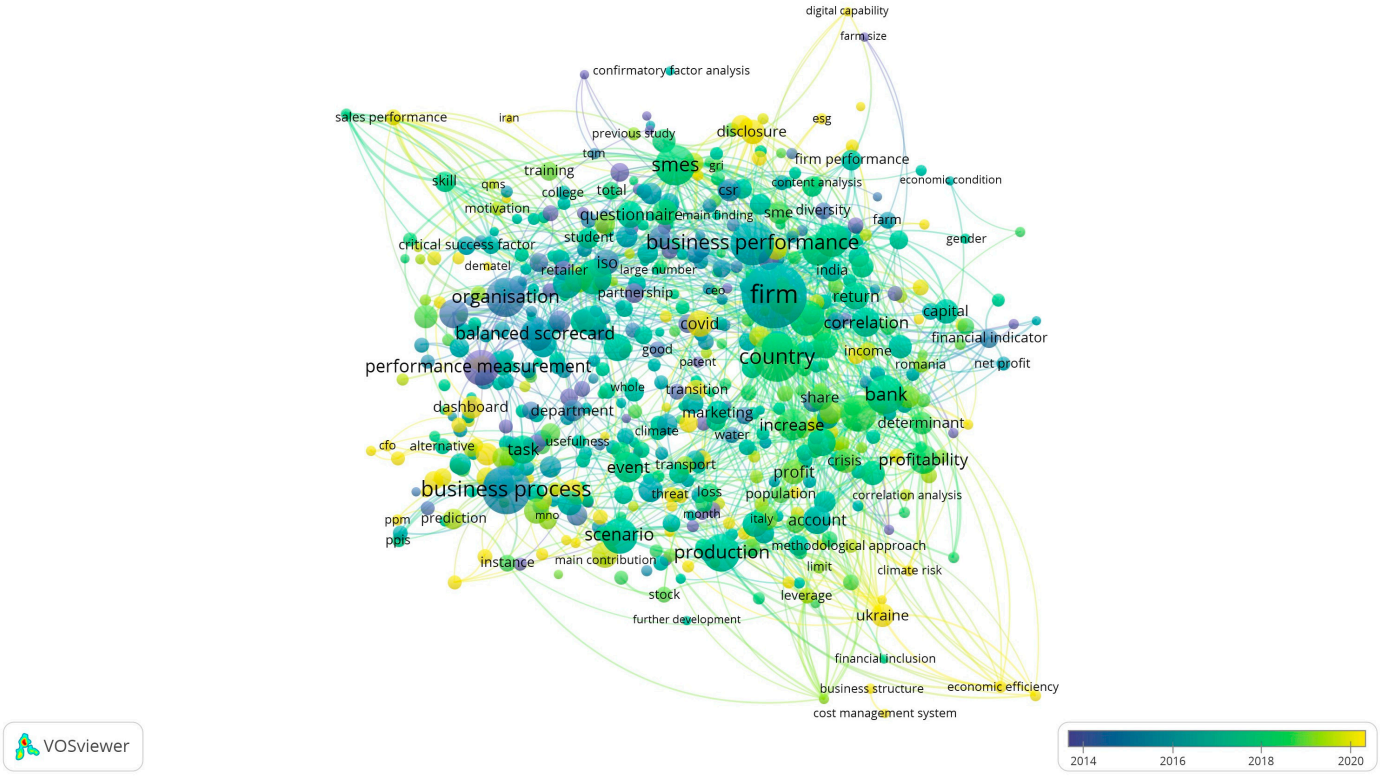

Figure 17. VOSviewer map of the most relevant key concepts.

VOSviewer identified 999 relevant key concepts and automatically calculated a relevance score for each term, reflecting its importance in the context of the scientific articles analyzed in our study. Of all the identified terms, the top 60% of most relevant terms were selected based on their calculated relevance scores. This selection was made to focus the analysis on the terms that are most significant and contribute most meaningfully to the understanding of the research domain. Thus, the created map visualizes the structure and relationships among the essential terms, highlighting crucial themes, topics, and connections within the analyzed articles.

The keyword map from Figure 17 generated 12 clusters as follows:

- Cluster 1: Technological Integration and AI in business processes—This cluster, with 154 keywords, includes keywords such as "accuracy", "artificial intelligence", "business process management", "customer service", "digitalization", "enterprise performance", "IoT", "machine learning", and "predictive model". These terms highlight the increasing integration of advanced technologies and analytics in enhancing business processes and performance. This cluster underlines the role of digital transformation and smart technologies in optimizing KPIs, suggesting a trend towards more data-driven and technology-enabled business strategies.
- Cluster 2: Business Environment and Competitive Strategies—Cluster 2, with 92 keywords, features terms like "agricultural enterprise", "auditor", "business incubator", "competitive environment", "digital transformation", "economic development", and "strategic management". This cluster indicates the importance of external economic factors and competitive dynamics in shaping business strategies and performance metrics. It underscores the necessity for businesses to adapt to economic changes and competitive pressures through strategic management and innovation.
- Cluster 3: Industrial and Educational Performance—This cluster includes 73 keywords such as "construction industry", "economic performance", "education", and "human factor". The focus here is on the performance metrics specific to different industries and sectors. The inclusion of terms related to education and human factors highlights the role of human capital and industry-specific knowledge in driving performance.
- Cluster 4: Business Intelligence and Strategic Planning—Cluster 4, with 65 keywords, contains terms like "agility", "balanced scorecard", "business intelligence", "cloud computing", and "strategic planning". This cluster points to the strategic tools and methodologies used in measuring and enhancing business performance. It highlights the use of balanced scorecards and business intelligence as essential tools in strategic planning and decision-making.
- Cluster 5: Environmental Performance and Sustainability—This cluster, containing 50 keywords, includes terms such as "circular economy", "environmental performance", "energy efficiency", and "social impact". It underscores the growing underline on sustainability and social responsibility in business performance metrics. This cluster reflects how environmental and social factors are becoming integral to the evaluation of business performance.
- Cluster 6: Business success and quality management—With 38 keywords, this cluster features terms like "DEA (Data Envelopment Analysis)", "business success", "Confirmatory Factor Analysis", and "quality management system". It indicates a focus on quality management and success metrics in various industries, particularly in the hotel industry. This cluster points to the use of sophisticated analytical methods to assess and improve business success and quality.
- Cluster 7: Financial Health and Risk Management—Cluster 7 includes 33 keywords such as "accounting", "capital", "financial distress", "financial ratio", "ICT investment", and "intellectual capital". This cluster highlights the financial metrics and risk factors that are critical to business performance. It emphasizes the importance of financial health, investment in information and communication technologies, and intellectual capital in achieving business success.
- Cluster 8: Corporate Responsibility and Reporting—Featuring terms like "annual report", "content analysis", "corporate social responsibility", "regulator", and "sustainability performance", this cluster underscores the importance of corporate governance, regulatory compliance, and social responsibility in business performance. It highlights the role of transparency and accountability in achieving sustainable business success.
- Cluster 9: Innovation and Training—This cluster includes terms such as "conceptual framework", "innovation performance", "sales performance", "training", and "skill". It underlines the role of innovation, skills development, and training in driving busi-

ness performance. This cluster suggests that continuous improvement and innovation are key to maintaining a competitive advantage.

- ➢ Cluster 10: Risk Indicators and Economic Crises—With significant terms like "business risk", "credit risk", "economic crisis", "financial risk", "firm performance", "operational risk", "risk management", and "risk indicator", this cluster highlights the critical importance of identifying, assessing, and managing risks in business. It underscores the various types of risks that can impact firm performance and the necessity of robust risk management strategies.
- ➢ Cluster 11: Value Creation and Stability—This smaller cluster, with 15 keywords, includes terms like "car company", "further development", "value creation", and "stability". It focuses on the industrial sector and the factors contributing to business stability and value creation.
- ➢ Cluster 12: Market and Economic Conditions—Containing six keywords, namely, "climate risk", "economic condition", "market value", "nation", "price", and "regression analysis", this cluster emphasizes the broader economic conditions and market factors that influence business performance and risk.

In order to validate the clusters formed and the trends resulting from the previous analyses, Table 8 was created, in which several works that support the analytical trends were extracted and reviewed. These references support the clusters identified in our bibliometric analysis, providing a comprehensive understanding of the key performance and risk indicators in business contexts.

Table 8. Empirical analysis for key findings on KPIs and KRIs.

Cluster	Keywords	Empirical Findings	References
Business process and technological integration	Accuracy, artificial intelligence (AI), business process management, machine learning (ML)	AI and ML improve business process efficiency and decision-making accuracy.	(Davenport and Rajeev 2018; Chen et al. 2022; Jawad and Balázs 2024)
Business environment and competitive strategies	Auditor, competitive environment, digital transformation, strategic management	Strategic management and digital transformation are important for competitiveness in various environments.	(Teece 2018; Hess et al. 2020)
Industrial and educational performance	Construction industry, economic performance, education	Improved construction processes and educational advancements enhance economic performance.	(Marginson 2016)
Business intelligence and strategic planning	Balanced scorecard, business intelligence, strategy map	Balanced scorecard and BI systems are vital for strategic planning and performance measurement.	(Kaplan and Norton 1996; Wixom and Watson 2010)
Environmental performance and sustainability	Circular economy, environmental performance, social impact	Circular economy principles and sustainability initiatives significantly improve environmental performance.	(Geissdoerfer et al. 2017; Marrucci et al. 2024)
Business success and quality management	Business success, confirmatory factor analysis, hotel industry	Quality management systems and confirmatory factor analysis are crucial for achieving business success in the hospitality sector.	(Ennis and Harrington 1999; Tambare et al. 2021)
Financial health and risk management	Accounting, financial distress, risk management	Financial ratios and risk management frameworks help mitigate financial distress and manage business risks.	(Brühl 2023; Cernisevs et al. 2023)

Table 8. *Cont.*

Cluster	Keywords	Empirical Findings	References
Corporate responsibility and reporting	Annual report, corporate social responsibility, sustainability performance	Corporate social responsibility (CSR) practices and integrated reporting enhance sustainability performance and stakeholder trust.	(Eccles et al. 2014; McCullough and Trail 2023)
Innovation and training	Conceptual framework, innovation performance, training	Innovation performance and training programs are key for maintaining competitive advantage and adapting to market changes.	(Damanpour and Aravind 2012; Filho et al. 2023)
Risk indicators and economic crises	Business risk, economic crisis, risk indicator	Identifying and managing risk indicators are critical for navigating economic crises and ensuring firm performance.	(Elyasiani and Jia 2019; Deverell and Ganic 2024)
Value creation and stability	Value creation, stability, further development	Creating value through strategic resource management ensures long-term business stability.	(Kavadis et al. 2024; Qiao et al. 2024)
Market and economic conditions	Climate risk, economic condition, market value	Managing climate risk and understanding economic conditions are essential for maintaining market value and sustainability.	(Pindyck 2013; Silva et al. 2024)

4. Discussion

In this section, a discussion regarding the research hypothesis is provided, along with a brief comparison in terms of scientific production, authors' keywords, and most cited papers of a dataset extracted from the Scopus database using the same extraction keywords.

4.1. Discussion on Research Hypotheses

This section focuses on discussing the research hypotheses proposed in our study on KPIs and KRIs in business. Through bibliometric analysis and various visualization methods, we gained valuable insights into the research landscape and the ways these concepts are applied and studied in the literature. We analyze each hypothesis in turn to highlight the main findings and their implications for organizational management and business policies. KRIs play an important role in risk management by providing early warning signs of potential threats. These indicators help organizations anticipate and mitigate risks before they escalate, ensuring the continuity and stability of operations. For instance, KRIs can be used to monitor financial health, supply chain vulnerabilities, and compliance risks, allowing for proactive risk management strategies. In the financial sector, the use of KRIs such as liquidity ratios and market volatility indicators has enabled firms to maintain financial stability during economic downturns. Similarly, in the manufacturing industry, monitoring KRIs related to supplier reliability and production downtime has helped companies mitigate supply chain disruptions. Integrating KPIs and KRIs into a unified performance and risk management system allows for organizations to achieve a comprehensive view of their operations. While KPIs focus on tracking and improving performance metrics such as sales growth and operational efficiency, KRIs provide insights into potential risks that could hinder these performance goals. For example, an organization might use KPIs to measure customer satisfaction and delivery times, while simultaneously monitoring KRIs related to cybersecurity threats and regulatory compliance to ensure uninterrupted service and adherence to legal standards.

Regarding hypothesis H_1, which proposed the investigation of a positive correlation between the use of KPIs and the improvement of organizational performance, several

results from our bibliometric analysis validated this correlation. The exponential growth in scientific production from 2004 to 2023 indicates increased interest in using KPIs, suggesting a positive correlation with organizational performance. Additionally, the analysis of highly cited documents and keywords shows continuous interest in performance measurement and management (e.g., "key performance indicators", "performance", "business performance"). This indicates that the use of KPIs is crucial for improving organizational performance, supporting hypothesis H_1. Furthermore, the word clouds highlight key terms such as "performance", "efficiency", and "impact", supporting H_1 and suggesting that the use of KPIs is essential for improving organizational performance. Essential concepts such as "key performance indicators", "performance", "performance measurement", and "business performance" further support the hypothesis that the use of KPIs is positively correlated with improving organizational performance.

Hypothesis H_2 proposed that the implementation of KRIs significantly contributes to reducing operational risks. This hypothesis is also validated, with the observation that KRIs are often documented and used in a broad sense as part of risk management. The fluctuation in citations during economic crises (2007, 2011, and 2019) indicates increased interest in KRIs for anticipating and managing risks, validating H_2. Additionally, terms such as "risk management" and "risk", identified in the co-occurrence analysis, factorial analysis, and word clouds, highlight the importance of identifying and managing risks within organizations. The cluster including these terms emphasizes the role of KRIs in anticipating and mitigating risks, supporting hypothesis H_2.

Hypothesis H_3 posited that international collaboration in KPI and KRI research is correlated with producing more influential and highly cited studies. This hypothesis is validated by our results. The analysis of affiliations and funding agencies shows extensive international collaboration, with institutions from various countries significantly contributing to research. For example, the Ministry of Education and Science of Ukraine and the Indian Institute of Technology reflect strong international collaboration. This indicates that global partnerships can lead to more robust and recognized results, supporting H_3. The analysis of international collaboration networks shows strong collaboration, with the USA, China, and the UK being research leaders, reflecting the influence of global collaboration on research quality. Word clouds highlight terms such as innovation, big data, and integration, suggesting the importance of collaboration and integration in research, supporting hypothesis H_3 regarding international collaboration and its impact.

Finally, hypothesis H_4 suggests that the diversity in KPIs and KRIs and their effective management contribute to organizational success. The tree field plot and cluster analysis highlights the diversity in research themes and the use of KPIs and KRIs in various contexts, underscoring their importance for organizational success. Additionally, the analysis of keywords, clustering, and co-occurrence networks shows the thematic diversity in research related to KPIs and KRIs (e.g., "sustainability", "corporate social responsibility", "supply chain management", "circular economy"). These themes are essential for organizational success, supporting hypothesis H_4.

In order to emphasize the previous conclusions, an empirical analysis was also carried out based on analysis developed in VOSviewer that highlighted 12 main clusters of key concepts related to KPIs and KRIs. Each cluster is supported by empirical references that demonstrate the validity and relevance of our conclusions. For example, Cluster 1, which includes terms such as artificial intelligence and business process management, is supported by studies showing how these technologies improve the efficiency and accuracy of decisions (Davenport and Rajeev 2018; Chen et al. 2022; Jawad and Balázs 2024). Similarly, Cluster 5, which focuses on environmental performance and the circular economy, is supported by work highlighting the positive impact of sustainable practices on organizational performance (Geissdoerfer et al. 2017; Marrucci et al. 2024).

Our detailed analysis supports all four hypotheses, highlighting the importance of KPIs and KRIs in improving organizational performance, reducing risks, fostering international collaboration, and thematic diversity. These conclusions underscore the relevance

and complexity of research in KPIs and KRIs, providing a solid foundation for understanding how these tools are used to ensure organizational success and value.

From our perspective, policy implications could include recommendations for establishing common standards and practices in the use of KPIs and KRIs across different industries. Additionally, our study emphasizes the importance of integrating these tools into organizational strategies to support informed decision-making and efficient risk management. The findings can guide the development of public policies by highlighting the benefits of using KPIs and KRIs in the contexts of sustainability, social responsibility, and operational efficiency. Moreover, this study can influence future research directions by encouraging further exploration of the interdependencies between these indicators in various industrial and cultural contexts.

4.2. Brief Comparison with Scopus Extracted Dataset

Using the methodology described in Section 5, we extracted a dataset from the Scopus database to provide a brief comparison between it and the previously obtained dataset. The purpose of this comparison is to determine whether relevant information might differ when using the WoS database compared to Scopus in this specific context.

First, in terms of extracted papers, as can be observed from Table 9, there is a difference of 559 papers. It shall be noted that for the papers' extraction from Scopus database we have used the same keywords as in the case of the papers extracted using WoS database. The "*" placed at the end of the keyword indicates that any ending is possible for the search keyword—e.g., the use of the "risk_indicator*" keyword will search for both "risk indicator" and "risk indicators" keywords. Also, it shall be noted that "_" used in the search keyword will return only the papers in which both words between which the "_" is used are subsequent in the text—e.g., not separated by another word or one/more phrase/s.

Table 9. Comparison results for datasets extracted from WoS and Scopus.

Exploration Steps	Questions on Web of Science/Scopus	Description	Query	Query Number	Count WoS	Count Scopus
1	Title	Contains specific keywords related to risk indicators or risk indicators in business context	(((TI = (risk_indicator*)) OR TI = (performance_indicator*))) AND TI = (business)	#1	64	94
2	Abstract	Contains specific keywords related to risk indicators or risk indicators in business context	(((AB = (risk_indicator*)) OR AB = (performance_indicator*))) AND AB = (business)	#2	2457	4053
3	Keywords	Contains specific keywords related to risk indicators or risk indicators in business context	(((AK = (risk_indicator*)) OR AK = (performance_indicator*))) AND AK = (business)	#3	231	1073
4	Title/abstract/keywords	Contains specific keywords related to risk indicators or risk indicators in business context	#1 OR #2 OR #3	#4	2602	4375
5	Language	Contains only documents written in English	(#4) AND LA = (English)	#5	2473	4224
6	Document type	Limited to articles	(#5) AND DT = (Article)	#6	1489	2086
7	Year published	Excludes 2024	(#6) NOT PY = (2024)	#7	1395	1954

As the quality of a research article highly depends on missing information, we performed a data quality check for the dataset extracted from the Scopus database and compared it with the one provided in Section 5 for the dataset extracted from WoS. The results of the data quality check in the case of the two datasets are presented in Table 10. In Table 10, the categories in which the extracted information is excellent are marked in green, the categories in which the information is good are in light green, the categories considered acceptable from the point of view of extracted information are in yellow, poor information is marked in yellow, and categories with completely missing information are marked in red. It should be noted that the data quality check was performed using Biblioshiny software 4.3.0.

Table 10. Data quality check for datasets extracted from WoS and Scopus.

Metadata	Description	WoS Extracted Dataset			Scopus Extracted Dataset		
		Missing Counts	Missing (%)	Status	Missing Counts	Missing (%)	Status
AU	Author	0	0.00%	Excellent	0	0.00%	Excellent
DT	Document type	0	0.00%	Excellent	0	0.00%	Excellent
SO	Journal	0	0.00%	Excellent	0	0.00%	Excellent
LA	Language	0	0.00%	Excellent	0	0.00%	Excellent
PY	Publication year	0	0.00%	Excellent	0	0.00%	Excellent
SC	Science categories	0	0.00%	Excellent	1929	100.00%	Completely missing
TI	Title	0	0.00%	Excellent	0	0.00%	Excellent
TC	Total citation	0	0.00%	Excellent	0	0.00%	Excellent
AB	Abstract	0	0.00%	Excellent	0	0.00%	Excellent
RP	Corresponding author	12	0.86%	Good	555	28.77%	Poor
CR	Cited references	13	0.93%	Good	1929	100.00%	Completely missing
C1	Affiliation	13	0.93%	Good	47	2.44%	Good
DE	Keywords	136	9.75%	Good	244	12.65%	Acceptable
DI	DOI	149	10.68%	Acceptable	261	13.53%	Acceptable

As can be observed from Table 10, the data quality check revealed that both datasets show excellent data quality for most metadata fields, including author (AU), document type (DT), journal (SO), language (LA), publication year (PY), title (TI), total citation (TC), and abstract (AB), with no missing data. However, significant discrepancies exist in other fields:

- Science Categories (SC): Completely missing in the Scopus dataset, whereas the WoS dataset is complete.
- Corresponding Author (RP): The WoS dataset has a 0.86% missing rate (good), while the Scopus dataset has a 28.77% missing rate (poor).
- Cited References (CR): The WoS dataset has a 0.93% missing rate (good), but the Scopus dataset is completely missing this data.
- Affiliation (C1): The WoS dataset has a 0.93% missing rate (good), compared to a 2.44% missing rate (good) for the Scopus dataset.
- Keywords (DE): The WoS dataset has a 9.75% missing rate (good), while the Scopus dataset has a 12.65% missing rate (acceptable).
- DOI (DI): The WoS dataset has a 10.68% missing rate (acceptable), slightly better than the Scopus dataset with a 13.53% missing rate (acceptable).

In conclusion, while both datasets maintain excellent quality in several core fields, the Scopus dataset shows notable deficiencies in science categories, corresponding author, and cited references compared to the WoS dataset. This observation supports our initial decision to conduct the analysis in the present paper by using only the WoS database.

In the following, we present some results obtained through the use of the Scopus extracted dataset and compare the results with the ones obtained through the use of the WoS dataset.

First, in terms of annual scientific production—as presented in Figure 18—the same trend can be observed as in Figure 1, with the only difference represented by the inclusion of publications starting from 1986, rather than from 1992 as in the case of the WoS extracted dataset.

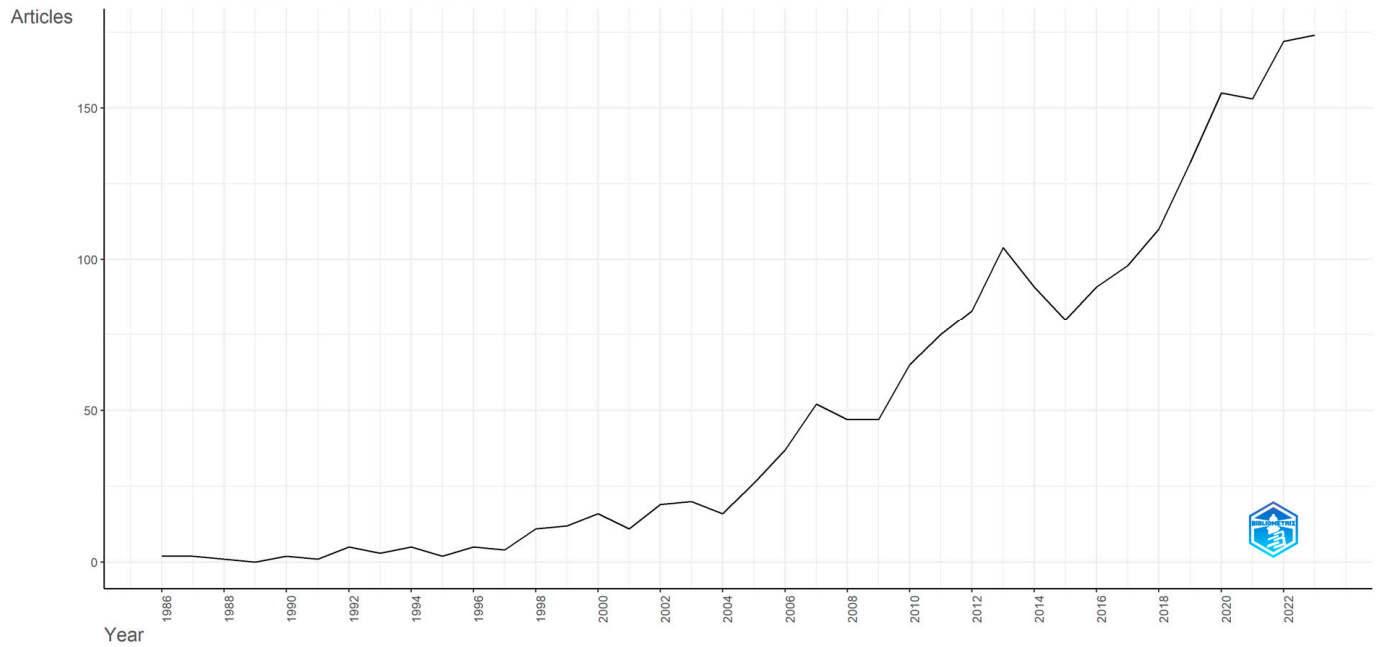

Figure 18. Annual scientific production (Scopus).

Second, in terms of the most relevant sources, the journal *Sustainability* (Switzerland) ranks first in both databases, with 65 publications in Scopus and 67 publications in WoS. The *International Journal of Productivity and Performance Management* holds second place in both Scopus and WoS, with 21 articles in each. This consistency indicates that the differences between the two databases are not significant enough to impact our results for the analyzed topic.

Furthermore, in Figure 19, we present a word cloud based on the authors' keywords from the Scopus database. The results obtained from the WoS database are similarly aligned, with "key performance indicators" being the central concept. Other prominent keywords include "performance measurement," "sustainability," "balanced scorecard," and "corporate social responsibility."

Figure 19. Word cloud based on authors' keywords—Scopus database.

Lastly, in Table 11, we present the top 7 most cited documents based on Scopus data. The ranking matches the one derived from the WoS source. The key difference is that the articles have more citations in Scopus, although the order remains the same.

Table 11. Top 7 most cited documents globally.

First Author, Year, Journal, References	Total Citations	Total Citation (TC) per Year	Normalized TC
Sun LY., 2007, *Academy of Management Journal*, (Sun et al. 2007)	1056	58.67	19.95
Hanna R., 2011, *Business Horizons*, (Hanna et al. 2011)	1037	74.07	31.29
Milne M.J., 2013, *Journal of Business Ethics*, (Milne and Gray 2013)	758	63.17	25.66
Ceccagnoli M., 2012, *MIS Quarterly*, (Ceccagnoli et al. 2012)	655	50.38	18.26
López M.V., 2007, *Journal of Business Ethics*, (López et al. 2007)	528	29.33	9.98
Lee A.H.I., 2008, *Expert Systems with Applications*, (Lee et al. 2008)	499	29.35	15.38
Hermann B.G., 2007, *Journal of Cleaner Production*, (Hermann et al. 2007)	280	15.56	5.29

Based on the above observations, it can be stated that similar trends are uncovered when using the Scopus database and WoS database for the field of key performance and risk indicators in Business.

5. Research Methodology

5.1. Conducting Bibliometric Analysis Using RStudio and VOSviewer

R is a programming language used for statistical computing and graphics, and RStudio is its integrated development environment (IDE). It offers a user-friendly interface that makes R more powerful and accessible to statisticians, data scientists, and academics (Hair et al. 2021).

A fundamental tool for data-driven research and decision-making, RStudio is excellent for data analysis, statistical testing, and data visualization. It is useful in many applications, from business analytics to academic research, thanks to its large package ecosystem and vibrant community (Gromping 2015).

Through comprehensive data visualization and reporting features, researchers may use RStudio to ensure repeatability, expedite workflow, and improve the impact and clarity of their findings.

Developed by Aria and Cuccurullo (2017), the Bibliometrix package in RStudio is an open-source tool used for quantitative and bibliometric research encompassing multiple analysis methods. Bibliometric analysis is considered a complex method applicable in any research area or discipline (Briner and Denyer 2012; Guler et al. 2016; Delcea et al. 2024), involving numerous complex stages. Several specialists recommend a workflow for scientific research analyses (Cobo et al. 2011; Zupic and Čater 2015), which includes five stages:

i. Study design, which may involve the narrative description of research hypotheses;
ii. Data collection using databases such as Scopus and Web of Science;
iii. Analysis of the extracted data;
iv. The use of specific techniques or tools for data visualization;
v. Interpretation of the results.

In our bibliometric study, we address the five stages to conduct a bibliometric analysis on scientific research in the field of KPI and KRI usage in business.

In Figure 20, a methodological diagram illustrating the data selection process and the stages of bibliometric analysis used in this study is presented. This approach aids in visualizing how the data were selected and processed, facilitating understanding of the analytical process employed in our study.

Initially developed in 2010 (Meng et al. 2020), VOSviewer 1.6.20 is a software solution that allows for the creation of maps based on input data extracted from data sources such as Web of Science (WoS), useful for bibliometric analysis. Elements in these networks

can be linked by co-authorship, co-appearance, citation, bibliographic, or co-citation links (Martins et al. 2022).

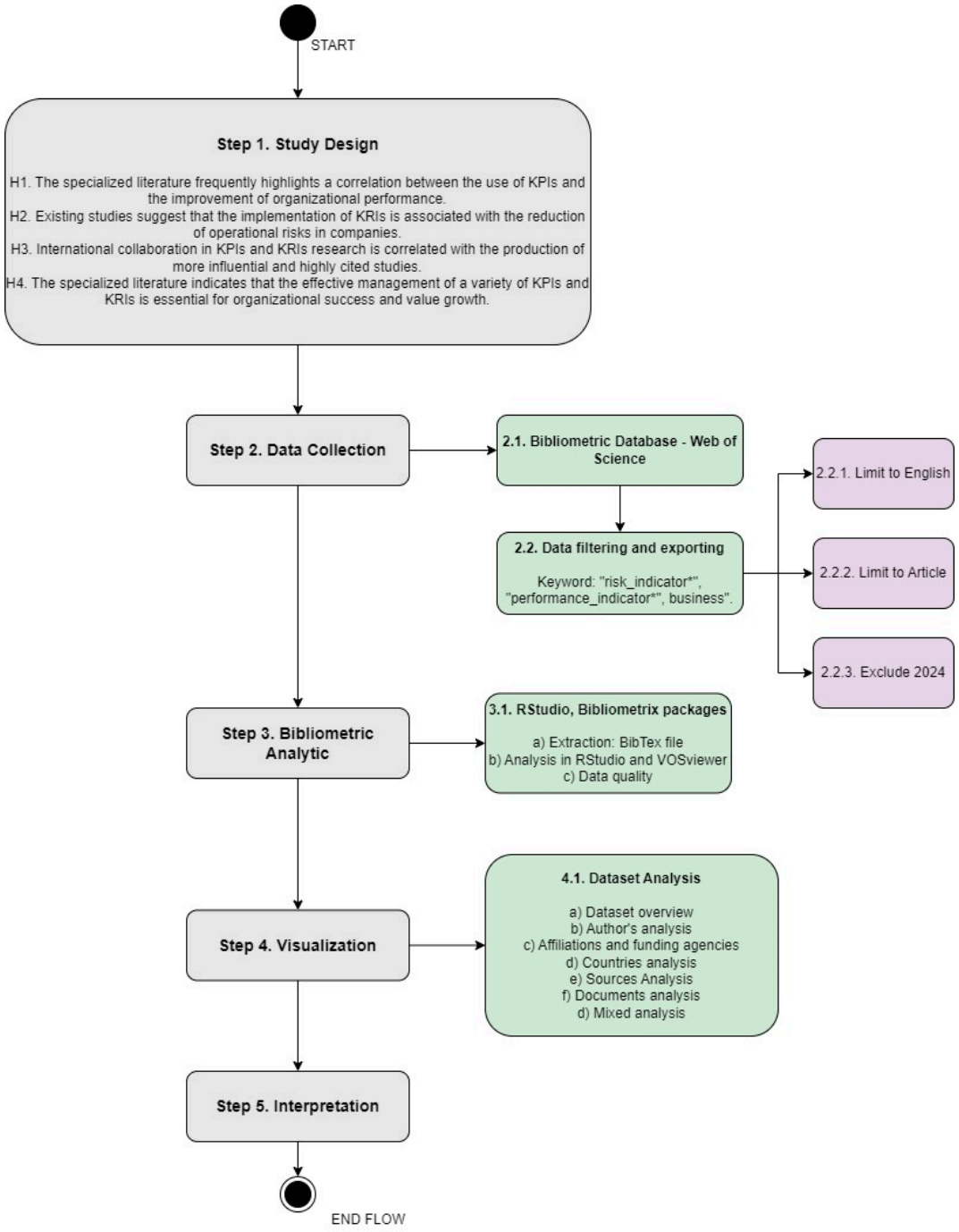

Figure 20. Methodological flow.

Bibliometric analysis is an essential tool for evaluating and understanding the academic literature in a specific field (Delcea et al. 2023; Ionescu et al. 2024). By using bibliometric techniques, researchers can identify research trends, collaborations between authors and institutions, and the influence of certain works or authors in the field (Nica et al. 2024a). This type of analysis helps map the research landscape, highlighting emerging themes and knowledge gaps (Nica et al. 2024b). In our study, bibliometric analysis allows for us to discover research trends in the use of KPIs and KRIs in business, showing the evolution of academic and practical interest. Additionally, by identifying the most cited

works and authors, we can determine the impact and influence of certain studies on the field, providing a framework for evaluating research quality and relevance. Moreover, the Bibliometrix platform enables us to conduct co-authorship and international collaboration network analyses, helping visualize research partnerships and highlighting cooperation between different institutions and countries. Another perspective we explore is the identification of emerging research themes. Through keyword co-occurrence, we can identify emerging research topics, offering insights into future study directions in the use of KPIs and KRIs. Thus, the results obtained from the bibliometric analysis can provide a solid basis for making informed decisions regarding research and development directions in the field of KPIs and KRIs.

5.2. Data Collection

In our study, we used the Web of Science (WoS) database of scientific publications to collect the data for analysis on the Bibliometrix platform using the *biblioshiny ()* library in RStudio. Although there are multiple data sources from which we can collect scientific research, such as Scopus, Crossref, or Dimensions, we decided to use the Web of Science platform because it has over 18 million documents, according to Visser et al. (2021). Although it is known that Scopus generally covers a larger database of scientific articles than WoS, this coverage varies greatly depending on the field of study (Thelwall et al. 2015; Mongeon and Paul-Hus 2016; Visser et al. 2021). For example, in Pranckutė's study (Pranckutė 2021), it was demonstrated that Scopus covers up to 99% of nursing journals that are also identified in WoS, whereas other studies focused on computer sciences cover only 63% of the documents retrieved by WoS and identified in Scopus (Bar-Ilan 2018). Moreover, to make an objective choice of the input data source, using the same queries, we extracted the database from Scopus to ensure that the results obtained from WoS are not skewed. It was observed that for our analyzed field, there were no significant differences, with both WoS and Scopus yielding the same results. Additionally, in the data quality stage, several criteria contain more missing data in Scopus than in WoS. This aspect cannot be generalized to any bibliometric research but only to our analyzed topic or other cases already identified in the scientific literature.

Regarding the dataset extraction, it is important to note that the WoS platform provides personalized access to data based on subscription. Consequently, as observed by (Liu 2019) and (F. Liu 2023), the results of bibliometric analysis are significantly influenced by the user's access to the ten indexes available on WoS. In this context, the authors recommend that bibliometric studies clearly specify the access levels users had to the WoS indexes (Liu 2019; F. Liu 2023).

The choice of the WoS platform is justified by its extensive coverage of a wide range of disciplines and its strong reputation within the scientific community, as highlighted in the literature (Cobo et al. 2015; Mulet-Forteza et al. 2018; Modak et al. 2019). Moreover, WoS is one of the few platforms that support data reading by both Bibliometrix and VOSviewer for datasets extracted based on the search criteria.

The first stage of the proposed five-step bibliometric analysis was conducted in the Introduction Section by defining four research hypotheses. The second stage involves data collection, as described in this subsection. Based on the established research hypotheses and the primary aim of our study, we selected the keywords "risk_indicator*", "performance_indicator*", and "business" for extracting scientific articles, with the asterisk "*" allowing for both singular and plural forms.

Within the WoS platform, using these keywords, we conducted the seven steps/queries described in Table 12.

In the first step, we searched for all scientific documents containing either the keyword "risk_indicator*" or "performance_indicator*" correlated with scientific articles that also contain the word "business" in the title. Thus, Query #1 extracted 64 scientific documents. In the second step, we performed the same query but for abstracts. Query #2 returned 2457 scientific documents. In Query #3, we conducted the same search but focused on

keywords, resulting in 231 documents. For Query #4, we used the "OR" operator to include all documents containing the keywords in the title, abstract, or keywords, resulting in 2602 scientific articles. The next query, #5, aimed to exclude all documents written in languages other than English, retaining only English-written articles. The English language is recognized as one of the most spoken international languages, facilitating the exchange of knowledge and collaboration among researchers from different countries. Bibliometric analysis requires a standardized approach to ensure data comparability and consistency. Translating articles from other languages would have been a complex process and could have introduced the risk of errors and ambiguities in interpreting the results. This query returned 2473 documents. Another criterion, Query #6, aimed to keep only scientific articles, resulting in 1489 documents. The final query, #7, excluded all articles from the year 2024, as they would not capture the full year's results or the scientific evolution of the last year. Thus, the analysis retained 1395 scientific documents.

Table 12. Data selection steps.

Exploration Steps	Questions on Web of Science/Scopus	Description	Query	Query Number	Count WoS
1	Title	Contains specific keywords related to risk indicators or risk indicators in business context	(((TI = (risk_indicator*)) OR TI = (performance_indicator*))) AND TI = (business)	#1	64
2	Abstract	Contains specific keywords related to risk indicators or risk indicators in business context	(((AB = (risk_indicator*)) OR AB = (performance_indicator*))) AND AB = (business)	#2	2457
3	Keywords	Contains specific keywords related to risk indicators or risk indicators in business context	(((AK = (risk_indicator*)) OR AK = (performance_indicator*))) AND AK = (business)	#3	231
4	Title/Abstract/ Keywords	Contains specific keywords related to risk indicators or risk indicators in business context	#1 OR #2 OR #3	#4	2602
5	Language	Contains only documents written in English	(#4) AND LA = (English)	#5	2473
6	Document Type	Limited to articles	(#5) AND DT = (Article)	#6	1489
7	Year published	Excludes 2024	(#6) NOT PY = (2024)	#7	1395

5.3. Quality Assessment of Bibliographic Data

In this stage of our analysis, we evaluated the completeness of various bibliographic metadata fields to ensure the quality and reliability of our dataset. This step is crucial, as it helps identify any gaps or missing information that could impact the accuracy and comprehensiveness of our bibliometric analysis (Delcea et al. 2023; Domenteanu et al. 2023; Sandu et al. 2024).

Table 13 evaluates the completeness of various bibliographic metadata fields in the dataset analyzed using Bibliometrix. We observe that the fields author (AU), document type (DT), journal (SO), language (LA), publication year (PY), science categories (SC), title (TI), total citations (TC), and abstract (AB) have no missing values, indicating complete and excellent-quality data. Good completeness with less than 1% missing is observed for corresponding author (RP) with 12 missing records, cited references (CR) with 13 missing records, and affiliation (C1) also with 13 missing observations. Additionally, for 149 records, DOI (DI) was not identified, indicating acceptable completeness. The metadata are mostly complete for the majority of fields, indicating good data quality for bibliometric anal-

ysis. However, the DOI field has significant gaps that may require attention to ensure comprehensive analysis.

Table 13. Completeness of bibliographic metadata.

Metadata	Description	Missing Counts WoS	Missing (%) WoS	Status WoS
AU	Author	0	0.00%	Excellent
DT	Document type	0	0.00%	Excellent
SO	Journal	0	0.00%	Excellent
LA	Language	0	0.00%	Excellent
PY	Publication year	0	0.00%	Excellent
SC	Science categories	0	0.00%	Excellent
TI	Title	0	0.00%	Excellent
TC	Total citation	0	0.00%	Excellent
AB	Abstract	0	0.00%	Excellent
RP	Corresponding author	12	0.86%	Good
CR	Cited references	13	0.93%	Good
C1	Affiliation	13	0.93%	Good
DE	Keywords	136	9.75%	Good
DI	DOI	149	10.68%	Acceptable

6. Conclusions

The study of key performance indicators (KPIs) and key risk indicators (KRIs) in business holds major relevance in the current context of organizational management. KPIs and KRIs are essential tools that help organizations monitor and improve performance, manage risks, and make informed decisions. In a world characterized by economic uncertainty and rapid changes, the ability to efficiently use these tools can determine an organization's long-term success. Our research contributes to a deeper understanding of how KPIs and KRIs can be implemented and managed to achieve strategic objectives and ensure organizational sustainability and competitiveness. Our bibliometric analysis revealed several key conclusions regarding the research landscape on KPIs and KRIs in business. Highly cited studies, such as those by Sun et al. (2007) and Hanna et al. (2011), emphasize the importance of KPIs in various organizational contexts, from human resource management to social media marketing. The frequent observations of the term's "sustainability" and "corporate social responsibility" in keywords indicate a growing concern for sustainability and the social impact of businesses. Clustering and co-occurrence network analysis highlighted that central themes include performance measurement, supply chain management, and corporate social responsibility. The clusters demonstrate the thematic diversity and relevance of these subjects in the specialized literature, indicating current research priorities.

Our results indicate that sustainability should be promoted. Considering the growing significance of the topic in both practice and research (Van De Ven et al. 2023), organizations should incorporate KPIs related to sustainability and corporate social responsibility into their strategic planning to ensure a sustained positive impact. Additionally, implementing and monitoring KRIs should be a priority (Mouatassim and Ibenrissoul 2015) to efficiently anticipate and manage operational risks. Moreover, promoting international research partnerships can lead to more robust and influential results, as evidenced in our analysis. Also, our findings confirm the initial hypotheses, demonstrating a positive correlation between the use of KPIs and the improvement of organizational performance, as well as the significant contribution of KRIs to reducing operational risks. The data support the hypothesis that international collaboration in KPI and KRI research leads to more influential studies. Furthermore, the effective management of a variety of KPIs and KRIs is important for organizational success and value growth. Based on the findings, we recommend that companies integrate both KPIs and KRIs into their management systems to improve performance and proactively manage risks. Researchers should further explore the interdependencies between these indicators to develop more robust models. Additionally,

future research should focus not only on qualitative analysis but also on exploring the impact of KPIs and KRIs across various industries and cultural contexts. Comparative studies between industries could provide valuable insights.

Regarding the limitations of our research, although the bibliometric analysis provides valuable information and a detailed holistic perspective, an extended qualitative analysis could further enhance our understanding of research themes, especially regarding KRIs. Another potential limitation could be the dependence on specific data sources (e.g., WoS, Scopus) in bibliometric analysis, and that the effectiveness of Bibliometrix may vary depending on the comprehensiveness and quality of data obtained from these sources. Excluding certain databases or non-indexed publications could limit the coverage and representativeness of bibliometric analyses. Therefore, another direction for future research could focus on conducting a comprehensive analysis by combining multiple specific databases.

Organizations can use the findings of this study to enhance their strategic decision-making processes through the efficient implementation of key performance indicators and key risk indicators. Our study demonstrates that the use of KPIs is positively associated with improving organizational performance, while KRIs play an important role in operational risk management by early identification of potential threats. Organizations should integrate these tools into their management systems to gain a comprehensive view of operations and facilitate informed decision-making. Implementing KPIs for performance measurement and simultaneous monitoring of KRIs for risk management ensures organizational success in a dynamic and fluctuating business environment.

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Impact of Audit Fees on Earnings Management and Financial Risk: An Analysis of Corporate Finance Practices

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Abstract: This study employs a robust quantitative ex post facto research design to investigate the complex relationship between audit fees and earnings management. The financial information of 164 firms admitted to the Tehran Stock Exchange (TSE) was used from 2010 to 2019 (pre-COVID period) to achieve the research goal. Analysing data from the Tehran Stock Exchange firms, the study uncovers an inverted U-shaped relationship between audit fees and earnings management. This suggests that moderate audit fees can lead to higher earnings management. Key contributions of this paper include highlighting the role of audit fees in influencing financial reporting quality and risk management, providing empirical evidence on the asymmetric effects of normal and abnormal audit fees on earnings management, and emphasising the need for balanced audit fee structures to ensure financial transparency and mitigate risk. The findings offer valuable insights for academics, practitioners, and policymakers in understanding the nuances of audit fees and their impact on corporate financial practices. This study advances the literature on financial risk management and corporate finance. It emphasises the importance of balanced audit fee structures for management teams, auditors, and policymakers to ensure transparent financial reporting practices.

Keywords: corporate finance; earnings management; financial risk; accounting comparability; financial reporting

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1. Introduction

As a measure of financial information quality, accounting comparability allows users to identify similarities and differences between items in financial statements and more rationally assess various lending-based investment opportunities (FASB 2010). For information comparability, similar items should be the same, and different items should seem different (Barth et al. 2018). The accounting comparability of financial information is so crucial that concept statement No. 8 of the Financial Accounting Standards Board addresses the increased financial information comparability as one of the most critical reasons that financial reporting standards are needed (Choi et al. 2019). Paying compensation and bonuses to managers as part of their wages is one of the most widely used practices motivating them to increase shareholders' wealth (Henderson and Fredrickson 2001). Compensation for firm managers usually includes fixed salary, cash, and non-cash bonuses. Theoretically, cash bonuses paid to managers are expected to suit their performance, resulting in more shareholder benefits (Zhang et al. 2018). Healy (1985) shows that compensation plans encourage managers to employ earnings management practices to maximise rewards. Therefore, managers can manipulate earnings to increase their rewards. A solution to this problem is to improve accounting information comparability. This concept can be viewed from internal and external aspects. Internal accounting comparability refers to a firm's consistency of practices over years of activity, whereas external accounting comparability shows a firm's status among peer firms (Lobo et al. 2018). Companies whose accounting systems are

similar to their peer firms are more likely to adjust their managers' compensation contracts based on accounting profits.

Many studies have shown that audit fees affect the quality of financial reporting (Gu and Hu 2015; Gandía and Huguet 2021). The findings indicate that audit fees may affect the quality of financial reporting in different economic settings. Nevertheless, it is noteworthy that accounting comparability, as a measure of financial reporting quality, may be influenced by audit fees as a measure of audit quality. As mentioned earlier, since accounting comparability can affect managers' compensation, it can be argued that audit fees, as a proxy for audit quality, can influence the relationship between accounting comparability and board compensation. This topic has not been investigated in previous research and has been neglected to some extent. This research examines the critical issue of audit fees and the relationship between comparability and compensation. Of course, looking at the previous study, it can be seen that the relationship between comparability and compensation has already been investigated by Lobo et al. (2018), Nam (2020), and Fattahi et al. (2021). However, in the scope of these studies, the effect of audit fees has not been investigated. Therefore, by taking the help of and following the previous literature, the current research tries to examine the existing literature in the field of financial reporting and the role of auditors' fees in its change.

On the other hand, Frankel et al. (2002) state that companies paying higher audit fees exhibit a lower level of earnings management, suggesting the additional fee charged by auditing firms may increase the auditing quality. Ferguson et al. (2004) showed that non-audit services fees negatively affect the accountant's independence. Their findings also reveal a positive relationship between the non-audit services fee and discretionary accruals. Antle et al. (2006) try to justify the relationship between audit fees and earnings management and argue that various economic factors and conditions may affect this relationship. Such studies indicate that audit fees can affect earnings management.

Given the above, in addition to examining the moderating effect of audit fees on the relationship between comparability and rewards, this study investigates the impact of audit fees on earnings management (actual and real) in a relatively risky environment with a high inflation rate. Previous research has investigated the relationship between audit fees and earnings management in other countries. For example, Gandía and Huguet (2021) investigated the relationship between remuneration and earnings management from the perspective of the type of auditor. Also, Donatella et al. (2019) investigated the impact of audit fees on earnings management in Swedish companies. In addition, Ben Abdelaziz et al. (2022) have conducted a similar study but introduced audit fees as a factor in reducing earnings management, which was followed by other studies such as Shehadeh et al. (2024) and Santos Jaén et al. (2023). Previous studies' primary focus has been examining the direct relationship between these two variables. However, the current research is the first conducted in Iran's economic environment, which has a high inflation rate and risky financial conditions. The audit fee is divided into normal and abnormal fees, and the asymmetric influences on earnings management are investigated. The study further investigates the relationship between earnings management, as the output of the financial reporting system (Wen et al. 2023), and compensation, which is influenced by the financial reporting system, with two measures of the financial reporting system, i.e., the comparability and audit fee.

The remainder of this paper is organised as follows: Section 2 presents the background and the development of the hypotheses. Section 3 outlines the data collection and describes the sample and research variables. Empirical models and econometrics results are shown in Section 4. Finally, discussion, conclusions and implications are provided in Section 5.

2. Literature Review

The audit fee is an essential indicator for assessing organisations' financial statements (Christensen et al. 2021). Simunic (1980) suggests a relationship between audit fees and audit risk. Many studies have shown a direct association between audit risk and fees (Sonu

et al. 2017). If comparability improves the quality of the accounting managerial estimates, the misstatement risk should be reduced irrespective of other factors. Comparability, which leads to the quality reporting of financial information, should decrease the inherent audit risk and reduce the audit fee.

On the other hand, the complexity of the entity is one of the factors that causes an increase in the audit fee (Lee et al. 2024). Entities that are more complex in operation and structure could pay more to the managers to control the process (Kalelkar et al. 2024). Furthermore, managers who gain a more significant earnings margin for the entity deserve more compensation. When the firm's operation is large-scale and complex, demand for supervision in financial reporting increases. Entities with complex procedures require a high level of audit services. As a result, they pay higher fees to the audit firms, which suggests that as the complexity of the entity's operation increases, the management's compensation amount also rises (Saleh and Ragab 2023).

Audit fees could be considered as a measure of an entity's reporting complexities (Wysocki 2010). Investors, shareholders, and other stakeholders pursue quality information and a lower level of risk simultaneously, and the management, as their representative, tends to maximise its compensation by improving its plans and performance and decreasing information uncertainty risk. Audits play an overriding role in bridging these groups together so that receiving a greater audit fee appears as an assurance concerning the management's performance and compensation by the manager (Utomo and Machmuddah 2023). So, it could be predicted that the audit fee will decrease as comparability increases, resulting in a decline in executive compensation. However, it can be argued that an increase in comparability could lead to a rise in executive compensation, highlighting the contradictory impact of audit fees on the relation between the comparability of the accounting information and executive compensation. Wysocki (2010) argues that if the settlements concerning the compensation are determined appropriately, the management will be motivated to perform better, which may reduce the need for audit activities.

Concerning this argument, the negative association between audit fees and compensation could be predicted. However, the audit fee could be another proxy connected with earnings management and financial reporting quality, which justifies the negative association between the comparability of accounting information and executive compensation.

To pursue a better analysis of the modifier and contradictory influence of the audit fee, Simunic (1980) considered normal and abnormal audit fees. Ridzky and Fitriany (2022) divide audit fees into 'normal' and 'abnormal' to examine the impact of audit fees on audit quality. They define an abnormal audit fee as the difference between the actual and normal fees (which could be different in different cities and countries) paid by the auditee to the external auditor. They further divide the abnormal audit fees into 'premium' and 'discount' audit fees. They describe the premium audit fee as the actual audit fee above the normal and call it a negative abnormal audit fee (discount) if it is below the normal. Given the above, we propose our first hypothesis as follows:

Hypothesis 1 (H1): *Audit fees have a differential impact on the relationship between accounting comparability and executive compensation performance.*

Hypothesis 1a (H1a): *Normal audit fees positively moderate the relationship between accounting comparability and executive compensation performance. This implies that standard audit fees contribute to improved accounting comparability, thereby enhancing the alignment of executive compensation with firm performance.*

Hypothesis 1b (H1b): *Abnormal audit fees (premium and discount) affect the relationship between accounting comparability and executive compensation performance. Specifically, premium audit fees (above the normal) are expected to strengthen this relationship by ensuring higher quality. In contrast, discount audit fees (below the normal) may weaken the relationship due to compromised audit quality.*

Previous studies have examined the relationship between audit fees and earnings management (Gu and Hu 2015; Gandía and Huguet 2021). However, these studies produced mixed results. For instance, Frankel et al. (2002) indicated that firms that pay a higher audit fee reflect a lower level of earnings management, which refers to the additional fee required by audit firms that enhances the audit quality. Ferguson et al. (2004) demonstrated that fees related to non-audit services have a negative impact on an auditor's independence. Their findings indicated a positive association between fees related to non-audit services and discretionary accruals. It is also argued that improved comparability increases the quality of financial information reporting, which can reduce the auditor's assessment of the audit's inherent risk, thus reducing the audit fee. So, we look for a probable asymmetric association between audit fees and earnings management to justify the relationship between comparability, earnings management, and audit fees.

Audit firms determine the required fee amount based on their clients' observed features, such as size, complexity, risk structure of the firm, etc., which is called an audit fee. Conversely, any additional fee received based on the relationship between the audit firm and the clients that is not related to the client's features, such as size, complexity, etc., is defined as the abnormal level of the audit fee. Antle et al. (2006) provide various reasons regarding the correlation between audit fees and earnings management. They believe that different economic factors can affect this correlation; therefore, different results ensue in other economic environments and conditions. While previous research has concentrated on total audit fees and their association with earnings management, recent studies follow a new method by dividing the entire fees into two levels, normal and abnormal, and investigating the correlation between the abnormal level of audit fees and earnings management (Mitra et al. 2009). However, these studies have produced mixed results. For instance, Asthana and Boone (2012) reported that both abnormal levels of positive and negative audit fees negatively correlate with the quality of financial reports. In contrast, Blankley et al. (2012) and Eshleman and Guo (2014) indicated that the positive level of abnormal audit fees is positively related to the quality of financial reporting.

Using five theories, Antle et al. (2006) assessed the relationship between audit fees and earnings management. Basic economic theory suggests that providing audit and non-audit services to the client creates a financial bond between the audit firm and the client, which can jeopardise the auditor's independence. The supply and demand theories concerning services indicate that increased discretionary accruals lead to increased demand for audit services. For instance, a higher level of abnormal accruals is related to a higher probability of future litigation risk; therefore, auditors perform additional audit procedures to reduce these risks. Although the theory of bribery suggests that auditors perform audit procedures in line with client's expectations to ensure their position as their clients' audit firm in future periods, this point increases auditors' chances of receiving non-audit service fees from clients; therefore, they receive additional fees (Sarhan and Cowton 2024). The theory of bias suggests a bias in audit procedures in favour of the client when a well-built relationship is built between the auditor and the client due to a lengthy tenure period. Finally, the theory of production assumes that the level of abnormal accruals is reduced due to the provision of non-audit services. This means that the rise in the effectiveness or efficiency of clients' operations through non-audit services puts constraints on the flexibility of managers in earnings management. This literature demonstrates that the impact of audit fees on the earnings management process would differ depending on the condition of the auditor and the client. This means there is an asymmetric association between audit fees and earnings management. Figure 1 shows the conceptual model of the study.

Given the theoretical and empirical evidence, our second hypothesis about audit fees on earnings management is specified as follows:

Hypothesis 2 (H2): *The relationship between audit fees and earnings management is asymmetric and contingent on the nature of the audit fees (normal versus abnormal).*

Hypothesis 2a (H2a): *Normal audit fees are associated with reduced earnings management. This suggests that standard audit fees provide adequate resources for auditors to conduct thorough audits, thereby mitigating earnings management practices.*

Hypothesis 2b (H2b): *Abnormal audit fees have an asymmetric effect on earnings management. Premium audit fees (above the normal) will likely reduce earnings management due to increased scrutiny and higher audit quality. In contrast, discount audit fees (below the normal) may be associated with increased earnings management due to potential reductions in audit quality and auditor independence.*

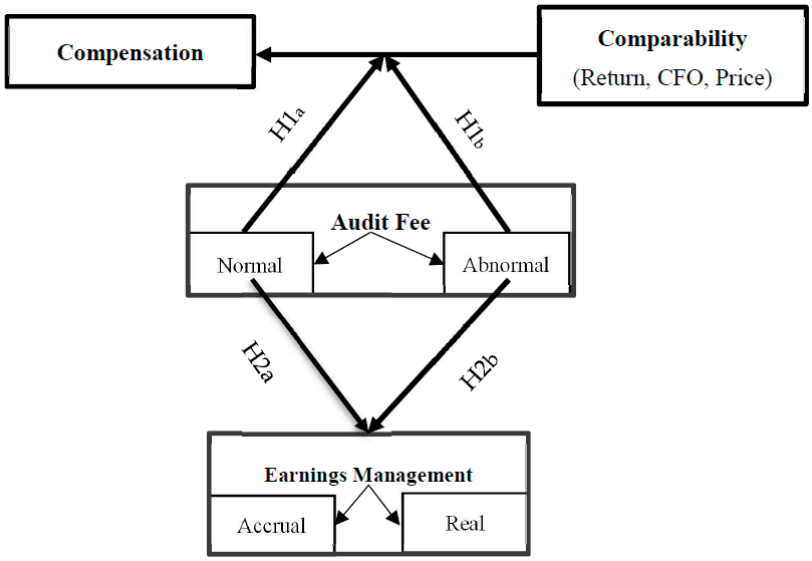

Figure 1. Research conceptual model.

3. Methodology

The present study employs a quantitative, ex post facto design. The population consists of all the companies listed on the Tehran Stock Exchange (TSE) from 2010 to 2019 (pre-COVID 19 period). We were able to add another 2–3 years of data to our sample, but due to the significant impact of COVID 19 on the performance and function of most firms, we excluded the data related to the COVID 19 Period. Data are primarily based on the TSE's audited financial statements and board reports, a reliable source of information (Daryaei et al. 2022; Namakavarani et al. 2021; Zadeh et al. 2022; Shandiz et al. 2022). However, the study compiles a purposive sampling; thus, financial firms such as banks and insurance firms are absent, because they have different conditions concerning firm characteristics. Listing firms must also have continuous operations during the study period, and their information must be available. Following these criteria, the study includes 164 firms (1640 firm-years). Purposive sampling was used to select a representative sample with the following four inclusion criteria (see Table 1).

Table 1. Sample computation for firms.

Sample Computation for the Year 2010–2019	Firms	(%)
Total population Less:	533	100
Firms inactive between 2010–2019	(189)	(35)
Financial services firms	(52)	(10)
Firms that did not provide complete information	(48)	(9)
Firms that were admitted to the stock market from 2010	(80)	(15)
Final sampled firms	**164**	**31**

Source: Created by authors.

4. Empirical Models and Econometrics Results

Table 2 presents the summary statistics of the variables. We utilised the one-way analysis of variance test (ANOVA) and Kruskal–Wallis test because they determine the difference between industrial sectors based on explanatory and control variables (see Table 3, Panel A). After data collection, we must ensure their stationary and non-stationary status to avoid false regression. ADF–Fisher tests were used, since the applied regression method involved ordinary data. Results are shown in Table 3.

Table 2. Descriptive statistics.

Variables	Mean	Median	Max	Min	Std	n
COMPENSATE	4.534	6.291	12.004	0.000	3.394	1640
COMP_CFO	−0.072	−0.062	−0.006	−0.255	0.035	1640
COMP_RET	−0.120	−0.105	−0.025	−0.504	0.061	1640
COMP_PRC	−5047.168	−3422.600	−1.514	−42,814.63	5044.544	1640
SQR	22.816	24.000	42.000	0.000	6.651	1640
CORR_ROA	0.367	0.701	1.000	−1.000	0.689	1640
CORR_CF	0.200	0.384	0.999	−0.999	0.706	1640
CORR_RET	0.457	0.787	1.000	−1.000	0.648	1640
INDHERF	0.221	0.245	0.482	0.000	0.124	1640
SIZE	13.819	13.614	19.374	9.797	1.571	1640
BM	0.515	0.418	1.974	−1.559	0.409	1640
LEV	0.588	0.563	1.363	0.012	0.214	1640
ROA	0.170	0.145	0.803	−0.729	0.156	1640
ADJROA	0.002	−0.003	0.563	−0.938	0.135	1640
RET	0.106	0.093	0.989	−0.997	0.317	1640
ADJRET	0.001	−0.009	1.092	−1.200	0.284	1640
GROWTH	0.194	0.161	1.460	−0.964	0.327	1640
DIVYIELD	0.105	0.078	0.809	0.000	0.114	1640
RETVOL	0.218	0.186	0.768	0.002	0.141	1640
CFVOL	0.076	0.061	0.619	0.000	0.060	1640
EM_ACC	0.000	0.000	0.900	−0.699	0.103	1640
ABAFEE	−0.003	0.001	2.700	−2.657	0.655	1640
LAF	6.620	6.731	9.606	2.928	1.362	1640
NFEE	6.624	6.514	8.860	4.683	1.207	1640

Table 3. (Panel A): ANOVA and Kruskal–Wallis of variables across twenty-four industrial sectors. (Panel B): ADF–Fisher. Null: Unit root (assume standard unit root test).

