FinTech

Special Issue Reprint

Financial Technology and Innovation Sustainable Development

Edited by
Otilia Manta, Mohammed K. A. Kaabar, Eglantina Hysa,
Ovidiu Folcuț and Anuradha Iddagoda

mdpi.com/journal/fintech

MDPI

Financial Technology and Innovation Sustainable Development

Financial Technology and Innovation Sustainable Development

Editors

Otilia Manta
Mohammed K. A. Kaabar
Eglantina Hysa
Ovidiu Folcuţ
Anuradha Iddagoda

MDPI

Basel • Beijing • Wuhan • Barcelona • Belgrade • Novi Sad • Cluj • Manchester

Editors
Otilia Manta
Center for Financial and Monetary Research "Victor Slavescu", and CE-MONT
Romanian Academy,
Bucharest
Romania

Mohammed K. A. Kaabar
Chinese Institute of Electric Power
Samarkand International University of Technology
Samarkand
Uzbekistan

Eglantina Hysa
Department of Economics
Epoka University
Tirana
Albania

Ovidiu Folcuţ
Department of Trade, Economic Integration and Business Administration
Romanian-American University
Bucharest
Romania

Anuradha Iddagoda
Management Science Unit, Faculty of Applied Sciences
University of Sri Jayewardenepura
Nugegoda
Sri Lanka

Editorial Office
MDPI AG
Grosspeteranlage 5
4052 Basel, Switzerland

This is a reprint of articles from the Special Issue published online in the open access journal *FinTech* (ISSN 2674-1032) (available at: https://www.mdpi.com/journal/fintech/special_issues/59RZMG405X).

For citation purposes, cite each article independently as indicated on the article page online and as indicated below:

Lastname, A.A.; Lastname, B.B. Article Title. *Journal Name* **Year**, *Volume Number*, Page Range.

ISBN 978-3-7258-2121-1 (Hbk)
ISBN 978-3-7258-2122-8 (PDF)
doi.org/10.3390/books978-3-7258-2122-8

Contents

About the Editors . . . . **vii**

Preface . . . . **ix**

Otilia Manta
Financial Technology and Innovation for Sustainable Development
Reprinted from: *FinTech* **2024**, *3*, 23, doi:10.3390/fintech3030023 . . . . **1**

Fábio Albuquerque and Paula Gomes Dos Santos
Recent Trends in Accounting and Information System Research: A Literature Review Using Textual Analysis Tools
Reprinted from: *FinTech* **2023**, *2*, 15, doi:10.3390/fintech2020015 . . . . **4**

Tao Zhu and Xinyu Sun
Enterprise Financialization and Technological Innovation: An Empirical Study Based on A-Share Listed Companies Quoted on Shanghai and Shenzhen Stock Exchange
Reprinted from: *FinTech* **2023**, *2*, 16, doi:10.3390/fintech2020016 . . . . **31**

Dora Almeida, Andreia Dionísio, Paulo Ferreira and Isabel Vieira
Impact of the COVID-19 Pandemic on Cryptocurrency Markets: A DCCA Analysis
Reprinted from: *FinTech* **2023**, *2*, 17, doi:10.3390/fintech2020017 . . . . **50**

Sunhilde Cuc
Unlocking the Potential of Blockchain Technology in the Textile and Fashion Industry
Reprinted from: *FinTech* **2023**, *2*, 18, doi:10.3390/fintech2020018 . . . . **67**

Sonia Kherbachi
Digital Economy under Fintech Scope: Evidence from African Investment
Reprinted from: *FinTech* **2023**, *2*, 27, doi:10.3390/fintech2030027 . . . . **83**

Bernhard Koelmel, Max Borsch, Rebecca Bulander, Lukas Waidelich, Tanja Brugger, Ansgar Kuehn, et al.
Quantifying the Economic and Financial Viability of NB-IoT and LoRaWAN Technologies: A Comprehensive Life Cycle Cost Analysis Using Pragmatic Computational Tools
Reprinted from: *FinTech* **2023**, *2*, 29, doi:10.3390/fintech2030029 . . . . **92**