Panel A			**Panel B**
Variables	**ANOVA (F)**	**Kruskal-Wallis (χ^2)**	**t-Statistics**
COMPENSATE	16.071 ***	308.324 ***	497.251 ***
COMP_RET	12.011 ***	256.126 ***	519.336 ***
COMP_RET	19.203 ***	318.874 ***	609.562 ***
COMP_PRC	17.305 ***	128.347 ***	437.164 ***
SQR	23.622 ***	547.824 ***	692.3216 ***
CORR_ROA	14.459 ***	361.213 ***	806.228 ***
CORR_CF	18.154 ***	327.267 ***	659.450 ***
CORR_RET	11.240 ***	471.289 ***	647.330 ***
INDHERF	14.642 ***	241.478 ***	708.029 ***
SIZE	11.246 ***	502.545 ***	415.260 ***
BM	14.913 ***	139.115 ***	558.116 ***
LEV	11.315 ***	207.831 ***	352.283 ***
ROA	12.459 ***	336.643 ***	549.686 ***
ADJROA	18.914 ***	327.267 ***	553.628 ***
RET	10.210 ***	471.289 ***	967.044 ***

Table 3. *Cont.*

Panel A			Panel B
Variables	**ANOVA (F)**	**Kruskal-Wallis (χ^2)**	**t-Statistics**
ADJRET	15.642 ***	141.478 ***	953.812 ***
GROWTH	11.246 ***	502.555 ***	977.738 ***
DIVYIELD	14.130 ***	139.115 ***	604.402 ***
RETVOL	11.243 ***	207.831 ***	466.964 ***
CFVOL	14.910 ***	236.643 ***	557.470 ***
EM_ACC	13.246 ***	241.873 ***	539.182 ***
ABAFEE	13.031 ***	539.551 ***	604.402 ***
LAF	15.142 ***	377.381 ***	664.694 ***
NFEE	13.019 ***	362.346 ***	575.074 ***

*** $p < 0.001$.

To examine H1a, we estimate Equation (1) with the interaction term.

$$\begin{aligned} COMPENSATION_{i,t} = \; & \beta_0 + \beta_1 COMP\_I_{i,t-1} + \beta_2 ABAFEE_{i,t} + \beta_3 ABAFEE_{i,t-1} * COMP_{Ii,t-1} \\ & + \beta_4 CORR\_ROA_{i,t-1} + \beta_5 CORR\_CFO_{i,t-1} + \beta_6 CORR\_RET_{i,t-1} \\ & + \beta_7 INDHERF_{i,t-1} + \beta_8 SIZE_{i,t-1} + \beta_9 BM_{i,t-1} + \beta_{10} LEV_{i,t-1} + \beta_{11} ROA_{i,t-1} \\ & + \beta_{12} ADJROA_{i,t-1} + \beta_{13} RET_{i,t-1} + \beta_{14} ADJRET_{i,t-1} + \beta_{15} GROWTH_{i,t-1} \\ & + \beta_{16} DIVYELD_{i,t-1} + \beta_{17} RETVOL_{i,t-1} + \beta_{18} CFVOL_{i,t-1} \\ & + YEAR\&FIRMFIXED + \varepsilon_{i,t} \end{aligned} \quad (1)$$

The dependent variable, *COMPENSATION*, is an indicator that equals the natural logarithm of cash compensation. We use three measures of accounting comparability (*COMP_I* is the annual decile rank of *COMP_CFO*, *COMP_RET, COMP_PRC*) based on the underlying logic that the accounting of two firms is more comparable if they report similar accounting amounts when they experience identical economic outcomes (Lobo et al. 2018).

Measure 1: The relationship between the profit in year t and the cash flow from year t − 1 operation is calculated using Equation (2).

$$Cfo_{i,t+1} = \beta_0 + \beta_1 NI_{i,t} + \varepsilon_{i,t} \quad (2)$$

$CFO_{(i,t)}$ is cash flow from operations divided by beginning total assets.
$NI_{(i,t)}$ is net income after deducting the current year's tax divided by the beginning total assets.

In the first step, each year, the firm calculates the β_0 and β_1 coefficients using Equation (2) and 14 years of data. Coefficients for each firm in each year represent the firm's accounting systems characteristics. In the next step, the calculated coefficients are put into Equation (2), and cash flows from firm i's expected operating activities are estimated for the same year. Suppose the logic is based on the similarity of firms' i's and j's accounting systems. In that case, the output from the estimate of the cash flows from the expected operations of firm i must show similar figures to the output of firm j's coefficients (Equation (3)).

Equation (3) is the estimate of the future cash flows for firm i based on the firm i's coefficients:

$$E(Cfo)_{i,i,t+1} = \hat{\beta}_{0,i} + \hat{\beta}_{0,i} NI_{i,t} \quad (3)$$

Equation (4) is the estimate of the future cash flows for firm i based on firm j's coefficients:

$$E(Cfo)_{i,j,t+1} = \hat{\beta}_{0,j} + \hat{\beta}_{1,j} NI_{i,t} \quad (4)$$

The more comparable the two firms' accounting systems are, the smaller the difference in the expected cash flows of the peer firms would be. According to the above, the comparability between firms i and j based on measure 1 is calculated as follows:

$$CompCfo_{i,j,t} = -\frac{1}{10} \times \sum_{t-9}^{t} \left| E(Cfo)_{i,i,t+1} - E(Cfo)_{i,j,t+1} \right| \tag{5}$$

Comparability is calculated for every pair of firms in the industry for the years under assessment. It means that, according to Equation (4), the cash flows from the expected operations for firm i are estimated based on this firm's equation and firm j's equation, which is its peer firm, and also the cash flow difference from operations of each firm and its peers is calculated every year. After organising all the obtained combinations of firm i, the COMP variable could be calculated for the $COMP_{i,j,t}$ through the average of the obtained numbers. So, the comparability figure for each firm year is achieved.

Measure 2: Model (6) calculates the accounting comparability by using the firm's schedule around the level and changes of the EPS and stock return.

$$\begin{aligned} Return_{i,t} = \beta_0 + \beta_1 \tfrac{NI_{i,t}}{P_{i,t}} + \beta_2 \tfrac{\Delta NI_{i,t}}{P_{i,t}} + \beta_3 LOSS_{i,t} + \beta_4 LOSS_{i,t} \times \tfrac{NI_{i,t}}{P_{i,t}} \\ + \beta_5 LOSS_{i,t} \times \tfrac{\Delta NI_{i,t}}{P_{i,t}} + \varepsilon_{i,t} \end{aligned} \tag{6}$$

$RETURN_{(i,t)}$: Annual stock return of the firm i in the current year.
$NI/P_{(i,t)}$: Net income after deducting tax per share in the current year divided by the beginning share price for firm i.
$\Delta NI/P_{(i,t)}$: Changes in net income per share in the current year compared to the previous year divided by the beginning share price for firm i.
$LOSS_{(i,t)}$: An artificial measure of a firm's loss. If the firm is unprofitable, it equals one. Otherwise, it equals zero.

To calculate accounting comparability through measure (2), the processes in Equations (2) and (3) are conducted. Therefore, comparability through measure (2) is calculated by using Equation (7):

$$CompReturn_{i,j,t} = -\frac{1}{10} \times \sum_{t-9}^{t} \left| E\Big(Return \Big)_{i,i,t} - E\Big(Return \Big)_{i,j,t} \right| \tag{7}$$

Measure (3): In this measure, using model (8), the relationship between net income per share and book value of the shareholder's equity per share with closing price per share in the current year is used to calculate accounting comparability.

$$Price_{i,t} = \beta_0 + \beta_1 NIPS_{i,t} + \beta_2 BVPS_{i,t} + \varepsilon_{i,t} \tag{8}$$

$Price_{(i,t)}$: Closing price per share in the current year.
$NIPS_{(i,t)}$: Net income after deducting tax per share for firm i in the current year.
$BVPS_{(i,t)}$: Book value of the shareholder's equity per share at the end of the period for firm i.

To calculate financial information through measure (3), the processes in Equations (2) and (3) are conducted. Therefore, financial information comparability through measure (3) is calculated by using Equation (9):

$$CompReturn_{i,j,t} = -\frac{1}{10} \times \sum_{t-9}^{t} \left| E\,(\,Price\,)_{i,i,t} - E\,(\,Price\,)_{i,j,t} \right| \tag{9}$$

ABAFEE refers to abnormal audit fees and is calculated by the residual of the following model (Blankley et al. 2012):

$$\begin{aligned} LAF_{i,t} = \beta_0 + \beta_1 LTA_{i,t} + \beta_2 CR_{i,t} + \beta_3 CA\_TA_{i,t} + \beta_4 ARINV_{i,t} + \beta_5 ROA_{i,t} + \beta_6 LOSS_{i,t} \\ + \beta_7 FOREIGN_{i,t} + \beta_8 LEV_{i,t} + \beta_9 INTANG_{i,t} + \beta_{10} OPINION_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{10}$$

where *LAF* denotes logarithm of audit fees in year t; *LTA* is the logarithm of end-of-year total assets in year t; *CR* is current assets divided by current liabilities in year t; *CA_TA* is current assets divided by total assets in year t; *ARINV* is the sum of accounts receivable and inventory divided by total assets in year t; *ROA* is earnings before interest and taxes divided by total assets in year t; LOSS is 1 if firm incurred a loss in year t and is 0 if otherwise; *FOREIGN* is 1 if the firm has any foreign operations in year t and is 0 if otherwise; *LEV* is long-term debt divided by total assets in year t; *INTANG* is the ratio of intangible assets to total assets in year t; *OPINION* is 1 if the auditor issues a going concern audit opinion and is 0 if otherwise in year t.

$CORR\_ROA_{(i,t-1)}$: Correlation between the average return of the current assets in the current year in firm i and its peer firms in the industry.

$CORR\_CF_{(i,t-1)}$: Correlation between the average cash flows from operations in the current year in firm i and its peer firms in the industry.

$CORR\_RET_{(i,t-1)}$: Correlation between the average annual return of the share in firm i and its peer firms in the industry.

$INDHERF_{(i,t-1)}$: Herfindahl–Hirschman Index, which is calculated by adding a market share of all active firms in the industry to the power of 2 by using Equation (10):

$$HHI = \sum_{i=1}^{k} {s_i}^2 \tag{11}$$

HHI: Herfindahl–Hirschman Index. K is the number of active firms in the market, and Si is the market share of firm i, which is calculated using Equation (11).

$$S_i = \frac{X_j}{\sum_{l=1}^{n} X_j} \tag{12}$$

X_j: Indicates sales of firm j, and 1 represents industry type.

$SIZE_{(i,t-1)}$: Firm size equals the natural logarithm of the total closing assets.

$BM_{(i,t-1)}$: Dividing the book value of the shareholder's equity by the market value of the shareholder's equity.

$LEV_{(i,t-1)}$: Dividing total liabilities by total closing assets.

$ROA_{(i,t-1)}$: Assets return obtained by dividing current year operating profit by the average of the firm's total assets i.

$ADJROA_{(i,t-1)}$: Firm's assets return minus the average of the peer firm's assets return.

$RET_{(i,t-1)}$: Annual return of firm i.

$ADJRET_{(i,t-1)}$: Annual return of firm i's share minus the average return of the peer firm share in the industry.

$GROWTH_{(i,t-1)}$: Firm growth equals the annual sales return, which is calculated using Equation (12).

$$Growth_{i,t} = \frac{Sales_{i,t} - Sales_{i,t-1}}{Sales_{i,t-1}} \tag{13}$$

$Sales_{i,t}$: Total firm sales in the current year.

$Sales_{i,t-1}$: The firm's sales in the previous year.

$DIVYIELD_{(i,t-1)}$: Dividing the total approved dividend in the current year by the market value of firm i's shares.

$RETVOL_{(i,t-1)}$: Standard deviation of firm i's annual return of the shares. A three-year measure of the standard deviation of the annual return is used to calculate firm i's yearly return on the shares.

$CFVOL_{(i,t-1)}$: Dividing the standard deviation of the cash flows from operations in the current year by the total beginning assets of firm i. A three-year measure of the standard deviation of the cash flows from operations is used to calculate the standard deviation of the cash flows from firm i.

5. Findings

The findings from the H1a test are provided in Table 4. The results of this test indicate that abnormal audit fees did not influence the board's compensation. Also, on the grounds of these findings, it could be raised that they improve the relationship between accounting comparability through the third criterion (relationship between stock price with book value and earnings per share) and board compensation. According to the existing literature, several studies have found that abnormal audit fees negatively affect financial reporting quality (Asthana and Boone 2012). However, Blankley et al. (2012) and Eshleman and Guo (2020) found that abnormal audit fees positively correlate with quality financial reports. Based on the findings of this research, audit fees have been influential on the quality of financial reports and their relationship with board compensation only through the informativeness of accounting information, which positively impacts the relationship between accounting comparability and board compensation.

Table 4. Models for earnings management.

Models	R^2 (Adj)	F Statistic	AIC (1)	SC (2)	HQC (3)
Jones (1991)	0.309	3.774	−1.232	−0.823	−1.136
Dechow et al. (1991)	0.386	3.716	−1.125	−0.833	−1.068
Kasznik (1999)	0.567	11.582	−1.310	−0.957	−1.105
Dechow and Dichev (2002)	0.510	9.202	−1.186	−0.733	−1.081
McNichols (2002)	0.586	12.162	−1.344	−0.984	−1.136
Kothari et al. (2005)	0.293	3.665	−0.919	−0.426	−0.814

(1) Akaike criterion; (2) Schwarz criterion; (3) Hannan–Quinn criterion.

To examine $H1_b$, we estimate Equation (14) with the interaction term:

$$\begin{aligned} COMP\_C_{i,t} = \; & \beta_0 + \beta_1 COMP\_I_{i,t-1} + \beta_2 NFEE_{i,t} + \beta_3 NFEE_{i,t-1} * COMP_{Ii,t-1} + \beta_4 CORR\_ROA_{i,t-1} \\ & + \beta_5 CORR\_CFO_{i,t-1} + \beta_6 CORR\_RET_{i,t-1} + \beta_7 INDHERF_{i,t-1} + \beta_8 SIZE_{i,t-1} \\ & + \beta_9 BM_{i,t-1} + \beta_{10} LEV_{i,t-1} + \beta_{11} ROA_{i,t-1} + \beta_{12} ADJROA_{i,t-1} + \beta_{13} RET_{i,t-1} \\ & + \beta_{14} ADJRET_{i,t-1} + \beta_{15} GROWTH_{i,t-1} + \beta_{16} DIVYELD_{i,t-1} + \beta_{17} RETVOL_{i,t-1} \\ & + \beta_{18} CFVOL_{i,t-1} + YEAR\&FIRMFIXED + \varepsilon_{i,t} \end{aligned} \tag{14}$$

where *NFEE* refers to the normal audit fee and is calculated using the following:

$$LAF_{i,t} - \varepsilon_{i,t}$$

The findings of the H1b test are provided in Table 5. The results of this test depict that normal audit fees were productive on the board compensation only in the presence of the third criterion of comparability. However, the interaction between comparability criteria and normal audit fee indicates that the normal audit fee positively affects (rectifies) the relationship between accounting comparability and board compensation. These findings show that a normal audit fee is a productive factor in the quality of the financial reporting, impacts the information comparability, and ultimately affects the board compensation.

To test the H2, the non-linear method of smooth panel transition regression (PSTR) was used. The PSTR has the advantage of solving the baseline model's nonlinearity, heterogeneity, and time instability problems. Based on the PSTR specification, the regression coefficients change smoothly as a function of a threshold variable. Because the threshold variable is individual-specific and varies with time, it is possible to estimate regression coefficients at any time and for any firm in a panel. Therefore, this new econometric technique is an attractive approach for investigating the relationship between audit fees and earnings management. The PSTR model comprises many regimes and panel data observations regarding thresholds (Chiou and Lee 2011). We employed a PSTR model, recently developed by González and Teräsvirta (2006). to model the non-linear impact of audit fees on earnings management. This method has been employed in recent financial and

accounting studies (Daryaei and Fattahi 2020). Interestingly, as discussed in the literature, this method renders satisfactory results because of its robust theoretical foundations.

Table 5. Abnormal audit fee and accounting comparability.

Variable	COMP_CFO	COMP_RET	COMP_PRC
COMP_CFO	6.287 ** (3.043)	–	–
COMP_RET	–	2.739 *** (0.744)	–
COMP_PRC	–	–	3.86×10^{-5} *** (1.48×10^{-5})
ABAFEE	0.267 (0.226)	−0.160 * (0.089)	0.065 (0.054)
ABAFEE * COMP_CFO	5.434 (2.858)	–	–
ABAFEE * COMP_RET	–	−0.722 (0.707)	–
ABAFEE * COMP_PRC	–	–	2.14×10^{5} *** (8.15×10^{-6})
CORR_ROA	0.105 (0.106)	0.059 (0.049)	0.069 (0.042)
CORR_CF	−0.119 (0.103)	−0.044 (0.045)	−0.066 (0.041)
CORR_RET	0.109 (0.117)	0.035 (0.057)	0.022 (0.047)
INDHERF	−2.124 (1.862)	−2.300 * (1.176)	−3.015 *** (1.004)
SIZE	0.642 *** (0.076)	0.365 *** (0.044)	0.691 *** (0.038)
BM	0.493 ** (0.226)	0.120 (0.111)	0.072 (0.105)
LEV	1.391 ** (0.542)	0.558 ** (0.247)	0.476 ** (0.222)
ROA	0.462 (1.282)	1.011 * (0.609)	0.277 (0.533)
ADJROA	3.210 ** (1.280)	0.805 (0.610)	1.596 *** (0.504)
RET	1.659 *** (0.406)	0.503 *** (0.180)	0.595 *** (0.161)
ADJRET	−1.466 *** (0.444)	−0.504 ** (0.207)	−0.664 *** (0.176)
GROWTH	−0.213 (0.236)	−0.020 (0.109)	−0.025 (0.097)
DIVYIELD	1.356 ** (0.736)	0.903 ** (0.389)	0.977 *** (0.367)
RETVOL	1.324 (0.552)	0.573 ** (0.246)	0.459 ** (0.226)
CFVOL	0037 (1.278)	0.282 (0.612)	0.594 (0.457)
Hausman Test (χ^2)	32.619	39.004	39.860
R^2 (Adj)	0.504	0.862	0.899
F statistic	7.627 ***	47.029 ***	67.487 ***
DW	1.764	1.961	1.857

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

In this research, discretionary accruals have been used to measure earnings management. In the financial and accounting literature, these items are defined as reflections of the methods and procedures available to management (Kashmiri 2014). To estimate discretionary accruals, several models and patterns exist, such as Healy (1985), McNichols (2002), amd Kothari et al. (2005). There are two approaches to profit or loss, and the balance sheet approach is used to calculate the accruals. In the profit and loss approach, accruals are obtained through the difference between net profit and cash flows from operations, in which a cash flow statement plays a role. However, balance sheet-based accruals are measured by deducting current liabilities (except the current portion of long-term debt) from the changes of the non-cash current assets. In this study, due to the limitation in gathering information related to the current portion of long-term debt, the profit and loss-based approach was utilised to measure the accruals, which are calculated according to the following relationship:

$$TA_{it} = EBIT_{it} - CFO_{it}$$

As mentioned above, there are various models to evaluate discretionary accruals as the measure of earnings management, which means that under these circumstances, a model that is best compatible with the research environment and can test the characteristics of the firms should be utilised. Reviewing conducted research on Iran's economic climate indicates that there is more of a tendency towards the model of Jones and its modified model than any other model among discretionary accruals measurement models. However, irrespective of its reasons, another model may be more compatible with Iranian firms and could better describe this variable. Also, in this research, the measurement of discretionary accruals as earnings management was conducted on the grounds of Jones (1991), Kasznik (1999), Dechow and Dichev (2002), McNichols (2002), and Kothari et al. (2005), and the explanatory power, error level, and other estimated statistics and the model have had more favourable statistics to be selected as the model of the discretionary accrual's evaluation and earnings management criterion. Based on the results from Tables 6 and 7, it is shown that the coefficients of determination—the F statistic, Adjusted R-squared, Akaike criterion (AIC), Schwarz criterion (SC), and Hannan–Quinn criterion (HQC)—in the McNichols model yielded a more favourable condition compared to other models. For instance, the Adjusted R-squared in McNichol's model was 0.586, which indicates that it is the more influential the explanatory variable in the accruals.

Moreover, this model's AIC, SC, and HQC criteria were lower than in other models, indicating the model's higher precision. Therefore, the absolute value of the remainder of the McNichols (2002) model was utilised as the discretionary accruals to evaluate earnings management. Equations (15)–(20) show how to estimate discretionary accruals as an earnings management criterion:

$$\frac{TA_{it}}{A_{it-1}} = \beta_0 + \beta_1\left(\frac{1}{A_{it-1}}\right) + \beta_2\left(\frac{\Delta REV_{it}}{A_{it-1}}\right) + \beta_3\left(\frac{PPE_{it}}{A_{it-1}}\right) + \varepsilon \quad (15)$$

$$\frac{TA_{it}}{A_{it-1}} = \beta_0 + \beta_1\left(\frac{1}{A_{it-1}}\right) + \beta_2\left[\frac{(\Delta REV_{it} - \Delta AR_{it})}{A_{it-1}}\right] + \beta_3\left(\frac{PPE_{it}}{A_{it-1}}\right) + \varepsilon \quad (16)$$

$$\frac{TA_{it}}{A_{it-1}} = \beta_0 + \beta_1\left(\frac{1}{A_{it-1}}\right) + \beta_2\left[\frac{(\Delta REV_{it} - \Delta AR_{it})}{A_{it-1}}\right] + \beta_3\left(\frac{PPE_{it}}{A_{it-1}}\right) + \beta_4\left(\frac{\Delta CFO_{it}}{A_{it-1}}\right) + \varepsilon \quad (17)$$

$$\frac{TA_{it}}{A_{it-1}} = \beta_0 + \beta_1\left(\frac{1}{A_{it-1}}\right) + \beta_2\left(\frac{CFO_{it}}{A_{it-1}}\right) + \beta_3\left(\frac{CFO_{it-1}}{A_{it-1}}\right) + \beta_4\left(\frac{CFO_{it+1}}{A_{it-1}}\right) + \varepsilon \quad (18)$$

$$\frac{TA_{it}}{A_{it-1}} = \beta_0 + \beta_1\left(\frac{1}{A_{it-1}}\right) + \beta_2\left(\frac{\Delta REV_{it}}{A_{it-1}}\right) + \beta_3\left(\frac{PPE_{it}}{A_{it-1}}\right) + \beta_4\left(\frac{CFO_{it}}{A_{it-1}}\right) + \beta_5\left(\frac{CFO_{it-1}}{A_{it-1}}\right) + \beta_6\left(\frac{CFO_{it+1}}{A_{it-1}}\right) + \varepsilon \quad (19)$$

$$\frac{TA_{it}}{A_{it-1}} = \beta_0 + \beta_1\left(\frac{1}{A_{it-1}}\right) + \beta_2\left[\frac{(\Delta REV_{it} - \Delta AR_{it})}{A_{it-1}}\right] + \beta_3\left(\frac{PPE_{it}}{A_{it-1}}\right) + \beta_4 ROA_{it} + \varepsilon \quad (20)$$

Table 6. Normal audit fee and accounting comparability.

Variable	COMP_CFO	COMP_RET	COMP_PRC
COMP_CFO	18.252 ** (8.928)	-	-
COMP_RET	-	3.015 *** (0.613)	-
COMP_PRC	-	-	0.0001 ** (5.98×10^{-5})
NFEE	0.083 (0.152)	−0.131 (0.120)	0.373 *** (0.087)
NFEE * COMP_CFO	3.032 ** (1.378)	-	-
NFEE * COMP_RET	-	0.485 *** (0.162)	-
NFEE * COMP_PRC	-	-	3.30×10^{-5} *** (1.01×10^{-5})
CORR_ROA	0.043 *** (0.014)	0.042 * (0.023)	0.057 (0.055)
CORR_CF	−0.070 *** (0.023)	−0.053 * (0.030)	−0.096 ** (0.048)
CORR_RET	0.014 (0.033)	0.042 (0.042)	0.201 ** (0.094)
INDHERF	−2.870 ** (1.407)	−2.297 (1.572)	−8.034 *** (0.374)
SIZE	0.689 *** (0.064)	0.627 *** (0.067)	0.720 *** (0.037)
BM	0.074 (0.073)	0.108 (0.079)	0.449 *** (0.098)
LEV	0.394 *** (0.138)	0.468 *** (0.152)	−0.185 (0.214)
ROA	0.435 * (0.248)	1.209 *** (0.363)	4.476 *** (0.606)
ADJROA	1.520 *** (0.376)	0.710 * (0.431)	0.177 (0.826)
RET	0.514 *** (0.137)	0.483 *** (0.135)	0.814 *** (0.203)
ADJRET	−0.605 *** (0.124)	−0.517 *** (0.139)	−0.821 *** (0.177)
GROWTH	−0.031 (0.081)	−0.027 (0.078)	−0.324 *** (0.124)
DIVYIELD	0.924 *** (0.299)	0.911 *** (0.328)	−0.501 (0.689)
RETVOL	0.558 *** (0.198)	0.486 *** (0.176)	0.426 * (0.239)
CFVOL	0.351 (0.418)	0.330 (0.473)	−1.841 *** (0.704)
Hausman Test (χ^2)	35.483	37.124	40.011
R^2 (Adj)	0.892	0.865	0.518
F statistic	62.111 ***	48.591 ***	91.106 ***
DW	1.764	1.753	1.965

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 7. LM and LR tests for linearity.

Tests	M = 1	M = 2
Lagrange multiplier test (LM) *H*0: *r* = 0 vs. *H*1: *r* = 1	6.003 ***	0.657
Likelihood ratio test (LR.) *H*0: *r* = 0 vs. *H*1: *r* = 1	21.586 ***	1.554

*** $p < 0.001$.

The variables used in the various models of accrual earnings management are defined as follows:

TA is the total accruals in year t defined as earnings before extraordinary items and discontinued operations minus operating cash flows (from continuing operations); *A* denotes the total assets in year t − 1; ΔREV is the change in net sales from year t − 1 to year t; *PPE* is the gross value of property, plant, and equipment; ΔAR is the change in account receivables from period t − 1 to t; *CFO* denotes the operating cash flows from t; *ROA* is the annual income before extraordinary items divided by the beginning total assets.

The simplest case of a PSTR model with two extreme regimes is defined as follows:

$$\begin{aligned} EM\_ACC_{i,t} = \mu_1 + \quad & \beta_0(ROA_{i,t} + Lev_{i,t} + Size_{i,t}) \\ & + \sum_{J=1}^{r} \beta_j g\left(LAF_{i,t}; \gamma_j; c_k\right)(ROA_{i,t} + Lev_{i,t} + Size_{i,t}) + \varepsilon_{i,t} \end{aligned} \tag{21}$$

Let i = 1, … , N, and let t = 1, … , T, where *N* and *T* denote the total number of firms and the size of the sample period in the panel, respectively. The variable of *EM_ACC* is a dependent variable and refers to accrual earnings management estimated using the McNichols (2002) model.

$$\frac{TA_{it}}{A_{it-1}} = \beta_0 + \beta_1\left(\frac{1}{A_{it-1}}\right) + \beta_2\left(\frac{\Delta REV_{it}}{A_{it-1}}\right) + \beta_3\left(\frac{PPE_{it}}{A_{it-1}}\right) + \beta_4\left(\frac{CFO_{it}}{A_{it-1}}\right) + \beta_5\left(\frac{CFO_{it-1}}{A_{it-1}}\right) + \beta_6\left(\frac{CFO_{it+1}}{A_{it-1}}\right) + \varepsilon \tag{22}$$

The variables used in the McNichols (2002) model are already defined. The variables *LAF*, *ROA*, *Lev*, and *Size* are explanatory variables and refer to the natural logarithm of the audit fee, the ratio of the asset (defined as net income before extraordinary items scaled by total assets), the leverage (debt to asset), and the firm size (natural log of assets). Here, the dependent variable is *LAF* (the audit fee). Also, μ_1 denotes the vector of fixed firm effects, $g\left(LAF_{i,t}; \gamma_j; c_k\right)$ is the transition function, and $\varepsilon_{i,t}$ is the error term. Based on the works of González and Teräsvirta (2006) n a panel framework, the current research considered the following logistic transition function:

$$g\left(LAF_{i,t}; \gamma_j; c_k\right) = \left(1 + \exp\left(-\gamma_j \prod_{k=1}^{m} INS_{i,t} - c_k\right)\right)^{-1} \quad \gamma > 0, c_1 \le c_2 \le \ldots \le c_m \tag{23}$$

where $c = (c_1, \ldots, c_m)$ is an m-dimensional vector of location parameters, and the slope parameter determines the smoothness of the transitions. The restrictions $\gamma > 0$ and $c_1 < \ldots < c_m$ are imposed for identification purposes. In practice, it is usually sufficient to consider $m = 1$ or $m = 2$, as these values allow for commonly encountered types of variation in the parameters. For $m = 1$, the model implies that the two extreme regimes are associated with low and high values of $LAF_{i,t}$ with a monotonic transition of the coefficients from β_0 to $\beta_0 + \beta_1$ as $LAF_{i,t}$ increases, where the change is focused around C_1. When $\gamma \to \infty$, $g\left(LAF_{i,t}; \gamma_j; c_k\right)$ becomes an indicator function I $[LAF_{i,t} > c]$, which is defined as I $[A]$ = 1 when the event A occurs and as zero otherwise. In that case, the PSTR model in (1) reduces to the two-regime panel threshold model of Hansen and Seo (2002). For m = 2, the transition function has its minimum at $(c_1 + c_2)/2$ and attains a maximum value of 10 both at low and high values of $LAF_{i,t}$.

A generalisation of the PSTR model to allow for more than two different regimes occurs in another model, which is presented below:

$$EM\_ACC_{i,t} = \mu_1 + \beta_0(ROA_{i,t} + Lev_{i,t} + Size_{i,t}) + \sum_{J=1}^{r} \beta_j g(LAF_{i,t}; \gamma_j; c_k)(ROA_{i,t} + Lev_{i,t} + Size_{i,t}) + \varepsilon_{i,t} \quad (24)$$

In the transition functions $g(LAF_{i,t}; \gamma_j; c_k)$ and j = 1, . . ., r, the slope parameter γ_j and the location parameter c_j are critical. Specifically, the multiple regime model (31) serves as a crucial alternative when performing diagnostic tests for the absence of heterogeneity. If m = 1, then all slope parameters are γ_j. As γ_j approaches infinity, the PSTR model (Panel Smooth Transition Regression) simplifies to multiple regime panel threshold regression models (PTRs), indicating a sharp transition between regimes (Heidari et al. 2015).

Table 7 presents the linearity test results. Before estimating the final panel smooth transition regression model, it is essential to perform both the linearity test and the test for no remaining non-linearity to identify the optimal specification of the panel soft transition regression model. In testing for no remaining non-linearity, the null hypothesis suggests the existence of a single transition function. In contrast, the alternative hypothesis posits the need for at least two transition functions within the panel smooth transition regression model. This study utilized the Lagrange Multiplier (LM) and Likelihood Ratio (LR) tests to assess non-linearity. The results from these tests indicate that considering just one transition function is sufficient to capture the non-linearity between the model variables.

The optimal threshold is identified when the Residual Sum of Squares (RSS), Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) reach their minimum values as indicated in Equation (7). Table 8 presents the threshold value ccc and the transition parameter γ. For the threshold variable of the audit fee (LAF), the RSS, AIC, and BIC values recorded at the 28th estimate are displayed in Table 7. It is evident that the optimal threshold of 4.651 is lower than the mean audit fee of 6.620. Additionally, the slope parameter γ, which indicates the transition speed between regimes, is 846.237. This high value suggests a relatively swift shift from the first regime to the second.

Table 8. Test results of the threshold value in PSTR estimates.

Search Range	Optimal Threshold Value (c)	Transition Parameter (γ)	RSS	AIC	BIC
LAF	4.951 *** (2.026)	846.237 *** (322.361)	−4.743	−55.709	−46.152

*** $p < 0.001$.

Table 9 shows the results of estimating the two-regime panel smooth transition regression model.

The gradient parameter (γ) indicates the transfer velocity of one regime to another, which equals 846.237, and the audit fee threshold equals 4.951. The threshold is the two regimes' turning point and specific point expressed in the panel smooth transition regression model. The threshold is the defining point of the two regimes described in the panel soft transition regression model, which varies according to the amount of the slope parameter estimates and the values of the transition variable (audit fee); these are the model estimates from one regime to another. Of course, the two first and second regimes are some of the limit states of the panel smooth transition regression model. The values of the regression coefficients vary somewhat concerning the observations of the transition variable. The number 4.951 indicates that the impact of audit fees before 4.951 and after 4.951 differs on the actual earnings management. In other words, the audit fee has a positive effect until the level of 4.951, and it has a different impact on accrual earnings management after the level of 4.951. In other words, an audit fee has a positive effect until 4.951 and negatively impacts the accrual earnings management above that level.

The regression F statistic is equal to 35.399 and is significant. In other words, independent variables have been able to explain the changes in the dependent variable. Also,

the modified coefficient of determination of the model is equal to 0.682. This indicates that independent variables explain 68% of the changes in the dependent variable and demonstrates the high explanatory power of the model.

Table 9. Parameter estimates of the PSTR model.

Panel A: Linearity Model			
	Coeff.	SE.	t-value
LAF	0.001	0.001	0.304
ROA	0.602	0.025	23.729
Lev	−0.015	0.010	−0.136
Size	0.009	0.001	5.809
Adjusted R^2	0.632		
F statistic	17.362 ***		
Panel B: Non-linearity Model (Regime 1)			
LAF	0.014 ***	0.005	2.823
ROA	-	-	-
Lev	-	-	-
Size	-	-	-
C1	4.651 ***	1.806	2.573
γ	846.237 ***	319.117	2.651
Adjusted R^2	0.621		
F statistic	10.713 ***		
Panel C: Non-linearity Model (Regime 2)			
LAF	−0.004 ***	0.001	−4.424
ROA	-	-	-
Lev	-	-	-
Size	-	-	-
C2	-	-	-
γ	-	-	-
Adjusted R^2	0.682		
F statistic	35.399 ***		
DW	1.94		

*** $p < 0.001$.

The Durbin–Watson value equals 1.94, which indicates that there is no consecutive correlation among error parts. As shown in Table 9, audit fees have a positive impact on accrual earnings management in the first regime and a negative effect on the accrual earnings management in the second regime; in a way that, as audit fees increase to a certain amount (4.951), accrual earnings management increases, and after that, an increase in the audit fee leads to the reduction in the accrual earnings management.

However, we observed (please see Table 10) that the interaction of the audit fees with the quality of reporting and the accounting comparability could lead to increased managers' compensation through the relationship between the accounting variables and stock prices.

Moreover, Table 11 and Figure 2 present the testing and results of the second hypothesis for companies with high-quality sustainability reporting. In this method (PSTR), we should use only panel data. So, we identified the companies with higher quality (higher than the median) using the following method: Suppose the number of sustainability reporting quality in more than half of the research period is more than the median (24.00). In that case, this company is recognised for sustainability reporting quality throughout the research period. The results show that earnings management increased with the audit fee increase from its lowest amount (2.928) to 3.614 in the first regime. These findings indicate that the auditors' efforts to a certain extent—because they were not of the required quality—could not reduce the process of earnings management and even coincided with the increase in earnings management. Of course, one can rely on the assumption that managers in companies seek earnings management, and this trend is constantly increasing. Auditors, as

a solid regulatory arm seeking financial accreditation, have been able to make dramatic changes in the impact of managers' efforts on profit accruals in line with their personal goals. In this case, by observing the second regime, we can see that with the increase in auditors' efforts and in consequently receiving more fees from the level of 3.614 onwards, this effect becomes reversed, and these efforts led to reduced earnings management by company managers. Point C in Figure 2 indicates the change in the impact of the auditors' actions on earnings management.

Table 10. Accounting comparability and board compensation: Audit Fee*SQR.

Variable	COMP_CFO	COMP_RET	COMP_PRC
COMP_CFO	6.614 ** (2.627)	-	-
COMP_RET	-	3.876 *** (0.851)	-
COMP_PRC	-	-	5.35×10^{-5} *** (1.19×10^{-5})
LAF	−0.122 * (0.069)	−0.101 *** (0.024)	−0.037 (0.024)
SQR	0.062 (0.157)	−0.033 (0.041)	0.262 *** (0.078)
SQR*LAF *COMP_CFO	−0.131 (0.669)	-	-
SQR*LAF *COMP_RET	-	−0.293 *** (0.105)	-
SQR*LAF *COMP_PRC	-	-	3.66×10^{-6} ** (1.55×10^{-6})
CORR_ROA	0.090 (0.066)	0.039 * (0.022)	0.049 *** (0.019)
CORR_CF	−0.139 (0.093)	−0.054 ** (0.036)	−0.072 *** (0.023)
CORR_RET	0.126 (0.127)	0.052 (0.036)	0.028 (0.029)
INDHERF	−2.155 (1.198)	−2.540 * (1.479)	−3.328 ** (1.426)
SIZE	0.635 *** (0.141)	0.639 *** (0.056)	0.679 *** (0.055)
BM	0.494 *** (0.136)	0.109 (0.076)	0.058 (0.084)
LEV	1.372 *** (0.405)	0.522 *** (0.126)	0.455 *** (0.127)
ROA	0.321 (1.356)	1.009 *** (0.351)	0.030 (0.253)
ADJROA	3.196 ** (1.499)	0.957 ** (0.403)	1.894 *** (0.327)
RET	1.679 *** (0.577)	0.531 *** (0.147)	0.633 *** (0.122)
ADJRET	−1.471 ** (0.664)	−0.584 *** (0.135)	−0.757 *** (0.110)
GROWTH	−0.178 (0.283)	0.000 (0.067)	−0.010 (0.063)
DIVYIELD	1.407 * (0.848)	1.010 *** (0.329)	1.065 *** (0.322)
RETVOL	1.263 *** (0.445)	0.505 *** (0.143)	0.377 ** (0.175)

Table 10. *Cont.*

Variable	COMP_CFO	COMP_RET	COMP_PRC
CFVOL	−0.010 (0.918)	0.306 (0.439)	0.521 (0.409)
Hausman Test (χ^2)	28.335	31.415	30.483
R^2 (Adj)	0.497	0.837	0.876
F statistic	6.995 ***	38.586 ***	53.047 ***
DW	1.858	1.873	1.861

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 11. Parameter estimates of the PSTR model.

Panel A: Linearity Model			
	Coeff.	SE.	t-value
LAF	0.021	0.008	2.625
ROA	0.536	0.083	6.457
Lev	−0.142	0.130	−1.092
Size	0.044	0.0.13	3.384
Adjusted R^2	0.616		
F statistic	14.222 ***		
Panel B: Non-linearity Model (Regime 1)			
LAF	0.010 ***	0.004	2.506
ROA	-	-	-
Lev	-	-	-
Size	-	-	-
C1	3.614 ***	1.679	2.152
γ	514.293 ***	119.202	4.299
Adjusted R^2	0.621		
F statistic	18.357 ***		
Panel C: Non-linearity Model (Regime 2)			
LAF	−0.012 ***	0.005	−2.418
ROA	-	-	-
Lev	-	-	-
Size	-	-	-
C2	-	-	-
γ	-	-	-
Adjusted R^2	0.621		
F statistic	28.106 ***		
DW			

*** $p < 0.001$.

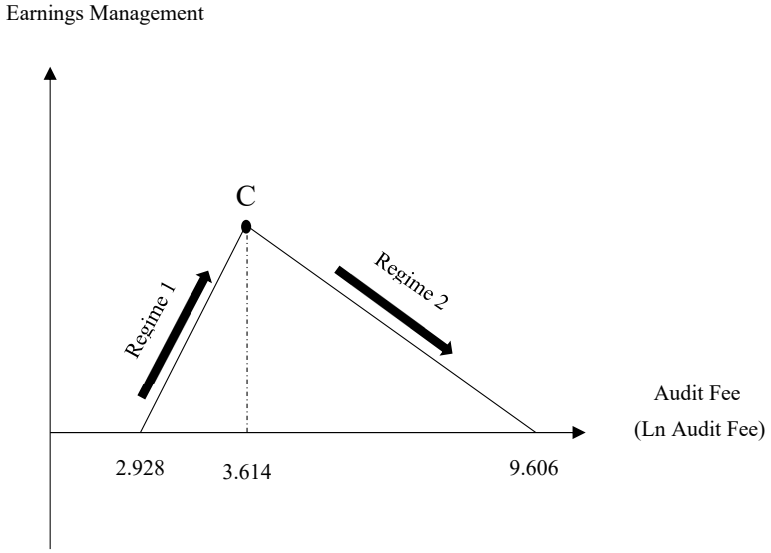

Figure 2. Asymmetric impact of audit fee on earnings management.

6. Discussion

This study employed a robust quantitative ex post facto research design to investigate the complex relationship between audit fees and earnings management. Analysing data from firms listed on the Tehran Stock Exchange, we uncovered an inverted U-shaped relationship between audit fees and earnings management, indicating that moderate audit fees can lead to higher earnings management. The key contributions of this paper include the following:

1. Highlighting the role of audit fees: This study underscores the influence of audit fees on financial reporting quality and risk management.
2. Providing empirical evidence: We demonstrate the asymmetric effects of normal and abnormal audit fees on earnings management.
3. Emphasising balanced audit fee structures: The need for balanced audit fee structures to ensure financial transparency and mitigate risk is evident from our findings.

The results show that normal audit fees positively affect the relationship between accounting comparability and executive compensation, while abnormal audit fees do not influence executive compensation. Specifically, our non-linear model reveals that audit fees positively impact accrual earnings management up to a certain threshold (4.951). Beyond this threshold, higher audit fees result in decreased accrual earnings management. These findings align with the results of Blankley et al. (2012) and Eshleman and Guo (2014).

Moreover, our results suggest that the interaction of audit fees with reporting quality and accounting comparability, through the relationship between accounting variables and stock prices, can lead to increased executive compensation. Audit fees up to a certain threshold (3.614 in our sample) significantly impact earnings management in companies with higher reporting quality. This inverted U-shaped relationship between audit fees and earnings management indicates that an initial increase in audit fees may reflect a lack of accounting comparability and provide room for higher earnings management. However, beyond a certain level, higher audit fees imply the need for more rigorous scrutiny of accounting transactions, thereby reducing earnings management.

In Iran's reporting and auditing environment, similar conditions may prevail. Given the limitations in Iran's audit market and the potential for insufficient competition among audit firms, increasing audit fees up to a certain level may reduce the comparability of financial statements, thus increasing earnings management. However, beyond that point, higher audit fees can enhance the accuracy and quality of audits, thereby reducing earnings management. These findings are particularly relevant for regulators and policymakers in Iran's accounting and auditing fields.

7. Conclusions

This study provides critical insights into the relationship between audit fees and earnings management within the context of the Tehran Stock Exchange. Our findings highlight an inverted U-shaped relationship, where moderate audit fees can lead to increased earnings management, while higher audit fees beyond a specific threshold can reduce it. The differentiation between normal and abnormal audit fees adds a nuanced understanding of how audit costs influence financial reporting quality.

Regulators and policymakers should consider these dynamics when developing guidelines for audit fee structures to ensure financial transparency and mitigate earnings management risks. Further research is recommended to explore these relationships in different economic and regulatory contexts, including comparative studies across various markets. Additionally, longitudinal studies could provide a deeper understanding of how these relationships evolve over time and under different economic conditions. Finally, integrating qualitative methods could offer more comprehensive insights into the practical implications of audit fees on financial reporting and earnings management.

Limitations:

While robust in its quantitative approach and comprehensive analysis, this study has several limitations. First, the sample was restricted to 164 companies listed on the Tehran

Stock Exchange from 2010 to 2019. This specific economic and regulatory environment may limit the generalizability of the findings to other markets with different characteristics. Additionally, the study focuses on the impact of audit fees on earnings management within a high-inflation and high-risk economic context, which might not be directly applicable to more stable economies. Another limitation is the division of the audit fees into normal and abnormal categories, which, while innovative, might oversimplify the complex dynamics between audit fees and financial reporting quality.

Suggestions for Further Research:

Future research could address these limitations by expanding the sample to include companies from diverse economic and regulatory environments to enhance the generalizability of the findings. Comparative studies across different countries and markets would provide deeper insights into the role of audit fees in varying contexts. Additionally, examining the interplay between audit fees and other factors such as corporate governance practices, auditor expertise, and economic conditions could provide a more holistic understanding of the determinants of financial reporting quality. Longitudinal studies that track changes over more extended periods and in different economic cycles would also be valuable in understanding the temporal dynamics of these relationships. Furthermore, qualitative research methods, such as case studies and interviews with auditors and company executives, could complement the quantitative findings and provide more prosperous, nuanced insights into the mechanisms at play.

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Lebanon's Economic Development Risk: Global Factors and Local Realities of the Shadow Economy Amid Financial Crisis

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Abstract: The shadow economy's size and impact remain subjects of extensive research and debate, holding significant implications for economic policy and social welfare. In Lebanon, the ongoing crisis since 2019 has exacerbated severe economic challenges, with the national currency's collapse, bank crisis, and foreign reserve deficits. The World Bank reports Lebanon's financial deficit surpassed $72 billion, three times the GDP in 2021. Despite a drastic decline in GDP, imports have surged to near-pre-crisis levels, exacerbating economic woes and indicating a constant outflow of foreign currencies. Considering such contracting facts, this paper aims to investigate global factors influencing the shadow economy and discern their manifestations in Lebanon during financial crises. Our methodology involves a comprehensive literature review, alongside a case study approach specific to Lebanon. This dual-method strategy ensures a detailed understanding of the shadow economy's impact and the development of actionable insights for policy and economic reform. Through this approach, we seek to contribute to a nuanced understanding of Lebanon's economic landscape and provide valuable guidance for policy decisions aimed at reducing corruption, promoting transparency, and fostering a robust formal economy. The increase in the shadow economy raises the formal economy risk, as resources and activities diverted to informal channels hinder the growth and stability of the official economic sector. Although focusing on Lebanon, this analysis deepens the comprehension of the economic landscape and provides valuable guidance for policymakers, researchers, and stakeholders, aiming to address the root causes of informal economic activities and promote sustainable growth in developing countries in general.

Keywords: institutional economics framework; formal economy risk; Lebanon; sustainable development; shadow economy

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1. Introduction

1.1. Research Context

The shadow economy—comprising unregulated economic activities that evade taxes and legal frameworks—presents a significant economic development risk due to its profound implications for economic stability and social welfare. The persistence of the shadow economy undermines formal economic structures, hampers effective policy implementation, and exacerbates socio-economic disparities. Understanding the dynamics of the shadow economy is crucial, especially during periods of financial crisis, as it can reveal how unregulated activities contribute to broader economic development risks.

Recent literature underscores the multifaceted nature of the shadow economy. Canh et al. (2021) highlight the influence of economic integration and institutional quality on shadow economic activities, while Chletsos and Sintos (2024) examine how International Monetary Fund (IMF) interventions can shape informal sectors. Dreher and Schneider (2010) explore the interplay between corruption and the shadow economy, revealing its extensive socio-economic consequences. Additionally, the shadow economy might also raise

environmental risks, as shown by Cozma et al. (2021), who highlight its significant impact on illegal logging. The study reveals how corruption and economic crimes, core elements of the shadow economy, exacerbate deforestation rates. By analyzing both qualitative and quantitative data, the research underscores the role of governance quality, press freedom, and wood export share in driving deforestation, thereby informing policies to combat illegal logging and protect the environment. This illustrates the extensive socio-economic and environmental consequences of the shadow economy. These studies illustrate how various factors, including governance quality and economic policies, contribute to the shadow economy's expansion, risks, and persistence.

Lebanon's late and ongoing economic crisis, which began in 2019, provides a pertinent context for studying the shadow economy. The collapse of the national currency, escalating trade deficits, and severe economic contraction (World Bank Group 2021b) have exacerbated the challenges facing Lebanon's formal economy.

According to one of the World Bank reports (World Bank Group 2021b), Lebanon's financial deficit exceeded $72 billion in 2021, which was three times the country's GDP. Furthermore, considering the downward trajectory of GDP from about $52 billion in 2019 to less than half in 2022 ($25.46 billion), the surge in imports exacerbates Lebanon's economic woes, underscoring the magnitude of the challenge at hand. Imports have remarkably rebounded to their pre-crisis levels, while the trade deficit continues to expand due to a decline in exports. In 2022, as per data from Banque Du Liban (BDL, the Central Bank of Lebanon), imports reached a staggering $19.05 billion, representing a significant increase of $5.41 billion compared to the previous year, marking a rise of 39.68% from 2021 ($13.64 billion) and a striking 68.47% surge from 2020 ($11.31 billion) (Banque du Liban (BDL) 2023b; Gemayel 2023). These import levels are almost equivalent to the figures recorded in the five years prior to the crisis, as shown in Figure 1.

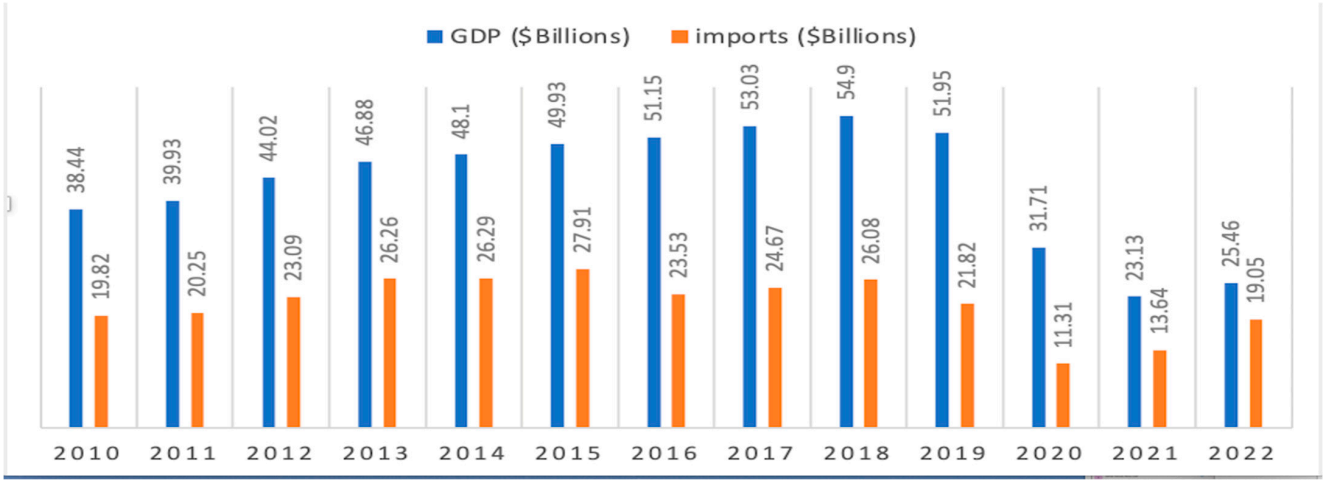

Figure 1. GDP and import fluctuations in Lebanon from 2010 to 2022 (authors' compilation of data from Banque du Liban (BDL) (2023b); World Bank 2023b).

The surge in imports amid Lebanon's economic crisis, coupled with the persistent downturn in GDP, signals a concerning trend: the formal economy is struggling to return to pre-crisis levels. Despite economic hardships, imports have rebounded to near-pre-crisis levels, indicating a reliance on external goods and services and thus a constant outflow of foreign currencies. With the recurrence of financial crises and their adverse effects, it becomes crucial to shed light on the informal economy, commonly known as the shadow economy. This sector represents a significant portion of a country's GDP, especially in developing nations. This suggests that the formal economy is not recovering as expected, potentially fueling informal economic activities and the expansion of the shadow economy.

The escalation of the shadow economy heightens the risk to the formal economy, diverting resources and activities into informal channels that impede the growth and sta-

bility of the official economic sector. Sustainability risks emerge across economic stability, environmental impact, social consequences, governance challenges, and long-term development goals. Addressing these risks requires robust policies to promote transparency, strengthen regulatory frameworks, and foster the formalization of informal activities, ensuring sustainable economic, environmental, and social outcomes.

In addition to internal concerns within companies, such as operational efficiency, internal controls, and corporate indebtedness, adopting strategic and personalized approaches to financing and risk management (Tavares et al. 2024), as well as financial education (Santos and Tavares 2020), remains essential for mitigating external risks. The shadow economy, in particular, can significantly impact risk management practices and overall performance by introducing uncertainties and unregulated activities that disrupt formal economic operations and planning.

In this paper, we utilize a dual-method approach: a comprehensive literature review and a case study specific to Lebanon. The literature review includes peer-reviewed journal articles, books, and reputable reports, ensuring a thorough understanding of the shadow economy's global and local dynamics. The case study provides contextual insights into Lebanon's economic conditions, allowing us to apply theoretical findings to the local context. This methodology enables a detailed examination of the shadow economy's impact and its implications for Lebanon's economic development.

Thus, the aim of this paper is to investigate the global factors influencing the shadow economy and to discern their specific manifestations within Lebanon, particularly during times of the financial crisis since 2019. By combining a broad literature review with a focused case study, we aim to provide a nuanced analysis that informs policy and economic reform efforts in Lebanon.

1.2. Research Aim, Questions and Value

Arising from the above, this study investigates two critical questions:

1. What are the key global factors influencing the shadow economy?
2. How do these factors and indicators manifest in the context of Lebanon during times of its financial crisis?

The research questions aim to elucidate two key aspects of the shadow economy's dynamics. The first question seeks to identify the general factors influencing the shadow economy, providing a broader understanding of international drivers that affect informal economic activities. The second question focuses on how these global factors specifically manifest within Lebanon during its financial crisis, aiming to apply these international insights to the local context.

The methodology is based on secondary data analysis and a comprehensive theoretical review at both the local and international levels. By concentrating on the variables identified in the literature, we analyze their applicability and relevance to the Lebanese context, thereby assessing the indicators and situation in Lebanon. Moreover, we address the gap in the existing literature by adopting a theoretical framework grounded in institutional economics to analyze the dynamics of the shadow economy in Lebanon. Unlike previous studies that predominantly rely on quantitative methods, our qualitative approach allows for a deeper exploration of contextual factors and socio-economic dynamics unique to Lebanon.

The significance of our research lies in its potential to contribute to the existing body of knowledge surrounding the factors impacting the shadow economy in general and in Lebanon in particular, with a focus on the effects on government revenues and social welfare. By unraveling the complexities of the shadow economy, we aim to provide actionable insights that can inform policy decisions for reducing corruption, promoting transparency, and fostering a robust formal economy. Through our analysis, we strive to deepen the understanding of Lebanon's economic landscape and offer valuable guidance for policymakers, researchers, and stakeholders. Ultimately, our work endeavors to address the

root causes of informal economic activities and promote sustainable economic development in Lebanon.

The paper begins with a literature review, exploring the informal economy and its ties to corruption and formal economic systems. It adopts an institutional economics framework to analyze secondary data on Lebanon's shadow economy. Then, it discusses key indicators of Lebanon's informal economy: unemployment, taxation, government regulations, financial crises, smuggling, and cash circulation. Policy recommendations follow. Finally, the paper emphasizes the need for structural reforms to address fiscal instability and promote economic and social welfare in Lebanon.

2. Literature Review

2.1. An Overview of the Informal Economy

The informal or shadow economy encompasses activities that occur outside the purview of "bureaucratic public and private" systems (Blanton and Peksen 2021). These activities involve elements such as smuggling, bribery to access desired services or products, and informal employment driven by market structures (Mishchuk et al. 2020).

Empirical studies, such as the work conducted by Schneider (2005), have been instrumental in estimating the size of the shadow economy in various countries, including those in the developing, transitioning, and highly developed OECD economies between 1990 and 2000. Schneider's study revealed that the shadow economy accounted for 41% of the official GDP in developing countries, 38% in transition economies, and 17% in OECD countries. A key driver for the growth of the shadow economy is the burden imposed by taxation and social security contributions. It was observed that a 1% increase in the shadow economy in developing countries leads to a 0.6% decrease in the growth rate of the official GDP, while in developed and transitioning economies, the shadow economy increases by 0.8% and 1.0%, respectively. Furthermore, the size of the shadow economy varies significantly across countries and time periods, with developing and transitioning economies typically exhibiting larger shadow economies than highly developed OECD nations (Schneider 2005).

As indicated by newer estimates from Medina and Schneider (2018), in Europe, the shadow economy is thought to account for approximately 20% of the GDP. However, in Eastern Europe and post-Soviet regions, the figures are even higher, ranging from 25% to 45% (Medina and Schneider 2018). Recent studies further expand on these findings:

Medina and Schneider's 2018 study utilized a light intensity method as an alternative indicator within the Multiple Indicators Multiple Causes (MIMIC) framework. This study provided estimates of the shadow economy for 158 countries from 1991 to 2015, addressing earlier criticisms by implementing the Predictive Mean Matching (PMM) method to enhance accuracy and reliability. This study underscores the shadow economy's complexity and the necessity for robust estimation methods (Medina and Schneider 2018).

Additionally, a 2023 report by the International Monetary Fund (IMF) reviewed shadow economies worldwide over the past 20 years, highlighting significant variations in their size across different regions and time periods. This report reinforced that developing and transitioning economies typically exhibit larger shadow economies than developed OECD nations. It also discussed the socio-economic impacts, such as the role of informal networks and social capital in perpetuating corruption and unethical behavior within shadow economies (International Monetary Fund (IMF) 2023).

Furthermore, a study published in Emerald Insight explored the interrelationship between corruption and the shadow economy, using data from the World Development Indicators database and building upon Medina and Schneider's 2018 estimates. The study found that shadow economies often rely on informal networks, which can facilitate corrupt practices due to a lack of accountability and transparency. This research further solidifies the understanding of how shadow economies and corruption are interlinked (Nguyen and Liu 2023).

While the shadow economy can be viewed as an engine of innovation, it also brings about significant social side effects, such as unprotected working conditions due to its unregulated and clandestine nature (Kraemer-Mbula and Wunsch-Vincent 2016). Other negative effects of the shadow economy include a high poverty rate, high share of income spent on basic expenditures (mainly food), lack of housing opportunities, and lack of social safety (Mishchuk et al. 2020). Furthermore, it has also been empirically proven the effects of the shadow economy on government revenues, unfair competition over pricing (between entities paying taxes and those functioning under an informal economy), and impacts on economic growth in developing countries (Tanzi 2002).

In the context of Lebanon, the informal economy plays a particularly significant role due to the country's ongoing economic crisis and political instability. Recent estimates suggest that Lebanon's informal sector is notably larger, exacerbated by the country's severe economic challenges. The International Monetary Fund (IMF)'s (2023) report highlights that Lebanon's shadow economy has expanded significantly as the formal economy struggles to recover, driven by regulatory deficiencies and economic collapse. Lebanon's shadow economy is intertwined with corruption and inadequate governance, exacerbating economic instability and undermining social welfare (Nguyen and Liu 2023). The impact of the shadow economy in Lebanon includes exacerbated poverty rates, increased reliance on informal networks, and reduced government revenues. Addressing these issues is crucial for developing targeted policies to enhance transparency, improve governance, and formalize informal economic activities, thus promoting sustainable economic development in Lebanon.

The next section will focus on the interconnections between corruption, the formal economy, and the shadow economy. By integrating this discussion into the literature review, we aim to offer a comprehensive understanding of the global dynamics influencing the shadow economy and lay the groundwork for analyzing its specific manifestations in Lebanon. This exploration will highlight how global factors intersect with local conditions in Lebanon, where corruption and institutional weaknesses significantly shape the shadow economy. By examining these interconnections, we seek to uncover the mechanisms and dynamics pertinent to Lebanon's economic context, thereby grounding our analysis in both global perspectives and local realities.

2.2. Interlinking Corruption, Formal Economy, and Shadow Economy

To investigate the complex relationship between corruption, the formal economy, and the shadow economy, it is important to establish clear conceptual boundaries. Corruption, defined as the misuse of public resources for personal gain, has been widely recognized as a major impediment to economic and social development (Rose-Ackerman 1999). The formal economy refers to registered economic activities that are governed by legal frameworks, regulations, and taxation systems. On the other hand, the shadow economy encompasses unregistered economic activities that operate outside the purview of official regulations and often involve noncompliance with tax obligations (Schneider and Enste 2000).

Previous research exploring the interaction between corruption and the shadow economy has focused on estimating the size and impact of the shadow economy and identifying the factors that contribute to its growth (Schneider and Buehn 2016; Sharipov 2015; Friedman 2014). Poor institutional quality and tax evasion have been identified as key drivers of the shadow economy (LaPorta et al. 1999; Tanzi 1999). Institutional economics emphasizes the role of institutional quality, including corruption, regulatory discretion, judicial systems, the rule of law, and bureaucracy, in shaping economic behavior (Phuc Canh 2018; Schneider and Enste 2000).

Corruption has a detrimental effect on institutional quality, leading to higher labor costs for official economic activities and incentivizing economic agents to engage in informal or concealed activities (Phuc Canh 2018; Schneider and Enste 2000). Inadequate constraints on government powers, regulatory burdens, and failing judicial systems create

an environment where individuals may opt for informal economic activities and participate in the shadow economy (Torgler and Schneider 2009; Dreher et al. 2009; Berdiev et al. 2018).

Conversely, the shadow economy can also influence corruption and the formal economy. Some studies suggest that the shadow economy can act as a substitute for corruption, allowing economic agents to avoid official taxes and bureaucracy (Choi and Thum 2005; Ackerman 1997). Factors such as political stability, competent governance, and effective regulations have been found to be negatively correlated with the size of the shadow economy, while bureaucracy shows a positive association (Friedman 2014). However, it is important to note that the relationship between corruption, the formal economy, and the shadow economy is multifaceted and can work in different ways depending on the specific context and circumstances.

The presence of a significant shadow economy poses risks to economic development and societal well-being. It leads to fiscal losses due to tax evasion, contributes to income inequality, and distorts the accurate measurement of income distribution. The shift of economic activities from the formal to the informal sector exacerbates income polarization, while the impact of the shadow economy on secondary income generation undermines social safety nets, resulting in challenges such as poverty, inefficient cost structures, and limited housing opportunities (Mishchuk et al. 2020).

Given these conceptual boundaries and the complexities of the relationship between corruption, the formal economy, and the shadow economy, it is imperative to understand the underlying mechanisms, dynamics, and potential policy implications. By examining these interconnections, this study sheds light on the factors that influence the size and behavior of the shadow economy and how corruption and institutional quality play a role in shaping these dynamics. Figure 2 summarizes the main factors related to the shadow economy and the cycle it creates based on the above literature review.

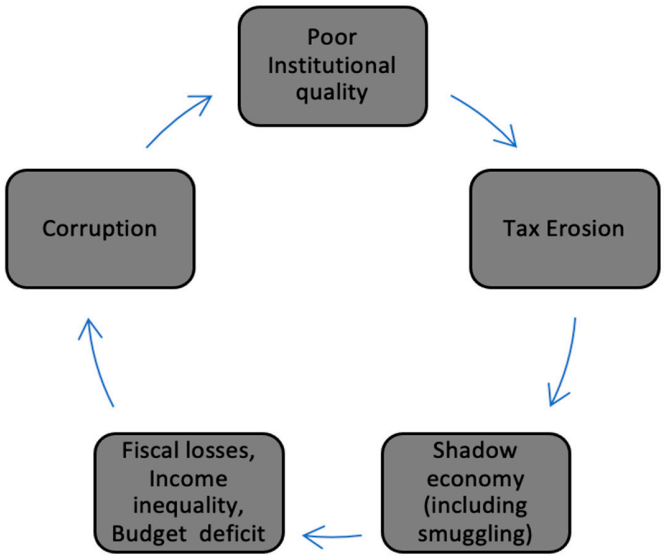

Figure 2. Summary of factors related to the shadow economy (source: author).

Schneider (2000) employed causal models incorporating latent variables to estimate the size of the shadow economy across different countries. These latent variables are not directly observable but have operational implications for the relationships among observable variables. The observable variables act as causes and serve as indicators of the hidden variables.

In his research, Kanniainen et al. (2004) built on that causal model. He utilized the Multiple Indicators Multiple Causes (MIMIC) method and formulated six hypotheses. He postulated that the shadow economy would positively respond to the following factors:

1. Tax rates (both direct and indirect) and social security contributions;

2. State regulation indicated by the percentage of total employment allocated to public administration;
3. Lower tax morality;
4. Decrease or deterioration of state transfer and public goods quality;
5. Higher unemployment and lower GDP per capita;
6. The amount of cash transactions.

The econometric results of Kanniainen's study suggest that taxation and social security variables significantly influence the expansion of underground economies. The research underscores the importance of controlling the tax burden to reduce the size of these economies and emphasizes the need for public education regarding the benefits of contributing to the formal economy. Additionally, economic factors such as unemployment and GDP per capita influence individuals' willingness to participate in the official economy. Social benefit policies may have more significant employment benefits than previously believed, and state transfers may act as incentives to draw individuals out of the underground economy. Furthermore, the size of a shadow economy is influenced by a country's economic performance, exhibiting significant variation across nations and over time.

Schneider and Buehn (2016) explored various methods for gauging the dimensions of the shadow economy and delved into their respective strengths and limitations. Their study serves a dual purpose. Firstly, it underscores the absence of an impeccable method for quantifying the size and evolution of the shadow economy. While delving into greater detail on the MIMIC method, which offers flexibility in obtaining macro-level estimates, the paper secondly concentrates on defining the shadow economy and its causative factors. It also provides a comparative analysis of the shadow economy's size using diverse estimation techniques. Their findings reveal significant disparities in measurement methods, yielding divergent and sometimes inconsistent results. The survey method predominantly focuses on households, occasionally overlooking firms, leading to issues such as non-responses, erroneous data, and limited financial figures instead of value-added metrics. The discrepancy method grapples with challenges arising from rough estimates, unclear assumptions, and a lack of transparency in calculation procedures. The monetary and electricity methods tend to generate elevated estimates, but only offer macro-level data, posing complications in converting electricity consumption into value-added estimates. The widely used MIMIC method provides relative coefficients rather than absolute values, and it is highly sensitive to changes in data and specifications, making it difficult to discern causal factors and indicators. The overall conclusion is that there is no single flawless method, underlining the importance of employing multiple approaches to enhance our comprehension of the shadow economy's size and evolution (Schneider and Buehn 2016).

Given the limitations inherent in estimating the size of the shadow economy and the complexities of the Lebanese market dynamics, this paper opts for a theoretical framework rather than quantitative analysis. While quantitative methods have traditionally been employed to measure the shadow economy, the intricacies of accurately quantifying informal economic activities in Lebanon pose significant challenges. Factors such as data availability, reliability, several exchange rates, and the dynamic nature of informal transactions contribute to the difficulty in conducting precise quantitative assessments. Therefore, a theoretical approach allows us to delve deeper into the underlying mechanisms and interdependencies between corruption, the formal economy, and the shadow economy. By examining existing literature and theoretical frameworks, we aim to provide a comprehensive understanding of the factors influencing the shadow economy in Lebanon and their implications for economic policy and social welfare. This theoretical lens enables us to explore the conceptual boundaries of corruption, institutional quality, and economic behavior, laying the groundwork for insightful analyses and policy recommendations.

2.3. Developing an Institutional Economics Framework

Following the concepts from the general literature review, our study adopts an institutional economics framework to delve deeper into the dynamics of the shadow

economy in Lebanon. Within this framework, our approach is qualitative, focusing on synthesizing insights from existing research and contextualizing them within Lebanon's socio-economic context.

Institutional economics examines how institutions, such as legal and regulatory frameworks, governance structures, and societal norms, shape economic behavior (Hodgson 1998; Dreher et al. 2009) Contemporary institutionalist thinking warns against excessive reliance on quantitative models, arguing that they often overlook the importance of institutions and fail to adequately address uncertainty. Instead, it advocates for a nuanced understanding of institutional dynamics and their impact on economic behavior and societal outcomes (McMaster 2012).

Given the significance of corruption, institutional quality, and regulations in influencing informal economic activities, this framework provides a pertinent lens through which to analyze the complex relationship between the formal and shadow economies (Murphy et al. 1993; Pluskota 2020).

The institutional economics approach allows us to explore the interactions between institutional factors and economic agents, shedding light on the complex interplay between formal regulations and informal practices within the Lebanese context.

3. Methodology

The methodology of this paper follows the structure represented in Figure 3, where the main body is organized by themes and topics derived from the literature review. Initially, we conducted a comprehensive review of existing literature to identify general factors, causes, and indicators related to the shadow economy. Subsequently, we focused on analyzing the applicability of these variables to the context of Lebanon. Through this approach, we aimed to provide a synthesized overview of the dynamics of the shadow economy in Lebanon, informed by insights gleaned from previous research and verified against reliable data sources.

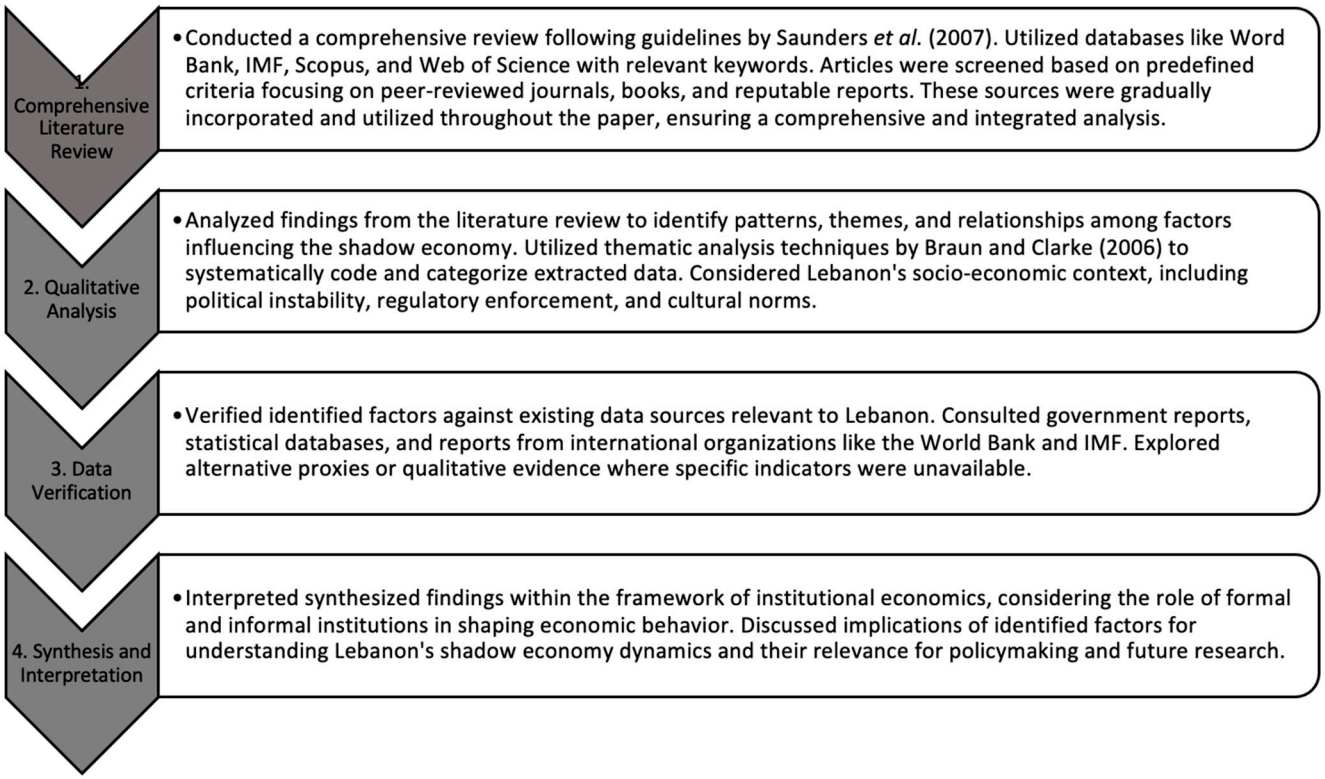

Figure 3. Study methodological steps (Saunders et al. 2007; Braun and Clarke 2006).

Inclusion criteria for the comprehensive literature review focused on peer-reviewed journal articles, books, and reputable reports published in English that are directly relevant to the shadow economy, corruption, and the formal economy internationally and with a particular emphasis on Lebanon or similar economies. Exclusion criteria eliminated nonpeer-reviewed articles, opinion pieces, and studies that were not available in full text. While some sources were accessed before this period, the primary search process for the review was conducted over an extended timeframe from January to June 2024. This comprehensive period included a meticulous evaluation of titles, abstracts, and full texts of eligible articles to ensure their relevance and quality for inclusion in this paper. In more details, throughout the paper, in addition to reliable sources like the World Bank, IMF, and BDL, we identified references indexed in Scopus and Web of Science or both databases.

Furthermore, a significant addition to the methodology is the incorporation of a case study related to Lebanon. This approach allows us to contextualize theoretical insights within the specific socio-economic conditions of Lebanon, thereby enhancing the relevance and applicability of our findings.

4. Indicators of Lebanon's Informal Economy: Investigating Key Factors

A study conducted by Kareh (2020) utilized the monetary approach for the estimation and analysis of the shadow economy's size and its ramifications within the context of Lebanon. The investigation spanned from 1998 to 2018 and revealed that the shadow economy constituted approximately 36.61% of the GDP during this period, as represented in Table 1. Notably, in 2018, tax evasion represented 30.04% of the shadow economy, a figure nearly equivalent to Lebanon's budget deficit. These findings underscore the existence of a significant underground economy in Lebanon, primarily driven by substantial tax evasion and expansion of the informal public sector. Additionally, the surge in cash transactions within this economy can be attributed to the support extended to Syrian refugees by both local and international NGOs, as well as the facilitative measures adopted by various banks (Kareh 2020).

Table 1. Lebanon shadow economy estimation from 1998 till 2018 (Kareh 2020).

Years	1998	1999	2000	2001	2002	2003	2004	3005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Shadow Economy % GDP	36.87	40.36	29.26	35.2	33.67	30.42	30.2	31.99	29.57	28.23	34.81	39.81	31.8	36.11	38.25	34.27	34.24	38.94	34.15	36.98	36.61

Lebanon ranks among the most corrupted countries worldwide, according to the CPI barometer (Transparency International 2022), and due to a lack of data and transparency, estimating the size of the shadow economy in Lebanon became increasingly challenging after the onset of the crisis in 2019. Specifically, in 2019, Lebanon ranked 137th out of 180 countries with a CPI score of 28, reflecting significant corruption, and by 2022, its position worsened to 150th with a CPI score of 24, indicating continued and severe corruption challenges.

The presence of multiple exchange rates further complicated the estimation process. As of 2021, the World Bank estimated that the cash economy in Lebanon was valued at approximately $10 billion, constituting over 45% of the country's GDP (World Bank Group 2021a). This estimation reflects data up to the end of 2021. By early 2023, the situation continued to be dire, with ongoing economic instability affecting accurate assessments and projections (World Bank 2023a).

Estimating the volume of Lebanon's informal economy is challenging due to the lack of reliable data. Medina and Schneider (2018), in their analysis of 157 shadow economies, mentioned that their model did not fully account for the significant influxes of refugees, potentially leading to underestimations of shadow economies in countries like Lebanon, Syria, Jordan, or Turkey. Additionally, since the war in Syria, the number of refugees in Lebanon has significantly increased, with the government registering 1.5 million refugees,

making Lebanon the country with the "highest number of refugees per capita in the world" (European Civil Protection and Humanitarian Aid Operations 2023).

Considering so, examining the extent and dynamics of Lebanon's shadow economy is essential given the country's distinct socio-political and economic circumstances, marked by political discord, civil turmoil, security issues, and a substantial influx of refugees. Furthermore, Lebanon's economic downturn, compounded by corruption, fiscal mismanagement, and currency devaluation, highlights the critical importance of comprehending the impact of informal economic practices on Lebanon's economic structure and societal welfare.

We will explore the indicators of the informal economy in Lebanon by narrowing our focus to key determinants previously identified in Section 2 of the literature review that positively influence the shadow economy. These factors include the taxation system, regulatory decisions facilitating smuggling, currency circulation, fiscal deficit, and fostering the expansion of informal economic activities. Furthermore, we will also consider the downturn in GDP and employment levels.

4.1. Higher Unemployment and Lower GDP per Capita

Lebanon has a long history of political tensions, regional unrest, civil wars, and security challenges. Furthermore, corruption, U.S. sanctions, and the presence of political parties designated as "terrorists" by the international community have contributed to budget deficits and an enormous public debt (Azar and Abdallah 2019). These conditions, coupled with financial engineering that drained the market and commercial banks of foreign currencies, resulted in significant losses for the central bank and increased bank exposures to sovereign risk. The situation deteriorated in 2019, with banks raising interest rates to approximately 10% on foreign currency deposits (even higher for local currency) to attract new flows of foreign currency (Banque du Liban (BDL) 2023b). However, due to a lack of trust, banks faced a liquidity crisis and implemented unofficial capital controls, preventing depositors from withdrawing their funds. This led to a rapid devaluation of the currency, with the market exchange rate reaching approximately 42,000 LBP/USD by the end of 2022 (after being pegged at 1500 LBP/USD since the 1990s), resulting in business closures and significant negative changes in the country's economic indicators between 2019 and 2021.

During this period, Lebanon's GDP contracted by 50%, as shown in Figure 1 (World Bank 2023b), while the unemployment rate increased from 11.4% to 29.6% (Azzi 2022). The inflation rate also rose from 3% to 154.9% (World Bank Group 2021b), and the poverty rate increased from 28% to over 55%. A survey conducted by the Central Administration of Statistics in 2022 revealed that around 49% of unemployed individuals had been searching for work for more than one to two years (Baff 2022). These statistics indicate the significant economic challenges facing Lebanon.

4.2. Tax Rates in Lebanon

The taxation system poses a significant challenge to the Lebanese economy, heavily relying on indirect taxation, including value-added taxes, excise taxes, and tariffs, which account for a substantial portion of total revenues. These indirect taxes are regressive in nature, disproportionately affecting the middle class and the poor. In comparison to other countries, Lebanon has a very low share of revenues collected through a progressive tax scheme, with only around 11% of taxes being levied progressively on wages, property income, and inheritance. This is significantly lower than comparative countries, where the share of progressive taxes is two to three times higher. The taxation of personal income in Lebanon is based on a separate rate for each income source, resulting in an archaic system (Azzi 2022).

Lebanon's tax system includes progressive rates for labor and rental income, while other categories such as capital gains and dividends are taxed at flat rates. However, the revenue from all types of income taxes is relatively low, accounting for 2.7% of GDP (refer to Figure 4). Corporate profit is taxed at a flat rate of 17%, representing a low share of total revenues. Inheritance and gift taxes are progressive, but their revenue is low, amounting to 0.2% of GDP. Real estate registration fees are flat at 5% of the property value and contribute

to 1% of GDP. Lebanon lacks taxes that promote public goods such as environmental protection or regional development (Bifani et al. 2021).

According to the study by Bifani et al. (2021), Lebanon has low tax rates compared to other countries, but tax revenues are significantly lower due to widespread tax leakages and inefficiencies in tax collection. The compliance gap for value added tax (VAT) and lost customs revenue at the border are estimated to be around 3.3% and 1% of GDP, respectively. Banking secrecy laws hinder tax collection from liberal professions and capital gains earned abroad, and there are exemptions and loopholes in the inheritance tax system. These leakages have a regressive nature, as direct taxes are more rigorously assessed for low-income taxpayers, while wealthier taxpayers have more opportunities for tax avoidance. Reforms are needed to improve tax collection, including addressing banking secrecy, exemptions, and loopholes, and making the tax system more progressive (Azzi 2022).

The challenges posed by Lebanon's taxation system, highlighted in Section 4.2, are compounded by significant fiscal losses and budget deficits, as discussed in the next section.

4.3. Fiscal Losses and Budget Deficits

From 2010 to 2022, Lebanon faced significant fiscal challenges characterized by fluctuations in its fiscal balance, government spending, and consumption amid economic instability. The fiscal balance varied markedly, with deficits reaching a peak in 2018 at −11.38% of GDP (Trading Economics 2023), pointing to unsustainable fiscal practices and the government's dependency on public debt and in financial engineering that drained the foreign reserves from the banks in Lebanon (International Monetary Fund (IMF) 2019; Azar and Abdallah 2019). A temporary fiscal balance improvement in 2021, at 1.2% of GDP, reflected drastic government spending cuts rather than genuine fiscal health. Government expenditure trends further illustrated the fiscal strain, with spending cuts in 2021, severely impacting social services and infrastructure and exacerbating economic contraction and social unrest (International Monetary Fund (IMF) 2023). Lebanon's fiscal experience from 2010 to 2022 emphasizes the critical need for structural reforms to achieve fiscal stability, reduce income inequality, and ensure economic and social well-being.

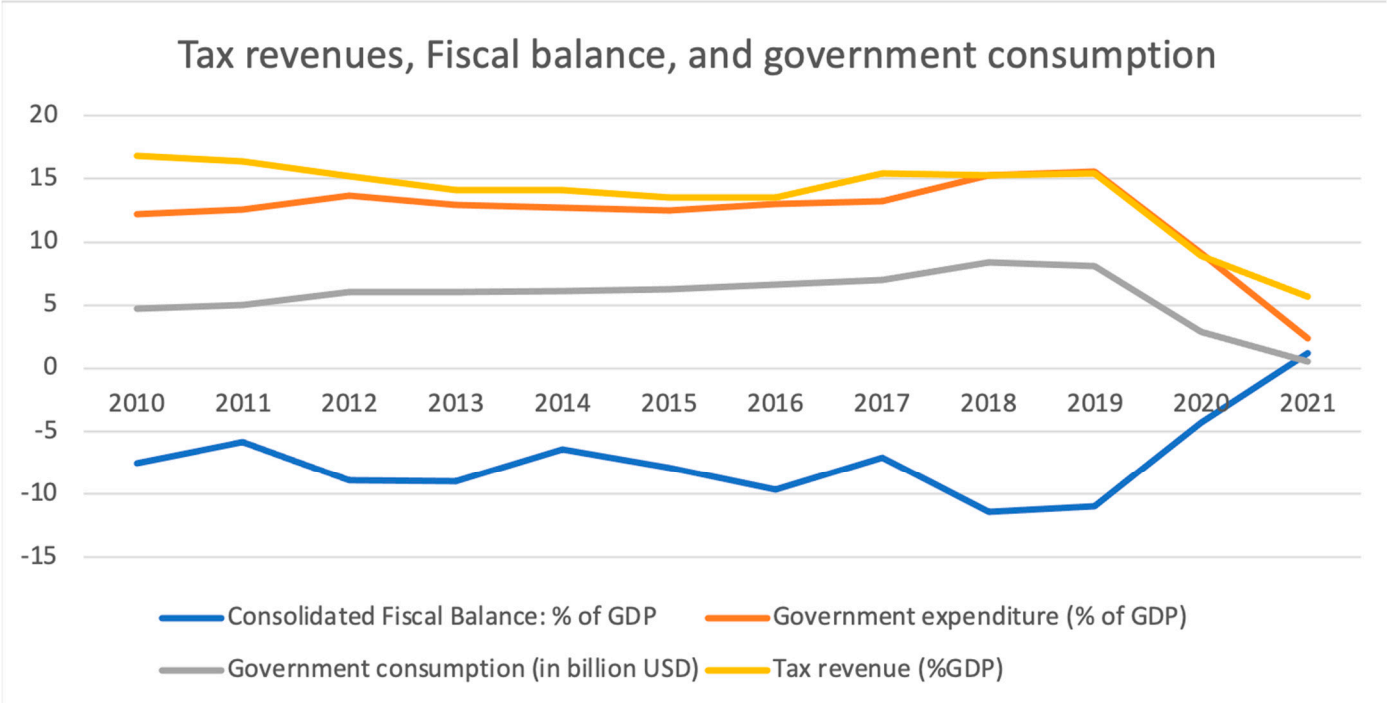

Figure 4. Fiscal balance and government expenditures (authors' compilation of data from Trading Economics 2023).

The financial crisis, exacerbated by fiscal challenges and taxation inefficiencies, amplifies the impact of smuggling activities in Lebanon, which contributes to the growth of the shadow economy and further strains the formal economy.

4.4. Financial Crisis and Smuggling in Lebanon

The smuggling relationship between Lebanon and Syria has a long-standing history, with around 150 illegal exchange points across the border (Daher 2022). In recent years, smuggling activities have taken on new dynamics, especially since the onset of the 2019 crisis. The most profitable among these activities is the smuggling of fuel oil from Lebanon to Syria, which occurred between October 2019 and October 2021 (LBCI Lebanon 2022).

The fuel price was much cheaper in Lebanon, being subsidized at a low official rate of 1500 LBP/USD, while the market rate was several times higher in both Lebanon (as represented in Figure 5) and Syria due to the ongoing crisis. Hezbollah oversees the illegal crossing points on the Syrian-Lebanese border, allowing them to regulate the flow of goods and relying on local actors on the Syrian-Jordanian border for their smuggling activities (Daher 2022).

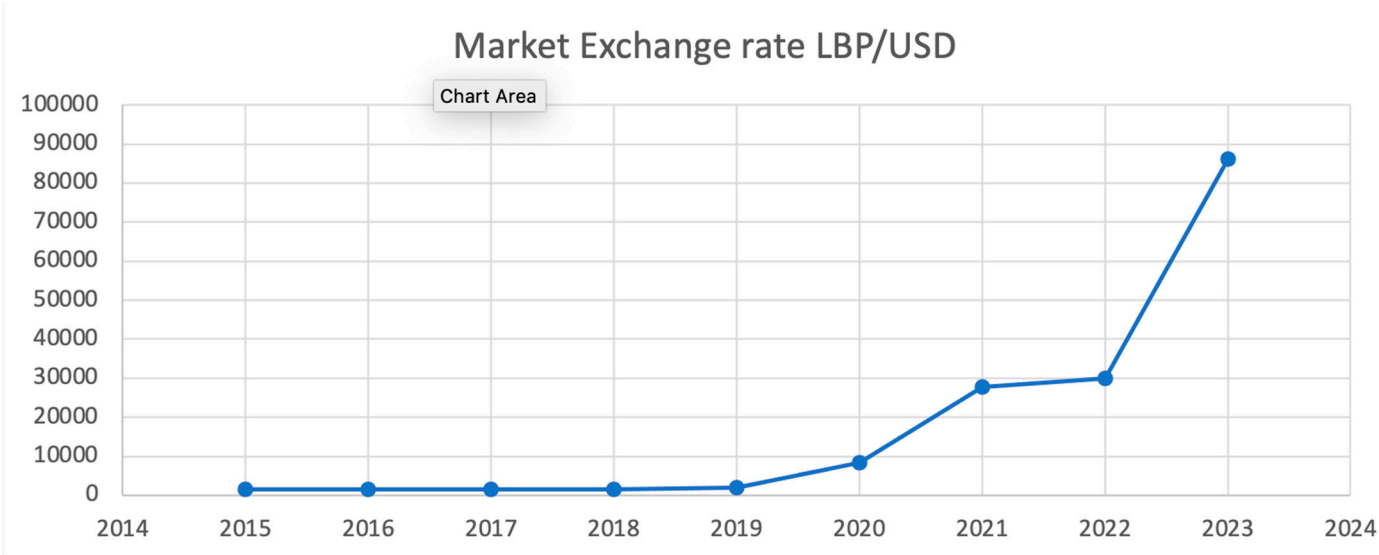

Figure 5. Market exchange rate in Lebanon (graph created by the authors using data from Lirarate 2023).

A study funded by the European Union and conducted by Daher (2022) suggests that Hezbollah, along with Lebanon's top political parties, has ties to customs and port officials that allow them to ship and receive their own cargos, resulting in an estimated loss of one to two billion dollars each year due to the evasion of customs duties. Corruption is prevalent at the port, with employees at every level, as well as state security officers, receiving bribes to speed up shipments, lower the value of imports, or avoid inspections.

In addition to fuel smuggling, other activities, such as the illegal trade of subsidized goods, tobacco, and drugs, also contribute to the growth of the shadow economy. Smuggling networks exploit the country's weak borders, corrupt officials, and the desperate economic situation to carry out their operations, further straining the formal economy and exacerbating the financial crisis in Lebanon (Daher 2022).

Section 4.5 discusses the financial crisis that has led to a surge in cash transactions and cash in circulation, exacerbating liquidity challenges and raising concerns about tax enforcement, money laundering, and terrorist financing.

4.5. Amount of Cash in Circulation

Banks in Lebanon imposed severe restrictions on accessing depositor foreign currency accounts, converting deposits to Lebanese pounds (LBP) upon withdrawal. Consequently, the volume of cash in circulation surged significantly from LBP 6474 billion in September 2019 to LBP 80,171 billion by December 2022 (Banque du Liban (BDL) 2023a) (Figure 6). This surge stemmed from various factors, including depositor distrust in the banking system, rapid currency depreciation, and regulatory directives prompting depositors to convert foreign currency holdings into LBP. These developments exacerbated the liquidity crisis and underscored the challenges confronting Lebanon's financial stability and broader economic framework.

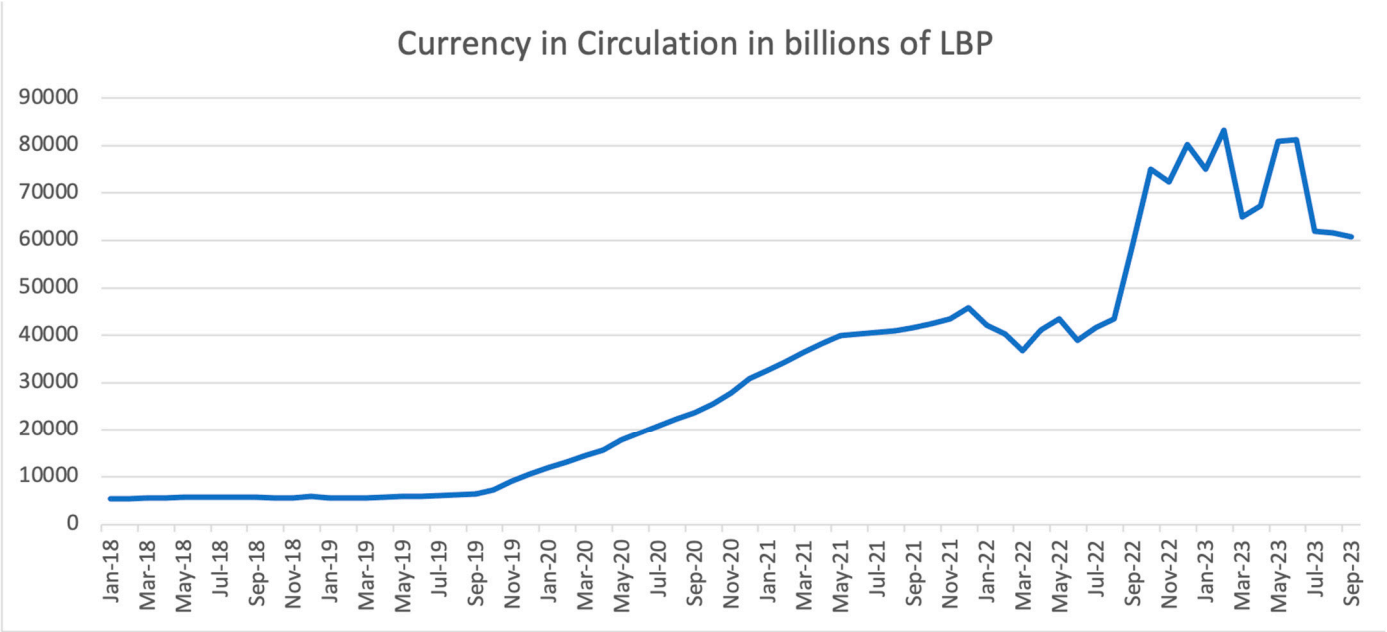

Figure 6. Fluctuation in currency in circulation in billions of LBL from January 2018 to September 2023 (graph created by the authors using data from Banque du Liban (BDL) 2023b).

The cash-based economy in Lebanon has made it challenging to enforce taxes and has raised concerns about money laundering and terrorist financing. Western governments are also worried that illicit transactions may rise as cash transactions are harder to track. The U.S. Department of the Treasury has sanctioned several entities and individuals in Lebanon for compliance issues, which are expected to increase. Recently, a Lebanese money exchanger was sanctioned for alleged ties to Hezbollah, a heavily armed, Iran-backed group (Gebeily 2023).

4.6. Government and Central Bank Regulations

Government and central bank decisions have played a crucial role in shaping Lebanon's economy. Preceding the 2019 crisis, Lebanon maintained a fixed exchange rate regime, pegging the Lebanese pound (LBP) to the US dollar (USD) at a rate of 1500 LBP/USD through financial engineering methods and unsustainable fiscal policies (Abdel Samad 2021). These included subsidies offered at artificially low official rates and the implementation of measures to support the fixed exchange rate system.

Amid Lebanon's ongoing financial instability, exacerbated by a banking sector crisis, the Lebanese Central Bank responded by implementing various measures. These included utilizing foreign reserves, amounting to $1.5 billion, to fulfill Eurobond payments and provide subsidies for vital commodities like fuel, wheat, medicine, and food. In an effort to alleviate the shortage of foreign currency liquidity and shield consumers from inflation, the Central Bank introduced new subsidies and circulars (Banque Du Liban (BDL) 2024)

concerning the withdrawal of foreign currencies. However, these decisions had unintended repercussions, including market distortion and ineffectiveness, primarily benefiting the affluent. For instance, the subsidies, pegged at an official rate of 1500 LBP/USD despite a market rate of around 30,000 LBP/USD, incentivized smuggling across the Syrian border and stockpiling by the privileged segment of the population (Nasrallah 2020). Additionally, these policies gave rise to a novel currency phenomenon, the "Lollar", symbolizing the trapped US dollars within Lebanon's banking system.

The "Lollar", a term coined during Lebanon's banking crisis, represents the devaluation of US dollar-denominated bank accounts due to circulars issued by the Lebanese Central Bank (Helou 2022). These circulars implied that accounts in foreign currency were no longer valued at their nominal worth, leading to the emergence of the Lollar as a new currency standard. As inflation surged alongside the black-market exchange rate, the purchasing power of individuals receiving Lebanese pounds declined, exacerbating poverty levels. The formula for calculating the real value of foreign currency accounts in Lollars demonstrated significant losses for depositors upon cashing their funds, with checks worth only a fraction of their nominal amount. The depreciation of the Lollar continued, with the cash value of a 1000 USD check plummeting to just 16% in January 2024, reflecting a substantial haircut on foreign currency accounts (Abdel Samad 2021).

5. Results and Discussion

Understanding the dynamics of Lebanon's informal economy is crucial amidst its socio-political instability and economic challenges. This section presents the results of our literature review and analysis, highlighting key factors contributing to Lebanon's shadow economy and discussing their implications.

5.1. Key Factors Identified

Through a comprehensive analysis of various indicators, several critical factors influencing Lebanon's informal economy have been identified. Table 2 examines the indicators linked to Lebanon's informal economy, shedding light on its implications. Each factor is analyzed along with its underlying reasons and how they align with the institutional economics framework, providing insights into the institutional context shaping informal economic activities in Lebanon.

Table 2. Summary of causes and indicators related to Lebanon's informal economy.

Causes and Indicators	Description	Reason	Institutional Economics Framework
Higher unemployment and lower GDP per capita	Political tensions, corruption, and economic crises have led to about 50% GDP contraction from 2019 to 2021, unemployment rising to 29.6%, and inflation soaring to 154.9% (World Bank Group 2021b).	Prolonged instability erodes formal job opportunities, pushing many into informal work.	Weak governance undermines institutional quality, fostering informal economic activity.
Tax rates in Lebanon	Regressive taxation and inefficient collection methods drive tax evasion, reducing revenue.	High taxes and lax enforcement incentivize evasion, fueling informality.	Inadequate regulation fosters tax evasion and informality, requiring institutional reforms.
Government and Central Bank regulations	Interventions to stabilize the economy led to market distortions, benefiting the wealthy and exacerbating inequality.	Policy interventions distort markets, encouraging informal economic practices.	Weak regulatory oversight allows for ineffective policies, necessitating stronger institutions.

Table 2. *Cont.*

Causes and Indicators	Description	Reason	Institutional Economics Framework
Financial crisis and smuggling	Economic desperation and corruption foster smuggling activities, resulting in substantial revenue losses.	Economic hardship and porous borders facilitate smuggling and illicit trade.	Weak enforcement and regulatory capture enable illicit activities, demanding institutional reforms.
Amount of cash in circulation	Financial sector deterioration prompts reliance on cash transactions, raising concerns about tax enforcement and illicit financing.	Banking distrust drives cash usage, facilitating tax evasion and illicit activities.	Weak financial oversight allows informal transactions to thrive, highlighting the need for regulatory reforms.
Fiscal balance (% of GDP)	Experienced significant fluctuations, with deficits peaking in 2018 (−11.38%). A brief positive balance in 2021 (+0.64%) (Statista 2024), which indicates drastic government spending cuts rather than healthy fiscal correction.	Economic instability, policy mismanagement, and lack of effective fiscal reforms.	Reflects the impact of government policy choices and institutional capacity on fiscal stability. Poor institutional quality contributes to erratic fiscal management and undermines economic stability.

(Source: Authors).

In the labyrinth of Lebanon's economic landscape, several intertwined factors perpetuate the shadow economy, leaving a trail of consequences. Among these, poor institutional quality acts as a catalyst, fostering an environment ripe for tax erosion and corruption (Svensson 2003). These elements, in turn, fuel the shadow economy, characterized by a web of informal activities, including smuggling. This cycle exacerbates Lebanon's economic woes, contributing to budget deficits and widening income disparities. Similarly, understanding the role of leadership and organizational culture in managing economic uncertainties within organizations, as highlighted in a recent study by Oliveira et al. (2022), underscores the importance of strategic management practices in mitigating systemic risks and fostering organizational resilience, thereby influencing broader economic outcomes. Importantly, these issues are not solely macroeconomic in nature but also manifest at the organizational and institutional levels. Critically analyzing Lebanon's case reveals the intricate relationship between institutional weaknesses and the proliferation of informal economic practices, highlighting the urgent need for structural reforms within the framework of institutional economics.

Our analysis revealed that the dynamics of Lebanon's shadow economy are intrinsically tied to the country's institutional framework.

5.2. Implications of Institutional Factors

Our study also unraveled the interconnectedness of these institutional factors and their adverse impact on Lebanon's economy (refer to Figure 7). These interwoven challenges further amplify economic and financial risks and issues in Lebanon, including high unemployment rates, declining GDP, and currency instability.

Our study reveals the intricate connections among institutional factors and their detrimental impact on Lebanon's economy. These challenges exacerbate economic woes, including high unemployment, GDP decline, and currency instability. Our findings emphasize the urgency of addressing these issues due to their far-reaching consequences on economic stability, government revenues, and societal well-being.

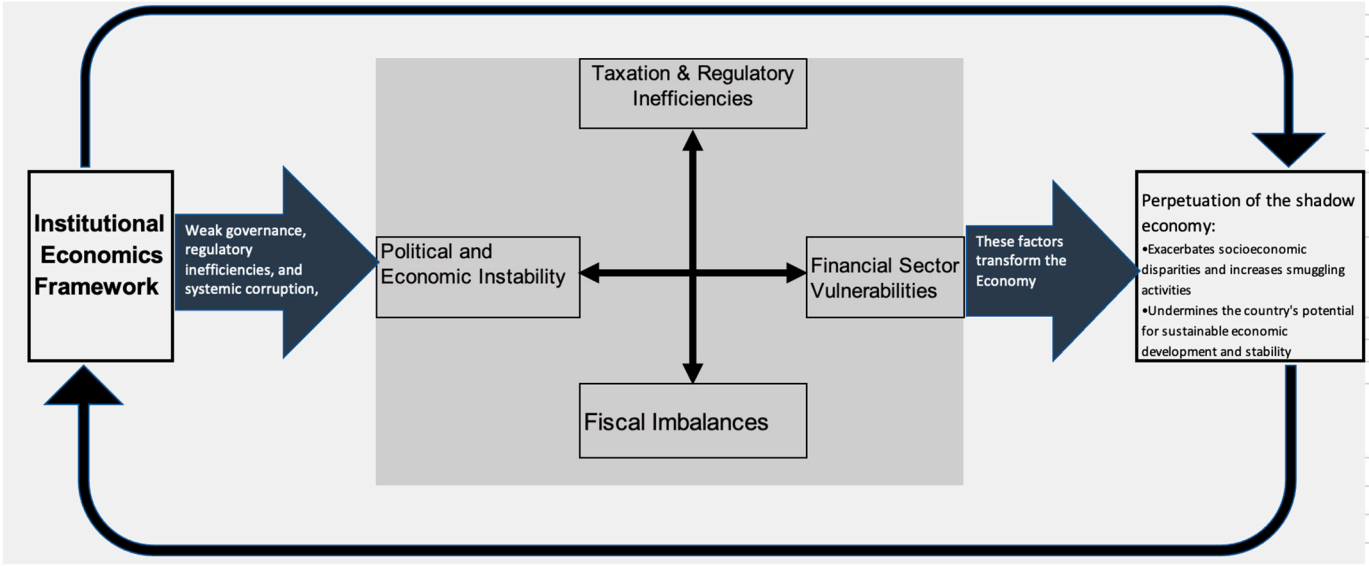

Figure 7. Main independent variables analyzed related to shadow economy and its impact in Lebanon (source: authors).

5.3. Addressing the Challenges

The current policies in Lebanon have proven ineffective in promoting sustainable development. To address these challenges, we recommend the following strategies, as mentioned in Figure 8:

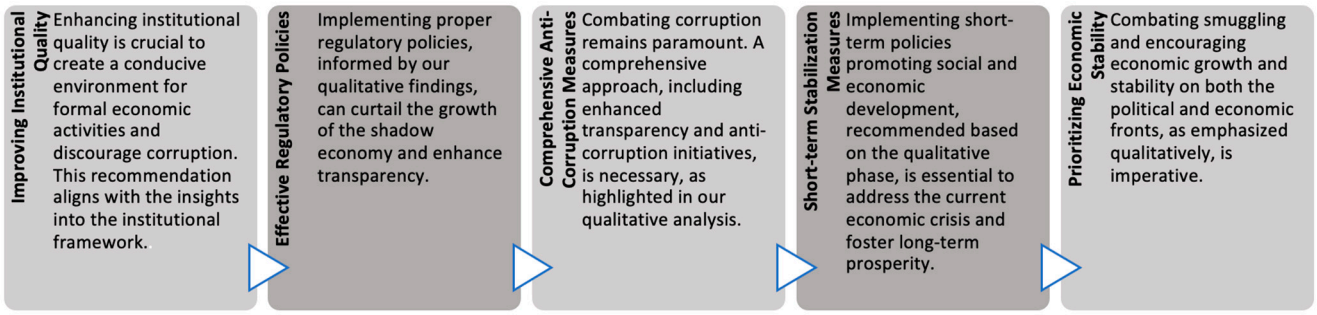

Figure 8. Recommendations to achieve long-term economic sustainability (source: authors).

5.4. Theoretical and Practical Implications

This research extends beyond theoretical insights, providing practical implications that can guide policymaking and real-world solutions to the challenges posed by the shadow economy in Lebanon.

This research enhances our theoretical understanding by demonstrating how institutional weaknesses in Lebanon exacerbate the shadow economy, reinforcing theories that link poor governance to informal economic activities. The study also broadens the theoretical framework by integrating macroenvironmental factors, such as servitization and market conditions, to explain how external elements influence the shadow economy. The influence of servitization on firms' foreign market entry mode decisions highlights the importance of macroenvironmental factors such as market attractiveness and institutional environment (Agnihotri et al. 2022), which are also critical in understanding and addressing the dynamics of the shadow economy. Additionally, the findings validate existing theories on corruption and tax evasion while suggesting refinements specific to Lebanon's institutional failures.

Practically, the study provides actionable recommendations for policy improvements, including enhanced regulatory frameworks, better tax collection mechanisms, and compre-

hensive institutional reforms. It also highlights the need for strategic management practices within organizations to mitigate risks associated with the informal sector. These insights offer valuable guidance for policymakers and can be applied to other similar economies, facilitating informed decision-making and comparative analysis.

6. Conclusions, Implications and Future Research Avenues

Our study sheds light on the complex dynamics of Lebanon's shadow economy amidst pervasive socio-political instability and economic challenges. Table 2 meticulously examines key indicators and underlying causes associated with Lebanon's informal economy, providing a nuanced understanding of its implications within the institutional economics framework.

The findings underscore the critical need for integrated strategies to combat the shadow economy, emphasizing the role of institutional quality, corruption dynamics, and regulatory frameworks in shaping informal economic activities. These insights not only deepen our comprehension of Lebanon's economic landscape but also contribute theoretically by establishing a robust framework for future research in similar contexts globally. By integrating concepts of risk management and financial resilience, our study lays a foundation for developing effective strategies to mitigate the risks associated with informal economic practices.

6.1. Policy Implications

Given the significant risks posed to economic development by the shadow economy, our study emphasizes the urgent need for evidence-based policies that strengthen regulatory frameworks, combat corruption, and promote formalization. Implementing these measures is crucial for enhancing economic stability and fostering sustainable development.

To effectively tackle the shadow economy, policies should encompass several critical areas. Enhancing regulatory frameworks is essential, which involves developing and enforcing robust regulations to combat tax evasion, smuggling, and other informal activities, along with improving transparency in financial transactions and strengthening anti-corruption measures. Fighting corruption requires the establishment of independent bodies with the authority to investigate and prosecute corrupt practices and increasing transparency in public procurement and government spending. Encouraging formalization can be supported by several decisions like simplifying business registration processes, reducing bureaucratic barriers, and providing incentives such as tax breaks or subsidies for businesses transitioning to the formal sector. Strengthening financial sector oversight involves bolstering the capabilities of regulatory authorities to manage financial risks associated with informal activities. Fostering public-private partnerships is crucial for developing effective strategies to address the shadow economy, with industry leaders contributing to best practices for compliance and transparency. Additionally, investing in economic diversification through technology and sustainable industries can create new formal job opportunities and reduce dependence on informal sectors. Importantly, governance reforms are vital, as highlighted by Abou Ltaif and Mihai-Yiannaki (2024), which emphasize addressing political patronage and strengthening institutional frameworks to foster long-term economic stability and development in Lebanon.

6.2. Executive Implications

Managers and industry leaders can derive practical insights from our findings by enhancing transparency and compliance within their organizations. Mitigating risks linked to informal economic activities necessitates rigorous risk management frameworks and adherence to ethical business practices. Embracing sustainable finance practices can further enhance organizational resilience and stakeholder trust amid economic uncertainties.

6.3. Future Research

Future research should build upon our macroeconomic analysis by investigating additional factors that influence the shadow economy. An initial focus should be on exploring macroeconomic elements such as foreign direct investment (FDI) flows, national income disparities, regulatory environments, and economic stability, which play a significant role in shaping informal economic activities. Following this, integrating microeconomic factors will provide valuable insights into how corporate finance strategies, capital structure optimization, and sustainable finance practices impact and interact with the shadow economy. Understanding these microeconomic dimensions can reveal how company-level decisions and practices contribute to the persistence of the shadow economy, thereby informing more targeted and effective policies, reforms, and economic decisions. This comprehensive approach will enhance our understanding of the shadow economy's dynamics and support the development of strategies to mitigate its adverse effects on economic stability and growth.

6.4. Concluding Remarks

In conclusion, our study not only provides valuable insights into Lebanon's shadow economy but also offers practical implications and theoretical frameworks to inform policy interventions and academic inquiry globally. By bridging theory with actionable recommendations, we aim to catalyze efforts towards building more resilient, inclusive, and sustainable economies worldwide. This collaborative endeavor requires concerted efforts from academia, policymakers, and industry stakeholders to translate insights into impactful actions that promote economic stability, effective risk management, and equitable development.

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Government Borrowing and South African Banks' Capital Structure: A System GMM Approach

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Abstract: This paper aimed to investigate the effects of government borrowing banks' capital structure using a sample of banks registered in South Africa from 2012 to 2021. Despite the extensive literature on this association, few prominent researchers have studied this phenomenon in the banking sector. Applying the generalised method of moments (GMM) model, the study established a positive but significant effect on the South African banks' capital structure from total government borrowing, local government borrowing and foreign government borrowing, and capital structure. Contrary to the crowding-out effects detected, the results revealed a positive and significant relationship between government borrowing and banks' capital structure. The crowding-in effect better explains these results, where government borrowing stimulates the local market for goods and services, motivating banks to borrow more in order to meet the demand for loans. Future research should test the cointegrating and causality relationship between government borrowing and bank capital structure. Also, given that the banking sector is constrained by Basel III's capital adequacy requirement, controlling for this factor is critical in future research.

Keywords: capital structure; government borrowing; crowding-in effect theory

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1. Introduction

The literature has examined several theoretical and empirical factors that determine capital structure. These factors that determine capital structure include risk, size, profitability, the tangibility of assets, growth potential, and debt versus non-debt tax shielding. The two main underlying theories to explain these determinants include the trade-off theory (Kraus and Litzenberger 1973) and the pecking order theory (Myers and Majluf 1984). According to the trade-off hypothesis, firms balance the costs and benefits of debt and adjust toward an optimal debt ratio (Kraus and Litzenberger 1973). In the pecking order theory, it is argued that the information asymmetry amongst managers and shareholders affects the cost of financing (Myers and Majluf 1984). However, government borrowing is a new factor deemed to influence company leverage (Akkoyun 2018; Demirci et al. 2019; Gao et al. 2022).

However, government borrowing (GB) can play an essential part in dealing with the economic crisis in the short term. Yet, it may crowd out private investment in the long run (Ayturk 2017). An escalation in government debt supply might decrease investors' demand for a firm's debt compared to equity. Meanwhile, government debt is a better substitute for a firm's debt than equity (Demirci et al. 2019). Hence, firms might regulate the capital structure and decrease their leverage. Friedman (1978) argued that if investors have an inadequate supply of funds and have favourites for the precise kinds of securities, for example, long-term versus short-term, government debt could affect a firm's financing.

Prior research on global capital structure examines the association between GB and capital structure; however, the empirical studies have contradictory findings. For instance, Bahal et al. (2018) explored whether public investment remained excessive or insufficient

before 1980. Utilising investment project data from the CapEx-CMIE, they also created a new data set of average public and private investment in India from 1996 to 2015. Their findings suggest that public investment may have crowded out commercial investment in India from 1950 to 2012. Yet, from 1980 to 2012, their results supported crowding in capital funding. Furthermore, their analysis revealed that crowding is confirmed by their quarterly model, which uses investment project datasets from CapEx-CMIE from 1996 to 2015.

Similarly, Ayturk (2017) looked into the connection between GB and corporate finance choices in 15 major European nations from 1989 to 2014. Using a country-level aggregate and a fixed-effects panel data model with aggregate flow data, they found a robust negative relationship between GB and company debt in advanced European countries. Furthermore, research revealed that the long-term debt of major credit-worthy enterprises is more complex than government debt in comparison to small, economically hampered firms. This suggests that long-term corporate debt issued by creditworthy companies is a better substitute for government bonds (Ayturk 2017).

Graham et al. (2014) studied the effect of government debt on commercial financing and investment in the United States. Their study discovers an insignificant link between government debt and company equity regulations. Nonetheless, they find a substantial positive link between government debt, corporate cash, and other short-term cash reserves, such as treasuries. Ayturk (2017) explored only a simple connection between GB and corporate funding. Yet, Graham et al. (2014) evaluated the impact of government debt on commercial financing and investments. What is not clear at the present moment is whether the transmission mechanism occurs when GB reduces the money supply, raises interest rates, and finally affects capital structure. Therefore, the study aims to determine the effect of GB on the capital structure of South Africa from 2012 to 2021.

In this paper, total government borrowing (TGB), local government borrowing (LGB), and foreign government borrowing (FGB) were utilised to measure GB. As a result, Figure 1 examines the trends in South Africa's average government borrowings from 2012 to 2021.

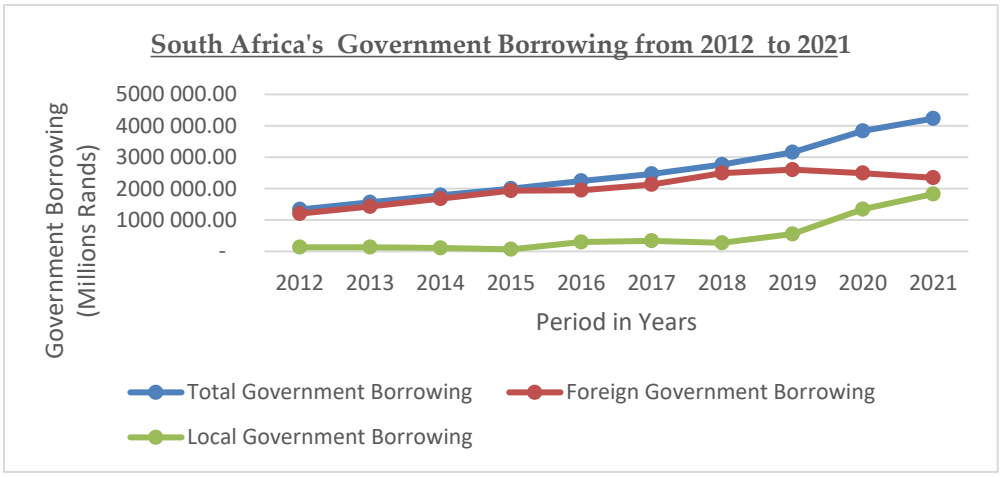

Figure 1. Source: author's own compilation based on the data extracted from SARB.

TGB rose from R1,334,110 in 2012 to R4,230,630 in 2021, based on Figure 1. FGB has increased from R1,202,942 in 2012 to R2,343,843 in 2021. Similarly, borrowing by local governments rose from R1,311,680 in 2012 to R1,827,764 in 2008. Previous research on global capital structure investigates the link between GB and capital structure (Gao et al. 2022; Demirci et al. 2019; Akkoyun 2018; Ayturk 2017; Graham et al. 2014). However, they found contradictory results. Friedman (1978) argued that it is vital to appreciate one probable impact of GB on corporate financing, denoted as financial crowding-out. In contrast, public capital is possibly utilised by increasing productive ability, a crowding effect. Yet, public capital typically complements private capital in the production and distribution of private output; a crowding-in effect. Although its impact has been studied, no consensus has been

reached on its reality, primarily because of the empirical identification problems. Hence, this study investigates the effect of GB on bank capital structure in South Africa from 2012 to 2021.

The research hypothesis in this paper is explained as follows: H1: Does government borrowing influence banks' capital structure?

FGB constitutes 80 percent of the GDP, while local government constitutes 20 percent of the GDP. Eighty percent of FGB implies that the government borrows 80 percent from foreign borrowings, and as FGB does not crowd out a local market, this condition may result in a crowding-in effect. Yet, 20 percent of the LCB implies that the government borrows 20 percent from domestic companies. This study contributes to the existing empirical literature on the relationship between GB and the capital structure of banks, using data drawn from registered banks in South Africa, as the capital structure of banks differs from that of non-financial firms. Previous studies focused on the determinants of capital structure have excluded financial firms (see, for example, scholars such as Jaworski and Czerwonka 2021; Kuč and Kaličanin 2021; Gharaibeh and Saqer 2020; Shahzad et al. 2021). The reason for excluding financial enterprises from capital structure research has been either because they are governed firms or because they have inherent key variables, like having charges or deposits as additional sources of funding (Sibindi 2018). However, few studies have focused on financial firms in South Africa (Sibindi 2018; Sibindi and Makina 2018). While the effect of GB has been studied in developed countries, little is known in developing countries about this issue, particularly in South Africa. Hence, the current paper differs from the papers mentioned above, since this paper focused on the effect of GB on South African banks' capital structure. Bank leverage is strongly regulated through the Basel III regulations, explicitly focusing on the capital adequacy ratio. The rest of this paper is structured as follows: the next section presents a review of the existing literature on the effect of GB on firms' capital structure. This is followed by the methodology that describes our econometric approach in depth. The findings are presented and discussed, and the discussion ends with a conclusion and recommendations.

2. Literature Review

In the literature, extensive research has been carried out to understand what factor influences the capital structure of companies, both technically as well as empirically. Modigliani and Miller (1958) (M&M) pioneered current work on capital structure theory. They demonstrate that the capital structure of a corporation determines its worth. Furthermore, M&M (Modigliani and Miller 1963) presented a revision to their prior study, stating that the firm's worth is independent of its capital structure; however, a gap is created by finance costs on debt. They explain that the discrepancy is attributable to interest payments being taxable income in various nations according to income tax laws. As a result, other academics produced capital structure theories, such as trade-off, pecking order, signalling, market, agency cost, and free cash flow theories.

In their research that establishes the theoretical basis of the static trade-off theory in the future, Kraus and Litzenberger (1973) showed that optimal leverage implies a trade-off between the tax benefits of debt and the burden costs of bankruptcy. Myers (1984) refined it in his static trade-off model, proposing that corporations establish a goal debt-to-value ratio and begin moving towards it, like how companies alter dividends to move towards a target payout ratio. A company's funding options are essentially two: debt and equity. Sibindi and Makina (2018) argued that in a trade-off framework, the company would take on additional debt to take advantage of the debt interest tax shield until the accruals exceed the present value of the interest tax shield. Myers and Majluf (1984), who developed the pecking order theory of capital structure, contend that giving safe assets over risky assets is generally preferable. Myers (1984) supports this argument by claiming that the corporation will indeed internally choose external financing and debt to equity if it can provide the security. As a result of the hypothesis, debt will climb for corporations when investment

exceeds internal financing, whereas indebtedness will fall once the asset becomes less valuable than carefully chosen finances.

The notion of the pecking order is also known as the asymmetric information theory. Information asymmetry emerges because management (internal stakeholders) has more information than investors (outsiders), whom they utilise to their benefit (Sibindi and Makina 2018). The signalling hypothesis stems from asymmetry ideas, which may be traced back to Ross' work (Ross 1977). According to the author, if managers have access to internal information, they can choose between a managerial incentive system and a financial structure that sends data to the market and confirms the significance of the signals in a team balance (Ross 1977). Although market time theory is a subset of the information theory, it has contributed to the creation of the signalling theory. Market time theory, likewise, ignores the concept of optimal capital structure, which has departed from the work of Baker and Wurgler (2002). They contend that managers time their stock offerings with the expectation of issuing fresh shares when the share price is recognised to be higher. They will, in contrast, acquire shares when they are believed to be lower.

However, the crowding-out effect idea can be explained using the neoclassical and Keynesian approaches. The neoclassical approach favours full employment and free markets over government action. According to the neoclassical loanable fund hypothesis, the interest rate system will respond to the equilibrium of savings. For instance, a rise in government spending raises interest rates, pushing the capital market back into balance and crowding out private investment (Arrow and Kruz 1970). This view was supported by David and Scadding (1974), who argued that an increase in government bond issuance crowded out an equivalent percentage of private capital, because deficit finance is considered public capital and the latter serves for private capital investment.

Yet, Keynes (1936) established the impetus for the idea that government expenditure does not crowd out private spending. It is assumed that government expenditure enhances private investment due to the positive impact of government spending on share prices; thus, crowding occurs. Carlson and Spencer (1975) stated that while the Keynesians constructed multiple models, they were never tested as interrelated components. Friedman (1978) proposes a portfolio crowding-out strategy based on the substitutability of public debt and many other assets in shareholders' portfolios, which could result in either the crowding-out or crowding-in of capital funding. This researcher sharply criticises the widespread mistaken notion that the negative effect of the wealth portfolio effect on private investment is the only way to solve the model.

The effect of GB on the firm capital structure has been studied in developed countries by Graham et al. (2014), Ayturk (2017), Akkoyun (2018), and Demirci et al. (2019). However, nothing has been done in developing countries regarding this issue, particularly in South Africa. Graham et al. (2014) investigated the impact of government debt on corporate financing and investment in the United States. Based on the findings, federal government debt issuance in the United States has a considerable impact on corporate financial policy. Furthermore, the study's findings demonstrate a high negative association between corporate debt, investment, and government debt, but a strong positive connection with firm liquidity. They contended that these relationships are clearer in larger- and lower-risk corporations and that debt is a faster alternative for treasuries.

Ayturk (2017) employed a country-level aggregate and fixed-effects panel data model, using aggregate flow data to analyse data in a study on the association between government borrowing and corporate financing decisions in 15 developed European nations from 1989 to 2014. The study discovers a substantial inverse link between government borrowing and company debt, yet no significant relationship between government indebtedness and equity. The study's findings contradict Graham et al. (2014), who found a strong negative link between company debt, investment, and government debt, yet a substantial positive connection with company liquidity. Contrary to those mentioned above, this study focused on the effect of government borrowing on a bank's capital structure.

Akkoyun (2018) examined a study on the impact of government debt on firm financing in the United States of America (USA) during World War 1. The study focuses on the war period because the status of the economy, the manner of corporate security of aid, and the alternative financing strategy of the United States government provide a suitable empirical context to identify the effect. Yet, our research focuses on how government debt impacts the capital structure of South African registered banks. The analysis found that long-term government bond issues had a negative impact on long-term company bonds with a life expectancy of more than five years, common stocks, and preferred stocks.

To investigate the impact of government debt on company capital structure selection, Demirci et al. (2019) used data from 40 nations from 1990 to 2014 and measured government debt using domestic government debt-to-GDPt-1 and external government debt-to-GDPt-1. After adjusting for the nation and year-fixed effects and country-level controls, the researchers discovered a negative effect on government borrowing and company leverage in both levels and variations of debt. They also found that the crowding-out effect is more substantial for superior and higher-returning enterprises, and companies in markets with more developed equity markets or lower bank dependence.

Utilising a sample of state-owned enterprises (SOEs) and non-SOEs, Liang et al. (2017) investigated the impact of local government debt on firm leverage in China from 2005 to 2007 and from 2011 to 2013. As a result, they eliminated 2008 to 2010 due to a lack of data. They tested the effects of crowding out and crowding in the impact of local government debt on company leverage using a benchmark econometric model. According to the findings of their analysis, China's domestic government debt has a considerable crowding-out impact on non-SOE's force, while being crowded in that of SOEs. Furthermore, the effect differed among industries and sectors.

Other empirical investigations have demonstrated a negative connection between government borrowing and capital structure (for instance, Gao et al. 2022; Cheema 2021; Orangian et al. 2021; Xia et al. 2021). An upsurge in government debt, the availability of surplus public debt, is absorbed by corporate investors seeking to impose a raise of the returns on borrowing, which could additionally end in less disbursement of lending; thus, corporate debt would crowd out public debt (Cheema 2021) because of increased government borrowing and firm leverage, and debt ratios may fall.

Emerging patterns, through a review of previous academic research, indicated that despite extensive research on the effect of GB on firm capital structure, there is still uncertainty and no consensus on which proxies GB should use. This has manifested in some discrepancies in in-country studies on the topic. In comparison with other studies, this article used TGB, FGB, and LGB indicators. Foreign government borrowing and local government borrowing were put into perspective since each type of borrowing has its strategic advantages and disadvantages. Therefore, this article accounts for the several factors that are considered when borrowing, including risk assessment, currency consideration, interest rates, regulations, and investor perceptions. The following section discusses the paper's methodology.

3. Materials and Methods

3.1. Data, Samples, and Variables

The population of this paper comprises all 16 registered domestic banks in South Africa. However, a sample of the paper consists of 11 registered banks in South Africa in the period from 2012 to 2021. These 11 registered banks in South Africa include First Rand Bank Limited, Absa Bank Ltd., Nedbank Ltd., Investec Bank Ltd., Capitec Bank Ltd., Standard Bank of South Africa, Grindrod Bank Ltd., Bidvest Bank Limited, Albaraka Bank Ltd., Sasfin Bank Ltd. and HBZ Bank Ltd. Five small banks, namely African Bank Limited, Deutsche Bank AG, Ubank LIimited, Grobank Limited, and Habib Overseas Bank Ltd., were excluded because of the difficulties in accessing financial data for the period of the study. These firms are considered sufficiently illustrative of the registered banks' population in South Africa from 2012 to 2021. The monthly and annual financial and

economic data were extracted from the iress database, the South African Reserve Bank (SARB) and Bankscope-Bureau van Dijk. These registered banks' sample size consists of 11 banks over a period of 10 years, leading to 110 observations for the banking sample. While the selection of the registered banks in South Africa is identified for this research, it is acknowledged that there were differences in the sampled registered banks' procedures, as mentioned earlier.