Hiranya Dissanayake, Catalin Popescu and Anuradha Iddagoda
A Bibliometric Analysis of Financial Technology: Unveiling the Research Landscape
Reprinted from: *FinTech* **2023**, *2*, 30, doi:10.3390/fintech2030030 . . . . **109**

Aurel Burciu, Rozalia Kicsi, Simona Buta, Mihaela State, Iulia Burlac, Denisa Alexandra Chifan and Beatrice Ipsalat
The Study of the Relationship among GCI, GII, Disruptive Technology, and Social Innovations in MNCs: How Do We Evaluate Financial Innovations Made by Firms? A Preliminary Inquiry
Reprinted from: *FinTech* **2023**, *2*, 33, doi:10.3390/fintech2030033 . . . . **125**

Medina Ayta Mohammed, Carmen De-Pablos-Heredero and José Luis Montes Botella
The Role of Financial Sanctions and Financial Development Factors on Central Bank Digital Currency Implementation
Reprinted from: *FinTech* **2024**, *3*, 9, doi:10.3390/fintech3010009 . . . . **167**

Otilia Manta and Maria Palazzo
Transforming Financial Systems: The Role of Time Banking in Promoting Community Collaboration and Equitable Wealth Distribution
Reprinted from: *FinTech* **2024**, *3*, 22, doi:10.3390/fintech3030022 . . . . **183**

About the Editors

Otilia Manta

I am an active member of the International Engineering and Technology Institute (IETI) and serve on various international academic boards, holding the esteemed titles of Professor PhD, Doctor of Economics (Finance), and Scientific Researcher of the Romanian Academy. I am also a Professor PhD in Fintech at the Romanian-American University. With over 25 years of experience in financial and banking consulting, EU project management, and scientific research across multidisciplinary fields, I have established myself as a leading authority in International Financial Relations, FinTech, and Entrepreneurship.

As an Evaluation Expert and Rapporteur for EU Projects, I specialize in investment projects, capacity building, and sustainable development at both local and global scales. Additionally, I have founded companies and NGOs, demonstrating my commitment to advancing societal well-being through innovative financial instruments and projects.

Throughout my career, I have authored various books, scientific papers, and articles published in international journals, and have served as both publisher and editor. I am also recognized as an international reviewer, contributing to the advancement of knowledge in various fields.

My academic and professional endeavors have focused on the development of innovative financial tools and interactive learning methodologies, particularly in the realm of FinTech. I have also been instrumental in the creation of intelligent learning environments aimed at enhancing financial literacy and fostering societal well-being through projects addressing financial technologies and insurance, innovative financial instruments, and other critical areas. Additionally, I have supervised many MSc students working on their theses.

Mohammed K. A. Kaabar

Prof. Mohammed K. A. Kaabar received his undergraduate and graduate degrees in Mathematics from Washington State University (WSU), WA, United States. Kaabar is a Palestinian mathematician, but he was born in Fujairah in the United Arab Emirates. He also completed several distance education programs and STEM and leadership courses offered by Harvard University, MIT, EPFL, University of Michigan, UC Berkeley, University of Toronto, University of Rochester, and University of British Colombia. He has a diverse cultural and educational experience, having visited various beautiful countries such as the USA, Canada, Malaysia, Singapore, and Indonesia. He has worked as an adjunct math professor at Moreno Valley College, CA, USA, and he also previously worked as a lab instructor and math tutor at WSU. He is the author of two mathematics books, and his research interests include fractional differential equations, applied mathematics, math education, data science and analysis, STEM education, and educational leadership. He is an invited Technical Program Committee (TPC) member for several conferences in applied mathematics and engineering indexed by IEEE Xplore and SCOPUS/ISI/Web of Science and held in several countries such as the USA, Italy, Canada, Spain, France, Taiwan, UK, Indonesia, Kazakhstan, Malaysia, India, UAE, Tunisia, Morocco, Jordan, and Bahrain. He is a former editor for the American Mathematical Society (AMS) Blog, and he is also a member of the math editorial board at Multimedia Educational Resource for Learning and Online Teaching (MERLOT) at California State University. He is currently serving as an associate editor for Bulletin of Electrical Engineering and Informatics (BEEI) and IAES International Journal of Robotics and Automation (IJRA). He is also a member of the expert editorial advisory board for the forthcoming Big Data and Advanced Wireless Technologies series to be published by Springer.