This paper used three measures of capital structure, namely total debt ratio (TDR), long-term debt ratio (LTDR), and short-term debt ratio (STDR), as dependent variables following other scholars (Saif-Alyousfi et al. 2020). According to Rajan and Zingales (1995), short-term, long-term, and total debt over total assets ratios are much more adequate indicators of financial leverage than the ratio of liabilities to total assets, since they provide a more precise sense as to whether the company is at the probability of insolvency in the near future and present a much more realistic assessment of previous sources of finance. In contrast, GB was used as an independent variable. Graham et al. (2014) state that GB practices play a significant part in enlightening the continuously improving inclination of companies to use leverage in unregulated sectors. Table 1 below shows the details of the dependent and independent variables and data sources.

Table 1. Summary of variables and proxies.

Variables	Proxies and Definitions	Proxies by	The Expected Sign of the Coefficient
Capital structure proxies (Dependent variables)			
Total debt ratio at book value (TDR_B)	TDR_B is defined as the ratio of the book value of total debt to the book value of total assets.	Saif-Alyousfi et al. (2020).	
The long-term debt ratio (LTDR)	LTDR is measured as the ratio of long-term liabilities over total assets	Frank and Goyal (2009), Palacín-Sánchez et al. (2013), Handoo and Sharma (2014), and Saif-Alyousfi et al. (2020).	
The short-term debt ratio (STDR)	STDR is measured as the ratio of short-term debts divided by total assets.	Vo (2017) and Saif-Alyousfi et al. (2020).	
Independent variables			
Total government borrowing (GTB)	Government debt to GDP ratio is defined as the total government debt as a percentage of gross domestic product (GDP) in-country.	Demirci et al. (2019).	Negative
Local government borrowing (GLB)	The percentage of gross domestic product (GDP) is used to determine local government debt	Ahmad et al. (2020), Demirci et al. (2019) and Liang et al. (2017).	Negative
Foreign government borrowing	The foreign government debt-to-GDP ratio refers to government debt due to non-residents.	Demirci et al. (2019)	Negative
Control variables			
Current ratio (CURR)	CURR is measured as the current assets divided by current liabilities	Rao et al. (2017)	Ambiguous
Economic growth measured by Gross domestic product (GDP).	GDP: The growth rate of real domestic product.	Hanousek and Shamshur (2011); Tesfaye (2012); Jõeveer (2013)	Ambiguous
Inflation rates	Annual consumer price index (CPI)	Harris and Roark (2019) and Saif-Alyousfi et al. (2020)	Ambiguous
Interest rates	Effective interest rate	Karpavičius and Yu (2017)	Negative
Size	Size—the natural logarithm of total assets	Frank and Goyal (2009); Jõeveer (2013) and Bandyopadhyay and Barua (2016).	Ambiguous

Source: Authors' own composition.

3.2. Model Specification

We use the dynamic generalised method of moments (GMM) model. The study used Arellano and Bond (1991) and Arellano and Bover (1995)'s endogeneity robust generalised

method of moments (GMM) to ascertain the impact of government borrowing and bank capital structure. The use of GMM was motivated by its ability to account for the persistence of bank capital structure, simultaneity, and time-invariant omitted variables. Furthermore, GMM considers cross-country variation in the model specification and accounts for small sample biases (Asongu et al. 2018). The model has the following form:

$$y_{it} = \alpha y_{i\,t-1} + \beta x_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

where

y_{it} represents the book value of the leverage measures for banks i in time t; x_{it} is the vector of the independent variable for banks and assets managers firms i for time t, representing the banks and assets managers' firm-specific variable; α_0 denotes a constant term; β is the elasticity of the explanatory variables, i.e., slope of variables; μ_i denotes fixed effects in banks and assets managers firms; ε_{it} is a random error term, the subscript i denotes the cross-section and t represents the time-series dimension. The panel data regression analysis was then used to analyse the relationship between government borrowing and banks' capital structure.

Our paper was based in South Africa; therefore, a single-country data approach was utilised. The objective to examine the critical determinants of leverage in South African commercial banks was achieved by regressing the leverage-dependent variables (TDRB, STDR, and LTDR) against the determinants in the following equations. Specifically, the relationship between capital structure and the explanatory variables of bank-specific determinants/macroeconomic determinants was expressed quantitatively in Equations (2)–(4) for empirical analysis.

$$\mathrm{TDR_{it}} = (\alpha - 1)\Delta\mathrm{TDR_{it-1}} + \beta_1\Delta\mathrm{TGB_{it}} + \beta_j\sum_{\frac{j}{t}=1}^{n}\Delta X_{ij} + \Delta\varepsilon_{it} \quad (2)$$

$$\mathrm{STDR_{it}} = (\alpha - 1)\Delta\mathrm{STDR_{it-1}} + \beta_1\Delta\mathrm{LGB_{it}} + \beta_j\sum_{\frac{j}{t}=1}^{n}\Delta X_{ij} + \Delta\varepsilon_{it} \quad (3)$$

$$\mathrm{LTDR_{it}} = (\alpha - 1)\Delta\mathrm{LTDR_{it-1}} + \beta_1\Delta\mathrm{FGB_{it}} + \beta_j\sum_{\frac{j}{t}=1}^{n}\Delta X_{ij} + \Delta\varepsilon_{it} \quad (4)$$

where

TDR_{it} represents total debt ratio at book value for banks i in time t, measured by the ratio of book value of total debt/book value of total assets, $STDR_{it}$ represents the total debt ratio for banks i in time t, measured by short-term/ book total assets, $LTDR_{it}$ represents the long-term debt ratio for banks i in time t, measured by long-term/total assets, TGB_{it} donates government debt to *GDP* ratio for bank i in time t, measured by total government debt as a percentage of gross domestic product *(GDP)* in-country, LGB_{it} is the percentage of gross domestic product *(GDP)* used to determine local government debt, FGB_{it} is the foreign government debt-to-GDP ratio, referring to government debt due to non-residents, $CURR_{it}$ is the current ratio measured by the current assets over current liabilities, $Size_{it}$ is the size of the ith banks on year t measured by the natural logarithm of total assets, X_{ij} is a panel of macroeconomic control variable measurements at the end, which includes interest rates and inflation rates. GDP_{it} represents the GDP growth of South Africa in year t, ε_{it} is the error term, α is the auto-regression coefficient, and β is a coefficient which represents the slope of variables.

4. Results

Banks may keep up to 26% of their weaknesses as short-term debt. The average total government borrowing (TGB) is 2,537,683 billion, with a standard deviation of 916,717.60. The minimum TGB was 1,334,110,000,000.00, and the maximum TGB was 4,230,630 billion. TGB relative to GDP reached a maximum of 0.78 percent. The situation is good, given that the country has financed roughly 78 percent of its GDP. According to the descriptive data, the average local government borrowing (LGB) throughout the period under review was 506,517 billion. LGB was 20% on average. This means that the government borrows

20% of its financing from domestic companies. Yet, the minimum LBG was 64,746.00, and the maximum LBG was 1,827,764.00. In local banks, the more expensive the LGB, the more the debt cost. Foreign government borrowing (FGB) averaged 2,031,165 billion. The average FGB in relation to GDP was 80%. This means that the government borrows roughly 80% of its financing from international markets. The minimum and maximum FGBs were 1,202,942.00 and 2,602,757 billion, respectively. The higher the FGB, the lower the debt cost in domestic banks. This means that an upsurge in the FGB triggers bank crowding in South Africa. Yet, the minimum current ratio (CR) of 0.01 indicates that the South African bank had the lowest CR of 1% during the investigation period. In Table 2, the maximum CR was 2.56, which means that banks can pay up to 2.56% of their short-term debt. The greater a bank's total CR, the lower its short-term obligations on its current assets.

Table 2. Descriptive statistics.

Variables	Mean	Median	Maximum	Minimum	Std. Dev	Skewness	Kurtosis	Jarque–Bera
TDR	2.19	0.92	145.70	0.56	13.81	10.34	108.00	52,493.33
LTDR	0.48	0.21	33.57	0.00	3.18	10.33	107.83	52,319.88
STDR	0.75	0.53	25.70	0.02	2.40	10.30	107.35	51,851.47
TGB (000,000)	2,537,683.00	2,355,683.00	4,230,630.00	1,334,110.00	916,717.60	0.53	2.11	8.74
LCB (000,000)	506,517.60	283,956.50	1,827,764.00	64,746.00	569,005.10	1.44	3.54	39.11
FGB (000,000)	2,031,165.00	2,038,478.00	2,602,757.00	1,202,942.00	459,239.90	−0.41	1.91	8.60
CR	1.38	1.41	2.56	0.001	0.27	−0.02	12.25	391.81
Size (000)	424,000,000	66,849,693	1,660,000,000	2,997,923	508,000,000	0.77	2.12	14.41
INF	4.60	4.70	5.60	3.10	0.85	−0.42	1.92	8.68
IR	3.89	3.71	5.89	2.31	1.09	0.39	2.27	5.26
GDPG	0.95	1.37	4.90	−6.43	2.77	−1.60	5.58	77.24

The average bank size (total assets) was 424 billion, with a standard deviation of 508 billion. The bank's size ranged from 2,997,923 billion to 1660 billion. With a standard deviation of 0.85 percent, the inflation rate averaged 4.60 percent. The minimum and maximum INF were 3.10 and 5.60, respectively. A larger scale implies consumer price uncertainty, which is particularly costly to the poor and small businesses as they lack a hedging strategy toward unexpected developments.

Likewise, the mean IR value was 3.89, with a standard deviation of 1.09. The minimum IR was 2.31, and the maximum was 5.89. Finally, the average rate of gross domestic product growth (GDPG) was 0.95 percent, with a standard deviation of 2.77 percent. Despite this, the minimum GDPG was −6.43, and the maximum GDPG was 4.90.

There is skewness and excess kurtosis in all of the variables under consideration. Because the variables are not evenly distributed, Jarque–Bera supports the results obtained on the standard typical evaluation.

As shown in Table 3, the correlation analysis illustrates the correlations between dependent and independent variables used in the banking sector. The total debt ratio (TDR) was found to be positively correlated with the long-term debt ratio (LTDR), whereas the inflation rate (INF) was found to be negatively though strongly linked to the total debt ratio (TDR). Nevertheless, the inflation rate (INF) was found to be significantly negatively associated with the long-term debt ratio (LTDR).

To capture the endogeneity of the lagged dependent variable and independent variables in this analysis, a matrix of internal instruments is built using the GMM estimator (see Arellano and Bond 1991; Arellano and Bover 1995; and Blundell and Bond 1998). The instruments were lag-dependent variables. A diagnostic estimate was used to test for the stationarity of the series and a correlation analysis in accordance with time-series and cross-sectional investigations. In line with Pesaran (2021), cross-section dependence was also examined because there is a chance of endogeneity in the explanatory factors. The

Sargan test was used to confirm the validity of the instruments (Sargan 1958). The results of the overidentifying constraints test agreed with Hansen (1982). Using the Arellano–Bond test (AR1) and (AR2), the correlation of the error terms—which ensures the suitability of the estimated results—was examined (see Arellano and Bond 1991; Roodman 2009). One further benefit of the system GMM is that it does not require the use of external instruments in addition to the variables that are already present.

Table 3. Correlation.

Probability	TDR	LTDR	STDR	CR	LCR	BLMI	SIZE	INF	IR	GDGP
TDR	1.000									
LTDR	0.9996 ***	1.000								
STDR	−0.0181	−0.0218	1.000							
CR	0.00410	0.0604	−0.0350	1.000						
SIZE	−0.00757	−0.0643	−0.0705	−0.0241	0.0739	0.1006	1.000			
INF	−0.1706 *	−0.1697 *	0.1171	0.1697 *	0.0030	0.1213	−0.1572 *	1.000		
IR	−0.0121	−0.0113	−0.0265	−0.0079	−0.0347	0.0324	0.0287	−0.1348	1.000	
GDPG	0.1371	0.1377	0.0220	−0.074	0.0239	−0.0184	0.0646	0.1964 **	0.2971 ***	1.000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Nevertheless, in Table 4 there is a positive but not significant link between IR and LTDR. However, there is a negative but insignificant relationship between IR and TDR and STDR. In addition, TDR and STDR show a negative yet insignificant connection with bank size. In terms of the macroeconomic parameter GDPG, there was a positive and significant effect on GDPG and capital structure. The results support the trade-off theory, which holds that quicker growth in the economy is linked to the greater proclivity of a firm to use debt to fund capital expenditure, since that facilitates greater tax benefits for debt financing (Guizani 2020). In a similar vein, the results support the pecking order theory, which contends that growth in the economy and capital structure are positively related (Guizani 2020).

Table 4. Determinant's capital structure: Effects of TGB and CR.

	2-Step System GMM	2-Step System GMM	2-Step System GMM
Variables	**TDR**	**LTDR**	**STDR**
L.TDR	1.690 *		
	(0.315)		
L.LTDR		1.660 *	
		(0.349)	
L.STDR			1.701 **
			(0.324)
EV	16.54 *	5.346	16.34 *
	(6.148)	(3.823)	(6.107)
GO	0.190 *	0.0711	0.196 *
	(0.0764)	(0.0758)	(0.0859)
TGB	11.30	18.98	12.49
	(10.70)	(16.00)	(10.86)
CR	61.63 ***	57.67 ***	60.89 ***
	(2.15)	(5.12)	(1.95)

Table 4. *Cont.*

	2-Step System GMM	2-Step System GMM	2-Step System GMM
Variables	**TDR**	**LTDR**	**STDR**
LSIZE	−1.648	1.121	−2.358
	(7.731)	(9.239)	(7.573)
GDPG	1.783 ***	1.574 *	1.803 ***
	(0.300)	(0.294)	(0.302)
IR	−0.940	0.740	−1.120
	(0.733)	(0.706)	(0.788)
INF	2.441 *	4.304 *	2.158 *
	(0.911)	(1.698)	(0.843)
COVID-19	7.620 ***	10.68 ***	6.831 ***
	(1.681)	(3.073)	(1.562)
N	88	88	88
Groups	11	11	11
Instrument	9	9	9
AR(1)	−1.29	−1.00	−1.28
AR(2)	−0.87	0.66	−0.92
Sargan Test	0.87	0.77	0.45
Hansen test	0.07	3.21	0.04

* Driscoll and Kraay robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

There was a positive and significant impact on INF with capital structure. These findings contradict Almanaseer's (2019) contention that throughout times of elevated inflation, banks strengthen their regulations to try to mitigate the effect of inflation on interest rates, thus decreasing borrowing. Furthermore, these findings contradict the findings of Bilgin and Dinc (2019), who discovered a negative yet significant connection between INF and capital structure. Finally, COVID-19 had a negative yet significant link with all capital structure. The results are consistent with Mohammad's (2021) discovery of a negative connection between COVID-19 and capital structure. This implies that the global outbreak had a negative effect on capital structure. Due to the ambiguity, banks may have turned to more secure capital.

In Table 5, there is a positive and significant link between TDR, LTDR, and the legged values of TDR and LTDR. Aremu et al. (2013) discovered a positive and insignificant connection between all bank capital structure metrics. However, there is a positive but insignificant link between STDR and its lagged worth.

The interaction between EV and all capital structure measures was positive and significant. The findings back up the pecking order belief that EV and capital structure have a positive nexus. The results, nevertheless, oppose the trading-off theory's assertion of a negative association between EV and capital structure (Assfaw 2020). The findings are in line with the findings of Assfaw (2020), who discovered a positive yet statistically significant connection between earnings volatility and bank capital structure.

Regarding growth opportunity (GO), there existed a positive and statistically significant connection between GO and TDR, LDTR, and SDTR. The results back up the pecking order theory, which holds that there is a positive link between the development of GO and capital structure.

Table 5. Determinant's capital structure: effects of LGB and CR.

	2-Step System GMM	2-Step System GMM	2-Step System GMM
Variables	**TDR**	**LTDR**	**STDR**
L.TDR	0.704 * (0.313)		
L.LTDR		0.814 * (0.269)	
L.STDR			0.250 (0.214)
EV	15.69 * (5.667)	18.08 * (8.129)	13.54 * (5.889)
	(6.148)	(3.823)	(6.107)
GO	0.273 (0.136)	(0.128) 3.043	(0.207) 2.506
LGB	2.130 (1.774)	3.043 (2.200)	2.506 (1.839)
	(10.70)	(16.00)	(10.86)
CR	54.15 * (18.68)	66.53 * −(27.03)	33.83 * (12.23)
LSIZE	−1.251 (3.183)	−1.499 (4.049)	−7.137 (4.461)
GDPG	0.651 * (0.228)	0.77 3 * (0.300)	0.503 * (0.205)
IR	−0.482 (0.496)	−0.429 (0.638)	−1.373 (0.872)
INF	2.295 * (1.012)	2.929 * (1.236)	0.0435 (0.919)
COVID-19	7.835 * (3.506)	9.754 (4.724)	1.420 (3.136)
N	88	88	88
Groups	11	11	11
Instrument	8	9	8
AR(1)	−1.56	−1.50	−0.80
AR(2)	−0.88	−0.63	−1.29
Sargan Test	0.37	0.64	2.26
Hansen test	0.59	0.29	0.81

Driscoll and Kraay robust standard errors in parentheses * $p < 0.05$.

For LGB as an indicator of government borrowing, there was a positive insignificant nexus between LGB and TDR, LTDR, and STDR. However, a negative and insignificant link existed between size, interest rate (IR), and TDR, LTDR, and STDR. GDPG had a positive and statistically significant association with TDR, LTDR, and STDR. The findings are equivalent to those addressed in Table 4.

A positive and significant connection exists between CR and TDR, LTDR, and STDR. The larger the total ratio, the greater the probability an entity is to be able to pay its costs. As a result, a larger ratio is more advantageous from the standpoint of the lender. However, from the standpoint of an investor, this has not been the case. Since current assets frequently have lower displayed yields than capital assets, shareholders ought to believe that current assets consume the bare minimum of the company's capital. The results correspond to the

findings reported by Rao et al. (2017). The latter found a link between financial leverage and the current ratio.

The annual inflation rate (INF) shows a positive association between INF and TDR, and LTDR. According to Bilgin and Dinc (2019), as inflation falls, firms enhance their financial obligation level; however, as inflation rises, firms reduce their debt level. The findings contradict those of Almanaseer (2019), who discovered a negative link between INF and bank capital structure. Nevertheless, there was a positive yet not significant connection between INF and STDR.

In terms of COVID-19, there was a positive connection between COVID-19 and TDR. The findings contradict Mohammad's (2021) finding of a negative link between COVID-19 and capital structure. However, COVID-19 had a positive yet non-significant interaction with the LTDR and STDR.

Table 6 demonstrates a positive yet insignificant link between TDR and LTDR, which lags at capital structure values. Nevertheless, STDR and its lagged capital structure values have a negative yet insignificant connection. Similarly, there is an insignificant connection between size, GDPG, IR, COVID-19, and capital structure. There was a positive and insignificant connection between EV and TDR, and LTDR. On the other hand, there is a positive but not statistically significant link between EV and STDR. The findings support the pecking order theory, which states that EV and capital structure have a positive link. However, the findings go against the trading-off theory prediction of a negative link between EV and capital structure (Assfaw 2020).

A negative and significant connection exists between GO, TDR, and LTDR. Nevertheless, the study found a positive and statistically significant association between GO and STDR. Guizani (2020) contends that when internal funds are scarce, banks with more investment options increase their reliance on financing through debt. The findings are consistent with the pecking order theory's expectation of a positive association between GO and capital structure (Myers and Majluf 1984).

Similarly, there was a negative statistically significant link between FGB and STDR. This suggests that because the government has borrowed foreign currency, the private sector is now borrowing short-term to buy the cheap foreign currency that the government would have borrowed to maintain the exchange rate. The findings are consistent with those of Demirci et al. (2019), who discovered a negative significant link between FGB and capital structure. Nevertheless, this study found a negative and significant link between FGB and STDR.

The current ratio and results are comparable to those in Table 5. All capital structure measures have a positive and significant connection with CR. In terms of the inflation rate (INF), there is a positive yet statistically significant link between INF and TDR, and LDTR. According to Anarfo (2015), when banks are able to anticipate the level of the rate, they may adjust their interest rate and reduce their burden of spending. However, as central banks monitor inflation and adjust interest rates in response to it, greater inflation will result in higher interest rates, leading banks to borrow less and increase their level of equity (Smaoui et al. 2020). Almanaseer (2019) discovered a negative relationship between INF and bank capital structure, which contradicts the results of this study. Nevertheless, INF and STDR have a negative yet not significant connection. On the other hand, there was a positive correlation between COVID-19 and TDR and LTDR. The result contradicts Mohammad's (2021) finding of a negative connection between COVID-19 and capital structure. However, there was a negative yet not significant link between COVID-19 and STDR.

Table 6. Determinant's capital structure: Effects of FGB and CR.

	2-Step System GMM	2-Step System GMM	2-Step System GMM
Variables	**TDR**	**LTDR**	**STDR**
L.TDR	1.048 (0.522)		
L.LTDR		0.646 (0.400)	
L.STDR			−6.863 (3.376)
EV	2.251 (4.294)	4.545 (3.727)	14.13 * (5.295)
GO	−0.158 (0.143)	−0.0682 (0.139)	0.183 * (0.0827)
FGB	66.70 (46.37)	57.26 (37.78)	−41.87 * (18.51)
CR	75.16 * (30.96)	71.71 ** (22.27)	33.83 * (13.76)
LSIZE	−6.453 (10.29)	−4.714 (10.74)	−5.293 (6.347)
GDPG	1.177 (0.619)	1.147 (0.562)	0.503 * (0.205)
IR	−0.692 (1.202)	−1.253 (1.715)	−1.683 (1.206)
INF	4.787 * (1.737)	3.511 ** (0.929)	−4.593 (2.636)
COVID-19	13.66 ** (4.238)	10.62 ** (2.959)	−1.379 (2.992)
N	88	88	88
Groups	11	11	11
Instrument	9	8	10
AR(1)	−1.23	−1.88	−0.62
AR(2)	−0.99	−0.96	−0.77
Sargan Test	16.40	8.02	0.03
Hansen test	1.63	0.17	0.13

Driscoll and Kraay robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$.

5. Conclusions

The article aimed to investigate the effects of government borrowing on 'banks' capital structure. This was done in a bid to put the crowding-out effect theory into perspective. A system GMM approach was employed, and the results were intriguing. Contrary to the crowding-out effects, the results revealed a positive and significant relationship between government borrowing and capital structure. Intuitively, government borrowing would crowd out the domestic market, but this is not the case in South Africa. In South Africa, the greater the government's borrowing, the greater the banks' leverage. Unlike Demirci et al.'s (2019) argument that a rise in government debt supply might decrease investors' demand for corporate debt compared to equity because government debt is a superior alternative for company debt to equity, banks in South Africa seem not to be constrained by this. Moreover, the results are inconsistent with the findings of Liang et al. (2017) and Wang et al. (2020), who find a negative association between LGB and capital structure.

Since government borrowing by all measurements did not crowd out a local market, this condition could be explained by the crowding-in effect. Further analysis indicated that foreign borrowing accounts for around 80% of overall government borrowing and does not crowd out domestic private companies. Demirci et al. (2019) argued that if resources are underutilised, public expenditure might promote investment and boost private spending, resulting in a "crowding in" effect.

Therefore, there is a need to strike a balance between government borrowing and the stimulation of the banking environment. The crowding-in effect implies that as long as the government can still provide services, they can continue to borrow, as this does not affect the banking sector. On the other hand, as long as the government seems to be borrowing more foreign than local, the bank should not be worried about the crowding-out effect. Therefore, they can still increase their debt ratios without any problems. Future research should test the cointegrating and causality relationship between government borrowing and bank capital structure. Also, given that the banking sector is constrained by Basel III's capital adequacy requirement, controlling for this factor is critical in future research.

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Uncertainty Reduction in Operational Risk Management Process

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Abstract: This paper proposes a new framework to reduce the variance and uncertainty in the risk assessment process. Today, this process is susceptible to background noise from sources of human factor biases and erroneous measurements. Our new framework consists of deconstructing the likelihood of failure function into its sub-factor and then reconstructing it in a formula that can reduce the variance and biases of a human auditor judgment. We tested our new framework on both a questionnaire study and a simulation of the risk assessment process, and the improvement in reducing the variance is significant.

Keywords: operational risk; risk management; risk factors; risk assessment; uncertainty reduction

1. Introduction

The notion of operational risk management process in organizations is an ongoing effort to identify, analyze, and assess the organization's risks and to respond to each scenario on strategic and operational management levels (ISO 31000:2018(en), Risk management—Guidelines n.d. (ISO 2018)). During the risk identification stage, the possible causes of disruptions and the magnitude of events are examined for external and internal factors. Next, the risk analysis process quantifies each event's risk level based on likelihood, results, and control mechanisms for reducing the risk and their effectiveness. Finally, a comprehensive risk assessment can be considered, and decisions can be made concerning addressing each risk.

The final stages of the risk assessment process in current practice consist of appraising the undesired outcomes of a process based on answering the questions "What is the likelihood of occurrence?" and "If it does go wrong, what are the consequences?". Both questions are subjective; thus, assessing the likelihood is not an objective truth and largely depends on the experience and personality of the assessor. In other words, the current state-of-the-art risk assessment process in operational management involves uncertainty regarding the events (as systems' complexity increases) and uncertainty regarding the risk analysis.

In recent years, the complexity of processes in projects and organizations has increased considerably (Qazi et al. 2016; Lochan et al. 2021), and such complexity contributes to the uncertainty of events (Aven and Zio 2011). In addition, the lack of knowledge and proper information regarding the process and the relations between factors significantly influences the ability to reach a high level of precision (Thomas et al. 2013). A new method that emphasizes the importance of knowledge on risk assessment was described in a paper (Aven 2013) that conditioned the risk level in the risk matrix as a function of knowledge of the system and the factors.

One of the most prominent challenges in risk management today is the auditor's subjectivity bias in determining the risk levels. While risk matrices (Elmontsri 2014) are still one of the most prominent evaluation tools for auditors, it is well known that they have several inherent limitations in defining and categorizing risk (Ball and Watt 2013). The most prominent restriction, as can be seen in Anthony Cox's paper (Anthony Cox 2008), states that the severity ratings in these matrices still depend on subjective risk attitudes. Others

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also point to significant deficiencies in the risk assessment process due to subjectivity, heuristics, and arbitrariness in ranking the risks (Thomas et al. 2013). Those deficiencies in everyday practice can be called cognitive biases and the human factor in the process. Significant cognitive biases such as anchoring, conformity, or overconfidence biases can inadvertently affect the accuracy and precision of the likelihood assessment process (Selvik and Abrahamsen 2017).

Considering the limitation mentioned above, there are many cases where, in practice, there are significant gaps in risk assessments that were conducted at the same organization by different auditors. There is no simple method to determine which auditor is more accurate, but it is clear that a lack of consistency between assessments is undesired. For example, we analyzed a few actual risk surveys conducted in 2015–2023 in industrial companies and service organizations. We compared two risk surveys for each company, that were conducted at the same time period, and studied the gaps between the different auditors. Specifically, we looked at four risk surveys containing 71 items. By analyzing the differences between the auditors, we could see an average difference of 24% between the risk levels evaluated by different auditors, which exemplifies the inconsistency in the risk evaluation results. This gap in the research is our focus in this work. The current literature does not provide an adequate methodology to reduce the variance and bias effect on the assessment process.

In our work, we provide a methodology that will decrease the variance in human auditors and consequently improve the reliability and accuracy of the risk assessment outcome. We decompose risk into its atomic subcomponents and evaluate these subcomponents directly. These subcomponents will then be combined to assess the original risk matrix (Zampeta and Chondrokoukis 2022). Our central intuition is that the magnitude of human error and their variance in subjective assessment will reduce when assessing smaller risk factors. This intuition stems from two sources. First, compounded risk is more complex to evaluate as different individuals can quantify it differently due to cognitive biases. A comprehensive article (Kleinmuntz 1990) suggests that combining intuition and a systematic approach can reduce biases due to subjective constraints and support decision-makers to improve precision. Second, from a statistical point of view, replacing a single measurement characterized by a variance σ2 with the average from n measurements, each characterized by a variance σ2, decreases the average result's variance to σ2/n. This property of variance of sample mean may reduce the volatility of the multifactor mean versus a single factor parameter of the assessment (Todinov 2017). In our literature review, we did not find papers in the field of our topic of research and no other frameworks to reduce uncertainty were suggested by scholars. There are papers that relate to the mitigation of uncertainty in the operational process (Durugbo and Erkoyuncu 2016), although their focus is not on risk assessment methods but only in quality control and managerial procedures.

Our framework utilizes techniques from causal inference and Directed Acyclic Graph (DAG) modeling (Shrier and Platt 2008) to study the mechanism behind the uncertainty and complexity in assessing the likelihood function of risk. By utilizing DAG for modeling, we can reveal the main components that affect the likelihood of risk mechanisms to quantify and define these factors precisely.

The new framework was evaluated both in an experimental setting and a simulation. In the experimental setting, we let human auditors assess a case study using the traditional method (a single score) and the new framework of sub-factors. The findings show that our new approach of segmentation into sub-factors significantly reduced the variance of the assessments compared to the traditional evaluation. Using a Monte Carlo approach, the simulation study included two groups of randomly selected scores. The first group generated a single factor, and the second group was programmed to generate six sub-factors and calculated the total likelihood score based on the formula. This simulation also significantly reduced the variance in the new framework and provided an additional mathematical verification for the new methodology of segmentation and deconstruction of the risk.

In Section 2, we discuss the current practice in risk assessment process and introduce our method of analyzing the sources of uncertainty in operations and the basic structure of our framework. In Section 3, we present the application of the new methodology in an experimental study and in a simulation of some stochastic processes. In Section 4, we discuss the implications of the novel framework and in Section 5, we conclude and suggest some research directions in this area.

2. Framework of Deconstructing the Risk Function

2.1. The Current Practice

The risk matrix is the primary tool for assessing and prioritizing risks based on their likelihood and impact today (Burstein and Zuckerman 2023). It visually represents potential risks, allowing organizations to make informed decisions about allocating resources for risk mitigation. The matrix (see Figure 1) typically consists of a grid with two axes: (1) likelihood: this axis represents the likelihood or frequency of a risk event occurring; it is often categorized as low, medium, or high; (2) consequence: this axis represents the potential consequences or severity of a risk event if it were to occur. Impact is also often categorized as low, medium, or high.

		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Figure 1. A generic risk matrix.

The matrix is divided into different cells or zones, each corresponding to a combination of likelihood and impact. These cells are usually color-coded or labeled to indicate the level of risk associated with that combination. Standard labels for the cells include "low risk", "medium risk", and "high risk". By plotting individual risks on the matrix, organizations can quickly identify and prioritize those that pose the most significant threats. This helps develop a targeted risk management strategy, focusing efforts and resources on mitigating the most critical risks. Additionally, it facilitates communication and decision making among stakeholders by providing a clear visual representation of the overall risk landscape.

Assessments of likelihood and consequence are the basic steps in determining the calculated risk score level in the matrices (risk = likelihood $\times$ consequence) (Burstein and Zuckerman 2023). Due to the biases, any small error in the likelihood directly affects the computed result. The consequence score is quantitative and thus easier to assess relatively accurately. In contrast, the likelihood score is more qualitative and obscure and highly susceptible to the auditors' judgment and bias.

This source of variance is a systematic problem of the risk matrix method; it reflects the differences between assessors and can lead to wrong information that reaches the decision-

makers. Due to many cognitive biases affecting the likelihood score, different auditors have different histories, personalities, and judgments, which is a given fact. Therefore, we suggest improving the variance by breaking down the likelihood structure. Our method will try to minimize the overall influence on the final score.

2.2. The Sources of Uncertainty in the Risk Analysis Process

Our research is based on developing a simple-to-apply framework for deconstructing the likelihood factor into its essential elements of sub-factors. The intuition behind the segmentation into sub-factors arose due to the understanding that some sources of uncertainty are related to an aleatory process and some lack of knowledge regarding the process parameters (Burstein and Zuckerman 2023). We can also relate free will and human factor interests and judgment as a source of uncertainty and unpredictability. Firstly, we can classify the different sub-factors into two main classes: the first consists of objective factors and the other of subjective factors. Here are some examples of factors belonging to each of these classes:

- Objective factors—machine output and tolerance, equipment maintenance according to specifications, mean time between failures, compliance with best practice standards, level of redundancy, and systems back-up and controls.
- Subjective factors—level of human resource integrity, level of personal training and awareness, level of process complexity, and level of variance or entropy in the process.

The class of objective factors consists of mechanisms or systems that allow us to obtain a relatively objective and quantifiable measure regarding the likelihood of risk. For instance, the mean time between failures (MTBF) is a well-known measure in which we can review experience (e.g., machine logs) to obtain an objective and reliable measure. The class of subjective factors consists of factors that are harder to quantify and often rely on subjective and qualitative evaluation. For example, the level of human resource integrity is a factor that measures, among others, the level of professionalism and commitment to the organization and to its mission. These values are more abstract and will probably have a high level of variability between different auditors.

One of the primary findings from our experience in real-world practice is that the uncertainty in the risk assessment process may be composed of a mixture of factors contributing to the total likelihood in many different directions. For example, in some cases in operational risk, we can identify situations where two minor risk factors can generate a very high-risk outcome due to positive feedback or cross effect and even the presence of an unobserved cofactor that amplifies the impact (sort of constructive interference). The combination of the threshold conditions of risk occurrence with the factors contribute to system failure. In our deconstruction framework, we can reduce the uncertainty of the assessment by quantitatively improving our understanding of the mechanism and factors behind these elements.

In Figure 2, we schematically describe the zone where the realization of two components might cause, with some likelihood, the occurrence of the risky event. These components are the natural frequency of the risk event to happen, $f(x)$, and the conditions for failure in dealing with it, $f(y)$. We posit that the risk occurrence is contingent on these two conditions; elsewhere, if any of them are not realized, the likelihood of a risk event is zero. The product $f(x) \times f(y)$ is the likelihood we seek when proposing this new formula.

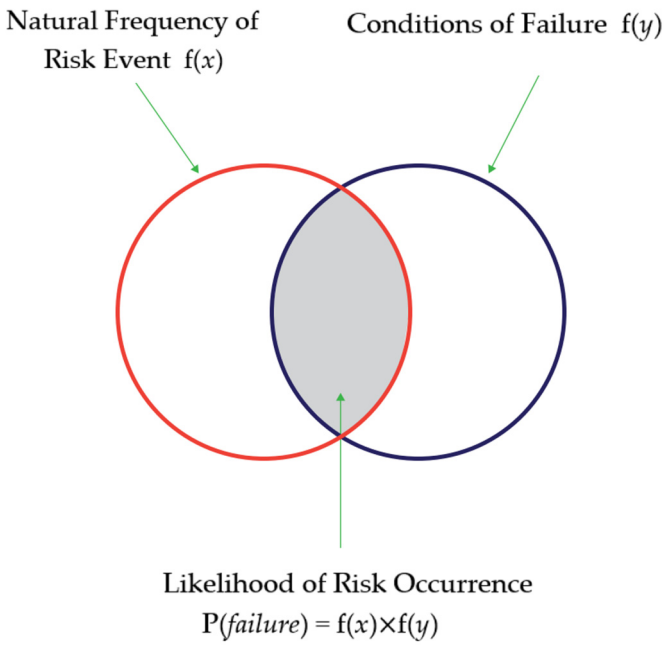

Figure 2. The conjunction of risk sources that cause failure.

2.3. The Natural Frequency of Risk Event-f(x)

This element consists of the frequency of the risk occurrence (low, medium, high) and the volatility or variance of the risk (low, medium, high). Thus, X = {frequency, variance}. We suggest that high variance can significantly increase the likelihood even if the expected risk frequency is relatively low because it "shifts" the likelihood density function into a fat tail distribution. In practical terms, we suggest that there is an amplifying effect when a high variance of the mean increases the area at the right end of the distribution. For example, when comparing two independent systems with a similar normal distribution of failure probabilities, we expect to find a higher risk of failure in the system with a higher variance on the same mean as shown in Figure 3.

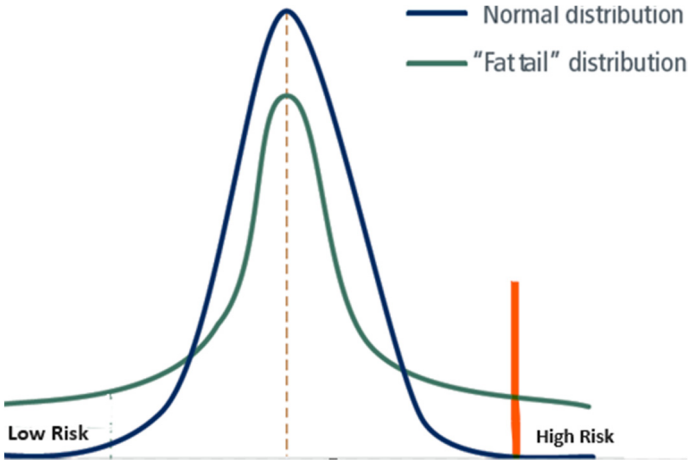

Figure 3. Normal vs. "Fat tail" distributions.

Table 1 depicts the effect of variance on the likelihood score. From our point of view, very few auditors are paying the required attention to this serious effect. Neglecting the fat tails' frequency of risk can increase errors and variance in the assessment. In this proposed method, the likelihood is computed as a function of the frequency of the occurrence, its variance. We mean that if the likelihood of event is low but the variance of outcomes is medium (or high) or in the case that the likelihood is medium but the variance is high, then

that effect increases the risk likelihood due to the uncertainty span. In contrast, a very low variance will not reduce the likelihood; it is a one-directional effect. This methodology can improve the precision in determining the natural frequency of risk events, a major parameter in the risk assessment process.

Table 1. The natural frequency of risk event as a function of likelihood and variance.

Likelihood of the occurrence	**High (5–6)**	High	High	High
	Medium (3–4)	Medium	High	High
	Low (1–2)	Low	Medium	High
		Low (1–2)	**Medium (3–4)**	**High (5–6)**
Variance of the Outcomes				

For example, let us assume that the likelihood of the occurrence is 4 (medium) and the variance is 5 (high). We compute f(x) to be 5 from these two parameters and the matrix below. The increase in risk level from 4 to 5 is due to the "fat tail" as given by the high variance level (of 5) and can be clearly seen in Figure 3 that there is higher density in the right "tail" of the distribution.

2.4. Conditions for Failure Occurrence-f(y)

Our method of refining the sources of uncertainty is based on analyzing the likelihood of failure using a Directed Acyclic Graph (DAG). The DAG helps break down factors and reveal the flow of association and causation. Prior research suggests that DAG modeling can reduce bias in causal inferences about exposure (Shrier and Platt 2008). We will use a DAG-based model to better understand the causes of the likelihood of failure in a system or an operational process.

Defining the root factors and their relations to the outcome is one of the most crucial steps in understanding and analyzing the causes or likelihood of failures. In Figure 3, we can see our suggestion for modeling the main sub-factors and variance generators on the likelihood of risk. If a need arises for more accuracy and precision, one can keep drilling further to a higher resolution by breaking each sub-factor into another layer of its sub-factors. In this study, we focused on the manufacturing industry just as a way to prove a concept of the framework. It can be utilized by some minor modifications or by adding a few sub-factors to fit it to other domains by finding the relevant sub-factors that influence the likelihood of a failure or a crisis and applying the novel methodology. We do not claim that the proposed model, as depicted in Figure 4, is optimal. Moreover, it is most probable that risk analysis in different sectors (e.g., financial vs. industrial sectors) will require a unique adaptation of the framework for better results. However, the level of granularity, as depicted in Figure 3, and the generic definition of the sub-factors provided were sufficient for presenting our framework and its evaluation.

We analyzed the likelihood of an event failing and devised four main sub-factors that substantially influence this outcome. The following details represent the main sources used in our formula to calculate the likelihood of failure. In our descriptions, we used values ranging from 1 (low-risk grade) to 6 (high-risk grade), but these values are ad-hoc and can be arranged as desired.

- Level of complexity—This, for example, can be described as the number of parts or moving parts in a mechanical system. In the context of a man-machine interface, it can be expressed as the number of options, elements, gauges, or operating buttons. In an organization, it can imply the number of functions or employees participating in a process. It can also be the number of outcomes and levels of entropy in the process.

A value of 1 will signify low levels of complexity, while 6 will signify a high level of complexity.

- Stability and predictability—The stability of a process can be viewed as the tolerance of the output in a process or the ability to predict a failure in a system based on its historical records. This is related to variance in the process and the ability to extrapolate an outcome based on the existing data and knowledge. In cases of randomness or stochastic process, the grade will be low, 1, and in a stable and deterministic process, the grade will be high, 6.
- Command, control, and redundancy—This sub-factor relates to the mechanisms and procedures taking place in the process that aim to reduce or prevent the chance of problems. In susceptible system elements, redundancy can be crucial to minimize failure. In cases of a well-controlled and redundant system, we will grade it as low risk, 1; cases with no controls or redundancy will be graded as 6.
- Knowledge, understanding, and training—Assessment of the organizational structure, organization culture, and human resource procedures that include training and qualifications to reduce sources of failure or crisis out of control. Another aspect of this sub-factor can be the auditor's knowledge of the process and system. Proper knowledge, understanding, and training will result in a low-risk value of 1, while poor knowledge and experience will result in a high-risk value of 6.

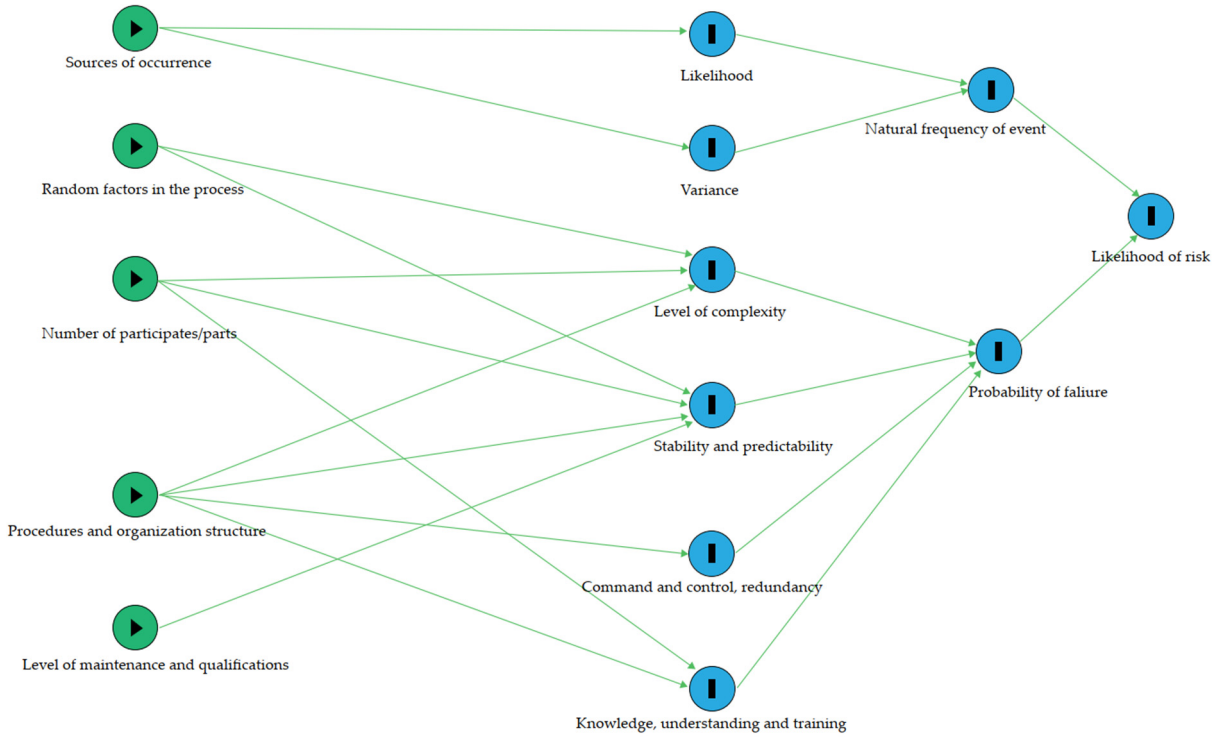

Figure 4. DAG of likelihood sub-factors.

2.5. A Computational Example of the Framework

As used in practice, the basic notion of calculating risk levels is based on one parameter representing the likelihood and one parameter representing the consequence—their multiplication results in the risk level that goes into the risk matrices. For example, when a procedure is assessed to have a likelihood level of 4 and a consequence of 5, the risk level of this procedure will result in $4 \times 5 = 20$. As pointed out in the body of this article, the consequence assessment is much more structured and easier to quantify, but the likelihood is more challenging to estimate due to its obscureness and fuzziness.

Using our proposed method for calculating the likelihood, we can see the following computation occurring:

$$Risk\ Level\ =\ \mathrm{f}(x) \times \mathrm{f}(y)$$

First, we begin by computing the natural frequency of the event, f*(x)*. For instance, let us assume that the frequency of the event is 4 and the variance of frequency is 6. We compute f(x) as 5 from these two and the likelihood matrix, the increase in frequency from 4 to 5 is due to the "fat tail" as given by the high variance level of 6 and can be clearly seen in Figure 3. Next, we compute the likelihood of failure, f*(y)*. We measure and quantify the values of the four sub-factors as follows: complexity (C) = 5, stability and predictability $(S)\ =\ 6$, command, control, and redundancy (R) = 4, and knowledge, understanding, and training (K) = 4. We take their average and arrive at 4.75 (denoted as P). Finally, we can compute the likelihood of the risk occurring, which is the product of the two functions; therefore, it is $5 \times 4.75\ =\ 23.75$. In our opinion, the reconstruction of the likelihood function in the new framework is more precise, less biased, and volatile. In the next section, we test our hypothesis in questionnaires and the simulation of an operational process.

3. Experimental Design and Results

To evaluate and analyze the performance of our model, we designed and conducted both an experimental study by questionaries and a simulation of a process using the Monte Carlo approach. The experiments were designed to verify the claims that applying this framework will result in fewer variations among auditors of the same situation, comparing our new method to the traditional method.

3.1. Human Evaluation Study

The study was designed to compare two groups of independent auditors that receive the same descriptions of two operational processes in each company. We formed two groups of auditors: one that used the new risk assessment framework (by a few sub-factors), and the second group conducted the traditional framework (a single number). Each group of auditors was asked to assess two textual descriptions of an operational scenario containing (1) a low-risk and (2) a high-risk level; the auditors in the first group were asked to assess the risk level of the process by the new method of a few factors that combined to a calculated total risk score. The auditors in the second group were asked to do the same but with the traditional method of ranking the risk level by only one parameter between 1 (low) and 6 (high). Our goal was to realize whether the new framework significantly reduces the variance between auditors within the group compared to the second group, which uses traditional risk assessment methods.

We conducted this study twice. The first run was on a high-risk operational scenario due to poor controls, and the second was a scenario of a well-controlled operation resulting in a low-risk operation. For the auditors of the new method, we calculated the risk level based on the data of the sub-factors they produced.

The process we applied in this study consisted of 35 randomly selected auditors aged 30–60 who were asked to reply to an internet-based questionnaire. We designed the study so that each person received a text (see Appendix A) that reflects a risk situation in an operational system. In one questionnaire, we were asked to assess the risk level traditionally (one score of 1–6 represents the risk level). In the other questionnaire, we were asked to assess the risk level using the new methodology by a set of six parameters (as explained in Section 2.5). We compute the total risk score in the new framework by calculating the average risk level of the sub-factors that construct the event multiplied by the likelihood level.

The low-risk scenario study showed the following: The traditional method resulted in an average likelihood score of 2.189 compared to a low average likelihood score of 0.806 when using the new method. Similarly, the variance of the results was 1.126 for the traditional method and 0.21 for the new method. This amounts to a reduction of 76.14%

in the variance between the groups. The difference in variance was significant using an analysis of variance test ($p = 0.00194$).

In the second part of the study, the high-risk scenario, the number of auditors was 35, and the results showed the following: The traditional method resulted in an average likelihood score of 5.058 compared to a low average likelihood score of 3.663 when using the new method. Similarly, the variance of the results was 0.306 for the traditional method and 0.073 for the new method. This amounts to a reduction of 81.35% in the variance between the groups. This study's results proved significant as we computed a $p < 0.001$ using an analysis of variance test.

3.2. Simulation Study

A complementary study to assess the mathematical validity of our proposed method was conducted using a Monte Carlo simulation. The simulation included two groups of randomly selected scores; the first group generated a single factor score, and the second group was programmed to generate six parameters that represent the sub-factors of the framework and calculated the total likelihood score based on the formula. We simulated 1998 iterations and then conducted the same Levene test, (Lim and Loh 1996) using the same procedure we used in the human evaluation study. The simulation was performed in different cases ranging from low-risk to mid-risk and high-risk scenarios that were tuned by the tolerance of the intervals of the random scores' generator. We then tested the p-values to check the equality of variance between groups of traditional and new methods of risk assessments. The results of Levene's test of the simulations reflect significantly lower variance in the new methodology.

The low-risk scenario simulation showed that the traditional method resulted in an average of 0.32985 likelihood compared to 0.10025 when using the new method. Similarly, the variance was 0.06137 for the traditional method and 0.010733 for the new method. This amounts to a reduction of 82.51% in the variance between the groups. The difference in variance was significant using an analysis of variance with Levene's test ($F = 1628.75$; $p = 5.4204 \times 10^{-299}$).

The medium-risk scenario simulation showed that the traditional method resulted in an average of 0.5841 compared to 0.2667 when using the new method. Similarly, the variance of the traditional method was 0.033185 and 0.015682 for the new method. This amounts to a reduction of 53.34% in the variance between the groups. The difference in variance was significant using Levene's test ($F = 506.47$; $p = 1.0708 \times 10^{-105}$).

Last, the high-risk scenario simulation showed that the traditional method resulted in an average of 0.733183 likelihood compared to 0.61941 when using the new method. Similarly, the variance was 0.04697 for the traditional method and 0.03448 for the new method. The difference in variance was significant using an analysis of variance with Levene's test ($F = 4.93$; $p = 0.0264$), although the improvement in this case is much lower.

4. Discussion

The results of both the questionnaire study and the simulations point out that the methodology of sub-factor assessments and calculating, as we suggest, can significantly reduce the variance of the likelihood risk score comparing the traditional method of one-factor assessment. In the questionnaire study, we received p-values that ranged between 0.00194 and 0.000679 and a substantial variance reduction of 76.14–81.35%. The simulation study of a similar structure resulted in a very significant improvement of variance reduction and p-values in the range of 0.0264–5.4204×10^{-299} and variance reduction improvement up to 82.5%. In this study, we also found an interesting fact in the simulations: the improvement in variation was greater in lower-risk and medium-risk scenarios compared to the high-risk scenarios. This can lead to future research and analyses to identify the causes that may occur due to the closeness to the limit of 100% likelihood in high-risk situations.

The main reason for breaking down each event to its predecessors is to get to the root cause of the given event and reduce their interdependencies. In many cases, weak

or strong interactions between sub-factors may produce positive or negative feedback or cross-action ("noise"). We address this situation by trying to give each sub-factor the risk level as objective as possible and by applying the formula that calculates the average risk level of all the sub-factors, which increases the precision and reduces the "noise" that can be an effect of these unobserved interactions. In future work, we will suggest continuing with deconstructing more layers of the cause factors to increase the accuracy and objectivity.

We believe applying the new methodology can be useful in practice and research. The segmentation of the likelihood factor into its sub-factors and calculation in the proposed formula that considers the frequency and the variance of the expected likelihood of conditions to risk occurrence combined with the average factors of a failure, given the basic conditions, can reduce errors and bias in the assessment.

5. Conclusions

In our research, we addressed the issue of reducing the uncertainty and bias due to the subjectivity of human auditors that conduct risk assessments. Our direction was that segmenting likelihood into its sub-factors could reduce the risk level assessment variance. In this work, we did not focus on the consequence part of the risk equation (i.e., risk = likelihood $\times$ consequence) and only tried to improve the precision of the likelihood factor. We designed and conducted a study of two groups of auditors. One used the new framework, and the second assessed the same process in the regular method of a single likelihood parameter. We expanded the research with a simulation in the same approach. Analysis of the questionnaire study results and the simulation of the risk assessment process conclude that there is an improvement in precision in applying the new framework by a significant reduction in the variance of risk assessment.

The new framework that we developed is easy to apply. The formula for calculating the likelihood of risk was tested and compared to the traditional risk assessment process that does not apply segmentation of sub-factors. The research shows that it is feasible to have accurate and precise assessments when applying a simple-to-use model. This framework has many applications and can be easily adopted in industry. Our vision is to continue in this line of action to reduce the biases and uncertainty in risk management by applying a mathematical formula used in a large database and refining the accuracy by fine-tuning the sub-factors and their ranges.

Regarding the limitation of our study, first and foremost, it was conducted on a relatively small sample of human auditors and had only two different risk scenarios. Although we robustly conducted the study by conducting a large-scale simulation (30 runs of 1998 respondents each), it will be worthwhile to increase the sample size and try to add more sub-factors to increase the resolution and sensitivity of the risk assessment.

Future studies can take various paths. One research study can improve both the accuracy and precision of likelihood assessment by combining machine learning techniques that can fit a well-known likelihood level to some sub-factors that we estimate and to be able to predict by the algorithm the precise and accurate risk level that fits best with the sub-factors that we find in the process. Another future research challenge could be adding one more layer to the DAG model that may allow the deconstructing of the sub-factors to another level, increasing the precision and sensitivity of the assessment process even further. Finally, one can also conduct a broader experimental setting by comparing human auditors using the new framework on a more varied set of industries and organizations. Applying this new framework to large-scale data can be useful for training a deep learning model that may reduce uncertainty in risk assessment missions. In this paper, we focused primarily on applying this novel framework as a new concept in the industry. The initial results are good, but in future work, we can try to increase the precision and accuracy of the modal by "fine-tuning" the parameters with the adjustments of weights of the sub-factors to the model.

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G.B.; writing—original draft preparation, G.B.; writing—review and editing, I.Z.; visualization, G.B. and I.Z.; supervision, I.Z.; project administration, G.B.; All authors have read and agreed to the published version of the manuscript.

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Appendix A

In the appendix, we present a sample of a questionnaire that was used to evaluate the risk of given situations in the traditional approach (with one risk score) and the new framework (with few parameters that are calculated in our formula).

Condition description number 1
In this case, we observed an organized and controlled industrial plant with an advanced and secure ERP information system. The production floor is computerized in an advanced way and includes automatic data transmission to management in real time; all logistical and financial activities are well controlled in the ERP system, and there is no manual work other than through the systems. In addition, there is a secure alternative backup site and regular backups. The professional staff is loyal and committed to the organization. There are written procedures and ongoing control over all functions. Human resource management adheres to training, implementation of a code of ethics, good discipline, and organization, and there is no tolerance for violence or improper employee activity. It is required to assess the likelihood that the business will have an operational failure or a problematic event that will cause large losses or damage. In this case, it is required to give evaluations according to several categories (evaluation between 1 and 6 according to the guidelines of each category).
(1) Frequency estimation for the occurrence of a problematic event (1—relatively rare [once every year or less]–6–very high frequency [daily-weekly])
(2) Level of complexity (1–relatively simple processes with a low number of people involved; 6–q complicated process with many participants and a high level of complexity)
(3) Estimating the number of possible situations or outcomes in the process (1–there are relatively few system modes or margins for errors and malfunctions; 6–there are many modes, and there is a high likelihood of errors in execution)
(4) Assessment of system reliability (1–the reliability of the system and the factors are very high; 6–low reliability of the system and the participating parties)
(5) Assessment of knowledge and understanding (1–we have extensive knowledge of the system above or similar systems and can evaluate and understand this situation well; 6–we do not have good knowledge and understanding of the system or similar systems from experience)
(6) Assessment of prevention mechanisms (1–there are good control and prevention mechanisms that will reduce the chance of a failure; 6–there is no effective control, and there are no sufficient mechanisms to prevent a problematic event)

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Shareholders in the Driver's Seat: Unraveling the Impact on Financial Performance in Latvian Fintech Companies

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Abstract: Fintech companies are relatively young and operate in a rapidly evolving and ever-changing industry, which makes it important to understand how different factors, including shareholder presence in management roles, affect their performance. This study investigates the impact of shareholder presence in director and manager positions on the financial performance of Latvian fintechs. Our investigation centers on essential financial ratios, including Return on Assets, Return on Equity, Profit Margin, Liquidity Ratio, Current Ratio, and Solvency Ratio. Our findings suggest that the presence of shareholders in director and manager roles does not significantly affect the financial performance of fintech companies. Although the statistical analysis did not yield significant results, it is important to consider additional insights garnered from Cliff's Delta effect sizes. Specifically, despite the lack of statistical significance, practical significance indicates that fintech companies in which directors and managers are shareholders show slightly better performance than other fintech companies. Beyond shedding light on the intricacies of corporate governance in the fintech sector, this research serves as a valuable resource for investors, stakeholders, and fellow researchers seeking to understand the impact of shareholder presence in director and manager roles on the financial performance of fintechs.

Keywords: shareholders; directors; management; financial performance; fintech; conflict of interest

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1. Introduction

The evolution of the fintech industry has captured widespread attention, driven by its unique characteristics and transformative impact on traditional financial services. Fintech companies operate at the nexus of finance and technology, leveraging innovation to revolutionize how individuals and businesses access and manage financial services. Their dynamic nature, fueled by technological advancements and entrepreneurial spirit, presents both challenges and opportunities that demand specialized examination. At the heart of fintech's allure lies its entrepreneurial finance dynamics, which encompass intricate investment structures, risk profiles, and performance metrics distinct from those of conventional firms. Unlike traditional companies, fintechs often navigate complex ecosystems of venture capital, angel investors, and strategic partnerships, shaping their growth trajectories and risk appetites in unique ways (Sahid et al. 2023). The growth and the ever-changing landscape of fintech companies have ignited significant interest in understanding the factors that impact their financial performance. Among these factors, the presence of shareholders as directors and managers has emerged as a critical aspect influencing decision making and resource allocation (Al-Matari et al. 2022). Investigating the relationship between shareholders as directors and managers on the one hand and financial performance on the

other can yield valuable insights into the dynamics of corporate governance in the fintech sector.

To the best of the authors' knowledge, the academic literature has not yet answered the question of the impact of shareholders as directors and managers on the financial performance of fintech companies (Najaf et al. 2022). Exploring the role of shareholders in governance has profound implications for corporate governance, a cornerstone of organizational effectiveness. Corporate governance structures determine decision-making processes, risk management strategies, and overall organizational performance. By examining how shareholder involvement in leadership roles shapes financial outcomes in fintech firms, we gain insights into governance practices in this dynamic sector. This knowledge is essential for enhancing investor confidence, ensuring regulatory compliance, and maintaining market stability. Furthermore, from the perspective of the economic literature, this research question addresses a significant gap in current research. Despite the rapid development and transformative influence of fintech firms on traditional financial services, empirical studies examining the specific impact of shareholder-directors and managers on financial performance in this sector are scarce. Our research fills this gap and advances the academic understanding of corporate dynamics within fintech firms. In addition to contributing to the academic discourse, this research provides practical insights for practitioners, policymakers, and stakeholders navigating the intricacies of the fintech landscape.

We address this research gap by examining the financial performance differences between three distinct fintech groups. The first group consists of companies where all directors and managers are shareholders[1] (DM1). The second group comprises companies where neither directors nor managers are shareholders (DM2). The third group has a mixed composition, where some directors and managers are shareholders while others are not (DM3). This study also addresses the potential conflict of interest that may arise when shareholders and management roles are separated, further enhancing our understanding of the governance landscape in the fintech industry.

Our analysis is grounded in two primary theoretical frameworks concerning corporate governance: agency theory (proposed by Jensen and Meckling (1976), further developed by Fama (1980)), and stewardship theory (introduced by Donaldson and Davis (1991)). These two theories provide contrasting views on the relationships between shareholders, directors, and managers, encompassing aspects of potential conflict of interest (CoI) (Hoi and Robin 2010). By applying these theories to the context of fintech companies, we aim to deepen our understanding of the governance challenges and opportunities inherent in this rapidly evolving industry

The study uses a sample of 96 Latvian fintech companies that were in operation during the year 2022. Our investigation centers on several vital financial ratios, including Return on Assets (ROA), Return on Equity (ROE), Profit Margin (PM), Liquidity Ratio (LR), Current Ratio (CR), and Solvency Ratio (SR). Our research design employs non-parametric tests, specifically Kruskal–Wallis tests, to assess potential statistical differences among the three groups DM1, DM2, and DM3. Furthermore, we utilize various graphical methods and visualizations, such as median heatmaps, bootstrap medians, and confidence intervals to gain further insights into the potential effect of shareholder presence on financial performance.

The Latvian fintech sector is of particular interest because Latvia-based fintech companies are not limited geographically; they have established a global presence, including in Switzerland, Africa, the UK, and Asia. These companies operate in various areas such as lending and payment services, showcasing the extensive global reach and potential impact of the Latvian fintech sector. Moreover, the fact that Latvia is a small country with a relatively modest economy allows for a comprehensive analysis of nearly all market participants. These factors collectively position the Latvian fintech sector as a compelling case study for other countries seeking to comprehend the influence of shareholder presence in director and manager roles on the financial performance of fintech companies.

Our study reveals that the presence of shareholders as directors and managers does not have a statistically significant impact on essential financial ratios of fintech companies compared to those fintech companies where ownership and management are separated. This result indirectly suggests that the potential conflicts of interest associated with shareholders being separated from directors and managers do not significantly impact the financial performance of fintech companies.

The research makes several contributions to the field of fintech and corporate governance. First, the study offers a comprehensive analysis of the relationship between shareholders as directors and managers and financial performance in fintech companies. By examining multiple financial ratios, the authors provide a holistic perspective on the impact of shareholders on various aspects of a company's financial performance. Second, the findings hold practical implications for decision makers, investors, and stakeholders in the fintech sector by focusing on aspects of corporate governance that are typically expected to have a significant impact on financial performance. Third, the study adds to the growing body of research on fintech companies' performance and governance dynamics, enriching the understanding of the factors influencing financial outcomes in this rapidly evolving industry. The inclusion of conflicts of interest as an aspect of investigation further advances the scholarly discourse on the complexities and challenges faced by fintech companies in their pursuit of optimal governance and sustained financial success.

This paper is structured as follows. In Section 2, we review the related literature and develop the hypotheses for the empirical analysis. Section 3 describes the dataset and methodology, followed by the presentation of the empirical findings in Section 4. The main findings are discussed in Section 5, with concluding remarks provided in Section 6.

2. Literature Review and Hypothesis Development

Conflicts of interest are a crucial factor that can undermine the objectives of both agency theory and stewardship theory. Jensen and Meckling's (1976) seminal work emphasizes the significance of board ownership as a mechanism for reducing agency costs that result from the potential conflicts of interest between shareholders and managers. Their findings indicate that when directors hold ownership stakes, there is a natural alignment of interests that encourages a more vigilant approach to decision making. This alignment leads to a reduction in the misuse of company resources for private benefits, a phenomenon known as "private perquisite consumptions." Consequently, board ownership is a proactive strategy for curbing agency costs and enhancing financial outcomes. Moreover, the link between board ownership and enhanced corporate performance finds support in the insights presented by Berle and Means (1991). Their research underscores the significance of shared incentives between directors and managers, and shareholders. According to this approach, with higher ownership stakes held by directors, there is a heightened commitment to the company's financial well-being and value creation. This alignment cultivates an environment in which directors and managers are more attuned to shareholders' concerns, motivating them to work diligently towards achieving improved performance. In the context of Stano's (1975) study, the data indicate that firms where CEOs are also owners (executive ownership) exhibit better financial performance compared to firms where CEOs are not significant owners.

Building on these concepts, Brickley et al. (1997) highlight how board ownership acts as a catalyst for efficient company operations and effective managerial oversight. The ownership interest provides directors and managers with a vested personal interest in the company's prosperity. This interest becomes a motivating factor for them to ensure careful oversight of managerial choices. This motivation aligns with the tenets of both the agency theory and the stewardship theory, where directors are incentivized to act in ways that promote the best interests of shareholders.

It is worth noting that many fintech companies share characteristics with startups and dynamic IT firms, often operating with a relatively smaller number of employees compared to traditional financial services providers (Jain et al. 2023; Dospinescu et al. 2021;

Grima et al. 2021). Within the context of fintech companies usually privately held and start-ups (Tzanaki et al. 2023; Sharma et al. 2023), the stewardship theory is of particular importance. The theory suggests that managers perceive themselves as custodians of the company's resources and are intrinsically motivated to act in the best interests of all stakeholders (Chrisman 2019). The close relationship between shareholders and managers in these small firms fosters a culture of stewardship, enabling managers to align their goals with the long-term success of the company (Davis et al. 1997), unlike in large public companies where the separation of ownership and control is more pronounced (Bonazzi and Islam 2007). The presence of shareholders as directors and managers may not have a significant impact on financial performance because both groups of managers (with and without shareholder presence) are intrinsically motivated to act responsibly and in the best interest of the company (Affes and Jarboui 2023; Caselli et al. 2023). They prioritize the long-term success of the company over personal gains, leading to similar financial performance outcomes regardless of whether shareholders are directly involved in the management roles.

Conversely, agency theory centers on potential conflicts of interest between managers and shareholders, stemming from the separation of ownership and control (Fama and Jensen 1983). This theory examines how agency costs may arise when managers prioritize their own interests over acting solely in the best interest of shareholders, potentially leading to reduced firm performance (Donaldson and Davis 1991).

When considering the influence of shareholders as directors and managers on financial performance in the Latvian fintech sector, the interplay between stewardship theory and agency theory adds complexity. Stewardship theory suggests that intrinsic motivations and shared interests may mitigate conflicts of interest, while agency theory underscores the potential for conflicts that can hinder decision-making alignment. Thus, an assessment of the interplay between these theories and conflicts of interest is essential in understanding the impact of shareholder involvement as directors and managers on financial performance. With this in mind, we hypothesize the following:

H1. *There are significant differences in financial performance of Latvian fintech companies based on shareholder involvement as directors and managers.*

We further subdivide this hypothesis by separating the roles of DM1, DM2, and DM3. Thus,

H1.1. *The financial performance of fintech companies with all directors and managers being shareholders (group DM1) differs from that of fintech companies where neither directors nor managers are shareholders (DM2).*

The first sub-hypothesis posits that fintech firms in which all directors and managers are shareholders (group DM1) will exhibit different financial performance than those in which neither directors nor managers are shareholders (DM2). This proposition is based on the principles outlined by Jensen and Meckling (1976), who emphasize the importance of board ownership in mitigating conflicts of interest between shareholders and managers. Their research suggests that when directors hold ownership stakes, there is a natural alignment of interests that promotes vigilant decision making and reduces the misuse of corporate resources for personal gain. In addition, Berle and Means (1991) support the idea that higher levels of director ownership correlate with increased commitment to the financial well-being and value creation of the firm. Consequently, we expect that fintech firms with all directors and managers as shareholders (group DM1) will exhibit superior financial performance compared to those without such shareholder involvement (group DM2).

H1.2. *The financial performance of fintech companies with all directors and managers being shareholders (group DM1) differs from that of fintech companies where some directors and managers are shareholders while others are not (DM3).*

The second sub-hypothesis suggests that fintech firms in group DM1 will exhibit different financial performance than those in which only some directors and managers are shareholders while others are not (DM3). This hypothesis is supported by the notion that differences in shareholder–manager alignment may contribute to differences in financial outcomes. Building on the insights of Brickley et al. (1997), who highlight the motivational effect of board ownership on managerial monitoring, we find that the presence of shareholder-directors and managers in group DM1 fosters a culture of stewardship and aligns incentives with the best interests of shareholders. Conversely, in group DM3, where shareholder–manager alignment is partial, the potential for conflicts of interest may persist, potentially affecting financial performance.

H1.3. *The financial performance of fintech companies where neither directors nor managers are shareholders (DM2) differs from that of fintech companies where some directors and managers are shareholders while others are not (DM3).*

The third sub-hypothesis focuses on comparing the financial performance of fintech firms where neither directors nor managers are shareholders (DM2) with those where some directors and managers are shareholders while others are not (DM3). This hypothesis is based on the assumption that partial shareholder–manager alignment in the DM3 group may lead to similar financial performance outcomes as in the DM2 group. Affes and Jarboui (2023) suggest that both groups of managers, regardless of the presence of shareholders, may be intrinsically motivated to act responsibly and in the best interest of the firm, thus minimizing the potential impact of conflicts of interest on financial performance. Consequently, we expect the financial performance of firms in the DM2 group to be comparable to that of firms in the DM3 group.

3. Methodology

3.1. Study Design

This study employed a three-stage approach to investigate the impact of the presence of shareholders as directors and managers on financial performance. In the first stage, we conducted a comprehensive examination of the data. This involved carefully reviewing and validating the dataset to ensure its accuracy, completeness, and suitability for analysis. We assessed the data for any inconsistencies, missing values, or potential errors that could impact the reliability of our findings. Specifically, we verified that the dependent variables are continuous in nature, allowing for meaningful interval/ratio measurements. Additionally, we confirmed that the observations are independent, ensuring that each data point is distinct and unrelated to others. However, it is worth noting that the assumption of normality and the absence of outliers were not met in our dataset, which is not uncommon in the context of innovative technology companies (Barnes 1982; So 2006). To identify this, we employed statistical tests, such as the Shapiro–Wilk test and visual methods, including histograms and scatter plots, to assess the data's distribution and identify any potential outliers. Due to the deviations from normality and the presence of outliers, we proceeded with non-parametric methods to perform robust and valid statistical analyses, considering the unique characteristics of our data.

In the second stage, a comparative analysis was conducted to identify potential differences between different groups of fintech companies based on their involvement of shareholders as directors and managers. Fintech companies were classified into three distinct groups: DM1, DM2, and DM3. To assess potential differences between these groups, the Kruskal–Wallis H test (Marx 2016), a non-parametric statistical test, was employed.

Additionally, in order to quantify the practical significance of any observed differences, Cliff's Delta effect sizes were calculated (Hollander et al. 2014).

In the third stage, graphical methods and visualizations were utilized to gain further insights into the potential effect of shareholder presence on financial performance. Median and correlation heatmaps were constructed to visually represent the relationships between various financial ratios (Raschka 2013). Bootstrap confidence intervals were used to provide a measure of uncertainty for key financial performance metrics, while boxplots facilitated the comparison of distributions between the different groups (Ramachandran and Tsokos 2021).

By combining non-parametric tests and graphical methods, this research design allows for a comprehensive and robust analysis of how the presence of shareholders as directors and managers may influence the financial performance of Latvian fintech companies.

3.2. Sample Selection and Data Collection

Understanding the characteristics of the fintech industry and selecting our sample presents a significant challenge due to the lack of an official list of fintech firms in Latvia. To address this, we adopted the definition of fintech provided by the Bank of Latvia, which includes companies that leverage new and innovative technologies in the financial services domain (Bank of Latvia 2020). These companies drive the development of novel financial products and services or significantly enhance existing ones. To identify such firms, we initially considered companies listed in the Rupeika-Apoga and Wendt (2022) study. Subsequently, we expanded our search to include fintech companies listed in Dealroom (Chiavarini et al. 2023) and the Startin database (Startin 2023) to include companies that started during 2022. We diligently verified whether these companies conformed to our defined criteria. Furthermore, we cross-checked the list of fintech companies with the Register of Enterprises of the Republic of Latvia to verify that only those entities registered in Latvia were taken into account for our study. This meticulous process of selection and verification enabled us to create a comprehensive and reliable list of Latvian fintech companies for our research.

In 2022, a remarkable surge in the fintech sector was observed in Latvia, with 106 active fintech companies officially listed in the Register of Enterprises of the Republic of Latvia. This notable increase reflects a substantial expansion compared to previous years, with 93 fintech companies identified in 2021, and 56 in 2019 (Rupeika-Apoga and Wendt 2022). Fintech companies inherently possess the flexibility to offer their services online, making it feasible for them to operate internationally. Nevertheless, despite the global nature of their services, these enterprises have actively chosen Latvia as their base of operations. The analysis of the names of the fintech owners reveals a strong connection to Latvian heritage. This trend signals a noteworthy presence of local entrepreneurs and businesses actively contributing to the industry's growth. However, as certain fintech companies mature and attain higher levels of development and success, they may embark on new ventures and explore opportunities in more prominent financial hubs and international arenas (for example, Bitfury).

Out of the initially identified 106 fintech companies, our analysis was conducted on 96 companies due to data availability limitations. However, the data collected on these companies provide valuable insight into the relationship between the presence of shareholders as directors and managers and financial performance among Latvian fintech companies.

The primary source of information for this research is derived from Bureau van Dijk's Orbis database, a subsidiary of Moody's Analytics. This database offers an extensive collection of financial and operational performance metrics as well as corporate governance characteristics of fintech companies in Latvia.

The following financial ratios were obtained from Bureau van Dijk's Orbis database for Latvian fintech firms for 2022. These indicators were selected because they cover essential aspects of financial performance, providing a comprehensive view of a company's financial

health. They encompass liquidity ratios (such as the Current Ratio and Liquidity Ratio), efficiency ratios (including Return on Assets and Return on Equity), profitability ratios (such as Profit Margin), and leverage ratios (such as Solvency Ratio).

$$\text{Liquidity Ratio (LR)} = (\text{Current Assets} - \text{Inventory})/\text{Current Liabilities} \quad (1)$$

$$\text{Current Ratio (CR)} = \text{Current Assets}/\text{Current Liabilities} \quad (2)$$

LR and CR assess a company's liquidity position, with lower values of these ratios generally reflecting worse financial performance.[2] Low levels of liquidity might also result from managers diverting funds for their private benefits as manifestation of conflicts of interest between managers and shareholders (Zaidi and Rupeika-Apoga 2021). For Latvian fintech companies, we observed that LR and CR were frequently equal or very close to each other. This is attributed to the absence or minimal presence of inventory.

$$\text{Return on Total Assets (ROA)} = \text{Profit or Loss before Tax and Extraordinary Items}/\text{Total Assets} \quad (3)$$

ROA is an essential metric for investors, creditors, and management, as it provides insights into how efficiently a company generates profits relative to the size of its asset base. Comparing ROA across fintech companies can help investors identify which companies are more effective at generating profits from their asset investments.

$$\text{Return on Equity (ROE)} = \text{Profit or Loss before Tax and Extraordinary Items}/\text{Total Shareholder Funds \& Liabilities} \quad (4)$$

Return on Equity (ROE) is a critical financial ratio that measures the return generated on the shareholders' equity invested in the company. It is an essential indicator of how efficiently a company is using the equity capital provided by shareholders to generate profits.

$$\text{Profit Margin (PM)} = \text{Profit or Loss before Tax and Extraordinary Items}/\text{Operating Revenue (Turnover)} \quad (5)$$

Profit Margin (PM) is a financial ratio that measures the company's ability to generate profit from its operating activities in relation to its total revenue. A higher profit margin indicates that the company is effective at controlling costs and managing its operating expenses relative to its revenue.

$$\text{Solvency Ratio (SR)} = \text{Total Shareholders' Equity}/\text{Total Assets} \quad (6)$$

The Solvency Ratio is a financial metric that evaluates a company's ability to meet its long-term obligations and debt. It measures the extent to which the company's assets are funded by the owners (shareholders) rather than external debt.

4. Results

4.1. Sample Characteristics and Descriptive Statistics

In 2022, the 96 Latvian fintech companies employed 2202 employees, reflecting the vibrant workforce within this dynamic industry. On average, each company maintained a team of approximately 23 employees. Notably, a significant number of these companies opted for a lean workforce, with a considerable portion comprising single-employee firms. For instance, 18 companies operated with just one employee, 16 fintech companies managed with a team size of two employees, while six fintech firms employed a slightly larger team of three employees each. This trend points to the possibility that entrepreneurs take on multiple roles or possess highly specialized skills to start and propel their fintech ventures forward. Consequently, it is evident that the majority of fintech companies in Latvia are relatively small-scale operations with a limited number of employees.

As we delve further into the management structure, the average Management-to-Employee ratio (ME ratio) for Latvian fintech companies in 2022 was observed to be 1:10,

i.e., for every one manager, there were ten employees within these fintech firms. Given the relatively small average company size and the ME ratio, it is likely that some directors and managers in these fintech companies took on multiple roles and responsibilities in managing various functional areas.

In 2022, there were 215 directors and managers within Latvian fintech companies. The distribution of sample by gender revealed that there was a significantly higher number of male directors and managers (188) than female directors and managers (27) within the Latvian fintech sector. The underrepresentation of women in such roles highlights a critical area of concern in fostering gender diversity and inclusivity in the industry.

Among the fintech companies analyzed, a notable pattern emerges in the relationship between directors and managers, and shareholders. Specifically, 76 individuals hold dual roles, serving as both directors/managers and shareholders. On the other hand, 139 individuals hold positions solely as directors or managers without direct ownership interests. Within the group of 76 individuals with dual roles, the majority of the group (69 individuals) are male, highlighting a significant underrepresentation of women in this group.

In addition to this ownership disparity, another aspect of gender imbalance is evident in the role of President/Chairman of the board within the analyzed Latvian fintech companies. Among the leadership positions, only one woman serves as President/Chairman, while an overwhelming majority of this group (46) are men. This striking contrast further emphasizes the lack of female representation in top leadership roles within the Latvian fintech industry.

We categorized the 96 companies into three distinct groups based on the relationships between directors and managers, and shareholders. The first group, DM1, consisted of 46 fintech companies where all director and manager positions were held by shareholders, indicating a direct financial stake in the companies they manage. The second group, DM2, comprised 40 fintech companies where none of the director and manager positions were held by shareholders, suggesting a clear separation between management and ownership roles. Finally, the third group, DM3, included 10 fintech companies where both shareholders and non-shareholders occupied director and management positions, suggesting a mix of ownership structures within these companies.

We used the key financial performance measures of ROA, ROE, PM, LR, and CR as metrics of the financial health of fintech companies. Table 1 reports the descriptive statistics of the variables of interest.

Table 1. Descriptive statistics.

Variable Name/ Statistics	ROA	ROE	PM	CR	LR	SR
Min.	−5.442	−3.502	−20.765	0.043	0.043	−10.626
1st	−0.145	−0.027	−0.240	0.635	0.635	0.005
Median	0.021	0.193	0.068	1.375	1.327	0.295
3rd	0.247	0.621	0.257	4.223	4.035	0.686
Max.	1.294	3.116	0.673	23.888	20.162	0.960
not available	-	-	6	2	2	2

The median ROA of 0.02 signifies that, on average, the companies generate a return of 2% on each unit of assets they utilize. Similarly, the median ROE of 0.19 indicates that, on average, the companies generate a return of 19% on the shareholders' equity invested in the business. Furthermore, the median profitability margin (PM) of 0.068 reveals that, on average, the companies translate 6.8% of their revenue into profit after accounting for all costs and expenses. In terms of Current Ratio (CR), the median value of 1.38 reflects stability in fulfilling short-term financial commitments. The Liquidity Ratio (LR) of 1.33 also indicates a reasonably good overall liquidity position. With a median value of 0.3, the

solvency ratio (SR) signifies that, on average, 29.5% of the assets are financed by equity, while the remaining 70.5% are financed by debt.

In our study, we observe that the levels of financial ratios in the Latvian fintech industry are consistent with previous findings (Rupeika-Apoga et al. 2023). We use both the Shapiro–Wilk tests and graphical methods, such as histograms, to check for normality of the data. The results show that the data did not follow a normal distribution (see Table A1). By adopting the winsorizing technique, we aimed to mitigate the impact of outliers on our analyses while maintaining the integrity of the original data distribution. This approach was especially relevant given the relatively small size of the fintech market and the potential for extreme observations to disproportionately influence results (Adams et al. 2018). Still, however, it is important to note that the data for financial ratios in the industry are not normally distributed. Given the dynamic nature of the fintech industry and the unique characteristics of companies within it, it is common to encounter significant variations in financial ratios. These discrepancies can be attributed to varying levels of performance and the continually changing economic and market conditions that influence fintech operations (Rupeika-Apoga and Solovjova 2016).

To address the non-normal distribution of data and the presence of extreme values or outliers, we have chosen to use medians as a more appropriate measure of central tendency. Medians provide a robust representation of the average value for each financial ratio, allowing us to gain a better understanding of the industry's performance while minimizing the impact of outlier data (So 2006).

4.2. Comparative Analysis

As our data did not follow a normal distribution, we employed the Kruskal–Wallis test to assess potential differences in financial performance between the groups. The test results revealed that there were no statistically significant differences between the groups (Table 2).

Table 2. Kruskal–Wallis Test for financial ratios among the three groups DM1, DM2, and DM3.

Variable Name/ Statistics	ROA	ROE	PM	CR	LR	SR
Chi-Square	1.1785	1.5866	3.9195	1.2924	1.0098	0.41495
Df	2	2	2	2	2	2
Asymp. Sig.	0.5547	0.4524	0.1409	0.524	0.6036	0.8126

To evaluate the reliability of the findings obtained from the Kruskal–Wallis test, we conducted a Robust Analysis of Covariance (Robust ANCOVA) while controlling for the number of employees. Fintech companies tend to be relatively small in scale, and a considerable proportion of them are characterized by having only a single employee. This control variable was introduced to account for potential variations in the results that could arise from differences in the size of the companies under investigation. The results revealed that, with the exception of the variable ROA, there were no statistically significant differences observed among the DM groups. However, DM1 exhibits a higher ROA compared to DM2.

4.3. Visualizing Shareholder Presence and Financial Performance: Exploring Correlations, Metrics, and Distributions

While no statistically significant differences emerged among financial ratios in various DM groups, we wanted to delve deeper and employ visual methods to examine the impact of shareholder presence on the financial performance of fintech firms. Recognizing the limitations of traditional statistical tests in our analysis of financial ratios among the three groups DM1, DM2, and DM3, we turned to median heatmaps as a powerful visual tool to uncover any potential trends or discrepancies in the data. Notably, DM1 consistently displays slightly higher medians across all financial ratios, suggesting a greater proportion

of revenue translating into profit, a stronger overall liquidity position, and a relatively higher ratio of assets funded by equity instead of debt. DM3, in contrast, tends to have lower medians across most financial ratios, suggesting weaker financial performance compared to the other two groups. However, the median heatmaps revealed no significant differences in financial ratios between the three DM groups (see Figure 1).

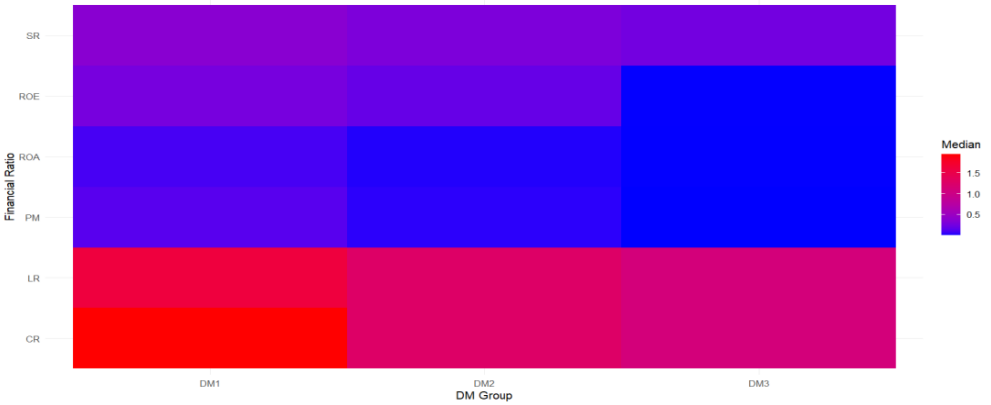

Figure 1. Median heatmaps for financial ratios for DM1, DM2, and DM3.

Despite observing these patterns, it is essential to assess the magnitude of these differences to understand their practical significance. The Cliff's Delta effect sizes were computed to quantify the differences in medians between the groups (see Table 3). The results show that for DM1 versus DM2, most financial ratios have effect sizes close to zero, indicating negligible differences. This suggests that the variations in medians between DM1 and DM2 may not have a meaningful impact in the real world, and such differences could merely be attributed to random fluctuations. Moreover, the small Cliff's Delta effect size for the PM financial ratio implies that, although there is a statistical difference between DM1 and DM2, its economic impact may be limited.

Table 3. Cliff's Delta effect sizes for financial ratios among the three groups DM1, DM2, and DM3.

Variable Name/ Statistics	ROA	ROE	PM	CR	LR	SR
DM1–DM2	negligible	negligible	0.194 (small)	negligible	negligible	negligible
DM1–DM3	negligible	0.222 (small)	0.333 (medium)	0.186 (small)	0.214 (small)	negligible
DM2–DM3	negligible	0.245 (small)	0.214 (small)	0.195 (small)	0.195 (small)	negligible

On the other hand, when analyzing group DM3, the results paint a different picture. Group DM3 exhibited worse performance compared to both DM1 and DM2 in terms of ROE, PM, LR, and CR. Although the effect sizes for these differences ranged from 0.195 to 0.245 (which is considered small according to conventional effect size guidelines), these values may have meaningful and practical implications when making financial assessments and investment decisions. Interestingly, an exception arises in the DM1–DM3 comparison, where the effect size is deemed medium, signaling that PM for the DM1 group surpasses that of the DM3 group. This finding may have interesting implications for the corporate governance debate.

In the next step of our analysis, we utilized a robust statistical approach called bootstrapped medians alongside confidence intervals (CIs) to delve further into our research findings. This method allowed us to address key challenges associated with uncertainty and variability in the data, making our conclusions more robust and reliable. In Figure 2, we use bars to represent the bootstrapped medians and error bars to show the confidence intervals for each group (DM1, DM2, and DM3) and financial ratio. Each bar represents the

median value of the bootstrapped samples for a particular group and financial ratio, and the error bars indicate the range within which we are 95% confident the true median lies.

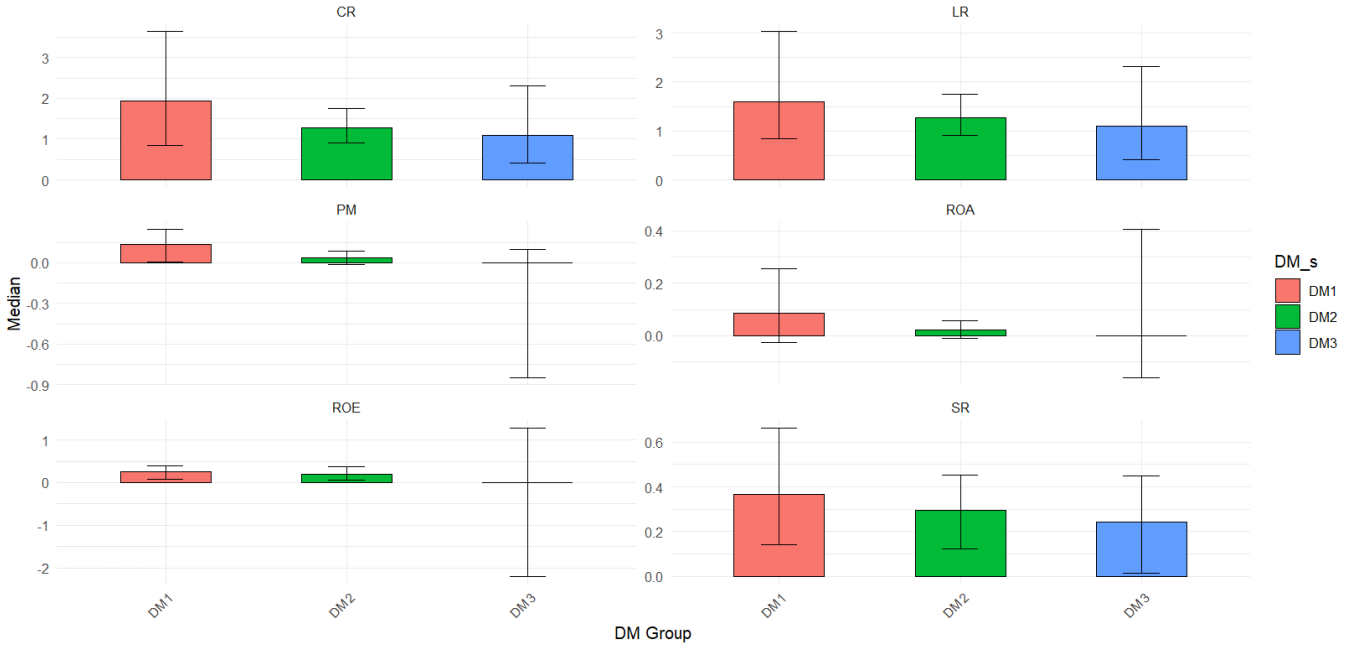

Figure 2. Bootstrapped median distribution with confidence intervals.

Based on the bootstrapped medians and their corresponding confidence intervals, we can make insightful comparisons among the DM groups with respect to their financial ratios:

- Profitability: Among the three financial ratios, DM1 consistently outperforms DM2 and DM3 in terms of median values. However, it is essential to consider the precision of these estimates. The confidence intervals for DM1 are relatively wider compared to those for DM2, indicating that there is less certainty in estimating the true population values for DM1. In contrast, the narrower confidence intervals for DM2 imply a more precise estimation of its true population values. Furthermore, the confidence intervals for DM3 overlap with both DM1 and DM2. This suggests that, statistically, there may not be significant differences between DM3 and the other two groups in terms of ROA, ROE, and PM.
- Liquidity: The analysis of liquidity measures presents a similar situation as observed for profitability ratios. DM1 exhibits larger median values for both LR and CR, indicating higher levels of liquidity compared to DM2 and DM3. However, similar to previous findings, the confidence intervals for DM1 are relatively wider, implying less precision in estimating the true population values for LR and CR. It is noteworthy that the confidence intervals for DM1 fully overlap with those of DM2 and partly with DM3 for both LR and CR. This statistical overlap indicates that there might not be significant differences in liquidity levels between DM1 and DM2, and there could be some overlap in liquidity with DM3 as well. While DM1 generally shows higher median values, the overlapping confidence intervals suggest that the differences between the groups may not be substantial.
- The analysis of the solvency ratio reiterates the pattern observed in liquidity ratios, where DM1 tends to have higher median values, indicating stronger solvency compared to DM2 and DM3. However, the wider confidence intervals for DM1 suggest caution in interpreting the results, as there is less precision in estimating its true population values.

In summary, DM1 stands out as having better performance in terms of median values across various financial ratios. However, the wider confidence intervals observed for some ratios (CR, LR, and SR) emphasize the need for caution in interpreting the results, as they indicate less precision in estimating the true population values. Moreover, the presence of overlapping intervals suggests that the differences between DM1 and the other groups (DM2 and DM3) in certain financial ratios may not be substantial.

It is important to acknowledge that our sample size is relatively small, and individual outliers within one group may have influenced some of the results. Nonetheless, these findings offer valuable insights into the interplay between different financial ratios within and between DM groups, shedding light on potential areas of focus for further analysis and decision making.

5. Discussion

Latvian fintech companies, much like their counterparts in other countries, predominantly comprise small businesses, and this often results in a scenario where a shareholder assumes the role of a director (Katalkina and Saksonova 2022). This scenario is particularly common in start-up companies. When founders establish a new company, they typically take on three essential corporate roles: they become the company's owners (as they hold shares), controllers (as they usually appoint themselves as directors), and active executives (as they often assume the position of CEO or a similar executive title) (Zhang et al. 2021). This combination of roles, especially when founders are major shareholders and directors, can be a potent force (Bachiller et al. 2015). In such cases, founders have the ability to control the company's strategic direction as directors, and they can safeguard their position by leveraging their rights as majority shareholders (Saksonova and Papiashvili 2021; Neralla 2022). In our sample of 96 Latvian fintech companies, 46 companies belonged to the DM1 category, which means that all directors and managers are shareholders. Among the DM1 companies, there were 36 that had one director and manager, eight companies with two directors and managers, and two fintech firms with three directors or managers.

As businesses grow and seek external financing, it is customary to appoint independent directors who have no or minimal ownership stakes in the business (Smith et al. 2010). The rationale behind this practice is to ensure good governance by holding directors accountable to shareholders for their decision making within the company. In the DM2 group (40 companies), there were no shareholders present as directors or managers. Among the companies in this category, it was observed that a significant number of fintech firms were led by a single individual, with 12 companies having a solo director and manager arrangement. Additionally, there were nine fintech companies with two individuals comprising the director and manager roles, and seven fintech companies with three individuals actively participating in director and management functions, while one company in the DM2 group had a maximum of 13 individuals involved in these roles.

The outcomes of the Kruskal–Wallis test suggested that there were no statistically significant differences observed between the DM groups concerning the financial ratios. This means that the presence of shareholders as directors and managers does not have a significant statistical impact on the financial ratios of the companies. These findings align with studies devoted to stewardship theory, which suggest that, in small companies, both owners and managers are incentivized to strive for optimal company performance, irrespective of their individual roles (Davis et al. 1997; Menyah 2013; Chrisman 2019). The stewardship theory suggests that managers who are also shareholders are motivated to act as stewards, working in the best interest of shareholders and stakeholders (Menyah 2013). In this context, their intrinsic motivation to protect and grow the company's resources should lead to similar efforts to enhance financial performance, regardless of their formal role as directors (Davis et al. 1997). These findings fail to support our initial hypothesis, which proposed that there are significant differences in the financial performance of Latvian fintech companies based on the presence of shareholders as directors and managers. Therefore, according to the stewardship theory, directors and managers who are shareholders (DM1

category) may demonstrate comparable levels of commitment to improving financial performance compared to directors and managers who are not shareholders (DM2 category). The shared ownership and involvement in management roles align their interests with those of shareholders, promoting a sense of stewardship and diminishing potential conflicts of interest. In the authors' opinion, it is important to note that the majority of Latvian fintech companies in the DM2 group are still relatively small. As a result, the limited scale and size of these companies may contribute to the absence of statistically significant differences in financial ratio performance.

Although we did not find statistically significant differences between the groups for financial ratios, we used graphical methods to uncover notable patterns. For example, the DM1 group consistently had slightly higher medians for all financial ratios, indicating better overall financial health. These findings suggest that active shareholder involvement in management may contribute to higher Return on Assets (ROA), better liquidity, and a greater proportion of assets financed by equity rather than debt. The practical significance of these findings lies in their potential real-world impact, highlighting the importance of shareholder involvement in management positions in improving a company's financial performance and sustainability. In addition, the calculation of Cliff's Delta effect sizes further supports the practical significance of our findings. Despite the lack of statistical significance, the small to medium effect sizes suggest meaningful differences in financial performance between the groups. Conversely, the DM3 group exhibited weaker financial performance than both DM1 and the majority of DM2 on most financial measures. These findings highlight the importance of considering the broader context and implications of our findings for decision making in the fintech industry.

6. Conclusions

This study has highlighted the intricate relationship between the presence of shareholders as directors and managers and the financial performance of Latvian fintech companies. While our analysis did not yield statistically significant differences in financial ratios across the DM groups, DM1 consistently demonstrated superior financial performance in terms of median values. The practical implications of our findings are noteworthy. For fintech firms, shareholder involvement in governance could serve as a strategic advantage, potentially leading to improved profitability, liquidity, and overall financial health. As shareholders themselves, managers and directors are likely to have a vested interest in maximizing shareholder value, which could translate into more prudent decision making and resource allocation. In addition, the alignment of interests between shareholders and management can mitigate agency conflicts and improve corporate governance practices, thereby promoting investor confidence and market stability. Moreover, the alignment of interests between shareholders and management may mitigate agency conflicts and enhance corporate governance practices, thereby fostering investor confidence and market stability.

However, it is imperative to approach these findings judiciously, given the existence of overlapping confidence intervals and the observed variability within DM2 and DM3. The lack of statistical significance can be attributed to a variety of factors, including the relatively small sample size and unobserved variables that could potentially impact financial performance results. The differences observed in DM2 and DM3 suggest that the impact of shareholder involvement in management roles may not be uniform across all fintech companies. Instead, it may depend on various factors, such as the company's size, business model, management practices, and external market conditions.

Our investigation contributes to the ongoing discourse surrounding potential conflicts of interest, thereby highlighting nuanced dynamics that warrant careful consideration. The complex interplay among corporate governance structures, shareholder participation, and financial outcomes suggests that the manifestation of conflicts of interest defies simplistic linear relationships.

The study has some limitations. First, the financial performance of Latvian fintech companies is based only on data from the year 2022. The use of single-year data may not fully capture the long-term trends and variations in financial performance, and it may be influenced by specific economic conditions or industry dynamics present in that particular year. Second, there are a lack of quality data for fintech companies. While some companies may submit their balance sheets and profit/loss statements, the information provided can be limited, especially for micro-companies. This constraint might have influenced the precision and comprehensiveness of our analysis. Third, we used non-parametric tests, such as the Kruskal–Wallis test, due to the non-normal distribution of the financial data. While these tests are suitable for our data, they may have limitations compared to parametric tests, which could be employed with a larger and normally distributed dataset.

Although our study has inherent limitations, we believe that it provides valuable insights into the relationship between shareholder presence as directors and managers and the financial performance of the fintech industry. We aim to encourage further research efforts that build upon our findings and address the identified shortcomings. Future research could explore longitudinal studies that track the financial performance of Latvian fintech companies over multiple years. This approach would provide a more comprehensive understanding of long-term trends and variations in financial performance, enabling researchers to discern patterns and identify factors that influence financial outcomes over time. Furthermore, conducting cross-country comparative studies between different countries or regions is a promising direction for future research. By examining the financial performance of fintech companies across diverse regulatory environments, economic conditions, and market landscapes, researchers can gain insights into the factors driving variations in financial performance.

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Appendix A

Table A1. Shapiro–Wilk test results.

Variable Name/ Statistics	ROA	ROE	PM	CR	LR	SR
			Group DM1			
Statistics	0.431	0.486	0.433	0.428	0.404	0.402
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
			Group DM2			
Statistics	0.200	0.148	0.283	0.355	0.355	0.241
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
			Group DM3			
Statistics	0.522	0.456	0.539	0.585	0.585	0.418
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Notes

[1] In this study, we adopt the Orbis classification of directors and managers, encompassing board members, committee participants, and executives.

[2] Even though very high levels of liquidity can be interpreted as inefficient use of financial resources, we do not consider the liquidity in any of the companies in the dataset as being excessive.

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Robust Portfolio Optimization with Environmental, Social, and Corporate Governance Preference

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Abstract: This study addresses the crucial but under-explored topic of ambiguity aversion, i.e., model misspecification, in the area of environmental, social, and corporate governance (ESG) within portfolio decisions. It considers a risk- and ambiguity-averse investor allocating resources to a risk-free asset, a market index, a green stock, and a brown stock. The study employs a robust control approach rooted in relative entropy to account for model misspecification and derive closed-form optimal investment strategies. The key contribution of this study includes demonstrating, using two sets of empirical data on asset returns and ESG ratings, the substantial influence of ambiguity on optimal trading strategies, particularly highlighting the differential effects of market, green, and brown ambiguities. As a by-product of our analytical solutions, the study contrasts ambiguity-averse investors with their non-ambiguity counterparts, revealing more cautious risk exposures with a reduction in short-selling positions for the former. Furthermore, three types of investors who employ popular suboptimal strategies are identified, together with two loss measures used to quantify their performance. The findings reveal that popular strategies, not accounting for ESG and misspecification in the model, could lead to significant financial costs, with the extent of loss varying depending on those two factors: investors' ambiguity aversion profiles and ESG preferences.

Keywords: model uncertainty; multi-attribute utility; ESG modeling

JEL Classification: C61; C20

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1. Introduction

Since Merton's seminal work (Merton 1975), numerous studies have explored optimal portfolio choices for investors with ambiguity aversion (also known as robust portfolio analysis or model specification) under various assumptions. Most of the literature underscores the importance of accounting for ambiguity when making investment decisions. However, only a limited number of studies have incorporated the concept of environmental, social, and corporate governance (ESG). In this study, we extend the portfolio choice problem to include ESG ambiguity aversion within a multivariate (also known as multi-attribute) utility framework.

Environmental, social, and corporate governance (ESG) encompasses a broad spectrum of financial activities, including sustainable investing, socially responsible investing (SRI), impact investing, green investing, value-based investing, ESG investing, and triple-bottom-line investing. These various approaches converge on a shared objective: the promotion of "green investing". While each investment style possesses distinct characteristics, they collectively address different facets of ESG with the aim of enhancing companies and portfolios for the benefit of stakeholders. Recent years have witnessed a notable trend among institutional investors with long-term perspectives: the integration of ESG criteria into investment decision-making and portfolio selection. According to a 2022 report by the Sustainable Investment Forum (SIF) (US SIF 2022), a staggering USD 7.6 trillion

in U.S.-domiciled assets have incorporated ESG criteria into their investment processes. This underscores the mounting significance of ESG considerations for enterprises, asset managers, and global shareholders (Edmans 2011; Jacobsen et al. 2019; Orsato et al. 2015). Meanwhile, there is a growing demand from both researchers and market participants to quantify ESG performance, driven by substantial needs in data analysis and financial modeling. Numerous studies have delved into ESG ratings, a key metric for quantifying the ESG performance of companies (e.g., Bermejo Climent et al. 2021; Clément et al. 2022; Drempetic et al. 2020; Polbennikov et al. 2016; Tarmuji et al. 2016). These investigations scrutinize the credibility of ESG ratings and explore their impact on financial assets and investors, establishing a foundation for further quantitative research in the realm of ESG that leverages these ratings. In this paper, we also utilize ESG ratings to discern green and brown stocks.

Moreover, numerous studies have incorporated investors' preferences for green investing into optimal portfolio strategies (e.g., some recent examples are Chen et al. (2021); Dorfleitner et al. (2012); Gasser et al. (2017)). Some of these studies utilize the framework of expected utility theory (EUT), which forms the foundation of our work. For instance, Ahmed et al. (2021) incorporate ESG as a non-pecuniary attribute of the portfolio, leading to bivariate constant absolute risk aversion (CARA) utility. Similarly, Dorfleitner and Nguyen (2017) employ bivariate CARA utility, where the ESG component appears as a non-pecuniary additive term, and compare it with the mean-variance (MVT) framework. Notably, Pástor et al. (2021) develop a single-period equilibrium model for green investing using exponential utility. Their study analyzes the impact of ESG preferences on asset prices, leading to the suggestion of an optimal three-fund separation for portfolio holdings, including a risk-free asset, a market portfolio, and an ESG portfolio. Furthermore, Escobar-Anel (2022) incorporates the ESG dimension by allowing for different levels of risk aversion for green and brown assets. This pecuniary approach accounts for the ethical dimensions of ESG and presents the first continuous-time ESG analysis with closed-form solutions within the EUT. In our work, we build upon this analytical framework by adding a market-risk dimension with a specific focus on ESG ambiguity aversions.

The literature on ambiguity aversion within portfolio choice is quite extensive; therefore, we provide a brief review with a focus on papers close to our approach. Maenhout (2004) adapted the general robust control framework developed by Anderson et al. (2003) to address the dynamic portfolio choice problem under power utility. His analysis focuses on the fundamental Merton model, featuring a single stock and a riskless asset with constant investment opportunities. He introduced the concept of ambiguity by considering uncertainty regarding the expected rate of return on stocks. Building on this work, Maenhout (2006) extended the examination to encompass the role of ambiguity aversion in scenarios involving time-varying expected stock returns. Liu (2010) expanded this analysis by incorporating Epstein–Zin preferences to explore the interplay of ambiguity aversion in portfolio choice. Meanwhile, empirical studies have indicated variations in ambiguity aversion levels for a given investor in regards to the underlying sources of risk. For instance, Dimmock et al. (2016) discovered a negative association between ambiguity aversion and stock market participation, the proportion of financial assets invested in stocks, and foreign stock ownership, as well as a positive correlation with ownership of company stocks. Similarly, Kocher et al. (2018) demonstrated that ambiguity attitudes are contingent on the outcome domain and likelihood range. More recent work by Klingebiel and Zhu (2023) utilized ambiguity aversion thresholds to elucidate why the same individual may seek some sources of ambiguity while avoiding others. Wang and Uppal (2002) were the first to consider varying levels of ambiguity aversion concerning the joint and marginal distributions of state variables. In the spirit of various ambiguity aversion levels, Branger and Larsen (2013) modeled stock prices using a jump-diffusion process, permitting separate ambiguity aversions to the diffusion and jump components. This framework enables a comparative analysis of the impact of ambiguity about the jump component versus ambiguity about the diffusive component on optimal portfolio choices. Similarly, Flor and Larsen (2014) explored scenarios in which

an investor grappled with ambiguity concerning models for both interest rates and stock returns, while Escobar et al. (2015) targeted ambiguity aversions about volatility and stock returns. When applying robust portfolio optimization in the realm of ESG considerations, Rubtsov et al. (2021) introduced the concept of climate uncertainty. This approach tackled the robust optimization problem within the context of an investor engaged in trading a stock index while also holding an illiquid claim designed to provide insurance against climate change risk. The findings of this study shed light on the significant influence of climate uncertainty on investment portfolios. Notably, heightened climate uncertainty tends to reduce investments in stocks. Subsequently, Rubtsov and Shen (2022) extended the scope by deriving an optimal stock–bond–cash portfolio. This expanded analysis delved into the repercussions of uncertainties surrounding climate change, taking into account portfolios with varying investment horizons. It is pertinent to note that both studies in this series operate on the premise of a univariate utility function and focus on a single source of uncertainty.

Our work, in its distinctive contribution to the field, diverges from previous literature by introducing an innovative ESG portfolio setting with multi-attribute utility while allowing for special considerations on green, brown, and market ambiguity aversions. Specifically, we consider a risk- and ambiguity-averse investor with the option to invest in a bank account (cash), a market index, a green stock, and a brown stock. Extending the work of Escobar-Anel (2022), this investor possesses a multivariate utility function with different risk aversions not only to green and brown stocks but also to the market index. This addition is critical, as the market index is neither green nor brown but rather an average, and it can be understood as the classical level of investor risk aversion. See Escobar-Anel and Jiao (2023) for further arguments.

Additionally, our investor contends with ambiguity regarding the dynamics of these assets. Depending on the available information, the agent may exhibit varying degrees of uncertainty regarding the models for the market index, the green stock, and the brown stock. Leveraging the robust control approach established by Anderson et al. (2003), we derive the optimal investment strategy and investigate the implications of ambiguity within this ESG context.

Our model assumes that the investor has a reference model for the market, the green stock, and the brown stock, but acknowledges that these models may be misspecified. It also recognizes the existence of alternative models that may better represent reality. Consequently, our investor seeks investment rules that are robust to model misspecification and capable of performing reasonably well across a range of plausible models. The degree of dissimilarity between the reference model and alternative models is quantified through relative entropy, which serves as a penalty in the optimization process. This penalty quantifies the investor's aversion to uncertainty concerning the reference model. The optimal portfolio is obtained in closed form after solving the relevant robust Hamilton–Jacobi–Bellman (HJB) equation (also known as the HJBI equation for HJB–Isaacs).

Several motivations underlie our assumptions regarding ambiguity concerning the market, the green stock, and the brown stock. First, the assumption of model ambiguity aligns with empirical studies, such as Ellsberg (1961), which reveal that individuals are averse not only to risk (where the probability distribution is known) but also to ambiguity (where the probability distribution is unknown). Second, as per the work of Wang and Uppal (2002), there is compelling evidence to suggest that investors exhibit different levels of ambiguity aversion toward different assets, that is, green, brown, and market. Hence, our model introduces flexibility to account for the varying levels of ambiguity aversion among investors. Third, as demonstrated by Merton (1980), accurately estimating expected returns remains a formidable challenge. In this context, it is important to emphasize that, within the framework of Anderson et al. (2003), model uncertainty primarily pertains to uncertainty about the drift of the state variables. Consequently, our study derives an optimal portfolio strategy that remains robust to model uncertainty, particularly regarding the equity risk premium of various assets.

In summary, this study makes several important contributions. Firstly, it introduces a distinctive analytical framework by segregating green, brown, and market investments within the investors' wealth process. This allows for an explicit study of the impact of each one of these asset categories on portfolio decisions, pushing the boundaries of existing methodologies.

Secondly, our work employs multi-attribute utility for risk aversions and delves into its interaction with various levels of ambiguity aversion. This interaction has not been explored in the literature, offering a novel perspective that can advance the application of multi-attribute utility.

Thirdly, our research not only provides analytical solutions but also underscores the significance of precise ESG modeling. This contribution lays the groundwork for further studies in this direction, with implications extending beyond robust portfolio optimization to contribute to the evolving landscape of ESG modeling.

Fourthly, this study underscores the substantial impact of ambiguity on optimal trading strategies while accounting for ESG preferences. In comparing the short-term effects of market, green, and brown ambiguities, we find that market ambiguity predominantly affects market weight, whereas both green and brown ambiguities influence not only the respective weights of these assets but also the market weight. Our numerical examples are based on empirical data on asset returns and ESG ratings obtained from the RepRisk database. The analysis further illustrates that this behavior extends to long-term investment strategies. Specifically, plausible levels of ambiguity can result in changes of over 50% in the optimal strategies.

Fifthly, we explore the effects of ambiguity by contrasting outcomes with those of non-ambiguity-averse investors. We provide compelling evidence that ambiguity-averse investors exhibit less aggressive exposure to risks. As demonstrated in our numerical example, ambiguity also leads to a reduction in short-selling positions.

Lastly, we categorize three types of investors who employ suboptimal strategies and two measures of welfare loss. We assess the welfare loss incurred by investors using suboptimal strategies. Our analysis reveals that investors who adopt suboptimal strategies experience non-negligible losses. For empirically relevant parameter values, the losses due to ignoring model uncertainty increase with greater ambiguity, amounting to close to 100% of the initial wealth.

The remainder of this paper is organized as follows. Section 2 outlines the portfolio choice problem. Section 3 provides a solution and outlines its general properties. In Section 4, we categorize three types of suboptimal investors and two measures of welfare loss incurred by an investor who follows a suboptimal investment strategy. Section 5 presents an analysis of the optimal portfolio through a numerical example, with Section 6 concluding, while the appendices contain proofs of important propositions and another numerical example.

2. Mathematical Setting

Let us assume that a financial market consists of one risk-free asset and three risky assets. These assets are invested over the period from time 0 to time T. Let all stochastic processes introduced in this paper be defined on a complete probability space $(\Omega, \mathcal{F}, \mathbb{P}, \{\mathcal{F}_t\}_{t\in[0,T]})$, where $\{\mathcal{F}_t\}_{t\in[0,T]}$ is a right-continuous filtration generated by standard Brownian motions (BMs).

This section is divided into three parts. First, we present a model for the underlying assets under the reference model. Section 2 constructs a family of alternative models, while Section 3 describes the self-financing wealth process and the underlying green, brown, and market synthetic portfolios.

2.1. ESG Market Model with a One-Factor Structure

We first introduce our model, which is characterized by three main assets. One asset is identified as the market portfolio (S_1). This could be a common index that merges all

assets of a given market or sectors of interest to the investor. The other two assets can be interpreted as two types of stock in the market: the so-called green stock (S_2) and the non-green alternative named, for the purpose of our study, brown stock (S_3). Both stocks are correlated with each other and with the index, resembling a one-factor CAPM model with the index playing the role of a single factor. Our model has the following structure:

$$\begin{aligned}
\frac{dS_{1,t}}{S_{1,t}} &= (r + \lambda_1\sigma_1^2)dt + \sigma_1 dz_m, \\
\frac{dS_{2,t}}{S_{2,t}} &= (r + \lambda_1\sigma_1\sigma_2\rho_{12} + \lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2})dt + \sigma_2(\rho_{12}dz_m + \sqrt{1-\rho_{12}^2}dz_g), \\
\frac{dS_{3,t}}{S_{3,t}} &= (r + \lambda_1\sigma_1\sigma_3\rho_{13} + \lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2})dt + \sigma_3(\rho_{13}dz_m + \sqrt{1-\rho_{13}^2}dz_b).
\end{aligned} \tag{1}$$

where z_m, z_g, and z_b are independent standard Brownian motions, representing three sources of risk: market, green, and brown, respectively. The volatilities of the three assets, namely S_1, S_2, and S_3, are represented by σ_1, σ_2, and σ_3, respectively. Additionally, our framework incorporates a risk-free asset, such as a cash account or government bond, with its return denoted as r. The dynamic of the risk-free asset is governed by $dB_t = rB_t dt$ and is not influenced by any source of risk. We capture correlations via $corr(S_1, S_2) = \rho_{12}$, $corr(S_1, S_3) = \rho_{13}$, and $corr(S_2, S_3) = \rho_{12}\rho_{13}$. The market risk premium (from z_m) is represented by $\lambda_1\sigma_1$, the green risk premium is expressed by $\lambda_g\sigma_2$, and the brown risk premium is $\lambda_b\sigma_3$.

2.2. Alternative Model

We refer to the market model presented in the previous section as the reference model. Our investor is uncertain about the probability distribution of the reference model and considers a set of plausible alternative models when making investment decisions. We assume that our investor is uncertain about the distributions of z_m, z_g, and z_b. Specifically, our investor is uncertain about the drifts of the stock prices. We cannot consider modeling the uncertainty of volatility because the limit of infinitely fine sampling would remove all estimation risks of the second moments. However, the first moments are notoriously difficult to estimate (Blanchard et al. 1993; Cochrane 1998; Merton 1980).

Let $\boldsymbol{e}_t := (e_t^m, e_t^g, e_t^b)$ be an $\mathbb{R}^3$-valued $\mathcal{F}_t$-progressively measurable process and define the Radon–Nikodym derivative process by

$$\Lambda_t^e = \mathrm{E}\left[\frac{d\mathbb{P}^e}{d\mathbb{P}}|F_t\right] = \exp\left\{-\int_0^t\left(\langle \boldsymbol{e}_\tau, d\boldsymbol{z}_\tau\rangle + \frac{1}{2}||\boldsymbol{e}_\tau||^2 d\tau\right)\right\} \tag{2}$$

where $d\boldsymbol{z}_t := (dz_{m,t}, dz_{g,t}, dz_{b,t})$. According to Girsanov's theorem, the process

$$\tilde{\boldsymbol{z}}_t = \boldsymbol{z}_t + \int_0^t \boldsymbol{e}_\tau d\tau \tag{3}$$

is a multidimensional Brownian motion under probability measure $\mathbb{P}^e$.

The investor's subjective measure $\mathbb{P}^e$ is assumed to be $\sigma-$finite on $(\Omega, \mathcal{F}_t)$, and absolutely continuous with respect to measure $\mathbb{P}$. $\boldsymbol{e}_t$ represents perturbations that enable the investor to deviate from the reference model. Although the reference model best characterizes the data available to the investor, they may also consider alternative models that are difficult to distinguish statistically from the reference model. Under the probability measure $\mathbb{P}^e$, the alternative model is

$$\begin{aligned}
\frac{dS_{1,t}}{S_{1,t}} =& (r + \lambda_1\sigma_1^2 - \sigma_1 e_t^m)dt + \sigma_1 d\tilde{z}_m, \\
\frac{dS_{2,t}}{S_{2,t}} =& (r + \lambda_1\sigma_1\sigma_2\rho_{12} + \lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2} - \sigma_2\rho_{12}e_t^m - \sigma_2\sqrt{1-\rho_{12}^2}e_t^g)dt \\
&+ \sigma_2(\rho_{12}d\tilde{z}_m + \sqrt{1-\rho_{12}^2}d\tilde{z}_g), \\
\frac{dS_{3,t}}{S_{3,t}} =& (r + \lambda_1\sigma_1\sigma_3\rho_{13} + \lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2} - \sigma_3\rho_{13}e_t^m - \sigma_3\sqrt{1-\rho_{13}^2}e_t^b)dt \\
&+ \sigma_3(\rho_{13}d\tilde{z}_m + \sqrt{1-\rho_{13}^2}d\tilde{z}_b).
\end{aligned} \tag{4}$$

2.3. Wealth Process and Portfolio Setting

Let W_t denote the investor's wealth process created by allocating in $S_{1,t}$, $S_{2,t}$, $S_{3,t}$, and B_t. Let π_i (a simplified notation for $(\pi_{i,t})_{t\in[0,T]}$) denote the proportion of wealth invested in $S_{i,t}$[1], according to the self-financing condition, the wealth process is

$$\begin{aligned}
\frac{dW_t}{W_t} &= \pi_1\frac{dS_{1,t}}{S_{1,t}} + \pi_2\frac{dS_{2,t}}{S_{2,t}} + \pi_3\frac{dS_{3,t}}{S_{3,t}} + (1-\pi_1-\pi_2-\pi_3)\frac{dB_t}{B_t} \\
&= (r + \pi_1\lambda_1\sigma_1^2 + \pi_2\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_2\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2} + \pi_3\lambda_1\sigma_1\sigma_3\rho_{13} \\
&\quad + \pi_3\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2})dt + (\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})dz_m + \pi_2\sigma_2\sqrt{1-\rho_{12}^2}dz_g \\
&\quad + \pi_3\sigma_3\sqrt{1-\rho_{13}^2}dz_b
\end{aligned} \tag{5}$$

The term rdt represents the return on the cash account. Let us distribute this return among the three synthetic assets by weighing the parameters θ_m, θ_g, and θ_b, satisfying $\theta_m + \theta_g + \theta_b = 1$[2]. Now, we are ready to write wealth in terms of three synthetic indices capturing the three independent sources of risk by equation

$$d\log W_t = d\log X_{m,t} + d\log X_{g,t} + d\log X_{b,t} \tag{6}$$

where we can see explicitly how each of these synthetic indices is impacted by its corresponding independent source of risk:

$$\begin{aligned}
d\log X_{m,t} &= [\theta_m r + \pi_1\lambda_1\sigma_1^2 + \pi_2\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_3\lambda_1\sigma_1\sigma_3\rho_{13} \\
&\quad - \frac{1}{2}(\pi_1\sigma_1 + \pi_2\sigma_2\pi_{12} + \pi_3\sigma_3\rho_{13})^2]dt + (\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})dz_m \\
d\log X_{g,t} &= [\theta_g r + \pi_2\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2} - \frac{1}{2}\pi_2^2\sigma_2^2(1-\rho_{12}^2)]dt + \pi_2\sigma_2\sqrt{1-\rho_{12}^2}dz_g \\
d\log X_{b,t} &= [\theta_b r + \pi_3\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2} - \frac{1}{2}\pi_3^2\sigma_3^2(1-\rho_{13}^2)]dt + \pi_3\sigma_3\sqrt{1-\rho_{13}^2}dz_b
\end{aligned} \tag{7}$$

Solving Equation (6), we obtain the terminal wealth at the end of time period $[0, T]$:

$$W_T = W_0\frac{X_{m,T}}{X_{m,0}}\frac{X_{g,T}}{X_{g,0}}\frac{X_{b,T}}{X_{b,0}} \tag{8}$$

The processes $X_{m,t}$, $X_{g,t}$, and $X_{b,t}$ can be interpreted as indices denominated in generic units, with their values from the beginning of period 0 to the conclusion of period T dictating the ultimate wealth W_T. We refer to $X_{g,t}$ as the Green Index and $X_{b,t}$ as the Brown Index to differentiate them from the green stock (S_2) and brown stock (S_3) in the market model. Since $X_{m,t}$ is driven by market risk, $X_{g,t}$ by green risk, and $X_{b,t}$ by brown risk, these terms represent their respective contributions to wealth growth.

Similarly, the investor considers the following alternative model for the indices under the probability measure $\mathbb{P}^e$.

$$\begin{aligned}
d\log X_{m,t} =&[\theta_m r + \pi_1\lambda_1\sigma_1^2 + \pi_2\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_3\lambda_1\sigma_1\sigma_3\rho_{13} \\
&- \frac{1}{2}(\pi_1\sigma_1 + \pi_2\sigma_2\pi_{12} + \pi_3\sigma_3\rho_{13})^2 - (\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})e_t^m]dt \\
&+ (\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})d\tilde{z}_m \\
d\log X_{g,t} =&[\theta_g r + \pi_2\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2} - \frac{1}{2}\pi_2^2\sigma_2^2(1-\rho_{12}^2) - \pi_2\sigma_2\sqrt{1-\rho_{12}^2}e_t^g]dt \\
&+ \pi_2\sigma_2\sqrt{1-\rho_{12}^2}d\tilde{z}_g \\
d\log X_{b,t} =&[\theta_b r + \pi_3\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2} - \frac{1}{2}\pi_3^2\sigma_3^2(1-\rho_{13}^2) - \pi_3\sigma_3\sqrt{1-\rho_{13}^2}e_t^b]dt \\
&+ \pi_3\sigma_3\sqrt{1-\rho_{13}^2}d\tilde{z}_b
\end{aligned} \tag{9}$$

3. Optimal Investment Strategies

As discussed in the literature (e.g., Escobar-Anel 2022), an investor may prefer to allocate their portfolio according to different degrees of risk aversion for market risk, green risk, and brown risk, respectively. Consequently, we specify our investor's utility as a function of $X_{m,t}$, $X_{g,t}$, and $X_{b,t}$. An investor can maximize their utility by assigning π_1, π_2, and π_3 to obtain the best combination of $X_{m,t}$, $X_{g,t}$, and $X_{b,t}$. Next, we explain the choice of utility.

We consider the multivariate utility function

$$u(X_m, X_g, X_b) = \frac{(X_m)^{\alpha_m}}{\alpha_m}\frac{(X_g)^{\alpha_g}}{\alpha_g}\frac{(X_b)^{\alpha_b}}{\alpha_b} \tag{10}$$

where we choose risk aversion parameters $\alpha_b \leq \alpha_m \leq \alpha_g < 0$, and the reward function realized by choosing the alternative model under $\mathbb{P}^e$

$$w^e(X,t;\pi) = \mathrm{E}^{\mathbb{P}_e}_{X,t}\big[u(X_{m,T}, X_{g,T}, X_{b,T})\big]. \tag{11}$$

Let $\mathcal{U}[0,T]$ represent the space of all admissible strategies π_i that are $\mathcal{F}_t$-progressively measurable, ensuring the wealth remains non-negative for $t \in [0,T]$ and satisfies integrability conditions necessary for Equation (11). We denote $\varepsilon[0,T]$ as the set of all $\mathcal{F}_t$-progressively measurable processes, ensuring that the process (2) is a well-defined Radon–Nikodym derivative process. The indirect utility function is defined as

$$\begin{aligned}
J(X,t) = \sup_{\pi\in\mathcal{U}[t,T]}\inf_{e\in\varepsilon[t,T]}\Bigg\{&\mathrm{E}^{\mathbb{P}^e}_t\left[\int_t^T\left(\frac{(e_\tau^m)^2}{2\Psi_m(\tau,X_\tau)} + \frac{(e_\tau^g)^2}{2\Psi_g(\tau,X_\tau)} + \frac{(e_\tau^b)^2}{2\Psi_b(\tau,X_\tau)}\right)d\tau\right] \\
&+w^e(X,t;\pi)\Bigg\},
\end{aligned} \tag{12}$$

where the expectation term in the equation functions as a penalty for the deviation from the reference model. The penalty depicts the relative entropy between the alternative and reference models, which is expressed as

$$D_{KL}(\mathbb{P}^e||\mathbb{P}) = \mathrm{E}^{\mathbb{P}^e}_t\left[\int_t^T\frac{1}{2}||\boldsymbol{e_\tau}||^2 d\tau\right] \tag{13}$$

and perturbations e_t^m, e_t^g, and e_t^b are scaled by Ψ_m, Ψ_g, and Ψ_b, respectively.