Eglantina Hysa

Professor Eglantina Hysa, a seasoned senior lecturer and experienced researcher of development economics, has been actively contributing to the field of higher education for around twenty years. Her body of work includes numerous scholarly publications, such as book chapters and technical reports, which have been featured by esteemed international journals and publishing houses like the Journal of Applied Economics, Cogent Economics and Finance, and Routledge. In addition to her research endeavors, she has been an integral part of various EU projects as a Bologna System expert for higher education. Furthermore, she has served as an expert evaluator for prestigious programs such as Horizon 2020/Europe and Erasmus+, while also being an International Expert in several European Accreditation Agencies for Higher Education.

She is a highly experienced and certified professional, with more than 15 years of experience in innovation and business consultancy, with a comprehensive background in business models with particular focus on strategy and business development, KPIs analysis, lifecycle management, digital economy, and sustainability. Additionally, she has extensive management experience, and has directed cross-functional teams, research groups, NGOs, and international projects.

Ovidiu Folcuţ

From 1997 to the present, Ovidiu Folcut held a range of positions, working as a teaching assistant, lecturer, associate professor, and finally, full professor at Romanian-American University. From 2001 to 2002, Ovidiu worked as a teaching assistant at James Madison University, and from 2008 to 2020, Ovidiu Folcut was a Rector of Romanian-American University. From 2013 to 2020, Ovidiu Folcut was Vice President of the National Council of Rectors and from 2021 to present, Ovidiu was a Member of the Consultative Commission of Romanian Agency for Quality Assurance in Higher Education. Currently, Ovidiu works as a full professor, and also holds a managerial role as the Vice President of University Senate.

In addition, Ovidiu Folcut has published 12 books and over 80 articles and scientific papers related to international trade, sustainable development, competitiveness and innovation, artificial intelligence, international business environment, ethics in business, and education, and has been a Director/Member of 14 research projects.

Anuradha Iddagoda

Dr. Anuradha Iddagoda is a PhD holder from the University of Sri Jayewardenepura Sri Lanka and a Human Resources researcher, whose current focus is on 'Employee Engagement'. She completed an MBA in Human Resource Management at PIM University of Sri Jayewardenepura, and earned a Master's degree in Information Technology (MIT) and a Bachelor's degree in Information Technology (BIT) degree at Charles Sturt University, Australia.

Preface

The future of finance is unequivocally digital. As consumers and businesses alike become increasingly dependent on digital financial services, market innovators are implementing cutting-edge technologies, while existing business models are undergoing significant transformations. The intersection of finance and technology has been evident since the advent of the telegraph in 1938, which marked our entry into the era of Fintech 1.0. Since then, we have witnessed rapid technological advancements, with notable developments taking place in 2014 and 2016 with the rise of blockchain technology. Today, in the era of Fintech 5.0, the primary challenge is not only developing "sustainable technology for maintaining anonymity," but also creating digital applications that manage risks in the virtual space and prevent "virtual bank failures".

The evolution of open digital financial technologies will be marked by the automation of various services through artificial intelligence-driven applications. These innovations are expected to transform financial products and services and revolutionize the very architecture of financial markets.