Ψ_m, Ψ_g, and Ψ_b capture ambiguity aversions toward market, green, and brown dynamics, respectively. For analytical tractability, we assume the following

$$\Psi_i = \frac{\phi_i}{\alpha_i J}, \quad i = m, g, b, \tag{14}$$

where $\phi_i > 0$ are recognized as ambiguity aversion parameters. Building upon the concept of 'homothetic robustness' proposed by Maenhout (2004), we depart from the conventional approach of Anderson et al. (2003), where a constant ambiguity aversion parameter ($\Psi_i(X_m, X_g, X_b, t) = \hat{\phi}_i$) is employed. Instead, we introduce a scaling factor, denoted as $\alpha_i J$, which divides ϕ_i. This modification ensures that the optimal weights remain unaffected by variations in the state variables X_m, X_g, and X_b, thereby preserving the homothetic nature of preferences amid the changing state variables.

As explained by Maenhout (2004), the consideration of homotheticity is not merely a modeling convenience; it carries significant implications for several reasons. First, despite the economic growth, rates of return remain stationary. Second, when the magnitude of the state variable becomes pertinent, the natural unit invariance of optimal decisions is disrupted, requiring adjustments in calibrations. Finally, homotheticity plays a pivotal role in facilitating aggregation and the construction of a representative agent, thereby enhancing the comprehensibility and applicability of the model.

Our construction also accommodates distinct values of ϕ_m, ϕ_g, and ϕ_b. Recognizing that investors may know more about the distribution of some assets than others, we employ ϕ_i to govern the degree of ambiguity aversion. This approach enables a systematic examination of how these ϕ_i values influence both the optimal weightings and resultant utility levels.

Therefore, the HJB equation for Equation (12) is

$$\begin{aligned}
&\sup_{\pi_1,\pi_2,\pi_3} \inf_{e^m,e^g,e^b} \Big\{ J_t + (\theta_m r + \pi_1\lambda_1\sigma_1^2 + \pi_2\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_3\lambda_1\sigma_1\sigma_3\rho_{13} \\
&- (\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})e^m)xJ_x + \frac{1}{2}(\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})^2x^2J_{xx} \\
&+ (\theta_g r + \pi_2\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2} - \pi_2\sigma_2\sqrt{1-\rho_{12}^2}e^g)yJ_y + \frac{1}{2}\pi_2^2\sigma_2^2(1-\rho_{12}^2)y^2J_{yy} \\
&+ (\theta_b r + \pi_3\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2} - \pi_3\sigma_3\sqrt{1-\rho_{13}^2}e^b)zJ_z + \frac{1}{2}\pi_3^2\sigma_3^2(1-\rho_{13}^2)z^2J_{zz} \\
&+ \frac{(e^m)^2}{2\Psi_m} + \frac{(e^g)^2}{2\Psi_g} + \frac{(e^b)^2}{2\Psi_b} \Big\} = 0,
\end{aligned} \tag{15}$$

where X_m, X_g, X_b are denoted as x, y, z. A subsequent proposition is obtained by solving the HJB equation presented above (see Appendix A.1).

Proposition 1. *The optimal weights for solving the HJB Equation (15) are given by*

$$\begin{aligned}
\pi_1^* &= \frac{\lambda_1}{1-\alpha_m+\phi_m} - \frac{\sigma_2}{\sigma_1}\rho_{12}\pi_2^* - \frac{\sigma_3}{\sigma_1}\rho_{13}\pi_3^*, \\
\pi_2^* &= \frac{\lambda_g}{\sqrt{1-\rho_{12}^2}(1-\alpha_g+\phi_g)}, \\
\pi_3^* &= \frac{\lambda_b}{\sqrt{1-\rho_{13}^2}(1-\alpha_b+\phi_b)}.
\end{aligned} \tag{16}$$

The value function can be expressed as

$$J(X,t) = \frac{X_m^{\alpha_m}}{\alpha_m}\frac{X_g^{\alpha_g}}{\alpha_g}\frac{X_b^{\alpha_b}}{\alpha_b}\exp(b(T-t)), \tag{17}$$

where

$$b = \frac{1}{2}\lambda_1^2\sigma_1^2\frac{\alpha_m}{1-\alpha_m+\phi_m} + \frac{1}{2}\lambda_g^2\sigma_2^2\frac{\alpha_g}{1-\alpha_g+\phi_g} + \frac{1}{2}\lambda_b^2\sigma_3^2\frac{\alpha_b}{1-\alpha_b+\phi_b} + (\theta_m\alpha_m + \theta_g\alpha_g + \theta_b\alpha_b)r. \tag{18}$$

The optimal wealth process is therefore

$$\frac{dW_t}{W_t} = (r + \frac{\lambda_1^2\sigma_1^2}{1-\alpha_m+\phi_m} + \frac{\lambda_g^2\sigma_2^2}{1-\alpha_g+\phi_g} + \frac{\lambda_b^2\sigma_3^2}{1-\alpha_b+\phi_b})dt + \frac{\lambda_1\sigma_1}{1-\alpha_m+\phi_m}dz_m + \frac{\lambda_g\sigma_2}{1-\alpha_g+\phi_g}dz_g + \frac{\lambda_b\sigma_3}{1-\alpha_b+\phi_b}dz_b. \tag{19}$$

Remark 1.

1. *As shown in Appendix A.1, if we do not specify* $\Psi_i = \frac{\phi_i}{\alpha_i J}$*, the optimal weights are*

$$\begin{aligned}\pi_1^* &= \frac{\lambda_1 J_x}{\Psi_m x (J_x)^2 - x J_{xx}} - \frac{\sigma_2}{\sigma_1}\rho_{12}\pi_2^* - \frac{\sigma_3}{\sigma_1}\rho_{13}\pi_3^*,\\ \pi_2^* &= \frac{\lambda_g}{\sqrt{1-\rho_{12}^2}}\frac{J_y}{\Psi_g y (J_y)^2 - y J_{yy}},\\ \pi_3^* &= \frac{\lambda_b}{\sqrt{1-\rho_{13}^2}}\frac{J_z}{\Psi_b z (J_z)^2 - z J_{zz}}.\end{aligned} \tag{20}$$

   To elaborate, if we were to assume constant values for Ψ_i*, then the optimal weights would be contingent on the state variables* X_m*,* X_g*, and* X_b*. However, to maintain homotheticity, we introduce a modification by setting* $\Psi_i = \frac{\phi_i}{\alpha_i J}$*. This adjustment ensures that the optimal weights are independent of variations in the state variables* X_m*,* X_g*, and* X_b*.*
2. *It is interesting to see that ambiguity aversion parameters act similarly to risk aversion parameters in the representation of the optimal weights. This is not new, as highlighted by Maenhout (2006) for the CRRA utility. This observation is important for our multi-attribute utility, as it conveys the notion that investors might, consciously or not, exchange risk aversion for ambiguity aversion and vice versa. This provides yet another motivation for the validity of a multi-attribute utility, that is, a utility that allows for different risk aversions for different sources of risk.*
3. *While an investor characterized by the utility function* $u(X_m, X_g, X_b) = \frac{(X_m)^{\alpha_m-\phi_m}}{\alpha_m-\phi_m}\frac{(X_g)^{\alpha_g-\phi_g}}{\alpha_g-\phi_g}\frac{(X_b)^{\alpha_b-\phi_b}}{\alpha_b-\phi_b}$ *and lacking ambiguity aversions would yield the same optimal weights as an ambiguity-averse investor, it is essential to highlight that the indirect utility functions do not align. Consequently, these two scenarios do not constitute the same utility problem. In this instance, we have a b of*

$$b = \frac{1}{2}\lambda_1^2\sigma_1^2\frac{\alpha_m-\phi_m}{1-\alpha_m+\phi_m} + \frac{1}{2}\lambda_g^2\sigma_2^2\frac{\alpha_g-\phi_g}{1-\alpha_g+\phi_g} + \frac{1}{2}\lambda_b^2\sigma_3^2\frac{\alpha_b-\phi_b}{1-\alpha_b+\phi_b} + (\theta_m(\alpha_m-\phi_m) + \theta_g(\alpha_g-\phi_g) + \theta_b(\alpha_b-\phi_b))r \tag{21}$$

   different to that of Equation (17).

4. Analysis of Suboptimal Strategies

Investors may at times adopt suboptimal strategies for various reasons. A frequent rationale for such decisions is the absence of sufficient knowledge to construct an optimal strategy. In our context, for instance, an investor might have varying degrees of ambiguity aversion toward their green and brown stocks. However, owing to the lack of requisite knowledge to formulate an optimal solution, they opt for a strategy that does not account

for robustness. Consequently, the resulting asset allocations for the investor are suboptimal, leading to a reduction in overall utility.

More formally, given portfolio weights $\boldsymbol{\pi}^s = (\pi_1^s, \pi_2^s, \pi_3^s)$ representing a suboptimal strategy, let us represent the value function obtained from such a suboptimal strategy as J^s. This is

$$\begin{aligned} J^s(X,t) = \inf_{e\in\varepsilon[t,T]} \Bigg\{ \mathrm{E}_t^{\mathbb{P}^e} \left[\int_t^T \left(\frac{(e_\tau^m)^2}{2\Psi_m(\tau, X_\tau)} + \frac{(e_\tau^g)^2}{2\Psi_g(\tau, X_\tau)} + \frac{(e_\tau^b)^2}{2\Psi_b(\tau, X_\tau)} \right) d\tau \right] \\ + w^e(X, t; \boldsymbol{\pi}^s) \Bigg\}. \end{aligned} \tag{22}$$

It is evident that $J^s \leq J$, indicating a suboptimal level of satisfaction for the investor stemming from the application of a suboptimal strategy, as demonstrated in the following proposition (see Appendix A.2).

Proposition 2. *The value function for the investor employing a suboptimal strategy* $\boldsymbol{\pi}^s = (\pi_1^s, \pi_2^s, \pi_3^s)$ *is given by*

$$J^s(X,t) = \frac{X_m^{\alpha_m}}{\alpha_m} \frac{X_g^{\alpha_g}}{\alpha_g} \frac{X_b^{\alpha_b}}{\alpha_b} \exp(b^s(T-t)), \tag{23}$$

where

$$\begin{aligned} b^s &= (\theta_m r + \pi_1^s \lambda_1 \sigma_1^2 + \pi_2^s \lambda_1 \sigma_1 \sigma_2 \rho_{12} + \pi_3^s \lambda_1 \sigma_1 \sigma_3 \rho_{13}) \alpha_m \\ &+ \frac{1}{2} (\pi_1^s \sigma_1 + \pi_2^s \sigma_2 \rho_{12} + \pi_3^s \sigma_3 \rho_{13})^2 \alpha_m (\alpha_m - 1) + (\theta_g r + \pi_2^s \lambda_g \sigma_2^2 \sqrt{1-\rho_{12}^2}) \alpha_g \\ &+ \frac{1}{2} (\pi_2^s)^2 \sigma_2^2 (1-\rho_{12}^2) \alpha_g (\alpha_g - 1) + (\theta_b r + \pi_3^s \lambda_b \sigma_3^2 \sqrt{1-\rho_{13}^2}) \alpha_b \\ &+ \frac{1}{2} (\pi_3^s)^2 \sigma_3^2 (1-\rho_{13}^2) \alpha_b (\alpha_b - 1) - \frac{\phi_m}{2} (\pi_1^s \sigma_1 + \pi_2^s \sigma_2 \rho_{12} + \pi_3^s \sigma_3 \rho_{13})^2 \alpha_m \\ &- \frac{\phi_g}{2} (\pi_2^s)^2 \sigma_2^2 (1-\rho_{12}^2) \alpha_g - \frac{\phi_b}{2} (\pi_3^s)^2 \sigma_3^2 (1-\rho_{13}^2) \alpha_b. \end{aligned} \tag{24}$$

The suboptimal wealth process W_t^s *follows*

$$\begin{aligned} \frac{dW_t^s}{W_t^s} =& (r + \pi_1^s \lambda_1 \sigma_1^2 + \pi_2^s \lambda_1 \sigma_1 \sigma_2 \rho_{12} + \pi_2^s \lambda_g \sigma_2^2 \sqrt{1-\rho_{12}^2} + \pi_3^s \lambda_1 \sigma_1 \sigma_3 \rho_{13} \\ &+ \pi_3^s \lambda_b \sigma_3^2 \sqrt{1-\rho_{13}^2}) dt + (\pi_1^s \sigma_1 + \pi_2^s \sigma_2 \rho_{12} + \pi_3^s \sigma_3 \rho_{13}) dz_m + \pi_2^s \sigma_2 \sqrt{1-\rho_{12}^2} dz_g \\ &+ \pi_3^s \sigma_3 \sqrt{1-\rho_{13}^2} dz_b \end{aligned} \tag{25}$$

There are three choices of suboptimal strategies that are meaningful to an investor.

1. First, we introduce the unintentionally unambiguous investor (UUI). This investor employs suboptimal strategies arising from a lack of model uncertainty. The investor chooses such a strategy not because of its lack of uncertainty but rather because of a lack of knowledge of a better/optimal solution. That is, if investors care about model uncertainty, yet they do now know how to generate and handle alternative models, they will suffer from utility loss by employing suboptimal strategies. They mistakenly choose the model with $\phi_m = \phi_g = \phi_b = 0$, and employ the suboptimal strategy:

$$\begin{aligned}\pi_1^s &= \frac{\lambda_1}{1-\alpha_m} - \frac{\sigma_2}{\sigma_1}\rho_{12}\pi_2^s - \frac{\sigma_3}{\sigma_1}\rho_{13}\pi_3^s,\\ \pi_2^s &= \frac{\lambda_g}{\sqrt{1-\rho_{12}^2}(1-\alpha_g)},\\ \pi_3^s &= \frac{\lambda_b}{\sqrt{1-\rho_{13}^2}(1-\alpha_b)}.\end{aligned} \tag{26}$$

Let us denote the corresponding value function as $J^{(s,UUI)}$.

2. The second case of interest is a sophisticated investor who is ambiguity-averse and capable of accommodating different levels of ambiguity aversion per source of risk (e.g., Branger and Larsen 2013; Wang and Uppal 2002). We denoted it as 'SAI'. Nonetheless, the investor does not know about multi-attribute utilities or the possibility of further accommodating preferences for green and brown sources of risk. Therefore, this investor considers $\alpha_g = \alpha_b = \alpha_m = \alpha$, with the corresponding suboptimal strategy:

$$\begin{aligned}\pi_1^s &= \frac{\lambda_1}{1-\alpha+\phi_m} - \frac{\sigma_2}{\sigma_1}\rho_{12}\pi_2^s - \frac{\sigma_3}{\sigma_1}\rho_{13}\pi_3^s,\\ \pi_2^s &= \frac{\lambda_g}{\sqrt{1-\rho_{12}^2}(1-\alpha+\phi_g)},\\ \pi_3^s &= \frac{\lambda_b}{\sqrt{1-\rho_{13}^2}(1-\alpha+\phi_b)}.\end{aligned} \tag{27}$$

The corresponding value function is denoted $J^{(s,SAI)}$. Needless to say, the suboptimal strategy described above is optimal for non-multi-attribute CRRA utility.

3. Thirdly, we explore a scenario in which an investor excludes the brown asset from its portfolio. This type of investor actively avoids exposure to the brown risk and focuses solely on investing in the market index and the green asset. However, they rigorously address the robust portfolio optimization problem in line with their specific risk preferences and ambiguity aversions. Given $\pi_3 = 0$, the suboptimal strategy is

$$\begin{aligned}\pi_1^s &= \frac{\lambda_1}{1-\alpha_m+\phi_m} - \frac{\sigma_2}{\sigma_1}\rho_{12}\pi_2^*,\\ \pi_2^s &= \frac{\lambda_g}{\sqrt{1-\rho_{12}^2}(1-\alpha_g+\phi_g)},\\ \pi_3^s &= 0.\end{aligned} \tag{28}$$

We categorize this type of investor as a 'selectively brown-avoidant investor' and denote the associated value function as $J^{(s,SBI)}$.

Next, we will introduce two measures to assess the losses that a suboptimal investor could suffer, either in satisfaction or money, due to acting suboptimally.

4.1. Percentage Loss in Satisfaction

We first create a measure to compute the loss to the investor by working directly with the reduction in the level of satisfaction, as measured by the value function.

This is, assuming a value function J^s from using a suboptimal strategy and the value function from the optimal strategy as J, we define the percentage loss in satisfaction (PLS) as follows:

$$R = \frac{J^s - J}{J^s}. \tag{29}$$

Note that R reaches its minimum value, $R = 0$, only when the suboptimal strategy is optimal. As the suboptimal strategy underperforms, resulting in a decrease in J^s, the value of R approaches 100% (indicating a complete loss). Therefore, we can define R within the range of $[0, 1)$, where smaller values of R signify poorer performance of the suboptimal strategy when compared to the optimal strategy.

The fact that J and J^s are all closed-form for the cases described in the previous section indicates that this percentage can be easily computed in the closed form:

$$R = 1 - \exp\{(b - b^s)T\}. \tag{30}$$

4.2. Green Wealth Equivalent Loss

We introduce the concept of Green-Index Wealth Equivalent Loss (GWEL) and explore the impact of suboptimal strategies. We define GWEL as a scalar q that satisfies the following equation:

$$J(X_m, X_g(1-q), X_b, 0) = J^s(X_m, X_g, X_b, 0). \tag{31}$$

Notably, GWEL closely resembles the conventional definition of WEL. Specifically, WEL can be defined as the value of q for which $J(W(1-q), 0) = J^s(W, 0)$. In our context, parameter q signifies the percentage-wise reduction in the Green Index's value that the optimal investor can tolerate while maintaining the same level of satisfaction as the suboptimal investor. This interpretation directly quantifies the degree to which the optimal portfolio deviates from a 'green' allocation to emulate the suboptimal choices made by investors.

As before, given that J and J^s are closed-form for the cases described in the previous section, the GWEL is given in closed form as follows:

$$q = 1 - \exp\left\{\frac{(b^s - b)T}{\alpha_g}\right\}. \tag{32}$$

5. Empirical Analyses

For empirical analysis, we used ESG ratings from the RepRisk database. This involved converting RepRisk Rating (RRR) scores into integers ranging from 1 (D) to 10 (AAA). We calculated the average RRR score to evaluate a company's ESG performance from 2010 to 2020. Without loss of generality, we classified the top 10 U.S. companies with the highest average RRR scores as 'green companies' and identified the bottom 10 companies with the lowest scores as 'brown companies'.

For benchmark purposes, we also determined the average RRR score for the entire U.S. market portfolio. This was achieved by computing the mean of the average RRR scores across all U.S. companies, resulting in an average RRR score of 7.3 for the entire U.S. market portfolio.

In our study, we present two illustrative examples, both employing the S&P 500 as our chosen index. The first example serves as the basis for the empirical analysis in this section, while the second is included in Appendix B as supplementary material. Considering data availability and consistency, we select two pairs of stocks for our analysis. The first pair consists of IDT Corp. (IDT), Newark, U.S., representing the green company, and Walmart Inc. (WMT), Bentonville, United States, representing the brown company. The second pair comprises Shenandoah Telecommunications Company (Shenandoah), Edinburg, United States as the green company and DuPont de Nemours, Inc. (DuPont), Wilmington, USA as the brown company.

We utilized Python for data retrieval, data processing, parameter estimations, and graph plotting. Table 1 provides a comprehensive overview of the parameters employed in our model for the two cases. These parameters were estimated on a monthly basis, using data from 2010 to 2020. To calculate the risk-free rate, we took the average of the monthly yields of the 3-month Treasury bills issued by the U.S. government during this time frame, resulting in a rate of 0.045%.

Table 1. Parameter estimations for empirical analysis.[3]

Name	σ	ρ	λ	Average RRR Score
S&P 500	0.0405	1	6.0464	7.3
IDT	0.1628	0.2937	0.7	9.4
Walmart	0.0486	0.3354	2.8672	3.4
Shenandoah Telecom	0.1064	0.291	1.0179	9.4
DuPont de Nemours	0.0866	0.767	−1.244	4.2

For consistency, our empirical analysis adopts a uniform time horizon of 10 years. Furthermore, we have set the risk aversion parameters at the following values: $\alpha_m = -4$, $\alpha_g = -2$, and $\alpha_b = -6$.

5.1. Optimal Weights

We examined the impact of ambiguity aversion parameters on the optimal weights and compared these robust optimal weights with the optimal weights without uncertainty consideration. Figure 1 depicts the drastic changes in portfolio allocation when we account for ambiguity aversion. In all three sub-figures, the weights of all stocks are significantly reduced, indicating increased investments in the risk-free asset. This result is not surprising, as investors would turn to safer assets when they begin considering the worst case of their investments. We can also observe that as one of the three ambiguity aversion parameters increases (green, for example), the weight of green stock also decreases. It is natural for investors to invest less in an asset if they do not trust the probabilistic model of that asset. However, market weight increased as green or brown ambiguity aversion increased. This is because the total weight of the three stocks is less sensitive to green and brown ambiguity aversion than the weight of green and brown stocks. As a result, the market weight increases to compensate for the decrease in green or brown investments. In other words, the total weight is mostly influenced by market ambiguity aversion, and the green or brown weight is influenced by green or brown ambiguity aversion.

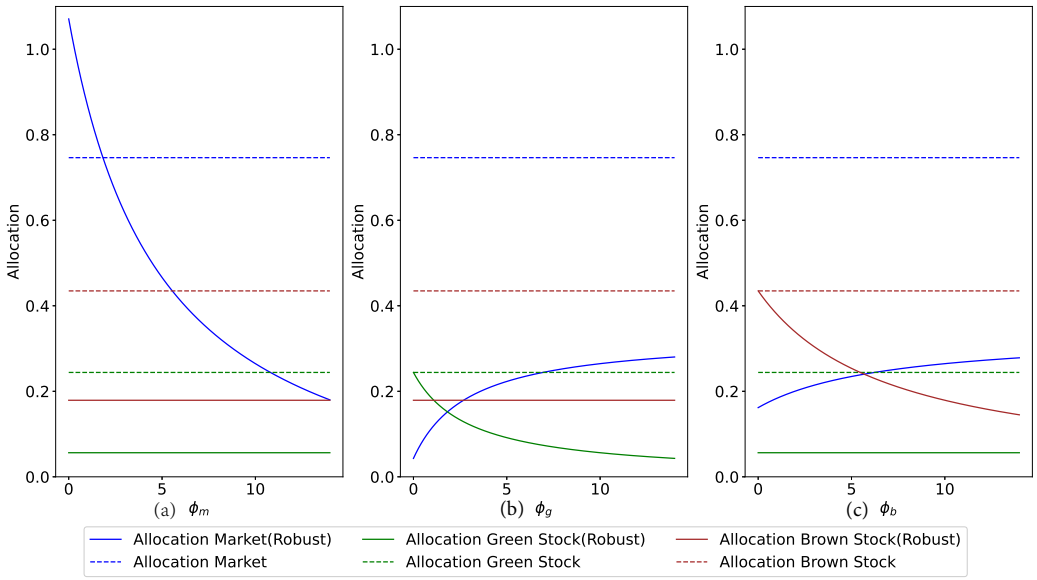

Figure 1. Impact of ambiguity aversion parameters on optimal weights in the IDT and WMT case.[4]

5.2. Detection Error Probabilities

When investors discriminate between the reference and alternative models, two types of errors are possible for a sample of length N: choosing the alternative model when the

reference model is correct, with probability p_1^N, and choosing the reference model when the alternative model is correct, with probability p_2^N. We weight these errors by assigning prior probabilities of one-half to each model and denote the detection error probability as ε_N:

$$\varepsilon_N(\phi_m, \phi_g, \phi_b) = 0.5p_1^N + 0.5p_2^N. \tag{33}$$

Following the notation in Equation (2), the log-likelihood ratio is formed as $\ell^N = \log \Lambda_N^e$ with $\boldsymbol{e}$ replaced by $\boldsymbol{e}^*$, that is,

$$\ell^N = -\int_0^N \left(\langle \boldsymbol{e}_\tau, d\boldsymbol{z}_\tau \rangle + \frac{1}{2}||\boldsymbol{e}_\tau||^2 d\tau \right), \tag{34}$$

where $\boldsymbol{e}^*$ are obtained by combining Equations (A1), (16), and (17):

$$\begin{aligned} (e^m)^* &= \frac{\lambda_1 \sigma_1 \phi_m}{1 - \alpha_m + \phi_m} \\ (e^g)^* &= \frac{\lambda_g \sigma_2 \phi_g}{1 - \alpha_g + \phi_g} \\ (e^b)^* &= \frac{\lambda_b \sigma_3 \phi_b}{1 - \alpha_b + \phi_b}. \end{aligned} \tag{35}$$

Then, we have $p_1^N = \Pr(\ell^N > 0 \mid \mathbb{P}, \mathcal{F}_0)$ and $p_2^N = \Pr(\ell^N < 0 \mid \mathbb{P}^e, \mathcal{F}_0)$. We observe that ℓ^N follows a normal distribution with a mean of $-\frac{1}{2}||\boldsymbol{e}^*||^2 N$ and a variance of $||\boldsymbol{e}^*||^2 N$. Thus, we have

$$\varepsilon_N(\phi_m, \phi_g, \phi_b) = \Pr(\Phi > \frac{1}{2}||\boldsymbol{e}^*||\sqrt{N}) \tag{36}$$

where Φ follows a standard normal distribution. In the IDT and Walmart case, for the parameters in Table 1, $N = 120$, and specifying $\alpha_m = -4$, $\alpha_g = -2$, $\alpha_b = -6$, we have Figures 2–4. These three figures depict the relationship between the detection error probability and one of the ambiguity aversion parameters, while the other two parameters are set to be $0, 5, 10$. In alignment with our speculation, as ambiguity aversion parameters increase, investors can better discern between reference and alternative models. Consequently, the probability of making a mistake decreases.

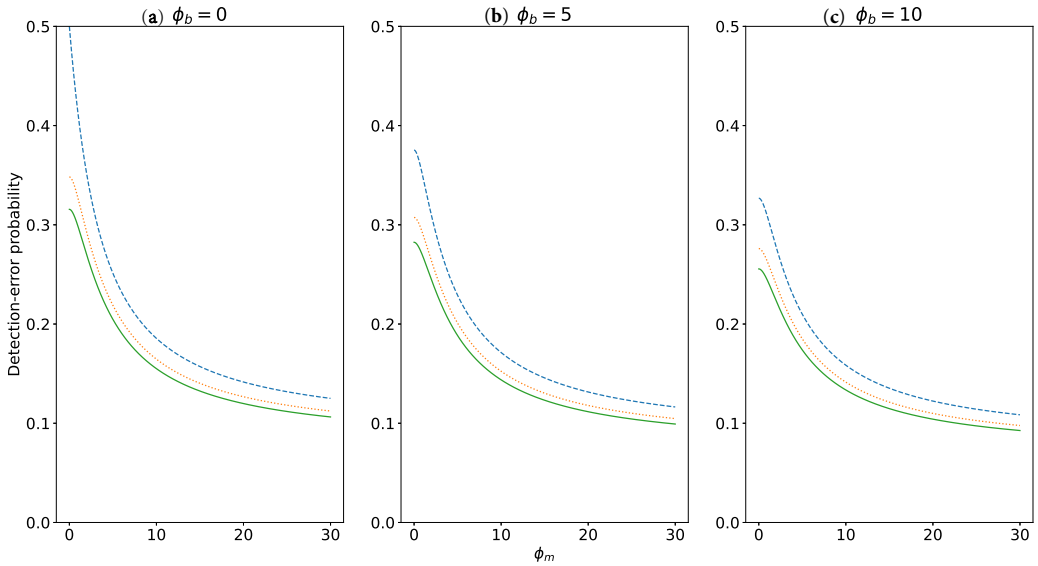

Figure 2. Detection error probability when ϕ_m, ϕ_g, ϕ_b changes in the IDT and WMT case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

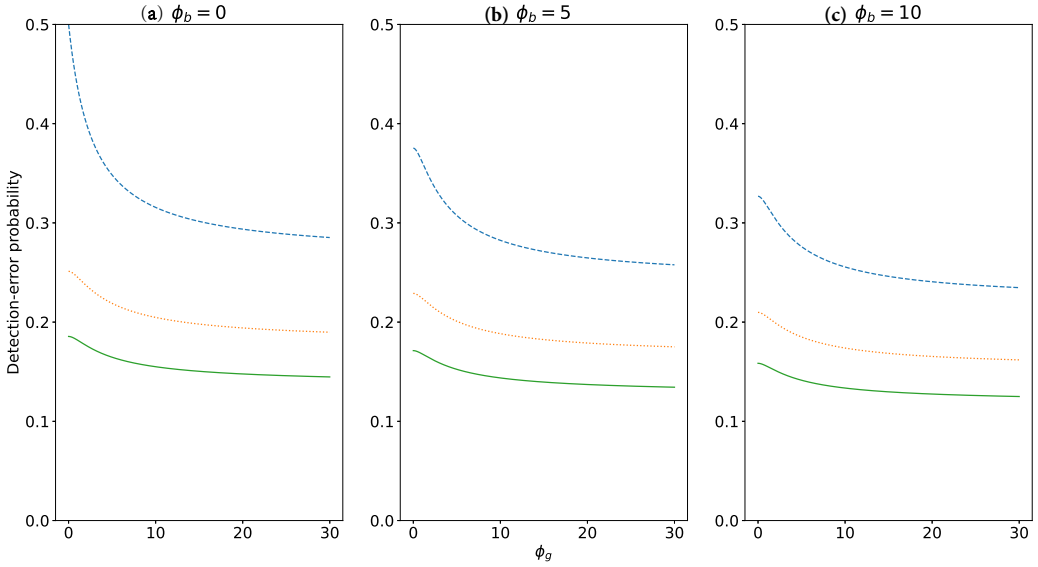

Figure 3. Detection error probability when ϕ_m, ϕ_g, ϕ_b changes in the IDT and WMT case. The dashed line is for $\phi_m = 0$, the dotted line is for $\phi_m = 5$, the solid line is for $\phi_m = 10$.

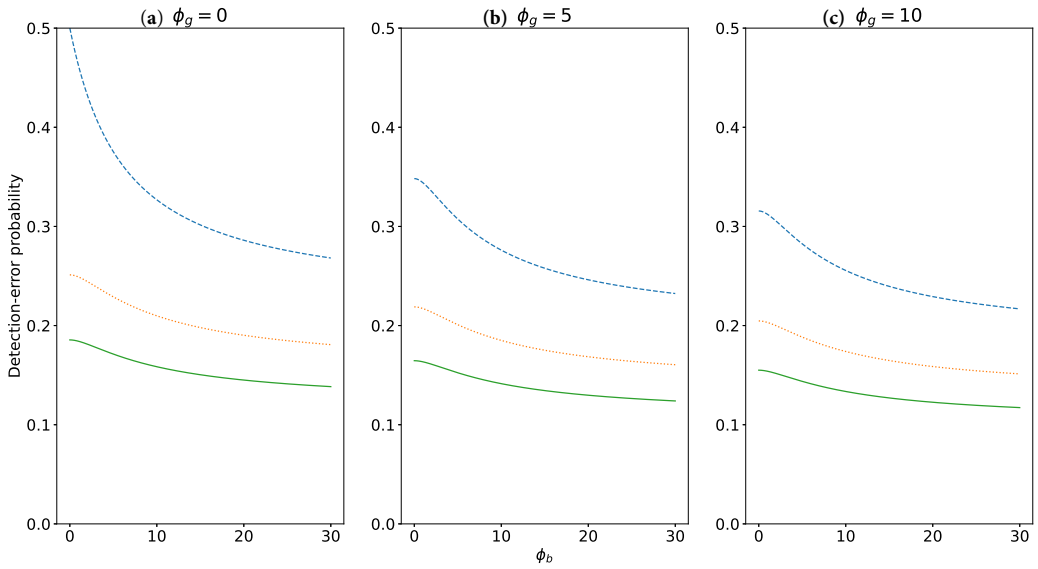

Figure 4. Detection error probability when ϕ_m, ϕ_g, ϕ_b changes in the IDT and WMT case. The dashed line is for $\phi_m = 0$, the dotted line is for $\phi_m = 5$, the solid line is for $\phi_m = 10$.

We can readily observe that ϕ_m exerts the most substantial influence on the detection error probability. A comparative analysis of Figures 2–4 reveals that an increase in ϕ_m has the greatest impact on the detection error probability. This is evident as Figure 2 exhibits a more pronounced curvature than Figures 3 and 4. Moreover, the detection error probability reaches its peak when $\phi_m = 0$ in all three figures.

Taking a closer look at the green curves in Figure 2c ($\phi_g = 10, \phi_b = 10$), Figure 3c ($\phi_m = 10, \phi_b = 10$), and Figure 4c ($\phi_m = 10, \phi_g = 10$), we can discern noteworthy distinctions. Specifically, the green curve in Figure 2c significantly deviates from its counterparts, resulting in a notably higher detection error probability when $\phi_m = 0, \phi_g = 10, \phi_b = 10$, approaching approximately 0.25. This is in stark contrast to the other two figures, where the detection error probability is approximately 0.15. Consequently, we conclude that green and brown stocks introduce more significant uncertainty. This is substantiated by the observation that when the investor possesses certainty about the market index ($\phi_m = 0$),

the detection error probability is higher than in scenarios where the investor has certainty about the green stock ($\phi_g = 0$) or the brown stock ($\phi_b = 0$).

In general, an increase in ambiguity aversion levels leads to a reduction in the detection error probability, enabling investors to better differentiate between reference and alternative models. This heightened discernment translates into a lower likelihood of making errors in model selection, thereby minimizing potential losses. The ensuing Section 5.3 delves into a detailed analysis of these diminished losses. Nonetheless, our investigation underscores that the uncertainty introduced by green and brown stocks remains resilient, even with heightened ambiguity aversion. Illustrated in Figure 2, when fixing $\phi_m = 0$, investors face approximately a 30% probability of making errors in discerning between reference and alternative models, irrespective of their ambiguity aversions towards green and brown stocks. Notably, the ambiguity aversion towards the market plays the most pivotal role in this discrimination between reference and alternative models.

Following the convention in Anderson et al. (2003), we are concerned with detection error probabilities larger than 0.1, in which case the investor has difficulty discerning the alternative model and the reference model. This explains why we chose ambiguity aversion parameters less than 10 in the previous section. In a later analysis, we will also confine the ambiguity aversion parameters to be less than 14 to ensure that the error detection probability is larger than 0.1 in all cases.

5.3. Suboptimal Loss Analysis

In this section, we present a comprehensive analysis of the percentage loss or reduction in satisfaction (PLS) and GWEL across the UUI, SAI, and SBI scenarios, maintaining a consistent temporal horizon of $T = 120$ months.

First, let us focus on the UUI case illustrated in Figure 5, which shows the percentage reduction in satisfaction. As expected, UUI investors witness a pronounced decline in satisfaction as ambiguity aversion parameters escalate, aligning with the relation

$$\begin{aligned} b - b^s =& \frac{1}{2}\lambda_1^2\sigma_1^2 \frac{\alpha_m}{(1-\alpha_m)^2} \frac{\phi_m^2}{1-\alpha_m+\phi_m} + \frac{1}{2}\lambda_g^2\sigma_2^2 \frac{\alpha_g}{(1-\alpha_g)^2} \frac{\phi_g^2}{1-\alpha_g+\phi_g} \\ &+ \frac{1}{2}\lambda_b^2\sigma_3^2 \frac{\alpha_b}{(1-\alpha_b)^2} \frac{\phi_b^2}{1-\alpha_b+\phi_b}. \end{aligned} \tag{37}$$

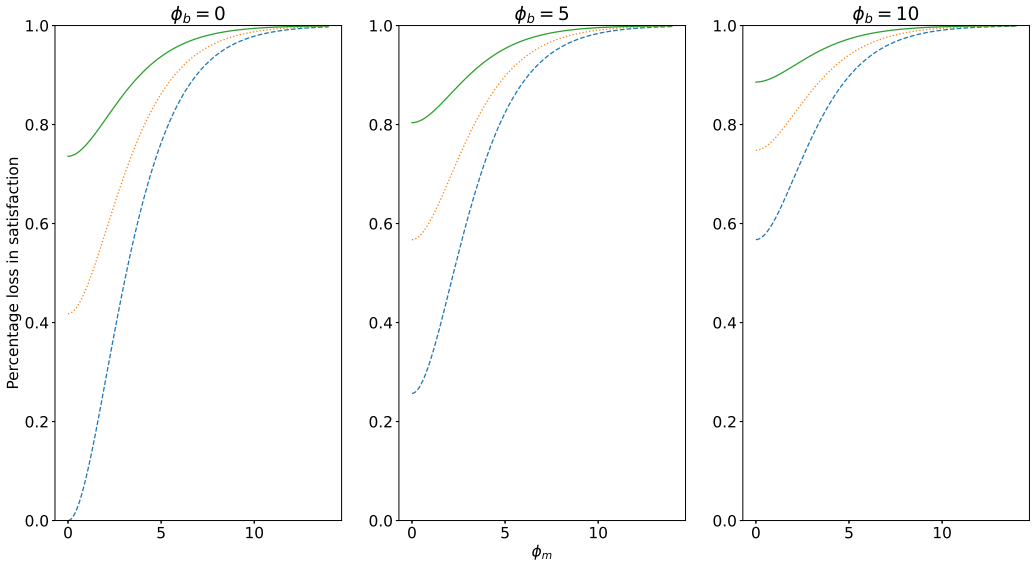

Figure 5. PLS for UUI when ϕ_m, ϕ_g, ϕ_b changes in the IDT and WMT case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

The heightened PLS can be attributed to any of the three ambiguity aversion parameters. Notably, ϕ_m exerts the most significant influence. As clearly depicted in the figures, when $\phi_m = 10$, there is a nearly 100% higher loss in satisfaction compared to $\phi_m = 0$, while maintaining ϕ_g and ϕ_b at 0. However, the influence of ϕ_m diminishes as the other two parameters increase. For instance, when $\phi_g = 10$ and $\phi_b = 10$, a change in ϕ_m only results in a 10% variation in the PLS. The loss in satisfaction reaches its zenith, nearly touching the 100% mark, when all three parameters are set to 10. It is also evident that PLS is more significantly impacted when any parameter increases from 0 to 5 compared to when it increases from 5 to 10. Beyond a value of 10, the effect becomes negligible.

Turning our attention to Figure 6, we investigate the variations in GWEL as ambiguity aversion parameters fluctuate over a ten-year duration in the UUI context. Notably, when all three ambiguity aversion parameters are set to 10, a staggering 95% loss is observed in the green index. This significant loss emerges because of the simultaneous increments in all three ambiguity aversion parameters. However, it is crucial to highlight that the escalation of GWEL is also more pronounced as ambiguity aversion parameters rise from 5 to 10 compared to the increase from 0 to 5. This underscores the heightened sensitivity of GWEL to investors with higher ambiguity aversion parameters. These findings are consistent with our model, emphasizing the need to incorporate uncertainty into portfolio optimization.

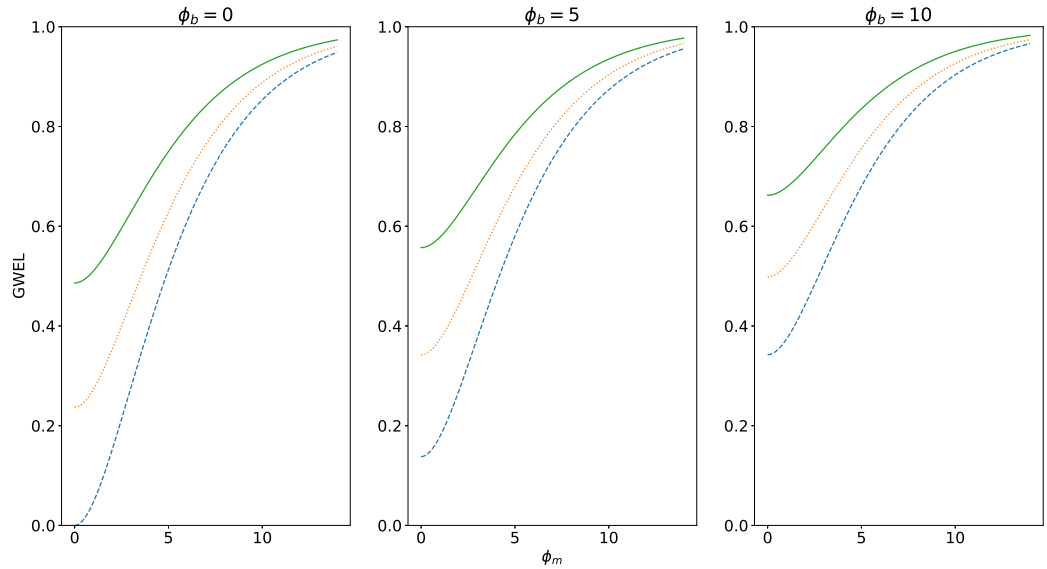

Figure 6. GWEL when ϕ_m, ϕ_g, ϕ_b changes for UUI in the IDT and WMT case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

Now, transitioning to the SAI case, we can discern from Figures 7 and 8 that both the percentage reduction in satisfaction and GWEL remain impervious to changes in the market ambiguity aversion parameter ϕ_m. However, an increase in either ϕ_g or ϕ_b leads to a decrease in both the percentage reduction in satisfaction and GWEL. This outcome is markedly different from the results of the UUI scenario. Notably, the solid green lines in Figures 7 and 8 occupy lower positions, in contrast to the dashed blue lines in Figures 5 and 6. This result is not surprising, as in the case of SAI,

$$b - b^s = \frac{1}{2}\lambda_g^2\sigma_2^2\frac{\alpha_g(\alpha_m - \alpha_g)}{(1 - \alpha_m + \phi_g)^2} + \frac{1}{2}\lambda_b^2\sigma_3^2\frac{\alpha_b(\alpha_m - \alpha_b)}{(1 - \alpha_m + \phi_b)^2}, \tag{38}$$

independent of ϕ_m. Moreover, it is worth emphasizing that the overall reduction in satisfaction is substantially smaller than that in the UUI case. The maximum loss is 22% when $\phi_g = \phi_b = 0$.

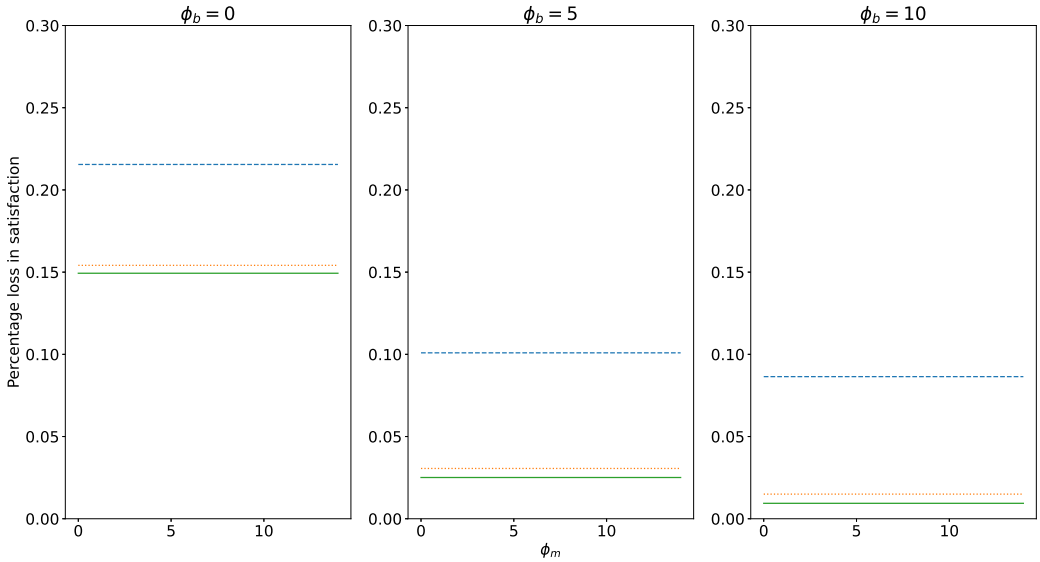

Figure 7. PLS when ϕ_m, ϕ_g, ϕ_b changes for SAI in the IDT and WMT case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

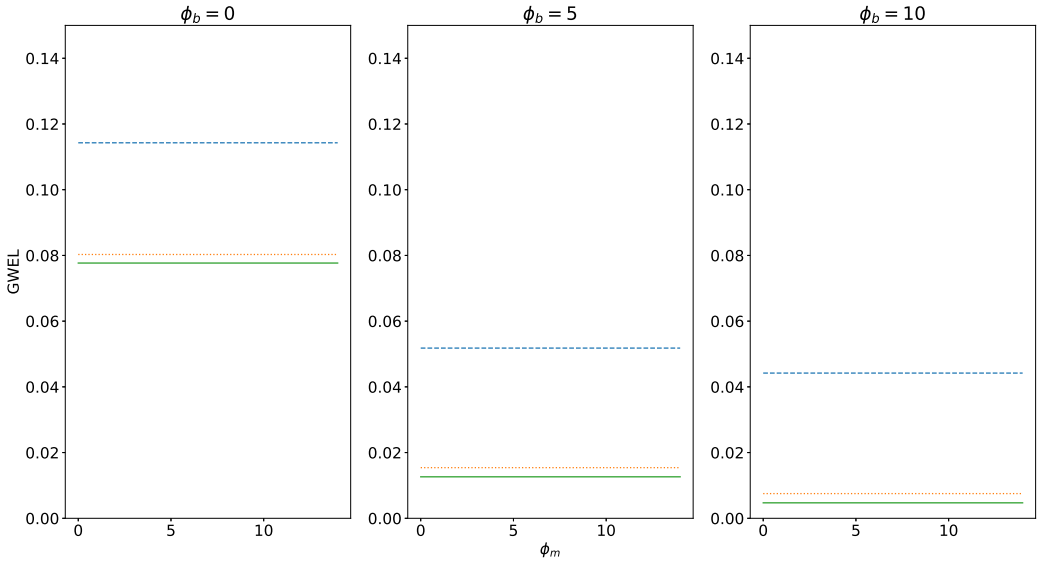

Figure 8. GWEL when ϕ_m, ϕ_g, ϕ_b changes for SAI in the IDT and WMT case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

Finally, when examining the SBI scenario, we find that both PLS and GWEL are exclusively influenced by ϕ_b, as shown in Figures 9 and 10. This result arises from the fact that

$$b - b^s = \frac{1}{2}\lambda_b^2 \sigma_3^2 \frac{\alpha_b}{1 - \alpha_b + \phi_b}. \tag{39}$$

It is worth noting that augmenting ϕ_b decreases both PLS and GWEL, resulting in a 30% reduction in PLS and a 20% reduction in GWEL when ϕ_b increases from 0 to 10. Furthermore, the SBI scenario occupies an intermediary position between UUI and SAI in terms of loss. The maximum loss is 62% when $\phi_b = 0$.

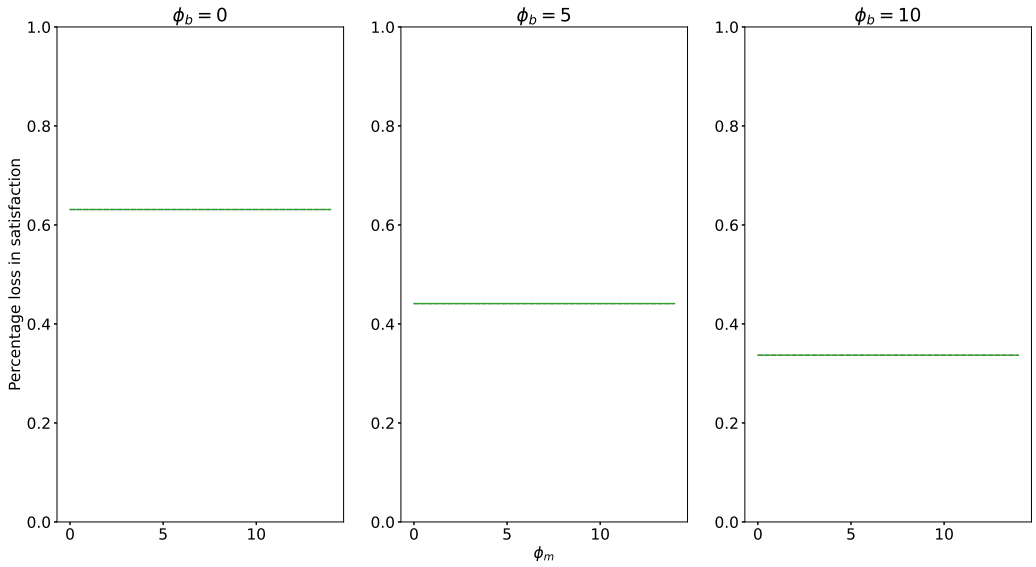

Figure 9. PLS when ϕ_m, ϕ_g, ϕ_b changes for SBI in the IDT and WMT case. The solid line is for $\phi_g = 0$, $\phi_g = 5$, and also for $\phi_g = 10$.

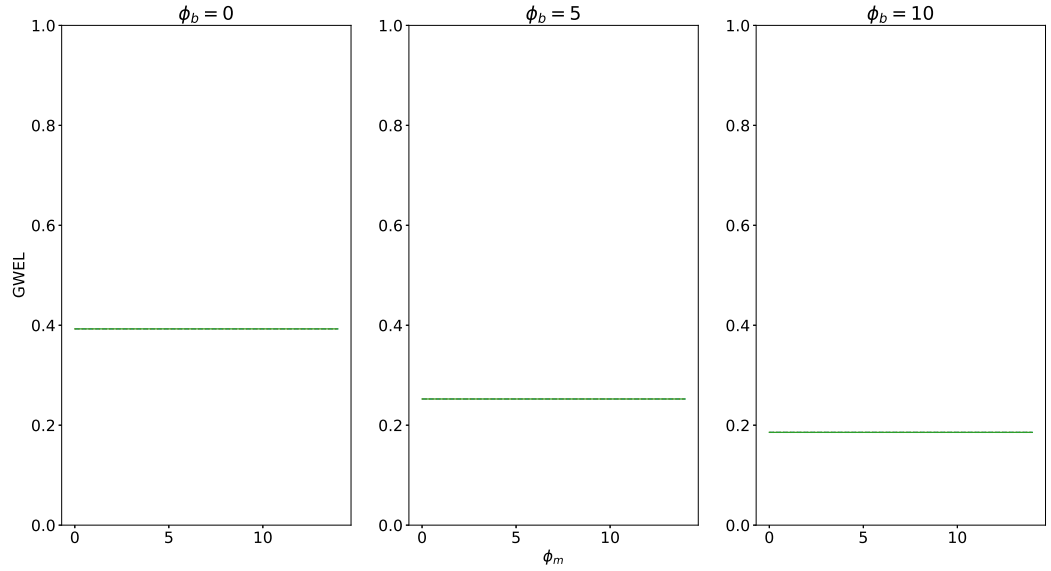

Figure 10. GWEL when ϕ_m, ϕ_g, ϕ_b changes for SBI in the IDT and WMT case. The solid line is for $\phi_g = 0$, $\phi_g = 5$, and also for $\phi_g = 10$.

These analyses of UUI, SAI, and SBI investors underscore the pivotal role of ambiguity aversion in financial decision-making. It emphasizes the necessity for investors to transparently communicate their risk preferences and ambiguity aversions to avoid selecting suboptimal models that could result in substantial losses. Investors characterized by higher ambiguity aversion levels should be particularly vigilant about their portfolio positions, given the potential for greater losses when deviating from optimal choices. This suggests a need for more frequent portfolio rebalancing. For asset managers, aligning their models with clients' ambiguity aversion becomes critical. Effective communication and a comprehensive approach to measuring ambiguity aversion are imperative for the success of asset managers aiming for ESG objectives. Despite the growing significance of ESG considerations, these findings emphasize the importance of ESG education for investors and

the necessity of fostering an open and efficient environment for communication regarding ESG investing.

6. Conclusions

This study bridges the gap between the well-established concept of ambiguity aversion in portfolio choice and the increasingly relevant field of environmental, social, and corporate governance (ESG) investing. It extends the existing literature by introducing ESG ambiguity aversions into the portfolio choice problem within a multivariate utility framework. We address the ambiguity aversion of an investor who can allocate resources to a risk-free asset, a market index, a green stock, and a brown stock. The robust control approach employed, which is based on relative entropy, allows us to derive optimal investment strategies and investigate the effects of ambiguity in the ESG context.

This study makes several significant contributions. First, it demonstrates the substantial impact of ambiguity on optimal trading strategies, highlighting the differential effects on market, green, and brown assets. Plausible levels of ambiguity significantly alter optimal strategies, with potential changes exceeding 50%. Second, the study provides insights into the comparative behavior of ambiguity-averse and non-ambiguity investors. Ambiguity-averse investors exhibit less aggressive risk exposure and reduced short-selling positions. Finally, the paper quantifies the welfare loss incurred by investors who neglect model uncertainty, revealing substantial financial costs amounting to nearly 100% for empirically relevant parameter values. Our findings about the impact of uncertainty are corroborated by two measures of performance (i.e., PLS and GWEL) and two case studies, each involving a green, brown, and market index. Moreover, this research highlights the importance of transparent communication regarding risk preferences and ambiguity aversions for both investors and asset managers. Advocating ESG education can enhance the effectiveness of this communication, thereby reducing the risk of substantial losses resulting from suboptimal strategies.

There are avenues for further exploration in our study. For instance, the inclusion of jumps, stochastic volatility, or stochastic correlation in our model could better capture extreme shifts in asset prices, particularly post-2020.

In summary, this study enriches the understanding of ambiguity aversion in the context of ESG-integrated portfolio optimization by emphasizing the nuanced impact of ESG ambiguity aversion and its potential welfare implications. This conveys valuable insights to investors, asset managers, and policymakers seeking to navigate the evolving landscape of responsible and sustainable investing. The integration of ESG criteria into the analysis of ambiguity aversion represents an original and vital contribution to the ongoing discourse in the field of finance.

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Data Availability Statement: The ESG ratings of the companies used in our empirical analysis were obtained from the RepRisk ESG Dataset. For additional information, please refer to the website: https://www.reprisk.com/ (accessed on 12 April 2023).

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Proofs

Appendix A.1. Proof of Proposition 1

Solving the infimization problem in Equation (15), we obtain

$$\begin{aligned}(e^m)^* =&\Psi_m x J_x(\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})\\ (e^g)^* =&\Psi_g y J_y \pi_2\sigma_2\sqrt{1-\rho_{12}^2}\\ (e^b)^* =&\Psi_z z J_z \pi_3\sigma_3\sqrt{1-\rho_{13}^2}.\end{aligned} \tag{A1}$$

Substituting Equation (A1) into the HJB Equation (15), J satisfies

$$\begin{aligned}&\sup_{\pi_1,\pi_2,\pi_3}\Big\{J_t + (\theta_m r + \pi_1\lambda_1\sigma_1^2 + \pi_2\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_3\lambda_1\sigma_1\sigma_3\rho_{13})xJ_x\\ &+\frac{1}{2}(\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})^2x^2J_{xx} + (\theta_g r + \pi_2\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2})yJ_y\\ &+\frac{1}{2}\pi_2^2\sigma_2^2(1-\rho_{12}^2)y^2J_{yy} + (\theta_b r + \pi_3\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2})zJ_z + \frac{1}{2}\pi_3^2\sigma_3^2(1-\rho_{13}^2)z^2J_{zz}\\ &-\frac{\Psi_m}{2}(\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})^2x^2(J_x)^2 - \frac{\Psi_g}{2}\pi_2^2\sigma_2^2(1-\rho_{12}^2)y^2(J_y)^2\\ &-\frac{\Psi_b}{2}\pi_3^2\sigma_3^2(1-\rho_{13}^2)z^2(J_z)^2\Big\} = 0.\end{aligned} \tag{A2}$$

Solving for π_1, π_2, π_3 in the above equation, the optimal weights have the form

$$\begin{aligned}\pi_1^* &= \frac{\lambda_1 J_x}{\Psi_m x(J_x)^2 - xJ_{xx}} - \frac{\sigma_2}{\sigma_1}\rho_{12}\pi_2^* - \frac{\sigma_3}{\sigma_1}\rho_{13}\pi_3^*,\\ \pi_2^* &= \frac{\lambda_g}{\sqrt{1-\rho_{12}^2}}\frac{J_y}{\Psi_g y(J_y)^2 - yJ_{yy}},\\ \pi_3^* &= \frac{\lambda_b}{\sqrt{1-\rho_{13}^2}}\frac{J_z}{\Psi_b z(J_z)^2 - zJ_{zz}}.\end{aligned} \tag{A3}$$

Given the linearity of the HJB, we assume that J has the form of $J = \frac{x^{\alpha_m}}{\alpha_m}\frac{y^{\alpha_g}}{\alpha_g}\frac{z^{\alpha_b}}{\alpha_b}\exp(b(T-t))$, together with Equation (14), we obtain

$$\begin{aligned}0 = &\sup_{\pi_1,\pi_2,\pi_3}\Big\{-b + (\theta_m r + \pi_1\lambda_1\sigma_1^2 + \pi_2\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_3\lambda_1\sigma_1\sigma_3\rho_{13})\alpha_m\\ &+\frac{1}{2}(\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})^2\alpha_m(\alpha_m-1) + (\theta_g r + \pi_2\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2})\alpha_g\\ &+\frac{1}{2}\pi_2^2\sigma_2^2(1-\rho_{12}^2)\alpha_g(\alpha_g-1) + (\theta_b r + \pi_3\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2})\alpha_b\\ &+\frac{1}{2}\pi_3^2\sigma_3^2(1-\rho_{13}^2)\alpha_b(\alpha_b-1) - \frac{\phi_m}{2}(\pi_1\sigma_1 + \pi_2\sigma_2\rho_{12} + \pi_3\sigma_3\rho_{13})^2\alpha_m\\ &-\frac{\phi_g}{2}\pi_2^2\sigma_2^2(1-\rho_{12}^2)\alpha_g - \frac{\phi_b}{2}\pi_3^2\sigma_3^2(1-\rho_{13}^2)\alpha_b\Big\},\end{aligned} \tag{A4}$$

Again, solving for π_1, π_2, π_3 in the above equation, we obtain the optimal weights

$$\begin{aligned}\pi_1^* &= \frac{\lambda_1}{1-\alpha_m+\phi_m} - \frac{\sigma_2}{\sigma_1}\rho_{12}\pi_2^* - \frac{\sigma_3}{\sigma_1}\rho_{13}\pi_3^*,\\ \pi_2^* &= \frac{\lambda_g}{\sqrt{1-\rho_{12}^2}(1-\alpha_g+\phi_g)},\\ \pi_3^* &= \frac{\lambda_b}{\sqrt{1-\rho_{13}^2}(1-\alpha_b+\phi_b)}.\end{aligned} \tag{A5}$$

Substituting the optimal weights back into Equation (A4), we obtain

$$J(X,t) = \frac{X_m^{\alpha_m}}{\alpha_m}\frac{X_g^{\alpha_g}}{\alpha_g}\frac{X_b^{\alpha_b}}{\alpha_b}\exp(b(T-t)), \tag{A6}$$

where

$$\begin{aligned} b =& \frac{1}{2}\lambda_1^2\sigma_1^2\frac{\alpha_m}{1-\alpha_m+\phi_m} + \frac{1}{2}\lambda_g^2\sigma_2^2\frac{\alpha_g}{1-\alpha_g+\phi_g} + \frac{1}{2}\lambda_b^2\sigma_3^2\frac{\alpha_b}{1-\alpha_b+\phi_b} \\ &+ (\theta_m\alpha_m + \theta_g\alpha_g + \theta_b\alpha_b)r. \end{aligned} \tag{A7}$$

In addition, substituting the optimal weights back into Equation (5), the optimal wealth process is given as

$$\begin{aligned} \frac{dW_t}{W_t} =& (r + \frac{\lambda_1^2\sigma_1^2}{1-\alpha_m+\phi_m} + \frac{\lambda_g^2\sigma_2^2}{1-\alpha_g+\phi_g} + \frac{\lambda_b^2\sigma_3^2}{1-\alpha_b+\phi_b})dt + \frac{\lambda_1\sigma_1}{1-\alpha_m+\phi_m}dz_m \\ &+ \frac{\lambda_g\sigma_2}{1-\alpha_g+\phi_g}dz_g + \frac{\lambda_b\sigma_3}{1-\alpha_b+\phi_b}dz_b. \end{aligned} \tag{A8}$$

Appendix A.2. Proof of Proposition 2

The infimization problem for the suboptimal value function J^s is

$$\begin{aligned} J^s(X,t) = \inf_{e\in\varepsilon[t,T]}\Bigg\{ & \mathrm{E}_t^{\mathbb{P}^e}\left[\int_t^T\left(\frac{(e_\tau^m)^2}{2\Psi_m(\tau,X_\tau)} + \frac{(e_\tau^g)^2}{2\Psi_g(\tau,X_\tau)} + \frac{(e_\tau^b)^2}{2\Psi_b(\tau,X_\tau)}\right)d\tau\right] \\ & + w^e(X,t;\boldsymbol{\pi}^s)\Bigg\}. \end{aligned} \tag{A9}$$

J^s satisfies the HJB equation

$$\begin{aligned} \inf_{e^m,e^g,e^b}\Bigg\{ & J_t^s + (\theta_m r + \pi_1^s\lambda_1\sigma_1^2 + \pi_2^s\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_3^s\lambda_1\sigma_1\sigma_3\rho_{13} \\ & - (\pi_1^s\sigma_1 + \pi_2^s\sigma_2\rho_{12} + \pi_3^s\sigma_3\rho_{13})e^m)xJ_x^s + \frac{1}{2}(\pi_1^s\sigma_1 + \pi_2^s\sigma_2\rho_{12} + \pi_3^s\sigma_3\rho_{13})^2x^2J_{xx}^s \\ & + (\theta_g r + \pi_2^s\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2} - \pi_2^s\sigma_2\sqrt{1-\rho_{12}^2}e^g)yJ_y^s + \frac{1}{2}(\pi_2^s)^2\sigma_2^2(1-\rho_{12}^2)y^2J_{yy}^s \\ & + (\theta_b r + \pi_3^s\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2} - \pi_3^s\sigma_3\sqrt{1-\rho_{13}^2}e^b)zJ_z^s + \frac{1}{2}(\pi_3^s)^2\sigma_3^2(1-\rho_{13}^2)z^2J_{zz}^s \\ & + \frac{(e^m)^2}{2\Psi_m} + \frac{(e^g)^2}{2\Psi_g} + \frac{(e^b)^2}{2\Psi_b}\Bigg\} = 0. \end{aligned} \tag{A10}$$

Assuming a constant $\boldsymbol{\pi}^s$, and $J^s = \frac{x^{\alpha_m}}{\alpha_m}\frac{y^{\alpha_g}}{\alpha_g}\frac{z^{\alpha_b}}{\alpha_b}\exp(b^s(T-t))$, together with Equation (14), we obtain

$$\begin{aligned} b^s =& (\theta_m r + \pi_1^s\lambda_1\sigma_1^2 + \pi_2^s\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_3^s\lambda_1\sigma_1\sigma_3\rho_{13})\alpha_m \\ &+ \frac{1}{2}(\pi_1^s\sigma_1 + \pi_2^s\sigma_2\rho_{12} + \pi_3^s\sigma_3\rho_{13})^2\alpha_m(\alpha_m-1) + (\theta_g r + \pi_2^s\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2})\alpha_g \\ &+ \frac{1}{2}(\pi_2^s)^2\sigma_2^2(1-\rho_{12}^2)\alpha_g(\alpha_g-1) + (\theta_b r + \pi_3^s\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2})\alpha_b \\ &+ \frac{1}{2}(\pi_3^s)^2\sigma_3^2(1-\rho_{13}^2)\alpha_b(\alpha_b-1) - \frac{\phi_m}{2}(\pi_1^s\sigma_1 + \pi_2^s\sigma_2\rho_{12} + \pi_3^s\sigma_3\rho_{13})^2\alpha_m \\ &- \frac{\phi_g}{2}(\pi_2^s)^2\sigma_2^2(1-\rho_{12}^2)\alpha_g - \frac{\phi_b}{2}(\pi_3^s)^2\sigma_3^2(1-\rho_{13}^2)\alpha_b. \end{aligned} \tag{A11}$$

Substituting $\boldsymbol{\pi}^s = (\pi_1^s, \pi_2^s, \pi_3^s)$ back into Equation (5), the suboptimal wealth process W_t^s is given as

$$\begin{aligned}\frac{dW_t^s}{W_t^s} =&(r + \pi_1^s\lambda_1\sigma_1^2 + \pi_2^s\lambda_1\sigma_1\sigma_2\rho_{12} + \pi_2^s\lambda_g\sigma_2^2\sqrt{1-\rho_{12}^2} + \pi_3^s\lambda_1\sigma_1\sigma_3\rho_{13} \\ &+ \pi_3^s\lambda_b\sigma_3^2\sqrt{1-\rho_{13}^2})dt + (\pi_1^s\sigma_1 + \pi_2^s\sigma_2\rho_{12} + \pi_3^s\sigma_3\rho_{13})dz_m + \pi_2^s\sigma_2\sqrt{1-\rho_{12}^2}dz_g \\ &+ \pi_3^s\sigma_3\sqrt{1-\rho_{13}^2}dz_b.\end{aligned} \tag{A12}$$

Appendix B. Empirical Analysis for the Shenandoah and DuPont Case

Appendix B.1. Optimal Weights

Compared with the IDT and WMT case, the Shenandoah and DuPont case shows similar behavior but not the same results. This is because DuPont has a negative price for the risk premium and is short-sold. Nevertheless, the reasoning is the same because the increased brown ambiguity aversion would reduce investors' risk exposure to the brown stock and, in this case, decrease the short-selling position in their portfolio. Similar to the IDT and WMT case, the decreased position is compensated by the market weight.

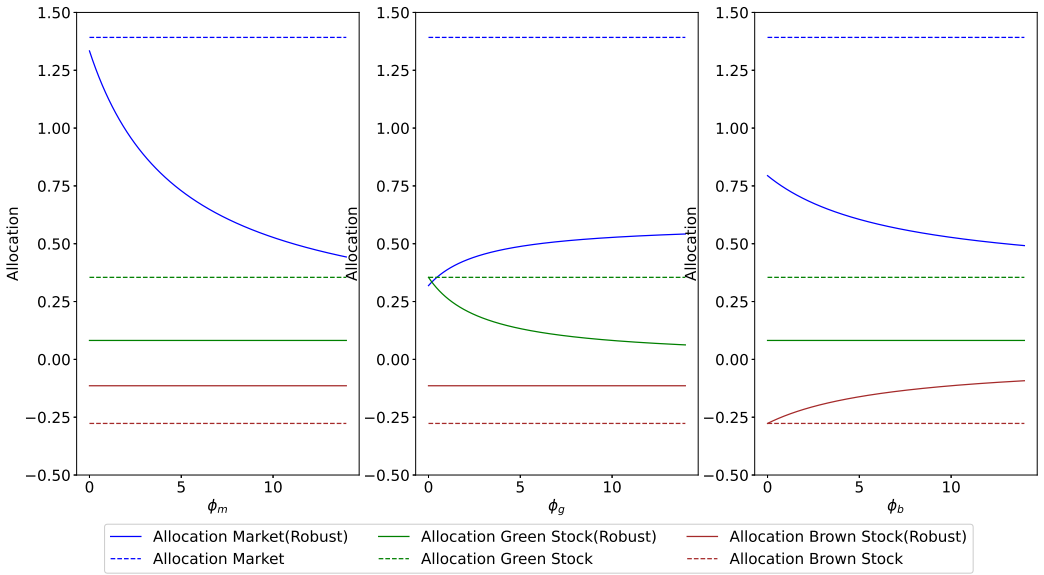

Figure A1. Impact of ambiguity aversion parameters on optimal weights in the Shenandoah and DuPont case.[5]

Appendix B.2. Detection Error Probabilities

Figures A2–A4 corroborate our speculation that as ambiguity aversion parameters increase, investors can better discern between the reference model and the alternative model. As a result, the probability of making a mistake decreases.

We also observe that ϕ_m exerts the most substantial influence on the detection error probability. Figure A2 shows that increases in ϕ_m have the greatest impact on the detection error probability, and Figure A2 exhibits a more pronounced curvature than Figures A3 and A4.

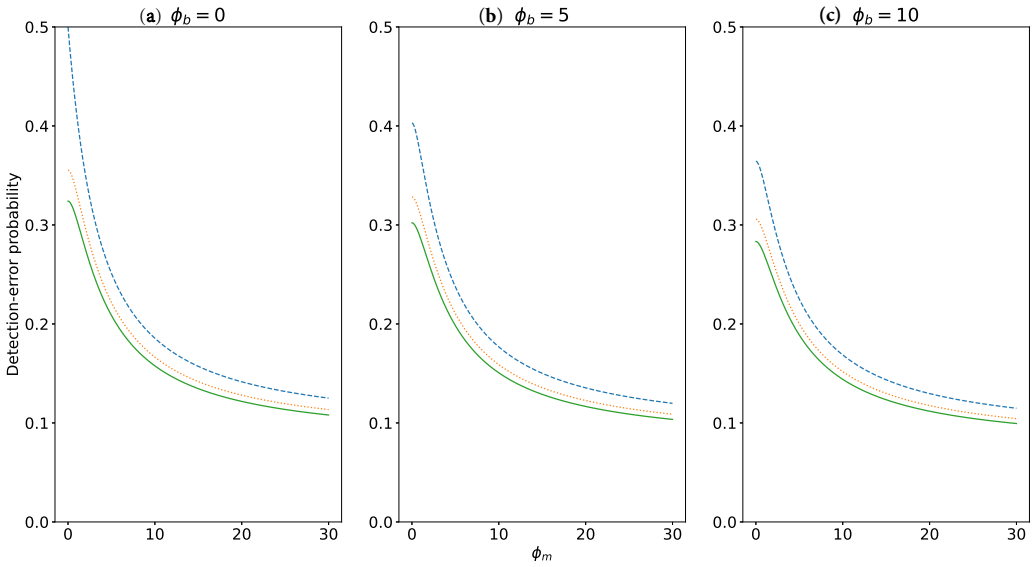

Figure A2. Detection error probability when ϕ_m, ϕ_g, ϕ_b changes in the Shenandoah and DuPont case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

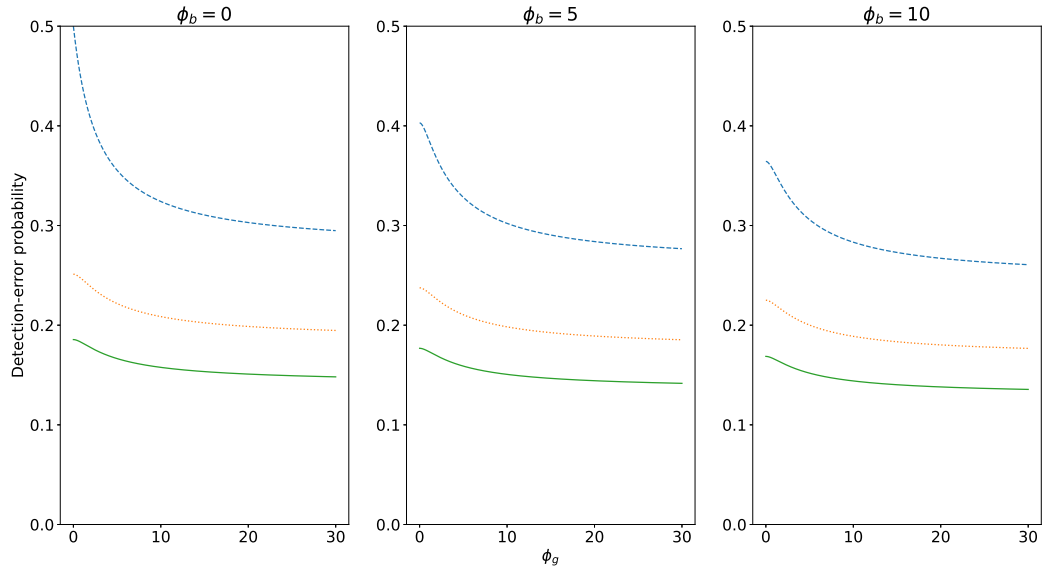

Figure A3. Detection error probability when ϕ_m, ϕ_g, ϕ_b changes in the Shenandoah and DuPont case. The dashed line is for $\phi_m = 0$, the dotted line is for $\phi_m = 5$, the solid line is for $\phi_m = 10$.

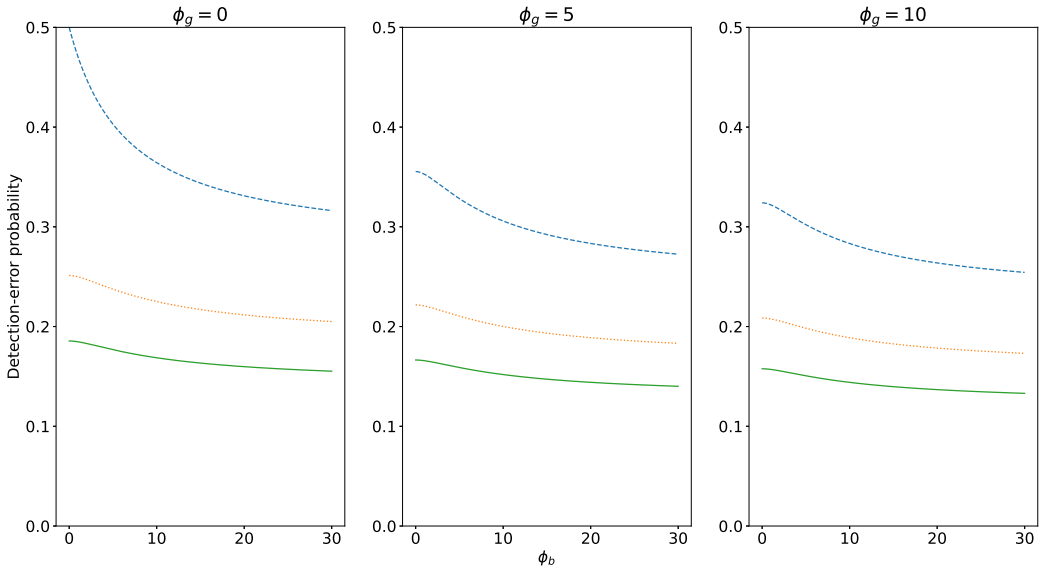

Figure A4. Detection error probability when ϕ_m, ϕ_g, ϕ_b changes in the Shenandoah and DuPont case. The dashed line is for $\phi_m = 0$, the dotted line is for $\phi_m = 5$, the solid line is for $\phi_m = 10$.

Appendix B.3. Suboptimal Losses Analysis

For the UUI case illustrated in Figure A5, UUI investors witness more pronounced declines in satisfaction as the ambiguity aversion parameters escalate. This heightened PLS can be attributed to any of the three ambiguity aversion parameters, with ϕ_m exerting the most substantial influence. Setting $\phi_m = 10, \phi_g = \phi_b = 0$ leads to a nearly 100% higher loss in satisfaction compared to when $\phi_m = \phi_g = \phi_b = 0$. Figure A6 shows a staggering 95% loss in the green index. Figure A6, while displaying a lower GWEL than Figure 6, reaffirms the heightened sensitivity of GWEL to investors with higher ambiguity aversion parameters.

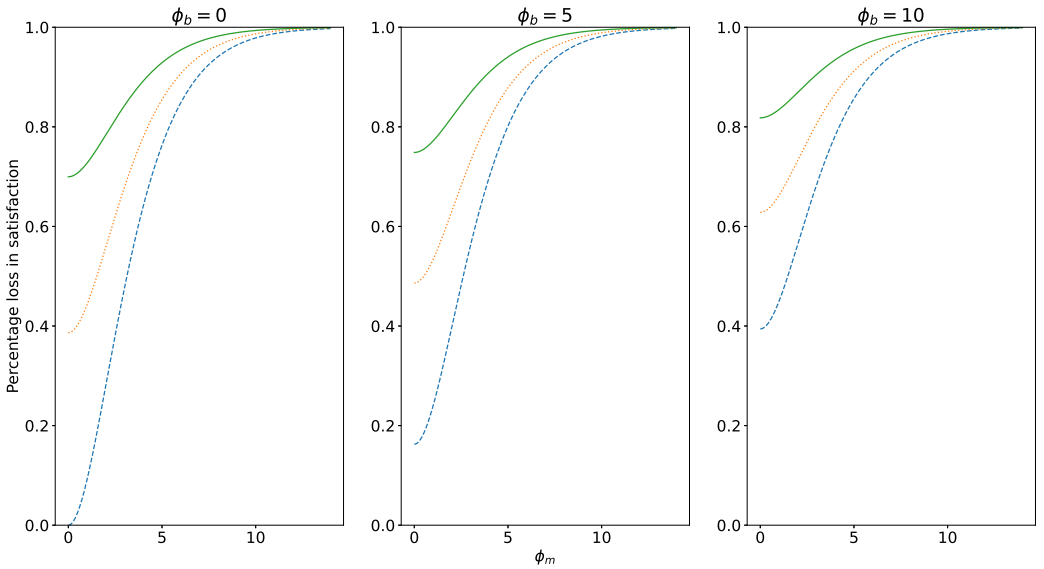

Figure A5. PLS when ϕ_m, ϕ_g, ϕ_b changes for UUI in the Shenandoah and DuPont case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

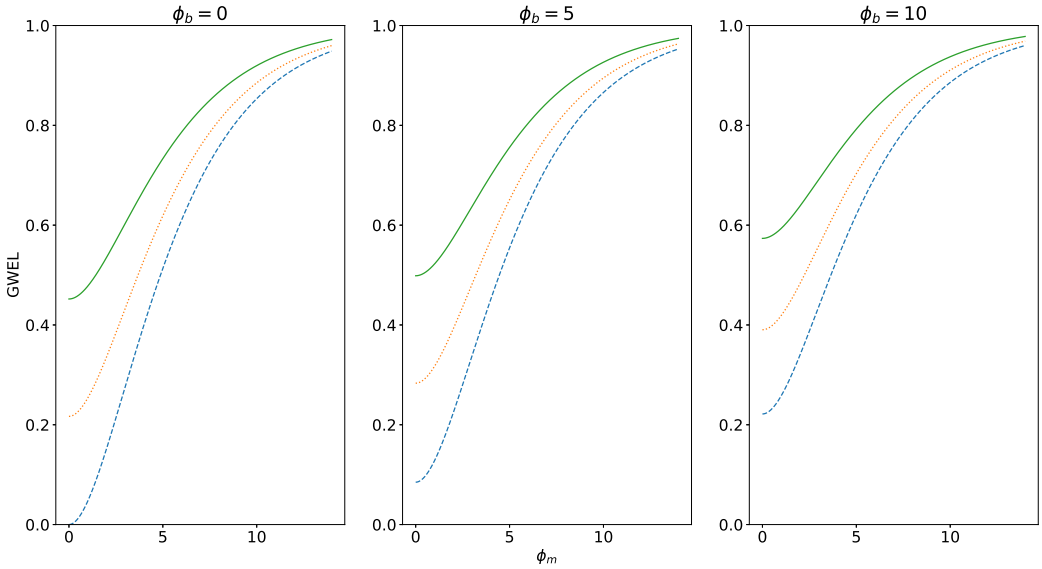

Figure A6. GWEL when ϕ_m, ϕ_g, ϕ_b changes for UUI in the Shenandoah and DuPont case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

For the SAI case, Figures A7 and A8 show that ϕ_m does not affect PLS and GWEL. However, it is worth emphasizing that the overall satisfaction reduction is substantially smaller than that in the UUI case.

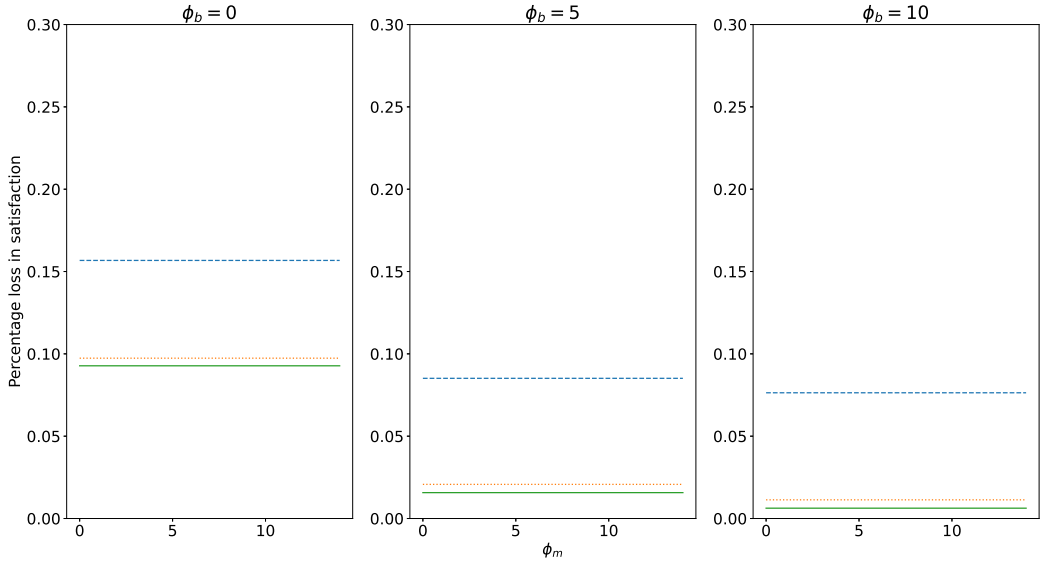

Figure A7. PLS when ϕ_m, ϕ_g, ϕ_b changes for SAI in the Shenandoah and DuPont case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

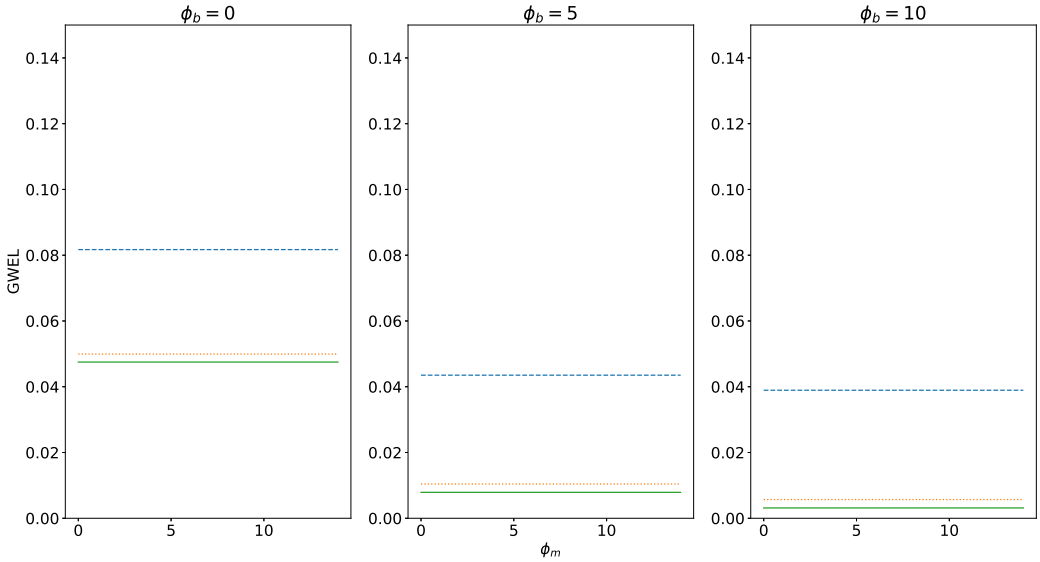

Figure A8. GWEL when ϕ_m, ϕ_g, ϕ_b changes for SAI in the Shenandoah and DuPont case. The dashed line is for $\phi_g = 0$, the dotted line is for $\phi_g = 5$, the solid line is for $\phi_g = 10$.

When examining the SBI scenario, both PLS and GWEL are exclusively influenced by ϕ_b, as shown in Figures A9 and A10. The SBI scenario occupies an intermediary position between UUI and SAI in terms of loss.

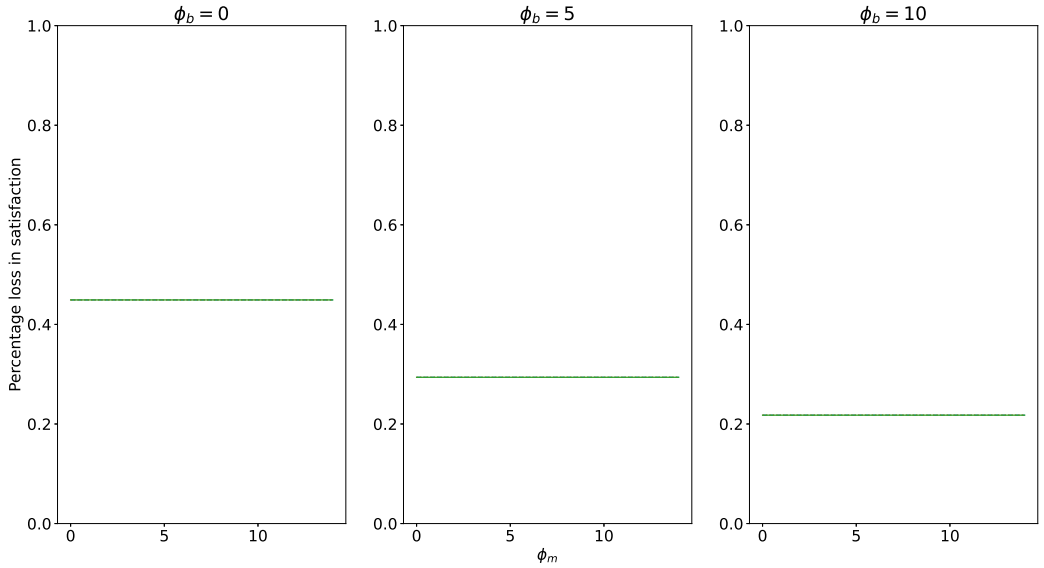

Figure A9. PLS when ϕ_m, ϕ_g, ϕ_b changes for SBI in the Shenandoah and DuPont case. The solid line is for $\phi_g = 0$, $\phi_g = 5$, and also for $\phi_g = 10$.

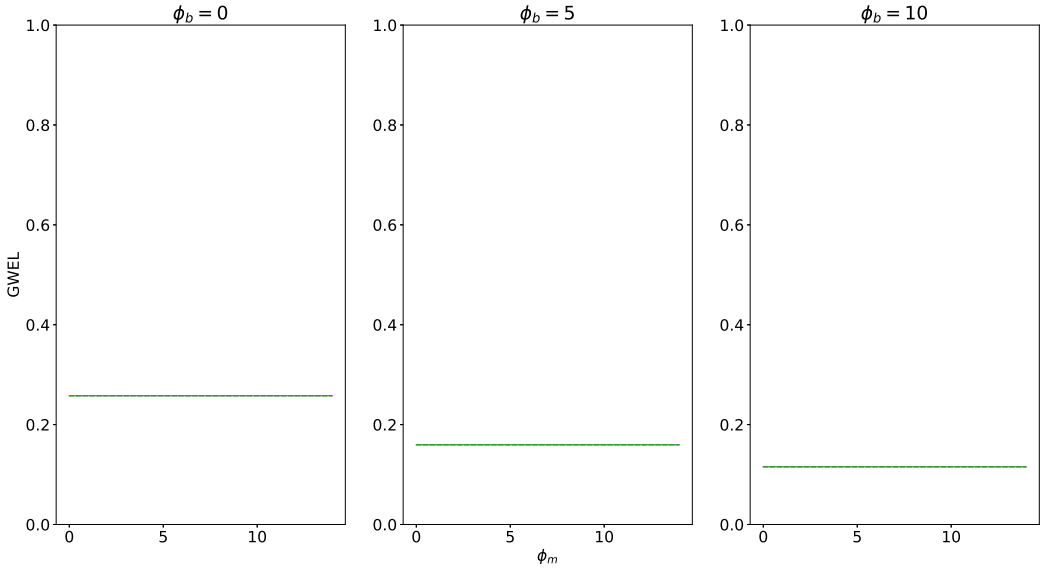

Figure A10. GWEL when ϕ_m, ϕ_g, ϕ_b changes for SBI in the Shenandoah and DuPont case. The solid line is for $\phi_g = 0$, $\phi_g = 5$, and also for $\phi_g = 10$.

Notes

1 Denoting the return of the wealth process as μ and the three volatilities as σ_i for $i = 1, 2, 3$, the proportions $\pi_i, i = 1, 2, 3$ must satisfy that μW_t is an $\mathcal{L}^1$-process and that $\sigma_i W_t$ is an $\mathcal{L}^2$-process for each $i = 1, 2, 3$.

2 For simplicity we will take $\theta_m = 1, \theta_g = 0, \theta_b = 0$ in the numerical section; this has the interpretation of treating the cash account as part of the market portfolio, ideally these weights should be related to the ESG rating of the source of this cash.

3 Parameter estimations for the empirical analysis involved computations for the standard deviation (σ), correlation (ρ), and risk premium factor (λ). These estimations were derived from monthly data on the adjusted close price of each asset spanning the period from 2010 to 2020. Additionally, the average RepRisk Rating (RRR) scores were determined by calculating the mean of the monthly RRR scores over the same time frame.

4 In each figure, one ambiguity aversion changes, and the other two are set to 10. The robust optimal weights (solid curves) are compared with the optimal weights without uncertainty consideration (dashed curves).

5 In each figure, one parameter changes, and the other two are set to be equal to 10. The robust optimal weights are compared with the optimal weights without uncertainty consideration.

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Features of the Association between Debt and Earnings Quality for Small and Medium-Sized Entities

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Abstract: The main source of financing is bank loans for Portuguese small and medium-sized entities (SMEs), which implies several constraints to obtaining additional funds. Relying on the argument of Positive Accounting Theory (PAT) that accounting choices are not neutral and on Agency Theory that information asymmetry prevails between insiders and outsiders, we analyzed the impacts of debt on earnings quality, focusing on its level, its increases, and its term of payment. We estimated econometric regressions using panel data with fixed effects over 2013–2019, using discretionary accruals as an inverse proxy of earnings quality. We found empirical evidence that the relationship between debt and earnings quality tends to vary in sign, as the quality of financial information deteriorates with debt, but as debt becomes high, firms tend to increase the quality of earnings. Furthermore, we found that short-term debt tends to decrease earnings quality more than long-term debt. This article aimed to contribute to the prior literature by collecting evidence that debt levels tend to be an incentive to increase earnings management and fill the gap by analyzing the influence of different debt features. This evidence is useful because earnings management may compromise both stakeholders' confidence and the efficient allocation of capital.

Keywords: earnings management; discretionary accruals; SMEs' debt; non-linear association

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1. Introduction

Financial statements (FS) are the main source of information for analyzing a firm's economic and financial performance, which stakeholders consider to make efficient decisions, as mentioned by Givoly et al. (2010) and Jeon and Oh (2020). However, the FSs are prepared according to flexible accounting regulations applied by a broad number and variety of industries and entities. Nevertheless, they may produce a negative impact on the quality of financial information when misused by managers, as suggested by Mendes and Lima Rodrigues (2007) and Cerqueira and Pereira (2019).

According to Positive Accounting Theory, the decisions of financial information preparers are not neutral, being influenced by several factors, such as debt covenants, compensation contracts, and political costs (Healy and Wahlen 1999; Watts and Zimmerman 1990). These factors become different incentives for earnings management. In the Continental European system, SMEs are predominant in economies, exhibiting a strong link between accounting and taxation and having bank funds as their main source of financing (Nobes 1998; Nobes and Parker 2020; Fearnley and Gray 2015). To obtain better negotiation conditions with creditors, managers may have incentives to engage in earnings management practices as argued by Pereira et al. (2023b). Relying on Agency Theory, given the existence of information asymmetry between the managers (insiders) and the users (outsiders) of accounting information, management may use discretion when preparing and reporting a FS for their benefit (Ghazali et al. 2015). Firms' stakeholders are aware of this information asymmetry. Cerqueira and Pereira (2020) argue that stakeholders look for high-quality

financial information and Monteiro et al. (2021) find that earnings quality determines the usefulness of financial information.

In this study, we focused on debt, which has been documented as a determinant of earnings management, as mentioned by Fields et al. (2001), Jelinek (2007), and Lazzem and Jilani (2018). Meanwhile, Ghosh and Moon (2010) find that high debt has a negative effect on earnings quality because managers may use accruals to avoid covenant violations. These authors document a non-monotonic relationship between debt and earnings quality, which is positive at low levels of debt and negative at high debt levels.

Conversely, the high level of indebtedness of Portuguese SMEs may lead to mitigated earnings management and then become a mechanism of corporate governance to capture creditors' confidence and obtain additional funds, as mentioned by Pereira et al. (2023b). In the same vein, Ewert and Wagenhofer (2015) argued that debt clauses are incentives for decision-makers to manage earnings. Our contribution in this paper is threefold: first, we provide evidence of the impact of banking system dependence on the earnings quality of Portuguese SMEs, taking into account different debt features. Second, we show that this effect varies with the level of debt, which tends to deteriorate earnings quality by leading to more earnings management activities to communicate better performance to externals. While we found evidence that the relationship between debt and earnings management tends to be exacerbated for SMEs with increasing levels of debt, it is mitigated for SMEs with the highest levels of debt. Third, we found that short-term debt is an incentive for decision-makers to engage in earnings management activities in response to the high demand for liquidity by Portuguese SMEs. Then, this study aimed to fill in the lack of evidence regarding the impact of debt and its different features on earnings management for SMEs, which are the most representative firms in several European economies.

The remainder of this paper is organized as follows. In Section 2, we provide a literature review and then we posit the hypotheses. In Section 3, we explain the empirical methodology design, namely the sample selection procedures, variables definitions, and the empirical model. In Section 4, we present the descriptive statistics and the results of the empirical tests. Finally, in Section 5, we provide our concluding remarks.

2. Literature Review

2.1. Earnings Management

Accounting earnings are a fundamental source of information for decision-making (Francis et al. 2004). Earnings quality plays a crucial role, especially in controversial financial markets times, allowing investors to make more efficient and less risky decisions as Kousenidis et al. (2013) argued.

According to Mukhametzyanov and Nugaev (2016), the use of financial information reduces uncertainty and leads to better decision-making, thus having a positive impact on company performance. It is possible to find a characteristic for earnings quality in Dechow and Schrand (2004) that in turn is the ability of earnings to feasibly reflect the firm's current performance. Bhattacharya et al. (2013) for the United States find empirical evidence that the quality of accounting information contributes to mitigating information asymmetry. While the IFRS aims to promote greater comparability and quality in financial information, these standards rely on flexibility, which allows earnings management activities (Toumeh and Yahya 2019). Then, based on PAT, the accounting choices rely on different motivations, such as to avoid political cost, not violate debt contract covenants, or to maximize the manager's bonus (Watts and Zimmerman 1978).

Earnings management is a globally used tool for long-term profitable firms and the reduction of bankruptcy risk (Durana et al. 2020). Considering that managers may have incentives to deteriorate earnings' quality, they may engage in earnings management practices by using privileged information to mislead stakeholders about the true performance of firms because they are no longer complete and transparent (Healy and Wahlen 1999). These authors presented a broader definition, pointing to the existence of earnings management, which is when managers use the subjectivity contained in the accounting standards to act

on the FS to hide the firm's true performance from stakeholders, or to influence the fulfillment of certain contracts that depend on financial information. For Schipper (1989), the activities of managers in the financial reporting process aim at obtaining a private benefit. Based on Koumanakos et al. (2005), earnings management is fundamentally characterized by the process in which managers take intentional actions, within the limits of generally accepted accounting principles, to achieve a desired level of earnings.

It is important to note that earnings management does not cover accounting fraud, but rather the flexibility contained in accounting standards to alter financial information without exceeding the legal limits. In addition, managers often use the flexibility contained in the standards to offer a true and fair view of the firm, allowing the users of financial information to make more educated decisions. Thus, according to Beneish (2001), earnings management can be seen from two perspectives: the opportunistic perspective, which seeks to mislead investors through the misrepresentation of disclosed information; and the informative perspective, in which managers seek to manipulate information to reveal to investors their private expectations about future cash flows.

Earnings management is associated with poor earnings quality. Monteiro et al. (2021) find that the quality of financial reporting is a predictive variable of the usefulness of financial reporting. It is important to analyze which factors may affect earnings quality.

Given that the quality of the earnings is not directly observable, several estimates have been developed in the literature (Dechow et al. 2010; Schipper and Vincent 2003), including earnings smoothing, conservatism by more timely recognition of losses relative to gains, discretionary accruals, and earnings persistence (Cerqueira and Pereira 2019). In this study, we used discretionary accruals as a proxy for earnings quality because we aimed to analyze the effect produced by debt on earnings quality.

2.2. Effect of Debt on Earnings Management and Hypothesis Development

Prior studies found conflicting empirical evidence regarding the effects of debt on earnings management.

While debt is associated with managers being engaged in earnings management activities behavior due to the need for additional financing (Khuong et al. 2022; Ewert and Wagenhofer 2015), earnings management is limited because with debt the supervision by external creditors increases, namely banking institutions (Mamatzakis et al. 2022; Vakilifard and Mortazavi 2016).

The research conducted by Lazzem and Jilani (2018), applied to a sample of French companies indexed on the CAC All-Tradable, examined the impact of leverage on accruals-based earnings management practices. Their results led to the conclusion that debt has a positive effect on earnings management. Thus, it was found that increases in debt provide an incentive for managers to manipulate results to avoid violating debt contracts. In a study conducted by Warrad (2017) on industrial firms listed on the Amman Stock Exchange (ASE) during the period from 2011 to 2015, it was concluded that there was a significant influence of debt ratio and ROA on earnings quality. Furthermore, Ewert and Wagenhofer (2015) argued that debt clauses are incentives for firms to engage in earnings management activities.

In contrast, firms with high levels of debt tend to avoid earnings management practices given that high levels of debt imply more risk of a firm's default, and thus, they are subjected to greater monitoring and scrutiny from external creditors (Jensen 1986). Consistently, Ghosh and Moon (2010) argue that high debt has a negative effect on earnings quality because managers may use accruals to avoid covenant violations. These authors document a non-monotonic relationship between debt and earnings quality, which is positive at low levels of debt and negative at high debt levels.

Meanwhile, Vakilifard and Mortazavi (2016) found empirical evidence that debt harms accruals earnings management but has a positive impact on real earnings management. Inayah et al. (2021) analyzed the impact of financial distress, leverage, and free cash flow on earnings management. These authors found evidence that leverage produces a negative impact on earnings management. In the same vein, Mamatzakis et al. (2022) found evidence

of a negative association between debt and earnings management for Greek firms. This negative effect can be explained by the fact that during the period under review, banks or creditors had a lot of control over companies, so managers had less flexibility to focus on managing earnings.

Given this conflicting evidence, we aimed to analyze the impact of debt on earnings management and whether it differs from the intensive level of debt. In addition, we controlled for factors that are likely to affect earnings management practices, in particular firms' features based on fundamentals, focusing on debt. Thus, based on credit agreements and the motivations for obtaining debt at favorable conditions for the company, the following research hypothesis is formulated:

H1. *Debt is positively associated with earnings management activities.*

On the other hand, Khuong et al. (2022) mentioned that firms with a high debt-to-asset ratio tend to have more difficulties in obtaining additional funds, which may be an incentive to increase earnings management. The results of Pereira et al. (2023a) are divergent from this vein by suggesting that debt reduces earnings management due to the high levels of debt of Portuguese SMEs; therefore, these firms have to capture creditors' and investors' confidence to obtain additional funds. In highly indebted firms, the debt levels increase the likelihood of defaults on future debt obligations, so in this situation, external creditors tend to increase monitoring of firms, decreasing opportunistic behavior by managers (Anagnostopoulou and Tsekrekos 2017; Zamri et al. 2014). Following the most recent trend, we posit the following hypothesis:

H2. *Firms with the highest levels of debt exhibit fewer earnings management activities.*

To further develop this research, we investigated whether firms that exhibit debt increases tend to manage their earnings in a more exacerbated manner than those firms with high leverage levels. Jelinek (2007) and Lazzem and Jilani (2018) found that the impact of debt on earnings management is different in debt-increasing firms and highly indebted firms. These authors found that firms experiencing increases in debt are more likely to engage in accrual-based earnings management practices than firms with consistently high debt because when firms have increases in their levels of debt, they tend to contract new debt. In addition, this enhanced propensity for earnings management is driven by the increased pressure on managers to maintain or improve earnings in response to the debt increase to persuade the lenders of good management. In the same sense, Khanh and Anh Phung (2019) identified a positive relationship between increasing leverage and earnings management. Then, we posit the third hypothesis:

H3. *Firms with increasing debt have higher earnings management activities.*

In addition, debt maturity is indicated as being able to explain the adoption of earnings management practices. Most of the literature focuses on the link between debt and earnings management but does not examine the differences between short-term and long-term debt (Ghazali et al. 2015; Jelinek 2007; Khanh and Anh Phung 2019; Koumanakos et al. 2005; Lazzem and Jilani 2018; Vakilifard and Mortazavi 2016).

Trung et al. (2020) argue that short-term debt is substantially different from long-term debt because the former presents a greater propensity for liquidity risk. Thus, short-term debt increases a firm's liquidity risk because cash flows are needed sooner to pay off that debt. Based on this theory, a positive relationship is expected between short-term debt and earnings management.

Fields et al. (2012) conclude that increasing short-term debt is associated with greater discretionary accruals, in particular for firms that are about to obtain new loans. These harmful repercussions are anticipated according to financial crisis theory (Fung and Goodwin 2013; Gupta et al. 2008). Since short-term debt is linked to liquidity risk, compared to long-term

debt, the positive correlation between short-term debt and earnings manipulation should be greater compared to (the more intensely investigated) relationship with the general debt. Taking these studies into account, the following hypothesis was formulated:

H4. *The positive impact of short-term debt on earnings management is more substantial compared to long-term debt.*

El-Rabat et al. (2023) argue that large firms have better internal control mechanisms and more experienced internal auditors compared to smaller ones, leading to disclosing more accurate financial information. Consistently, Kalbuana et al. (2021) mention that external auditors give more attention to larger firms, and consequently, these firms tend to engage less in earnings management activities. In the case of return on assets and interest expenses, firms engage in earnings management activities to meet contractual debt obligations and to mitigate the negative effects of interest on net income (Anagnostopoulou and Tsekrekos 2017; Zamri et al. 2014). In this empirical study, we controlled for the effect of firm size and the amount of interest expense on earnings management.

3. Results

3.1. Descriptive Statistics

For the statistics work, we used RStudio software version 2022.07.2, namely to estimate the econometric regressions. Table 1 presents the descriptive statistics for the dependent and independent variables included in the models, which are all based on annual financial reporting:

The mean absolute value of the discretionary accruals, which are not the result of economic activity but of managers' discretionary actions, represent 8% of the total assets. Although slightly higher, this is consistent with that shown by Cerqueira and Pereira (2015) for a previous Portuguese case (4.45%).

Regarding the Debt variable, the total debt scaled by total assets, we can conclude that in general, Portuguese SMEs are not highly leveraged, with an average value of 32%. However, the sample period coincides with the aftermath of the global financial crisis, which was characterized by a lack of liquidity in the economy, particularly in the Portuguese financial market. In this table, the variable Size is presented in euros instead of its log to be clearer in its interpretation. The variation in size by company is high, as can be seen from the standard deviation. The minimum size is around 5 million and the maximum is 107 million. This value is above the 20 million for the maximum value for assets, but the two other limits, turnover and the number of employees, are below the maximum values allowing the entity to be classified as an SME. In addition, these firms have a low ROA, 3% on average. This suggests that these firms have little ability to finance their assets through their resources, often leading them to opt for borrowed capital to the detriment of equity. In addition, the short-term debt scaled by total assets is 14%, while the long-term, most suitable for investment, is higher (19%).

Table 1. Descriptive statistics.

Variable	Mean	Median	Min	Max	St.d
Debt	0.32	0.30	0	1.04	0.21
DebtH	0.5	0	0	1	0.5
DebtST	0.14	0.10	0	0.61	0.13
DebtLT	0.19	0.14	0	0.87	0.18
Size	9845	5457	507	107,838	14,927
ROA	0.03	0.02	−0.20	0.26	0.07
IntExp	0.05	0.04	0	0.52	0.07
|DAC|	0.08	0.05	0.00	0.54	0.09

Source: Authors' calculations.

Table 2 documents the correlations between the variables used in the models.

Table 2. Correlation matrix.

	DAC	Debt	DebtST	DebtLT	DebtH	Size	ROA	IntExp	Growth
DAC	1								
Debt	0.08 ***	1							
DebtST	0.14 ***	0.51 ***	1						
DebtLT	−0.02 ***	0.77 ***	−0.13 ***	1					
DebtH	−0.01	0.55 ***	0.21 ***	0.47 ***	1				
Size	−0.08 ***	0.12 ***	−0.05 ***	−0.17 ***	0.13 ***	1			
ROA	0.03 ***	−0.24 ***	−0.14 ***	0.17 ***	−0.14 ***	0.00 ***	1		
IntExp	0.07 ***	−0.25 ***	−0.13 ***	−0.2 ***	−0.08 ***	−0.02 ***	−0.02 ***	1	
Growth	0.16 ***	0.21 ***	0.15 ***	0.13 ***	0.00	0.16 ***	0.00 ***	−0.13 ***	1

*** represents the level of significance at 1%.

The correlations between the dependent variable and the independent (no control) variable vary from −8% (Size) to 14% (DebtST).

The highest correlation coefficients between the independent variables are observed between Debt variables, but the coefficients between Debt and the other independent variables are low, suggesting that this sample has no multicollinearity problems.

3.2. Econometric Regressions Results

We analyzed the association between earnings quality and indebtedness features by estimating the dynamic fixed models using the generalized method of moments (GMM) in two-stage squares (2SLS) with the instrumental variable discretionary accruals lagged, which is a way of dealing with potential endogeneity issues. Table 3 documents the results with panel data using fixed effects for a sample period of seven years.

Table 3. Impact of debt on discretionary accruals.

Variables	Predicted Sign	Model 1	Model 2	Model 3	Model 4
Lag (DAC;1)		0.0438 ***	0.05 ***	−0.0656	0.0447 ***
		(2.8779)	(3.2573)	(−1.6282)	(2.9425)
Debt	(+)	0.0486 ***			
		(3.9656)			
DebtH	(-)		−0.0083 **		
			(−2.2706)		
DebtInc	(+)			−0.0021	
				(−0.1803)	
DebtST	(+)				0.0543 ***
					(3.435)
DebtLT					0.0347 **
					(2.5449)
ROA	(+)	0.0128	0.0100	−0.0649	0.0124
		(0.5867)	(0.4562)	(−19.0943)	(0.5679)
IntExp	(+)	0.0849 ***	0.0646 ***	0.4912 **	0.0832 ***
		(4.4899)	(3.4676)	(2.1561)	(4.4131)
Size	(-)	−0.0369 ***	−0.0356 ***	−0.0241	−0.0370 ***
		(6.3371)	(−6.0678)	(−1.2919)	(−6.3543)
Growth	(+)	0.0723 ***	0.0881 ***	0.1142 ***	0.07472 ***
		(0.5257)	(14.0256)	(7.5963)	(11.1280)
Firm-year obs.		32,788	32,788	6186	32,788
Sargan test (X^2)		19.6970	18.5972	15.0375	19.1865
Autocorrelation (1)		−27.5684 ***	−27.5145 ***	−6.6673 ***	−27.5442 ***
Autocorrelation (2)		2.5350 **	2.6643 ***	−0.1908	2.5650 **
Wald test (X^2)		240.336 ***	244.5344 ***	71.1135 ***	236.4554 ***

***, **, represent the level of significance at 1%, 5% respectively. The statistics given in the parentheses under the coefficients of independent variables are Z-values. Source: Authors' calculations.

To test the robustness of the results, we used Sargans' over-identification of restrictions test under the null hypothesis that the restrictions imposed are valid. The results led to the acceptance of the null hypothesis, concluding that the restrictions are valid and the results are robust for all models. We also tested the null hypothesis of the absence of the first and second order autocorrelation. These results mostly rejected the null hypothesis. Finally, to test the quality of the adjustment of the independent variables as a whole in relation to the dependent variable, we carried out a Wald test. The results rejected the null hypothesis, suggesting that the independent variables are statistically significant to globally explain the model.

The Debt variable in model 1 is statistically significant at the 1% level and its estimated sign is positive, as expected. This result suggests that debt positively affects earnings management, which in turn means that debt is negatively related to earnings quality. This evidence empirically supports our first hypothesis and is consistent with Kalbuana et al. (2021), Khanh and Anh Phung (2019), and Lazzem and Jilani (2018).

Concerning the control variables, the coefficients are statistically significant at a 1% level, except for ROA, which is not statistically significant. Moreover, the estimated coefficient exhibits the expected sign: IntExp is positive, suggesting that firms with higher interest expenses are associated with greater earnings management. This result is in line with Jelinek (2007), Vakilifard and Mortazavi (2016), Anagnostopoulou and Tsekrekos (2017), and Kalbuana et al. (2021). Furthermore, managers are also attempting to meet the expectations of creditors (Lazzem and Jilani 2018). In the case of Size, its estimated coefficient is negative. Lager firms have stronger internal control systems and are audited by external organizations, justifying the decrease in earnings management activities (El-Rabat et al. 2023; Kalbuana et al. 2021). The coefficient of the variable associated with Growth is positive, as expected, and statistically significant at 0.1%. This result suggests that firms with higher business growth have higher levels of discretionary accruals, in line with Al-Najjar and Riahi-Belkaoui (2001). This result shows that firms with greater growth opportunities increase their flexibility to adopt earnings management practices.

Model 2 analyzed the impact of high levels of corporate debt on earnings management activities, focusing on the variable DebtH. Its estimated coefficient is statistically significant at a 5% level, with a negative sign, as expected. This is consistent with high-debt firms engaging in fewer earnings management activities, which is in line with Anagnostopoulou and Tsekrekos (2017), Jensen (1986), and Zamri et al. (2014). This evidence empirically supports H2, suggesting that increasing leverage tends to increase earning quality as it reduces managers' opportunistic behavior, as it increases the likelihood of defaulting on debt services in the future, thereby increasing monitoring by external creditors. This means that the need to meet interest and debt payment obligations reduces the flexibility of managers' decisions. This result is in line with the finding of a non-monotonic relationship between debt and earnings quality reported by Ghosh and Moon (2010), although with opposite signs because these authors found that the relationship is positive at low levels of debt and negative at high debt levels.

The results for the control variables are consistent with the expected and similar to model 1 and to the prior literature in the case of IntExp with Jelinek (2007), Vakilifard and Mortazavi (2016), Anagnostopoulou and Tsekrekos (2017), and Kalbuana et al. (2021); for Size with El-Rabat et al. (2023) and Kalbuana et al. (2021); and for Growth with Al-Najjar and Riahi-Belkaoui (2001).

Model 3 analyzed the impact of the increase in debt on earnings management activity, focusing on the variable DebtInc. Its estimated coefficient is not statistically significant, which does not allow us to empirically support H3.

Regarding the control variables, the IntExp variable and Growth are statically significant at a 5% and a 1% level, respectively. Their estimated signs are positive as expected.

Model 4 analyzed the impact of the existence of short-term debt on earnings management activity. The estimated coefficient of the DebtST variable is statistically significant at the 1% level and the sign is positive, as expected, suggesting that short-term debt increases

earnings management activities, thus harming earnings quality. In the case of DebtLT, it is significant at a 5% level, also exhibiting a positive sign. As both the significance and coefficient of DebtST are higher than DebtLT, these findings allow us to empirically support H4, that the positive impact of short-term debt on earnings management is more substantial than that of long-term debt. The short-term need of liquidity is associated with greater discretionary accruals, particularly for firms that intend to obtain new loans, consistent with Fields et al. (2012).

For the control variables, the results are consistent with the expected and similar to model 1 and to the prior literature in the case of IntExp with Jelinek (2007), Vakilifard and Mortazavi (2016), Anagnostopoulou and Tsekrekos (2017), and Kalbuana et al. (2021); for Size with El-Rabat et al. (2023) and Kalbuana et al. (2021); and for Growth with Al-Najjar and Riahi-Belkaoui (2001).

4. Empirical Methodology

4.1. Sample Selection

This study focused on a sample of Portuguese SMEs taking into account national accounting standards, which must meet two of these three requirements: total assets between 350,000 EUR and 20,000,000 EUR; turnover between 700,000 EUR and 40,000,000 EUR; and annual average number of employees between 10 and 50 (at the end of the year). All of the financial data were collected using the SABI database (Iberian Balance Sheet Analysis System). The sample period covered 7 years for the estimation of econometric regressions, covering the years 2013 to 2019 to avoid the COVID-19 pandemic effect. To include a firm in the sample it must report data for the variables under study for the entire analysis period. In addition, we excluded financial and insurance firms as they have specific regulations, and industries with less than 30 firms.

After the selection procedures, the final sample consisted of 4684 firms, representing 32,788 firm-year observations.

4.2. Empirical Models

Consistent with previous studies, discretionary accruals were used as a proxy for earnings management.

To obtain the discretionary accruals, we first computed total accruals through Equation (1):

$$TA_{i,t} = NI_{i,t} - FCO_{i,t} \quad (1)$$

where:

i, t represents firm i for period t.

TA is total accruals for firm I in year t.

NI is the variation in net income between periods, given by the net income of year t minus the net income in the previous year ($t - 1$).

FCO is the cash flow from operating activities of year t.

After obtaining the total accruals, we estimated the discretionary accruals based on the Jones model modified by Dechow et al. (1995) with the return on assets from the previous period as proposed by Kothari et al. (2005). The discretionary accruals were the residuals of the cross-section estimation of Equation (2). These residuals represent the component of accruals that remains after controlling for firm performance, economic activity, and investment in tangible fixed assets, and are likely to be associated with managers' discretionary choices:

$$TA_{i,t} = \alpha_0 + \alpha_1 Rev_{i,t} + \alpha_2 PPE_{i,t} + \alpha_3 ROA_{i,t-1} + \varepsilon_{i,t} \quad (2)$$

where:

TA is the value of total accruals computed by Equation (1).

Rev is the change in sales, given by the difference between sales in the current year (t) and sales in the previous year (t − 1), minus the change in accounts receivable, given by the difference between accounts receivable in the current year and accounts receivable in the previous year.

PPE is the tangible fixed assets.

ROA is the return on assets in the previous period (t − 1).

All variables are scaled by the total assets of year t − 1.

$\varepsilon_{i,t}$, are the residuals of the regression estimation.

After estimating the residuals, $\varepsilon_{i,t}$, we tested the hypotheses, namely regarding the relationship between different levels of debt and discretionary accruals as a proxy for earnings management. Furthermore, discretionary accruals are an inverse proxy for the earnings quality because the residuals from accrual models represent management discretion or estimation errors, both of which reduce decision usefulness (Dechow et al. 2010).

In addition, we controlled for the firm's size and the level of interest expenses. For that purpose, we estimated four regressions, using panel data with fixed effects, whose selection was based on the Hausman test:

$$|\mathrm{DAC_{i,t}}| = \alpha_0 + \beta_1 \mathrm{Debt_{i,t}} + \beta_2 \mathrm{ROA_{i,t}} + \beta_3 \mathrm{Size_{i,t}} + \beta_4 \mathrm{IntExp_{i,t}} + \beta_5 \mathrm{Growth_{i,t}} + \mu_{i,t} \quad (3)$$

where:

$|DAC|$ is the absolute value of the residuals of the total accruals (discretionary accruals) scaled by the average total assets[1].

Debt is the amount of total indebtedness over the total assets for the previous year (t − 1). To support our first hypothesis, it is expected that the coefficient β_1 in Equation (3) will be positive and statistically significant.

In addition, based on prior literature regarding the determinants of discretionary accruals, we included the following control variables:

ROA is the return on total assets as measured by net income divided by average total assets. We expect a positive sign in the relationship because firms with high ROA tend to engage in earnings management activities to pay less taxes (Anagnostopoulou and Tsekrekos 2017; Jelinek 2007; Kalbuana et al. 2021; Vakilifard and Mortazavi 2016);

Size corresponds to firms' size measured by the logarithm of total assets in the previous year (t − 1). We expect a negative sign in the relationship because larger firms have better internal controls and are audited by more experienced auditors (El-Rabat et al. 2023; Kalbuana et al. 2021; Vakilifard and Mortazavi 2016);

IntExp is given by interest expense and other financial costs scaled by the total debt of the previous year (t − 1). Managers have to satisfy the expectations of creditors and investors, leading them to engage in earnings management activities (Lazzem and Jilani 2018);

Growth corresponds to the company's growth proxy, measured by the percentage growth of total assets. This variable is expected to have a negative coefficient, consistent with the studies by Khanh and Anh Phung (2019) and Jelinek (2007);

$\mu_{i,t}$ are the residuals of the regression estimation.

We then ran the following regression to test our second hypothesis:

$$|\mathrm{DAC_{i,t}}| = \alpha_0 + \beta_1 \mathrm{DebtH_{i,t}} + \beta_2 \mathrm{ROA_{i,t}} + \beta_3 \mathrm{Size_{i,t}} + \beta_4 \mathrm{IntExp_{i,t}} + \beta_5 \mathrm{Growth_{i,t}} + \mu_{i,t} \quad (4)$$

where:

DebtH is a dummy variable that takes the value 1 if the firm's debt ratio, the ratio of debt to assets, is above the third quartile, ranging between 75% and 100%, and 0 otherwise. We divide the sample into quartiles based on the ratio of debt to assets, and then firms whose ratio is at the upper limit of a data set, i.e., in the third quartile, are considered to be highly indebted.

This hypothesis is supported if the coefficient β_1 is statistically negative because firms with high levels of debt tend to decrease their earnings management activities to capture creditors' confidence and obtain additional funds, thereby improving earnings quality.

All of the other variables present the same definition.

The third hypothesis is tested by the following regression:

$$|DAC_{i,t}| = \alpha_0 + \beta_1 DebtInc_{i,t} + \beta_2 ROA_{i,t} + \beta_3 Size_{i,t} + \beta_4 IntExp_{i,t} + \beta_5 Growth_{i,t} + \mu_{i,t} \quad (5)$$

where:

DebtInc is a dummy variable that takes the value 1 if the firm exhibits an increase in debt from year $t - 2$ to year t and 0 otherwise. A company is classified as having increased its indebtedness if it is in the first quartile in year $t - 2$ and moves to the third or fourth quartile in year t, or if it is in the second quartile in year $t - 2$ and moves to the fourth quartile in year t. This variable analyzes the impact of the increase in debt in a static way without the occurrence of debt variations.

This hypothesis is supported if the coefficient β_1 is statistically positive.

All of the other variables have the same definition.

Concerning the impact of debt maturity, to test hypothesis 4, we estimated the following equation:

$$|DAC_{i,t}| = \alpha_0 + \beta_1 DebtST_{i,t} + \beta_2 DebtLT_{i,t} + \beta_3 ROA_{i,t} + \beta_4 Size_{i,t} + \beta_5 IntExp_{i,t} + \beta_6 Growth_{i,t} + \mu_{i,t} \quad (6)$$

where:

DebtST is the short-term debt ratio, measured by the total value of current financing scaled by total assets in the previous period;

DebtLT is the long-term debt ratio, measured by the total value of long financing scaled by total assets in the previous period;

All of the other variables have the same definition.

5. Conclusions

In this study, our main objective consisted of analyzing the effects of debt levels on earnings quality. Our results showed a significant and positive association between the levels of debt and earnings management. This may be due both to the need to obtain additional funds and to have better credit covenants, which is consistent with the PAT. Furthermore, our results show that firms with increasing debt tend to engage in more earnings management practices, producing negative impacts on the quality of financial information and then increasing information asymmetry between outsiders and insiders. However, our empirical evidence suggests that this association is non-linear because when firms have extreme levels of debt, they tend to mitigate earnings management activities to capture their creditors' and investors' confidence. In addition, we found evidence that short-term debt increases in a more substantial manner in earnings management activities than long-term debt, as firms that increase this type of debt tend to have higher discretionary accruals to obtain new loans, which allows them to fulfill commitments that require high liquidity.

Thus, this paper shows that debt levels do not tend to be a mechanism for regulating the managers' activities to increase the quality of financial information. On the contrary, they contribute to increased earnings management, compromising the confidence of stakeholders as well as efficient decision making, except for firms with high levels of debt.

These results are important for creditors and investors, but also for managers, as they contribute to an alignment of interests with the respective mitigation of agency costs. Furthermore, this empirical evidence can be particularly useful for managers of SMEs, mostly in European economies, to consolidate more responsible management behavior toward society.

A major limitation of this study is the exclusion of more recent years aiming to avoid possible bias in the empirical results due to the dramatic effects of the COVID-19 pandemic on the economy.

For future research, we propose to split the sample by quantiles to analyze the non-linear effect of debt as well as including larger firms with other sources of financing as the capital markets.

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Note

[1] It should be noted that our aim is not to analyze whether earnings management activities are motivated by the willingness to increase or reduce earnings, but rather the magnitude of earnings management.

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Simulation of Dynamic Performance of DeFi Protocol Based on Historical Crypto Market Behavior

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Abstract: In a rapidly evolving and often volatile crypto market, the ability to use historical data for simulations provides a more realistic assessment of how decentralized finance (DeFi) protocols might perform. This insight is crucial for participants, developers, and investors seeking to make informed decisions. This paper presents a comprehensive study evaluating the dynamic performance of a newly developed DeFi protocol—NOLUS. The main objective of this paper is to present and analyze the built realistic model of the platform. This model could be successfully used to analyze the stability of the platform under different environmental influences by performing various simulations and conducting experiments with different parameters that could not be realized with the real platform. In the article, the key components of the platform are presented in detail and the main dependencies between them are clarified, in addition to the ways of forming multiple variables, and the complex relations between them in the real protocol are explained. The main finding from the experimental part of the study is that the performance of the protocol representation accounts for the expected system behavior. Hence the system simulation could be successfully used to reveal essential protocol behaviors resulting from potential shifts in the crypto market environment and to optimize the protocol's hyper parameters.

Keywords: DeFi protocol simulation; crypto market; risk; historical data

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1. Introduction

Decentralized finance (DeFi) has emerged as a transformative paradigm within the financial landscape, harnessing the capabilities of blockchain technology to reshape traditional financial services. As the DeFi space continues to evolve rapidly, there is a growing need to comprehensively understand and assess the performance of these protocols in dynamic and unpredictable market conditions.