In this evolving landscape, experts in finance and financial technologies play a crucial role in fostering an entrepreneurial mindset. This involves developing and providing programs dedicated to financial innovations across all levels of education and application. Entrepreneurship education in FinTech, as well as the creation of entrepreneurial programs in financial technology applications, is key to enhancing entrepreneurial orientation within the FinTech sector. Despite the growing interest, there is a need for in-depth discussion on and analysis of the role of experts in advancing digital finance. Specifically, how universities, businesses, and financial institutions can contribute through education and innovation; how to design and implement entrepreneurial financial education in the practice of innovative financial technologies; how to measure the impact of open finance, entrepreneurial finance, and digital finance; what activities should be promoted; which approaches can best stimulate financial mindsets in the current context; and the differences between countries are all critical considerations.

This Special Issue aims to provide a deeper understanding of the role of open finance, entrepreneurial finance, and digital finance, as well as digital financial technologies, in developing an entrepreneurial mindset. It explores how this mindset can be understood, promoted, and developed in the context of sustainable development at both the industry level and societal level.

The Special Issue includes the following key papers:

Albuquerque and Dos Santos offer a comprehensive review of recent trends in accounting and information systems, utilizing textual analysis tools. Their research identifies emerging topics such as sustainability and new auditing methods and provides a broad overview of the evolving landscape and potential future research directions.

Zhu and Sun investigate the impact of corporate financialization on technological innovation in China's A-share-listed companies. Their study reveals that financialization inhibits technological innovation, especially in non-state-owned enterprises and those in eastern China, and they provide various policy suggestions that could help to mitigate these effects.

Almeida et al. analyze the impact of the COVID-19 pandemic on cryptocurrency markets, showing increased market integration and contagion across short timescales. Their research demonstrates that cryptocurrencies were vulnerable to financial turbulence during the pandemic, highlighting the breakdown of correlations in times of crisis.

Cuc S. explores the transformative potential of blockchain technology in the textile and fashion industry. Their study highlights blockchain's ability to enhance supply chain transparency, traceability, and sustainability, and offers critical insights into its applications and challenges.

Kherbachi S. examines the impact of digital technology satisfaction on job satisfaction within the fintech sector in Africa and underscores the importance of aligning technology with task requirements to boost productivity and job satisfaction, providing insights for optimizing digital transformation strategies in healthcare services.

Koelmel et al. present a life cycle cost analysis of NB-IoT and LoRaWAN technologies, which are crucial for IoT applications. Their study offers a pragmatic approach to evaluating the economic and financial viability of these technologies and presents a methodology that can be applied to other IoT technologies.

Dissanayake et al. provide a bibliometric analysis of the FinTech research landscape, identifying key trends, contributors, and emerging themes. Their study serves as a roadmap for researchers and industry professionals, offering guidance for future studies and innovations.

Burciu et al. explore the role of disruptive technologies in financial innovation strategies within multinational corporations, identifying digital technologies, managerial decisions, and market forces as key drivers. This research proposes principles for continuous financial innovation in the FinTech sector.

Mohammed, De-Pablos-Heredero, and Montes Botella examine the impact of financial access, stability, and sanctions on the adoption of CBDCs across 71 countries. Their findings reveal that nations with financial sanctions or significant offshore loans are more likely to adopt CBDCs, particularly in regions with limited financial access.

Manta and Palazzo investigate the concept of time banking as an innovative financial instrument that promotes community collaboration and equitable wealth distribution. Their research highlights time banks' potential to reduce dependence on traditional currency and foster financial inclusion in an increasingly digital financial landscape.

Together, these papers will improve readers' understanding of how financial technology and innovation can drive sustainable development. The authors offer theoretical insights, practical methodologies, and policy recommendations that can influence future research, industry practices, and global financial strategies and emphasize the critical role of FinTech in shaping the future of global finance and sustainable development.

We believe that this collection will serve as a valuable resource for academics, policymakers, FinTech industry experts, and anyone interested in the intersection of education, research, and entrepreneurship in FinTech, as well as the development of entrepreneurial programs in financial technology applications. We extend our heartfelt thanks to all contributors, the FinTech Journal editorial team for their exceptional support, and the reviewers and authors for their significant contributions to the literature. Special thanks go to our fellow professors who served as editors for this Special Issue.