In a space where innovation and experimentation abound, the ability to simulate and analyze the behavior of DeFi protocols becomes paramount for both developers and participants. One of the key challenges lies in predicting how these protocols will perform under varying market scenarios, which are inherently influenced by the volatile nature of the cryptocurrency market.

Against the backdrop of dynamic cryptocurrency trading, a myriad of platforms has mushroomed globally, each contributing to the evolving narrative of DeFi. These platforms, while presenting distinct advantages and limitations, share a common thread: the direct connection of economic entities for mutual gains in cryptocurrency trading.

Prominent actors in the DeFi lending space include Uniswap, Sushiswap, Compound, and Aave. Despite their progress, challenges persist, ranging from scalability issues, to elevated transaction costs and barriers, and the seamless onboarding of new users. The current state of research in DeFi lending protocols reflects a robust exploration of facets such as smart contract architecture, token mechanics, governance models, and user behavior.

Uniswap, operating on the Ethereum blockchain, utilizes an Automated Market Maker (AMM) model, promoting trustless and permissionless token trading. Researchers

(Adams et al. 2021; Angeris et al. 2019; Daian et al. 2019) have scrutinized its pricing mechanism, liquidity provision strategy, security vulnerabilities, and optimization strategies.

Sushiswap, born as a decentralized exchange (DEX) and AMM, distinguishes itself by amplifying liquidity and incentives for liquidity providers (LPs). Research (Fan et al. 2023) undertakings delve into the intricacies of liquidity mining incentives, the sway of economic factors on liquidity providers' decision making, and strategies to alleviate impermanent loss.

Compound, a decentralized lending protocol, revolutionizes DeFi by enabling users to lend or borrow based on algorithmic interest rates. Researchers (Saengchote 2023; Kao et al. 2020) have evaluated its market risks, liquidation mechanism, and economic security through agent-based modeling and simulation.

Furthermore, a nuanced exploration branches into the broader financial ecosystem, with a focus on three prominent Peer-to-Liquid Funds (PLFs)—Aave, dYdX, and Compound, presented in (Gudgeon et al. 2020). Market liquidity, efficiency, and interdependence among these PLFs take center stage, unraveling operational patterns during periods of high utilization and the potential risks associated with liquidity concentration.

Aave, akin to Compound, stands as a decentralized lending and borrowing platform with a distinctive feature—flash loans. The founder's whitepaper (Aave n.d.) provides a comprehensive elucidation of Aave's innovative lending pool model, flash loans, and governance structure. The research (Sun et al. 2023) threads weave through topics such as risk management, interest rate models, and liquidity provision, offering valuable insights into the multifaceted dynamics of the Aave protocol.

The cryptocurrency market is renowned for its inherent volatility, characterized by rapid and sometimes unpredictable price fluctuations across various digital assets. This volatility is a key distinguishing feature of the crypto market and is influenced by a myriad of factors. In (Gupta and Chaudhary 2022), the authors empirically found that there is the presence of high volatility among the returns of four cryptocurrencies—Bitcoin, Ether, Litecoin, and XRP—which makes them very risky assets for investments.

One of the primary contributors to cryptocurrency market volatility is the market's relative nascency. Compared to traditional financial markets, the crypto space is relatively young and less mature. As a result, it tends to be more susceptible to sudden market sentiment shifts, speculative trading, and external influences. In a period where positive sentiment regarding the adoption of cryptocurrencies becomes widespread, financial institutions and large corporations increasingly integrate cryptocurrencies into their operations and investment portfolios. Increased adoption by traditional financial players can significantly boost the credibility and acceptance of DeFi platforms. Positive market sentiment often correlates with increased demand and can positively influence the valuation of cryptocurrencies.

Other factors affecting the volatility of cryptocurrencies are the regulatory developments. A global push among major economies for clearer and more favorable cryptocurrency regulations may introduce regulatory frameworks that legitimize and provide clear guidelines for the operation of decentralized finance (DeFi) platforms. This regulatory clarity could positively impact investor confidence, potentially leading to increased participation in platforms such as NOLUS. Conversely, adverse regulatory developments could introduce uncertainty and hinder growth.

The decentralized nature of many cryptocurrencies also plays a role. Without a central governing authority, market movements can be more reactive to news, social media trends, or macroeconomic factors. In terms of a global economic downturn, traditional financial markets experience a recession, and central banks implement expansive monetary policies to counter economic challenges. Economic downturns might drive investors toward alternative assets, including cryptocurrencies, as a hedge against economic uncertainties. This shift could influence the demand for cryptocurrencies and impact their pricing dynamics.

Liquidity, or the ease with which an asset can be bought or sold, is another factor amplifying crypto market volatility. Low liquidity in certain markets can result in larger price swings, as a relatively small volume of trades can have a significant impact.

Moreover, significant technological advancements in blockchain and decentralized technologies also affect the volatility of crypto markets. This could include the widespread adoption of more efficient consensus algorithms, scalability solutions, or interoperability protocols. Technological progress can enhance the efficiency and functionality of DeFi platforms. If these platforms integrate these advancements, they might gain a competitive edge, attracting more users and positively affecting their valuation.

In recent years, the crypto market has witnessed efforts to mitigate volatility. The introduction of stablecoins pegged to traditional fiat currencies, algorithmic stablecoins, and decentralized finance (DeFi) protocols seeking to stabilize token values are examples of such endeavors. However, volatility remains a characteristic element of the crypto landscape, offering both opportunities and challenges for investors and traders.

The novelty of our approach rests on the integration of historical crypto market data into the simulation of a newly developed protocol performance. By leveraging past market behaviors, we create a realistic environment that captures the complexities of real-world conditions, enabling us to evaluate the performance, risks, and potential outcomes of the real protocol with greater precision.

The subsequent sections of this paper focus on the details of our simulation methodology, the data sources and variables used, and the results of our analyses. Through researching the dynamic performance of the presented protocol using historical market simulations, we contribute to the ongoing discourse surrounding the evolution of DeFi, its potential challenges, and the opportunities it presents within the ever-evolving landscape of decentralized finance.

The Supplementary Materials section of the article provides an address that directs to the repository where the actual model of the real platform is published. This facilitates the ability of other researchers to replicate and build upon the presented results.

2. Mechanisms for Implementation of a DeFi Protocol Simulation

2.1. Event: Interest Generation

2.1.1. Lessees Interest (LS Interest)

The interest rate definition plays a crucial role in DeFi protocols as it directly impacts the functioning and effectiveness of these platforms. The accurate and well-defined determination of interest rates is essential for maintaining stability, attracting users, and ensuring efficient capital allocation within the DeFi ecosystem.

One of the key aspects of DeFi protocols is lending and borrowing activities, where users provide or borrow funds from the platform. The interest rate serves as a fundamental mechanism for incentivizing participation, balancing supply and demand, and managing risk.

A clear and transparent interest rate definition is important for several reasons. Firstly, it ensures fairness and equal treatment of all participants. By having a standardized and objective method of calculating interest rates, users can trust that their loans or deposits are subject to consistent and predictable terms.

Secondly, the interest rate definition helps to maintain stability and mitigate risks within the DeFi ecosystem. Through careful consideration of market conditions, collateralization ratios, and other factors, protocols can establish interest rates that align with the underlying assets' risk profiles. This helps to protect the platform and its users from excessive volatility and potential defaults.

Moreover, the interest rate definition enables efficient capital allocation by incentivizing borrowing or lending activities when they are most needed. By dynamically adjusting interest rates based on supply and demand dynamics, protocols can influence user behavior and optimize resource allocation.

Furthermore, the interest rate definition in DeFi protocols is an area of active research and innovation. It involves considerations of economic theories, game theory, and algorithmic mechanisms. Researchers and developers are constantly exploring novel approaches to improve interest rate models, liquidity provision, and risk management to enhance the overall efficiency and sustainability of DeFi platforms. In (Gudgeon et al. 2020), the authors presented evidence of the inefficiency of DeFi tokens regarding their liquidity, market efficiency, and interest rates. They investigate the mechanisms used to set the interest rates in several DeFi protocols in order to find how to equilibrate the supply and demand for funds.

In (Piñeiro-Chousa et al. 2022), the authors investigate the impact of certain traditional assets on specific DeFi tokens, focusing on their volatility. The study suggests that there are connections between traditional assets, user-generated content, and DeFi tokens. These relationships indicate that DeFi tokens may serve as safe havens and provide a hedge against stock market volatility.

The value of LS Interest due on the smart contracts in the NOLUS platform is calculated daily and it consists of two components: a predefined Base Interest Rate and an additional part dependent on the Utilization Rate of the relevant pool.

The first component—the Base Interest Rate—is set for the platform and it serves as a minimum return that is guaranteed throughout the entire duration of the smart contract, except for the cases in which conditions for liquidation occur.

The second component—the Utilization Rate—is calculated daily from the ratio between the total amount of assets in stable currency already borrowed from the respective pool and the value of the deposited amounts in stable together with the accumulated interest in stable. It represents the part of the assets from each pool that are borrowed from the LSs.

For calculation of the Utilization Rate on a daily basis for every pool, the following formula is used:

$$U = \frac{\sum B_{stb}^{t}}{TVL^{t}}, \tag{1}$$

where

- U—Utilization Rate per pool;
- $\sum B_{stb}^{t}$—the total amount borrowed from the pool's native asset in stable for a specified timestamp;
- TVL^{t}—the Total Value Locked (TVL) amount of the pool's native asset in stable for a specified time.

The TVL is further discussed in Section 2.3 of this article.

At the end of each day, when the smart contracts are closed, the Utilization Rate for each pool is calculated, and the following day, this Utilization Rate is taken for calculation of the LS interest rate for the current day.

In case at any day a 100% Utilization Rate is reached for a specific pool, no contracts are opened on that day and the day is restarted.

The interest rate for each individual pool, which represents the interest rate for the LS contracts, is calculated as per the formulas below, according to the level of utilization of the respective pool:

(1) when the Utilization Rate for the pool is smaller than or equal to the Optimal Utilization Rate, i.e., $U \leq U_{optimal}$:

$$R_v = R_{vo} + \frac{U}{U_{optimal}} \cdot R_{slope1}, \tag{2}$$

(2) when the Utilization Rate for the pool is higher than the Optimal Utilization Rate, i.e., $U > U_{optimal}$:

$$R_v = R_{vo} + R_{slope1} + \frac{U - U_{optimal}}{1 - U_{optimal}} \cdot R_{slope2}, \quad (3)$$

where

- R_v—a variable interest rate per pool;
- R_{vo}—a predefined Base Interest Rate;
- U—the Utilization Rate;
- $U_{optimal}$—a predefined Optimal Utilization Rate for the stable pool;
- R_{slope1}—a predefined parameter, showing the increasing of the interest rate when $U \leq U_{optimal}$;
- R_{slope2}—a predefined parameter, showing the increasing of the interest rate when $U > U_{optimal}$.

This approach can be found also in the Aave protocol (Aave n.d.).

2.1.2. LP Interest

When a new liquidity provider (LP) deposit is opened, the amount of the deposit is stored both as an asset and is recalculated in stablecoins. The LP interest rate for a particular timestamp is calculated on a daily basis for each separate pool, according to the formula:

$$R_{LP}^t \,\% = \frac{R_v^t - R_{tr}}{365} \cdot 100, \quad (4)$$

where

- R_{LP}^t—the LP interest rate for a particular timestamp;
- R_v^t—a variable interest rate per pool for a particular timestamp;
- R_{tr}—a predefined Treasury Interest Rate.

At the time of withdrawal of the deposit from the LP, the cumulative amount of each LP's interest is paid to them, together with the amount of their deposit and the additional profit in the form of NOLUS tokens (NLSs).

An important point to mention is a specific characteristic of the platform, regarding the number of LS contracts that will be opened daily, in reference to the change in the interest rate. The number of newly opened LS contracts depends on the interest rate and the Utilization Rate for the particular day.

The number of LS contracts that will be opened for the respective day decreases when the interest rate increases.

This functionality is achieved using the following formula:

$$dem = \frac{e^{int - int_{min}} - e^{int_{max} - int_{min}}}{1 - e^{int_{max} - int_{min}}} \cdot (demint_{min} - demint_{max}) + demint_{max}, \quad (5)$$

where

- dem—percentage demand;
- int_{min}—minimal LS interest;
- int_{max}—maximal LS interest;
- $demint_{max}$—the maximum value of the variation in the parameter demand when forming the corresponding structure;
- $demint_{min}$—the minimum value of the variation in the parameter demand when forming the corresponding structure.

It is foreseen that there is a predefined maximum allowed LS interest rate. The parameter "dem" is calculated, which shows the percentage of the contracts for the corresponding day that will be opened depending on the interest rate calculated for the particular day.

This functionality demonstrates that the interest of the LSs can decrease depending on the increase in the interest rates for the new contracts.

The maximum Pool Utilization, predefined in the config file, is used for LS demand reduction. If the maximum Pool Utilization is reached, the staked daily counts of new contracts are multiplied by weight for the purpose of reduction.

2.2. Event: Repayment of Loans by LSs

In the context of smart contracts, repayment refers to the process of returning borrowed assets to the lending platform after a borrower has completed their loan term.

In (Carapella et al. 2022), the authors provide an overview of blockchain basics and the major DeFi protocols and products they offer, together with the mechanisms for repayment of smart contracts, and finally they cover potential risks associated with these technologies and use cases. In (Gudgeon et al. 2020), the authors conduct an empirical analysis to observe the behavior of interest rate rules since their introduction, focusing on their responses to various levels of liquidity.

There are three types of liquidation transactions in NOLUS protocol, regarding the payment of loans by the LSs:

- Regular payment or liquidation due to penalty;
- Partial liquidation;
- Total liquidation.

The first type of liquidation refers to the regular payments made by the LSs to repay their obligations under the smart contracts. These regular payments are executed without the need for manual intervention once the smart contract has been deployed on the blockchain. Regular payments in smart contracts provide several advantages, including reducing administrative overhead, enhancing trust and transparency, and ensuring timely and accurate payments.

The partial liquidation mechanism is crucial for maintaining the stability and safety of the protocol. It helps protect lenders and maintain the overall health of the system by preventing excessive losses in the event of volatile market conditions or borrower defaults. Partial liquidation refers to the reduction in a given asset of the LS as a result of one of the following two events: omitted payments or a shake-up in market conditions. When partial liquidation occurs, the smart contract will automatically sell or auction off a portion of the user's collateral to cover their outstanding debt and ensure that the protocol remains solvent. By liquidating only a part of the collateral, users have the opportunity to restore their position and prevent the complete loss of their assets.

Full liquidation refers to the process of completely liquidating a user's collateral in the smart contract when they are unable to meet their debt obligations or the value of their collateral falls below a critical threshold. Full liquidation is an essential risk management mechanism in the protocol, as it helps to mitigate the impact of defaulting borrowers and ensures the stability and security of the system. By fully liquidating a user's collateral, the protocol can recover the debt owed and maintain the integrity of its reserve funds, which are critical for providing liquidity and maintaining the overall health of the platform.

There are some assumptions regarding the liquidation of contracts in the NOLUS platform that should be mentioned, as follows:

$$LA_a^{t=0} = B_a^{t=0} + C_a^{t=0}, \tag{6}$$

where:

- $LA_a^{t=0}$—the value of the LSs loan (loan amount) at the conclusion of the contract in asset;
- $C_a^{t=0}$—the collateral (downpayment) in asset provided by LSs upon conclusion of the smart contract;
- $B_a^{t=0}$—the borrowed amount of asset from the LSs.

$$LA^t_{stb} = LA^t_a \cdot MP^t_a, \tag{7}$$

where:

- LA^t_{stb}—the value of the LSs loan at a given time in stable;
- MP^t_a—the market price of the particular asset for the current timestamp.

All obligations due on the contract at a given time in stable, LL^t_{stb}, can be calculated as follows:

$$LL^t_{stb} = LSP^t_{stb} + LSI^t_{stb}, \tag{8}$$

where

- LL^t_{stb}—all obligations due on the contract at a given time in stable;
- LSP^t_{stb}—the principal due on the LS contract at a given time in stable;
- LSI^t_{stb}—the LS interest due on the contract at a given time in stable.

In turn, the following formula is used to determine the LSP^t_{stb}:

$$LSP^t_{stb} = B^{t=0}_a \cdot MP^{t=0}_a - PP^t_{stb}, \tag{9}$$

where

- $MP^{t=0}_a$—the market price of the relevant asset at the time of opening the smart contract;
- PP^t_{stb}—the already paid part of the principal.

The value of LSI^t_{stb} indicates the current interest standing at any given time. In the Monte Carlo simulation, the interest is used as the standing interest for the next month (example: when a contract is opened initially, LSI^t_{stb} is set as the value of the interest for 1 month).

$$LL^t_{stb}\ \% = \frac{B}{C} \cdot 100, \tag{10}$$

where:

- LL^t_{stb}—Lease Liability: ratio between borrowed to collateral at a given time.

There are three parameters, regarding the Lease Liability:

- LL_{init}—Lease Initial Liability: a predefined initial Lease Liability in %;
- LL_{health}—Lease Healthy Liability: a predefined healthy Lease Liability in %;
- LL_{max}—Lease Max Liability: a predefined maximum Lease Liability in %.

It is foreseen that the LL^t_{stb} for every opened contract is recalculated daily. The LL^t_{stb} of the contracts should be smaller than or equal to LL_{health}, and LL_{health} is smaller than LL_{max}, to ensure that the protocol will work optimally and that no shortage of funds will occur in the pools.

2.2.1. Liquidation Type 1: Regular Payment/Liquidation Due to Penalty

It is expected that in the majority of cases, the contracts in the platform will be paid out in a timely manner; hence, there will be no penalty payments. In these cases, for the regular repayment of every smart contract, the following formula is used:

$$RA_{stb} = (B_{stb} + B_{stb} \cdot \frac{R_v}{12 \times 100} \cdot N_{pmnt}) / (N_{pmnt} + M_{pnl})), \tag{11}$$

where

- RA_{stb}—the amount of the regular payment (repayment amount);
- B_{stb}—the principal of the contract together with the newly achieved asset in stable;
- N_{pmnt}—the number of regular payments under the contract (payment);
- M_{pnl}—the number of omitted payments under the contract (penalty).

For calculation of the omitted payments the following formula is used:

$$PA_{stb} = B_{stb} \cdot \frac{R_v}{12 \times 100} \cdot M_{pmnt} / (N_{pmnt} + M_{pnl}), \tag{12}$$

where

- PA_{stb}—the amount of the omitted (penalty) payment.

As mentioned, there are two conditions for a partial or a full liquidation to occur: missed contract payments or market shocks. When any of these events occurs and a set depreciation threshold is reached, part of the LS's asset is sold in order to bring it to a sustainable state.

At the opening of the contracts for the current day, LL^t_{stb} for each contract is calculated and the following rule applies:

If $LL^t_{stb} \geq \frac{LL_{max}\%}{100} \cdot LA^t_{stb}$, it indicates that $LL^t_{stb} \geq LL_{max}$; then, the liquidation amount in stable at the current moment (LQA^t_{stb}) is calculated and the amount is stored in a specific structure of the protocol.

The following formula is used to define LQA^t_{stb} and the smaller of the following two values is taken:

$$LQA^t_{stb} = min(LA^t_{stb}, \left(LL^t_{stb} - \frac{LL_{health}\%}{100} \cdot LA^t_{stb} \right) / (1 - \frac{LL_{health}\%}{100})), \tag{13}$$

where

- LQA^t_{stb}—liquidation amount for a given time in stable: the amount in stable by which the LA^t_{stb} should be reduced after the partial liquidation for the current time.

2.2.2. Liquidation Type 2: Full Liquidation

If $LQA^t_{stb} = LA^t_{stb}$, then a full liquidation is enforced.

After all liquidations past time for the totally liquidated contracts are removed, a liquidation record is created and a closing record for each fully liquidated contract is created.

2.2.3. Liquidation Type 3: Partial Liquidation

If $LQA^t_{stb} < LA^t_{stb}$, then a partial liquidation is enforced.

LA^t_{stb} after the partial liquidation is calculated as follows:

$$LA^t_{stb} = LA^{t-1}_{stb} - LQA^t_{stb}, \tag{14}$$

After that, LSI^t_{stb}, representing the current interest standing at any given time, is also reduced in compliance with the new parameters of the smart contract.

2.3. Event: Total Value Locked

Total Value Locked is a crucial metric in the decentralized finance (DeFi) ecosystem, representing the total amount of assets locked in a specific protocol or across multiple protocols. It provides valuable insights into the protocol's performance and helps investors, users, and the wider community make informed decisions in the rapidly evolving DeFi landscape. According to the empirical evidence presented by (Maouchi et al. 2022), TVL can be used to evaluate DeFi tokens and monitor the market, and can be used as an indicator of the growth and success of that market (Şoiman et al. 2022).

In (Saengchote 2021), the author provides insights into the potential significance of TVL in DeFi and emphasizes the intricate nature of DeFi analysis and market monitoring. The author highlights that TVL is determined by the market value of tokens that are deposited or locked within the system, which inherently makes it sensitive to token prices. Consequently, there is an anticipated notable correlation between this variable and valuations. The study of (Metelski and Sobieraj 2022) aims to assess key DeFi performance metrics, particularly focusing on protocol valuations. Through a quantitative analysis of 30 selected protocols

across decentralized exchanges, lending, and asset management classes, the research explores relationships between protocol valuations and variables such as Total Value Locked (TVL), protocol revenue, total revenue, gross merchandise volume, and the inflation factor. Utilizing Granger causality tests and fixed effects panel regression models, the study reveals that DeFi protocol valuations exhibit dependencies on various performance measures, with distinct magnitudes and directions for different variables.

The significance of TVL can be found in several directions:

- Measure of protocol adoption: TVL provides a measure of the level of adoption and acceptance of a DeFi protocol. A higher TVL indicates that more users are trusting and utilize the protocol to lock their assets, which demonstrates confidence in its security, functionality, and potential returns.
- Indicator of liquidity: TVL serves as an indicator of the liquidity available within a protocol. Higher TVL implies a deeper pool of assets, which enhances trading efficiency, reduces slippage, and attracts more participants to engage in transactions.
- Market perception and reputation: TVL plays a role in shaping the market perception and reputation of the DeFi protocol. A protocol with a substantial TVL is often seen as more reputable, reliable, and trustworthy by users, investors, and the wider DeFi community. This can attract further adoption and partnerships, enhancing the protocol's long-term sustainability.
- Comparative analysis: TVL allows for comparative analysis among different DeFi protocols. By assessing TVL across various platforms, investors and users can evaluate the relative popularity and growth potential of protocols, aiding in investment decision making and identifying emerging trends in the DeFi space.
- Protocol governance and influence: TVL often influences the governance power within a DeFi protocol. Some protocols allocate voting power based on the amount of assets locked, giving higher TVL participants a stronger voice in decision-making processes. This aligns the interests of token holders with the protocol's development and ensures the protocol evolves in a way that benefits the majority of participants.

The definition of TVL in the protocol is the following:

$$TVL^t = CDA^t_{stb} - CW^t_{stb} + CLSI^t_{stb}, \quad (15)$$

where

- CDA^t_{stb}—the cumulative deposited amount in the platform for the current time in stable;
- CW^t_{stb}—the total amount of withdrawals of LPs from the platform for the current time, together with the corresponding LP interest;
- $CLSI^t_{stb}$—the accumulated interest from LSs in the platform for the current time.

2.4. Event: NLS Price Definition

The price of the NLS tokens should be simulated as there is no historical information. It is formed of two components: the market price of the NLS and the impact of the protocol's performance on the price. These two components are taken in a specified proportion and the final price of NLS is calculated.

The first component is a representation of the historical price of the currencies that participate in the platform, taken in a specific proportion.

The second component that participates in the formation of the final price of NLS tokens is the work of the protocol itself. To determine the influence of the platform on the level of the price of NLS tokens, the Total Value Locked is used.

This process is implemented in the following steps:

1. The ratio between the current value of all assets locked in the platform, calculated in stablecoins, and the total value of assets from the previous moment, is determined as follows:

$$\Delta TVL\ \% = \frac{TVL^{t-1}}{TVL^{t}}, \tag{16}$$

where

- TVL^{t}—the TVL of the pool's native asset, calculated in stable for a specific time;
- TVL^{t-1}—the TVL of the pool's native asset, calculated in stable for a previous time.

2. The proportion in which the two components will participate in forming the final price of the currency is determined.
3. The final price, taking into account both the market price and the impact of the platform over the price of the NOLUS tokens, is calculated according to the formula:

$$P_{nls}^{t} = MP_{nls} \cdot w_m + P_{nls}^{t-1} \cdot (1 - w_m) \cdot \Delta TVL\ \%, \tag{17}$$

where

- P_{nls}^{t}—the price of NLS tokens for the current timestamp;
- MP_{nls}—the market price of NLS tokens;
- w_m—the weight of the market price;
- $(1 - w_m)$—the weight of the platform;
- P_{nls}^{t-1}—the price of NLS tokens for the previous timestamp.

2.5. LP Rewards Distribution

The Treasury is a part of the protocol where the profit from the work of the protocol is stored. In the beginning it is provided that there is an initial investment in the Treasury in the form of NLS tokens, which will ensure the necessity of having some funds in case any LP withdraws their deposit earlier, when the profit of the Treasury is not enough.

There are three cash inflows into the Treasury:

1. Transaction fees, paid by both LSs and LPs, charged for each transaction

For the purposes of the simulation of the protocol, it is assumed that each LS and LP will pay a predefined number of transactions every month, so the total value of all transaction fees for the platform per month is calculated as follows:

$$TRNF = c_{ls} \cdot TR_{ls} \cdot P_{trn} + c_{lp} \cdot TR_{lp} \cdot P_{trn}, \tag{18}$$

where

- $TRNF$—total transaction fees;
- TR_{ls}—the number of transactions made by each LS per month, predefined in the config file;
- TR_{lp}—the number of transactions made by each LP per month, predefined in the config file;
- c_{ls}—the number of opened LS contracts per month;
- c_{lp}—the number of opened LP deposits per month;
- P_{trn}—the transaction price for each transaction in stable, predefined in the config file.

2. SWAP fees—a one-time fee paid by each LS upon conclusion of the smart contract, predefined in the config file as a percent from the LS loan amount in stable:

$$SWAP = LA_{stb}^{t=0} \cdot sw, \tag{19}$$

where

- $LA_{stb}^{t=0}$—LS loan amount in stable at the opening of the contract;
- sw—a predefined percent in the config.

3. Treasury interest (TRI)—A predefined part of the interest paid by LSs

The cash outflow from the Treasury, which leads to a decrease in the accumulated funds in the Treasury, is the distribution of rewards to the LPs. These rewards are distributed among all LPs based on their percentage contribution to the pools on a daily basis.

The total amount of rewards per pool that are distributed among all LPs for a particular pool daily due to the initially deposited amount by each LP is calculated as follows:

$$TRR^t_{stb} = \frac{TVL^t_{pool} \cdot trw}{365}, \tag{20}$$

where

- TRR^t_{stb}—Treasury rewards: the total amount of rewards per pool distributed among all LPs on a daily basis;
- trw—preliminary defined percentages of rewards per pool;
- TVL^t_{pool}—TVL per pool at the current time of the spread.

trw represents preliminary defined percentages that determine the relationship between the amount of TVL for all pools and the percentage of rewards for LPs. This relationship indicates the percentage of the TVL that will be distributed among the LPs. This value is extracted from the available funds in the Treasury and used for buyback of NLS tokens that will be spread among the LPs through rewards.

The rewards that each LP will receive from the Treasury daily are calculated as a percentage of all rewards that will be distributed among all LPs from the respective pool for the current day. This percentage depends on the amount of the deposit with which the respective LP participates in the specific pool, relative to the total deposited amount of all contracts for the current time for the pool in stable. After the individual percent for each LP is calculated, the amount of the rewards for the current day for each LP is determined.

In this way, the total cash inflow and outflow from the work of the protocol is stored in the Treasury and can be represented as follows:

$$TRP^t_{stb} = TRNF^t_{stb} + SWAP^t_{stb} + TRI^t_{stb} - TRRD^t_{stb}, \tag{21}$$

where

- TRP^t_{stb}—Treasury profit, being the amount entered in the Treasury on a daily basis in stable;
- $TRNF^t_{stb}$—total transaction fees on a daily basis in stable;
- $SWAP^t_{stb}$—SWAP fees on a daily basis in stable;
- TRI^t_{stb}—the Treasury interest on a daily basis in stable;
- $TRRD^t_{stb}$—Treasury rewards in stable that should be distributed among all LPs on a daily basis in stable.

The current state of the Treasury is recorded in stable in a specific structure, namely, NLS, which appears to be a cumulative table indicating the available funds in the Treasury at the current time, according to the following formula:

$$TRA^t_{stb} = TRA^{t-1}_{stb} + TRP^t_{stb} - TRRD^{t-1}_{stb} \tag{22}$$

An important feature of the platform, related to the distribution of rewards to the LPs from the protocol, is the established mechanism, which ensures that, if for a specific day there is not a sufficient number of tokens in the Treasury to be distributed among all LPs, then for the corresponding day no rewards are distributed.

3. Dynamic Performance Simulation Based on Historical Crypto Market Behavior

3.1. Research Methodology

Expanding the model detailed in the previous section, a comprehensive simulation of the NOLUS protocol is conducted, utilizing the actual protocol as a basis. This simulation spans a historical timeframe of three years, from 1 February 2020 to 31 January 2023,

capturing a diverse range of market conditions. In this simulation, the pricing dynamics of the NOLUS protocol currency are intricately tied to various currencies, with differential weights assigned based on their influence in the broader crypto market. Notably, primary currencies, particularly wrapped bitcoin, wield substantial weight due to their pronounced impact on the overall market.

During the specified period, the prices of multiple currencies were considered, each contributing to the formation of the presumed value of the NOLUS protocol currency. The proportional representation of these currencies in the simulation, presented in Table 1, holds significance, reflecting their varying impacts on the NOLUS protocol's valuation.

Table 1. Participation of different cryptocurrencies in forming the market price of NOLUS tokens.

Currency	Proportion in the Final Price
wrapped-bitcoin	0.250
weth	0.150
binancecoin	0.100
avalanche-2	0.060
cosmos	0.050
injective-protocol	0.050
band-protocol	0.050
kava	0.040
juno-network	0.040
osmosis	0.040
secret	0.040
akash-network	0.040
crypto-com-chain	0.030
stargaze	0.030
sentinel	0.030

In order to simulate the expected behavior of the market for carrying out the present simulation, hypotheses are also set for a number of variables, including the number of participants in the platform, the duration and size of loan contracts, the duration and size of deposits, and the number and size of delays of contract payments. The F-distribution is used to generate these variables, as it best represents the expectations for the distribution of their values.

Each of these variables is set to be a hyper parameter of the simulation model, enabling researchers to fine tune their values. This also provides the opportunity to simulate various environmental effects that impact the work of the platform, on one hand, and to modify the parameters of the platform itself. This model makes it possible to simulate structural changes or regime shift type of behavior. Based on these assumptions, the anticipated performance of the protocol during the simulated period is presented in the following subsections of the article.

3.2. Simulation of Dynamic Operational Performance

This section provides an exposition of the simulation outcomes based on the initially defined parameters and presumed hypotheses. The visual representations in the form of graphs for each variable offer a clear demonstration that the anticipated interaction mechanisms among distinct variables accurately align with the preconceived expectations.

3.2.1. Interest Rates

The interest rate within the platform is dynamic, contingent upon the prevailing state of the platform and market conditions at each timestamp. With a surge in the number of LPs, a substantial reservoir of available funds emerges in the pools, consequently mitigating the expense for new LSs seeking to borrow assets from the platform. This results in a decreased interest rate for these newly introduced LSs, leading to a corresponding reduction in the interest rates earned by recently enrolled LPs.

From Figure 1, it can be seen that the expected relationship between LP and LS interest rates is satisfied and they are change correctly depending on the Pool Utilization Rate. As the Utilization Rate per pool increases, the interest rates for both LSs and LPs also increase.

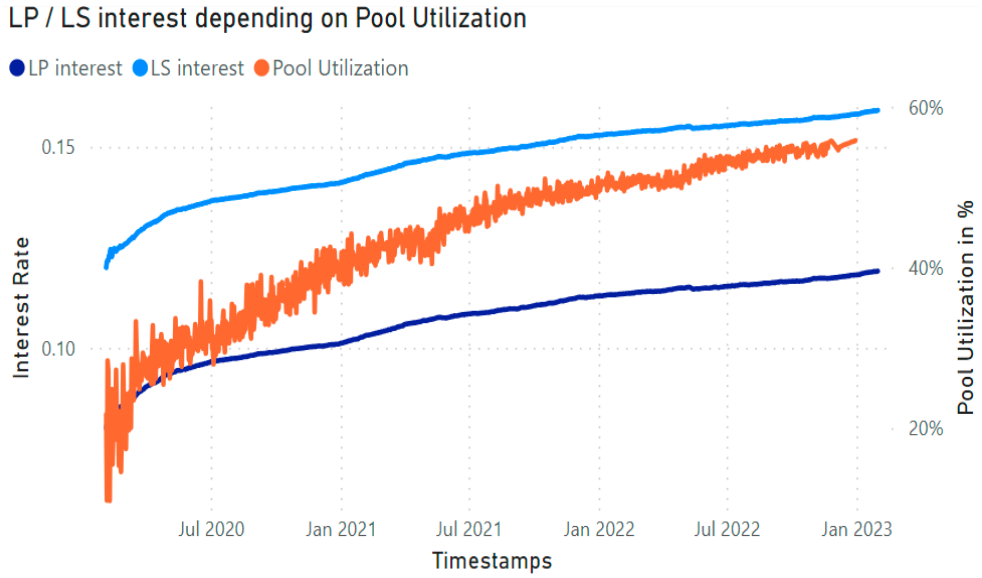

Figure 1. Interest rate depending on Pool Utilization.

In Figure 2, it can be seen that the established mechanism for changing the number of LP and LS contracts depending on the change in the interest rate functions properly. It is noticeable that over time and with a smooth and continuous increase in interest rates, the number of LPs exceeds the number of LSs. On the one hand, an increase in the interest rates leads to an increase in the number of LPs over time, as increased interest rates attract more and more LPs. At the same time, rising interest rates cause a slight decline in LS contracts, as the cost of borrowing becomes higher at higher interest rates.

In the current simulation, the maximum utilization of the funds from the pools is not reached and therefore there the opening of new contracts does not terminate. In subsequent articles, this functionality will be demonstrated by running various MC simulations.

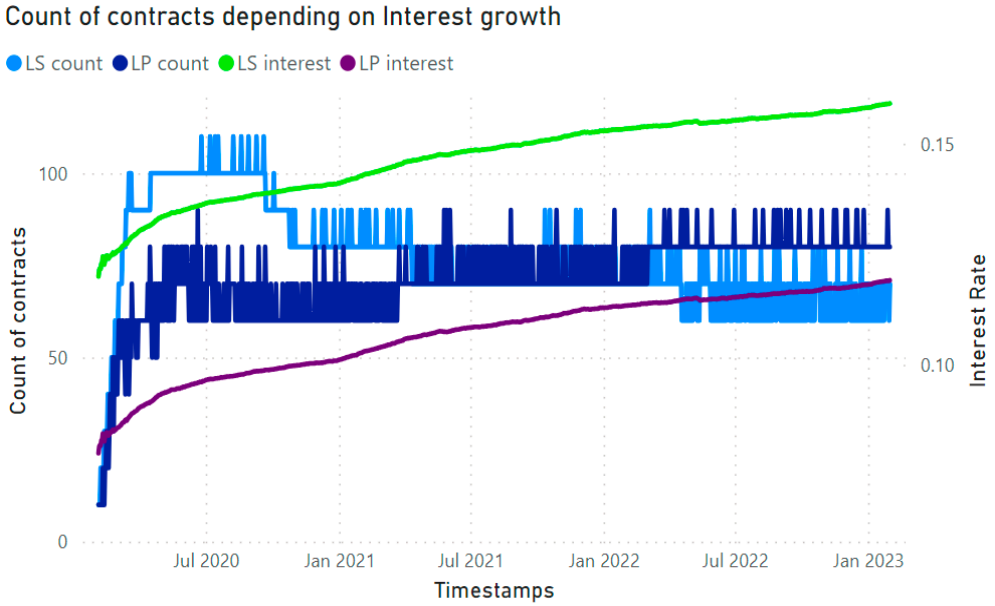

Figure 2. Count of LS and LP contracts depending on interest rate.

3.2.2. Repayment of Loans

The repayment process in smart contracts is usually automated and executed based on the terms agreed upon at the time of borrowing. Once the borrower fulfills their repayment obligations, the smart contract releases the collateral held as security back to the borrower, and the loan is considered fully repaid.

Regular Payments

Figure 3 shows an example of a smart contract with only regular payments, demonstrating that the underlying mechanisms in the protocol are met. This particular contract has five regular payments. This can be seen on the bottom of Figure 3, represented by Liquidation Type: 1, and it indicates that the Lease Liability decreases in accordance with the repayments made. Since the ratio between the obligations under the contract and the value of the contract does not exceed the healthy levels, partial liquidation (in the sense of penalty payments) and full liquidation are therefore not required. Moreover, the market price of the asset is consistent, which indicates that in stable or favorable market conditions, penalty liquidations are not common or necessary. At the end of the period, the contract is fully repaid.

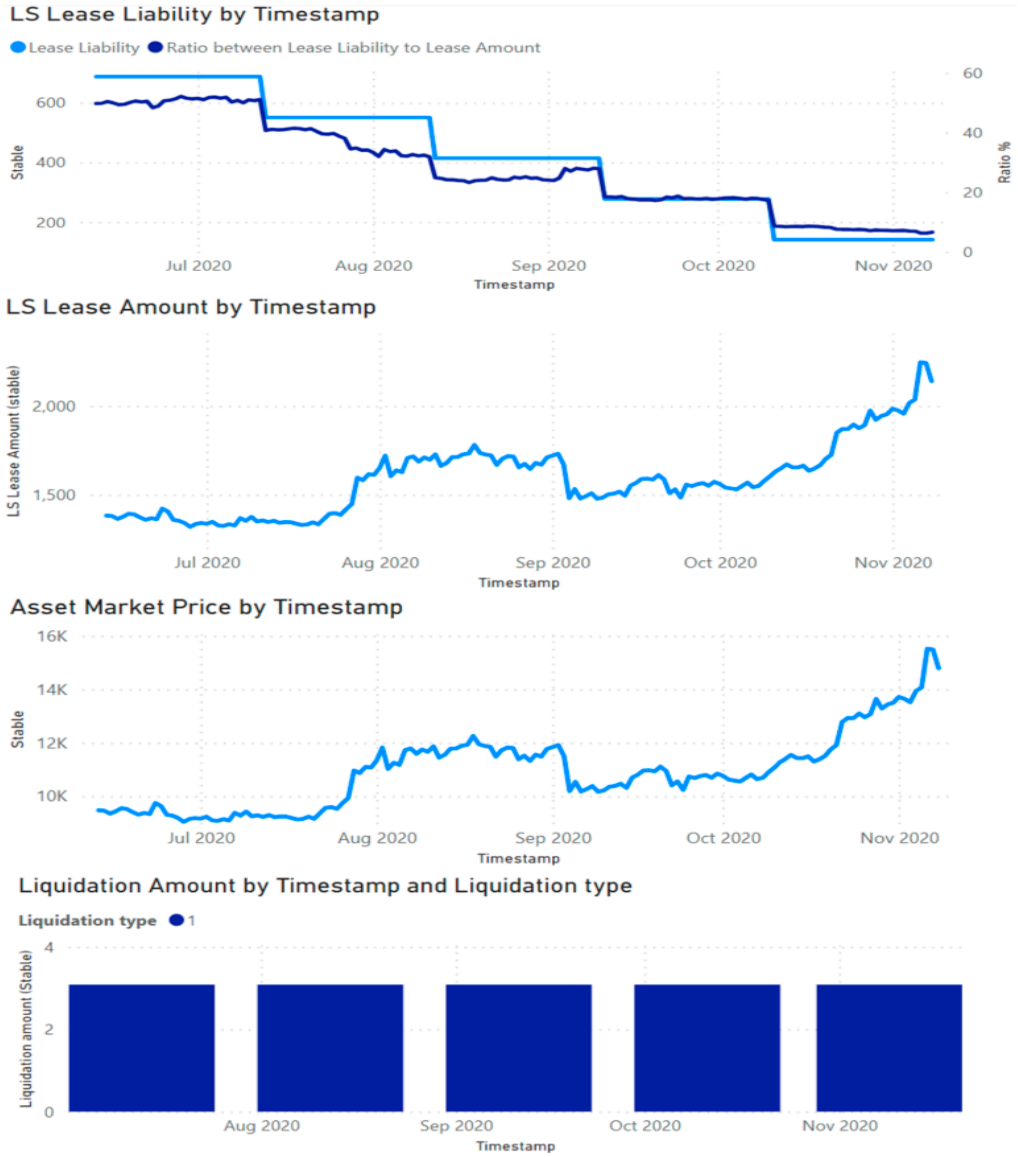

Figure 3. Repayment of loans. An example of regular payments.

Partial and Full Liquidation

Figure 4 shows an example of a contract in which events occur that lead initially to a partial liquidation and subsequently to a full liquidation of the contract. It is noticed that on the 13 March 2020 there is a collapse in the market, due to which the loan amount loses its monetary value (lease amount), pushing the smart contract close to the preliminarily determined critical healthy levels. Therefore, a partial liquidation occurs, represented by Liquidation Type: 3, as part of the smart contract is liquidated, reducing the liability of the smart contract back to healthy levels. The liquidation amount is determined by Liquidation Amount (formula number 13). Subsequently, on 15 March 2020 the conditions for partial liquidation occur again and a second partial liquidation is fulfilled. As a result, the conditions for full liquidation also occur and on 16 March 2020 the contract is fully liquidated (represented by Liquidation Type: 2).

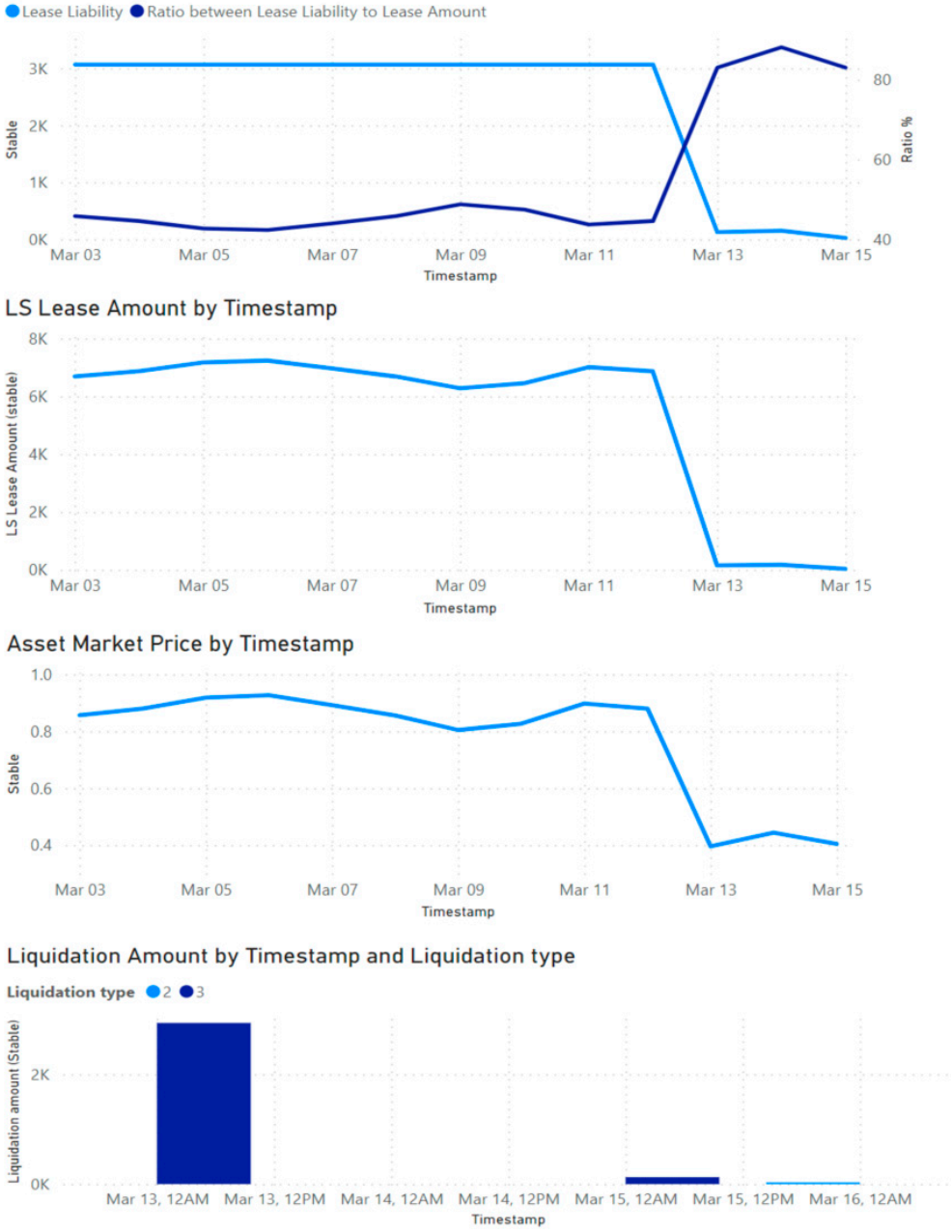

Figure 4. Repayment of loans. An example of partial and full liquidation.

3.2.3. Total Value Locked

Within the NOLUS protocol, TVL serves as a determinant influencing both the NLS price and the platform's interest rate. The anticipation is that a higher value of funds locked in the platform enhances the protocol's appeal. Consequently, this is anticipated to result in elevated interest rates and a simultaneous increase in the value of NLS tokens.

Figure 5 shows the state of the platform in terms of funds locked in the protocol for the simulated period. It is noticed that in the beginning of the period there is an increase in TVL because of the expected enhanced interest in the protocol, and subsequently, the levels are established at a plateau, with a slight increase over time.

In subsequent articles, various Monte Carlo simulations will be carried out, through which it is expected to determine how TVL will change under various assumptions, both in terms of conditions external to the platform, such as economic conditions and the financial services market in particular, and those internal to the platform, such as the number of participants and interest rates.

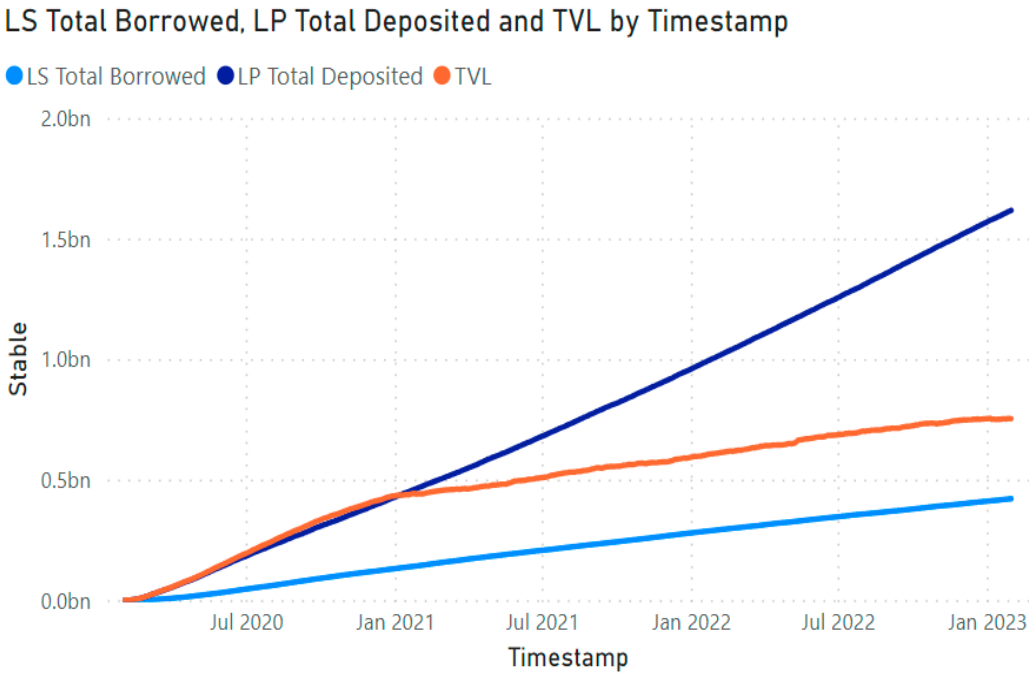

Figure 5. Status of funds in the platform.

3.2.4. NLS Price Definition

The components of the NOLUS price, described in Section 2.4. Event: NLS Price Definition, are the simulated market price of the NLS and the impact of the protocol's performance.

Figure 6 presents the prices of cryptocurrencies that participate in the formation of the market component of NOLUS tokens for the selected period from 1 February 2020 to 31 January 2023, according to the proportions described in Section 3.2. Research Methodology.

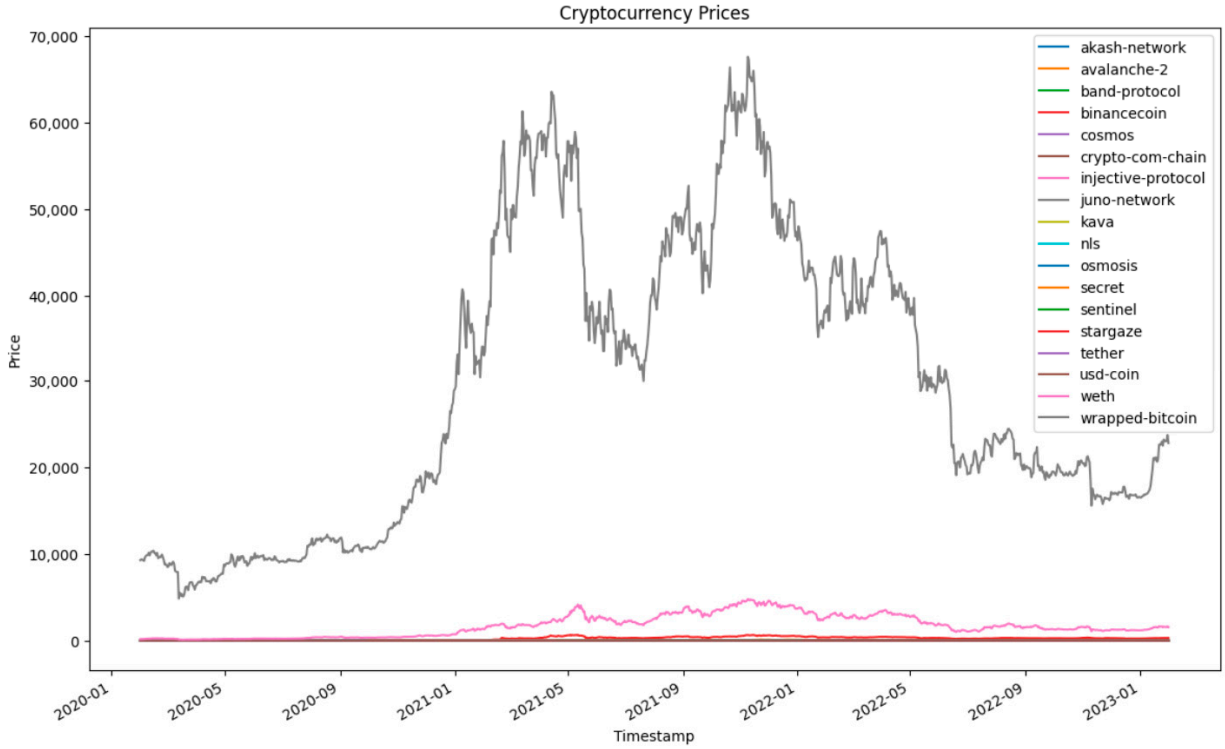

Figure 6. Cryptocurrencies that participate in the formation of the NOLUS price.

Figure 7 presents the movement of the NLS price for the period of the simulation of the operation of the protocol.

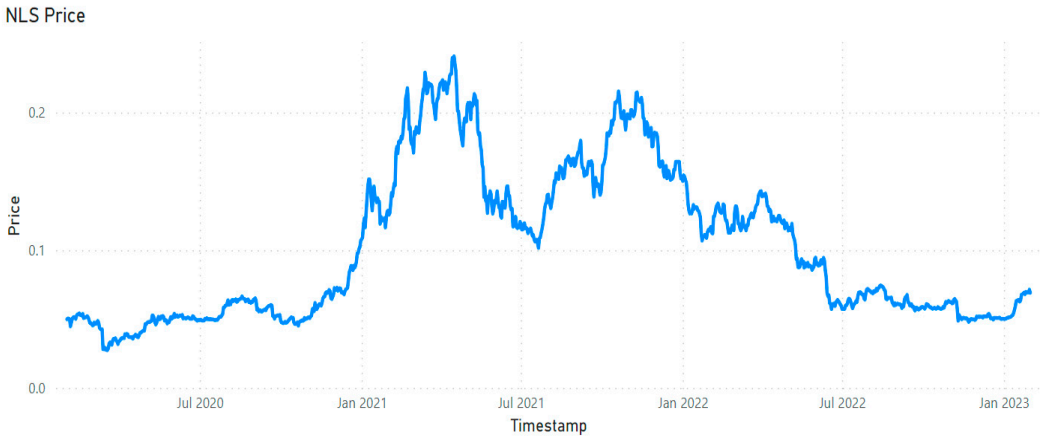

Figure 7. NLS price by timestamp.

It is observed that the NOLUS price movement closely aligns with the collective movement of all considered currencies, with a notable emphasis on the movement of wrapped bitcoin. This emphasis is justified by the prominent role of wrapped bitcoin in the broader crypto market, acting as a key indicator and influencing factor. Wrapped bitcoin, being a representative token pegged to the value of bitcoin, holds a pivotal position, affecting market sentiments and contributing to the overall price dynamics of the NOLUS protocol.

3.2.5. Rewards Distribution

From Figure 8, it can be seen how the funds available in the Treasury, presented both in assets and in stable, change over time. It is noticed that at the beginning of the

protocol's work until about the middle of the second year, as a result of the large number of accumulated funds in the platform, rewards are distributed every day. After the middle of the second year, the level of funds in the Treasury is depleted due to distributing large rewards at the beginning, as a result of which such rewards are spread inconsistently every other day when enough funds are accumulated in the Treasury to cover the amount of all necessary rewards.

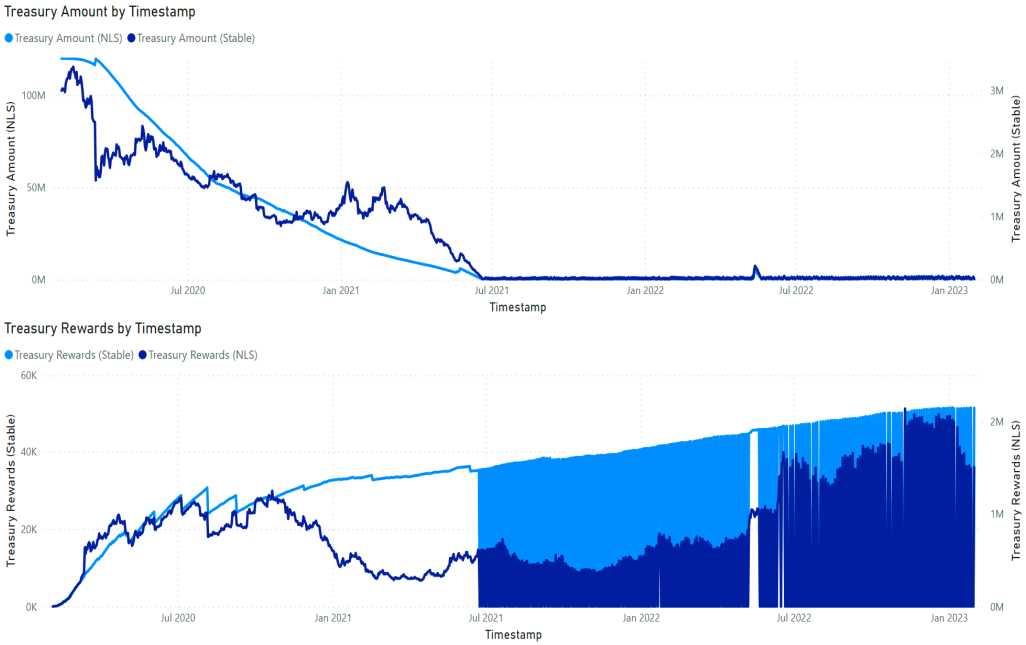

Figure 8. Treasury amount and Treasury rewards by timestamp.

Moreover, it is observed from Figure 9 that with the temporary increase in Treasury profit towards the middle of the third year, for a short period of time the funds in the Treasury are enough to cover all the required rewards; therefore, for a short period, the rewards are distributed daily.

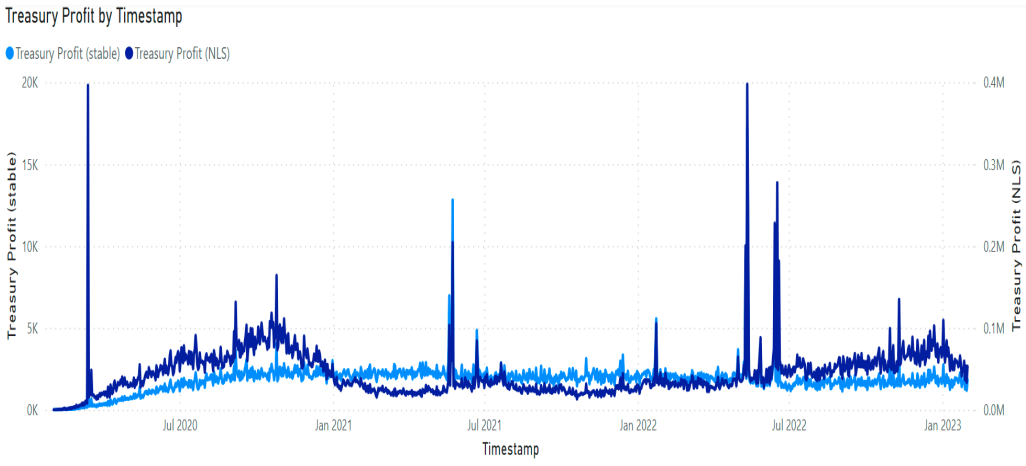

Figure 9. Treasury profit by timestamp.

4. Conclusions

In conclusion, the simulation of the NOLUS protocol presented in this paper marks a significant stride toward comprehending the intricate interplay between decentralized finance protocols and the broader crypto market landscape. By harnessing historical crypto market data, we have effectively simulated the dynamic behavior of the NOLUS protocol.

The article explores several prominent DeFi protocols within the broader cryptocurrency market, with a specific focus on comparing the NOLUS platform, introduced in the article, to these established protocols. It provides an elaborate description of the developed software model that mimics the real protocol, delving into the core dependencies among its components. The article thoroughly examines the fundamental interdependencies among the various elements constituting the NOLUS protocol. Through a series of carefully conducted experiments, the platform's functionality is scrutinized, utilizing predetermined values for numerous simulation parameters. The outcomes of these experiments affirm that the constructed model effectively mirrors the intricacies of the actual platform, presenting a highly accurate representation.

This simulation methodology has the potential to uncover critical protocol behaviors caused by potential crypto market dynamics, identify optimization opportunities, and highlight best practices for adjustment of the key protocol hyper parameters. As the DeFi ecosystem continues to evolve, these insights will prove instrumental in fostering a robust and sustainable DeFi landscape.

The simulation presented in this article is a one-time implementation of the actual DeFi platform NOLUS. As it involves numerous random factors and is based on certain assumptions about their distribution, this singular simulation is constrained by the initial hypotheses. Concurrently, historical cryptocurrency price data spanning three years was employed to replicate the platform's behavior, intending to illustrate its hypothetical performance over that period. Recognizing these constraints, it is important to note that a detailed simulation of every operational aspect of the real platform might not be feasible. However, utilizing the developed model, which encapsulates the platform's embedded mechanisms, and conducting multiple simulations, could facilitate a more profound analysis of the protocol.

The implications of this research extend beyond the immediate scope of the study. Building upon the insights gained from this simulation, our intention is to employ a Monte Carlo simulation framework to explore a variety of different scenarios. This approach will allow us to systematically assess the protocol's performance across a spectrum of potential market events, encompassing periods of stability as well as heightened volatility. The deployment of multiple Monte Carlo simulations aligns with our goal to provide a more comprehensive and holistic understanding of the NOLUS protocol's behavior. Such simulations enable us to project its performance under conditions that mimic real-world market dynamics, serving as a valuable tool for risk assessment, strategic decision making, and scenario planning.

The subsequent stages of conducting multiple Monte Carlo simulations for diverse scenarios will be published in upcoming articles and hold the promise of enhancing our understanding of DeFi protocols' dynamic performance and fortifying their resilience against the complexities of the crypto market. As we venture forward, we are poised to contribute to the ongoing discourse on the intricacies of DeFi, while equipping stakeholders with the knowledge needed to navigate this innovative financial frontier.

Supplementary Materials: The model of the platform is published in GitHub: https://github.com/nolus-protocol/mc-nolus (accessed on 20 December 2023).

Author Contributions: Conceptualization A.E.; data curation, A.K. and R.M.; methodology, A.E.; software, A.K. and R.M.; validation, A.K., I.G. and A.E.; funding acquisition, A.E.; formal analysis, A.K., I.G. and A.E.; investigation, A.K. and I.G.; writing—original draft preparation, I.G. and A.K.; writing—review and editing, A.E. and I.G.; visualization, A.K. and I.G.; supervision, A.E. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: To generate the simulated price of NLS tokens, the real prices of the currencies mentioned in the article were used, gathered from the following web site: https://www.coingecko.com (accessed on 20 December 2023).

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