Otilia Manta, Mohammed K. A. Kaabar, Eglantina Hysa, Ovidiu Folcuţ, and Anuradha Iddagoda
Editors

FinTech

Editorial

Financial Technology and Innovation for Sustainable Development

Otilia Manta [1,2]

[1] Centre for Financial and Monetary Research "Victor Slăvescu", Romanian Academy, 050711 Bucharest, Romania; otilia.manta@icfm.ro
[2] Research Department, Romanian American University, 012101 Bucharest, Romania

Citation: Manta, O. Financial Technology and Innovation for Sustainable Development. *FinTech* **2024**, *3*, 424–426. https://doi.org/10.3390/fintech3030023

Received: 22 August 2024
Accepted: 23 August 2024
Published: 26 August 2024

This Special Issue on "Financial Technology and Innovation for Sustainable Development" includes a diverse collection of research papers that explore the evolving landscape of financial technologies (*FinTech*) and their implications for sustainable development. This editorial highlights the significant contributions made by the published papers, underscoring their relevance to ongoing discussions in global finance, technology, and innovation. This Special Issue contains 10 papers, which were each accepted for publication after a rigorous review process.

In Contribution 1, the authors, Albuquerque and Dos Santos, provide a literature review on recent trends in accounting and information systems using textual analysis tools. Their research identifies emerging topics in accounting, such as sustainability and new methods in auditing, offering a comprehensive overview of the evolving landscape and suggesting avenues for future research.

In Contribution 2, the authors, Zhu and Sun, investigate the impact of corporate financialization on technological innovation in China's A-share-listed companies. This study concludes that financialization tends to inhibit technological innovation, particularly in non-state-owned enterprises and those in eastern China. It also emphasizes the role of financing constraints in this dynamic, offering policy suggestions to mitigate the negative effects of financialization.

In Contribution 3, the authors, Almeida et al., analyze the impact of the COVID-19 pandemic on cryptocurrency markets, revealing increased market integration and contagion across short timescales. Their research demonstrates that cryptocurrencies did not offer protection against financial turbulence during the pandemic, providing a pertinent example of how correlations breakdown in times of crisis.

In Contribution 4, the author, Cuc S., explores the transformative potential of blockchain technology (BT) in the textile and fashion industries. This study identifies blockchain's ability to enhance transparency, traceability, and sustainability in the supply chain. Through case studies, this research underscores the increasing adoption of BT and its potential to revolutionize the industry, offering critical insights into its applications and challenges.

In Contribution 5, the author, Kherbachi S., investigates the impact of digital technology satisfaction on job satisfaction within the field of FinTech in Africa. This study highlights the importance of aligning technology with task requirements to enhance productivity and job satisfaction. The findings enhance our understanding of factors that drive the digital economy, particularly in the context of healthcare services in Africa, offering insights for optimizing digital transformation strategies.

In Contribution 6, the authors, Koelmel et al., provide a comprehensive life cycle cost analysis of NB-IoT and LoRaWAN technologies, which are pivotal for IoT applications. This study presents a pragmatic approach to evaluating the economic and financial viability of these technologies, offering a methodology that can be applied to other IoT technologies. This work is essential for decision makers considering technology adoption in the IoT.

In Contribution 7, the authors, Dissanayake et al., present a bibliometric analysis of the FinTech research landscape, identifying key trends, contributors, and emerging themes. This study serves as a roadmap for researchers and industry professionals, highlighting the intellectual structure of FinTech research and offering guidance for future studies and innovations.

In Contribution 8, the authors, Burciu et al., explore the role of disruptive technologies in financial innovation strategies within multinational corporations. The study cross-examines innovative capacities at the firm and country levels, identifying digital technologies, managerial decisions, and market forces as key drivers. This research offers valuable theoretical and practical insights by proposing principles for continuous financial innovation in the FinTech revolution.

In Contribution 9, the authors, Mohammed, De-Pablos-Heredero, and Montes Botella, examine the impact of financial access, stability, and sanctions on the adoption of CBDCs across 71 countries. Their findings reveal that nations with financial sanctions or substantial offshore loans are more likely to adopt CBDCs, particularly in regions with limited financial access. This research provides critical insights into how national financial conditions influence CBDC adoption, contributing to the broader discourse on the future of global finance.

In Contribution 10, the authors, Manta and Palazzo, explore the concept of time banking as an innovative financial instrument that promotes community collaboration and equitable wealth distribution. Their research highlights the potential of time banks to reduce the dependence on traditional currency and foster financial inclusion, particularly in an increasingly digital financial landscape.

Collectively, these papers provide valuable contributions to the understanding of how financial technology and innovation can drive sustainable development. They offer theoretical insights, practical methodologies, and policy recommendations that could influence future research, industry practices, and global financial strategies. This Special Issue underscores the critical role of FinTech in shaping the future of global finance and sustainable development.

Conflicts of Interest: The author declares no conflict of interest.

List of Contributions

1. Albuquerque, F.; Dos Santos, P.G. Recent Trends in Accounting and Information System Research: A Literature Review Using Textual Analysis Tools. *FinTech* **2023**, *2*, 248–274. https://doi.org/10.3390/fintech2020015.
2. Zhu, T.; Sun, X. Enterprise Financialization and Technological Innovation: An Empirical Study Based on A-Share Listed Companies Quoted on Shanghai and Shenzhen Stock Exchange. *FinTech* **2023**, *2*, 275–293. https://doi.org/10.3390/fintech2020016.
3. Almeida, D.; Dionísio, A.; Ferreira, P.; Vieira, I. Impact of the COVID-19 Pandemic on Cryptocurrency Markets: A DCCA Analysis. *FinTech* **2023**, *2*, 294–310. https://doi.org/10.3390/fintech2020017.
4. Cuc, S. Unlocking the Potential of Blockchain Technology in the Textile and Fashion Industry. *FinTech* **2023**, *2*, 311–326. https://doi.org/10.3390/fintech2020018.
5. Kherbachi, S. Digital Economy under Fintech Scope: Evidence from African Investment. *FinTech* **2023**, *2*, 475–483. https://doi.org/10.3390/fintech2030027.
6. Koelmel, B.; Borsch, M.; Bulander, R.; Waidelich, L.; Brugger, T.; Kuehn, A.; Weyer, M.; Schmerber, L.; Krutwig, M. Quantifying the Economic and Financial Viability of NB-IoT and LoRaWAN Technologies: A Comprehensive Life Cycle Cost Analysis Using Pragmatic Computational Tools. *FinTech* **2023**, *2*, 510–526. https://doi.org/10.3390/fintech2030029.
7. Dissanayake, H.; Popescu, C.; Iddagoda, A. A Bibliometric Analysis of Financial Technology: Unveiling the Research Landscape. *FinTech* **2023**, *2*, 527–542. https://doi.org/10.3390/fintech2030030.
8. Burciu, A.; Kicsi, R.; Buta, S.; State, M.; Burlac, I.; Chifan, D.A.; Ipsalat, B. The Study of the Relationship among GCI, GII, Disruptive Technology, and Social Innovations in MNCs: How

Do We Evaluate Financial Innovations Made by Firms? A Preliminary Inquiry. *FinTech* **2023**, *2*, 572–613. https://doi.org/10.3390/fintech2030033.
9. Mohammed, M.A.; De-Pablos-Heredero, C.; Montes Botella, J.L. The Role of Financial Sanctions and Financial Development Factors on Central Bank Digital Currency Implementation. *FinTech* **2024**, *3*, 135–150. https://doi.org/10.3390/fintech3010009.
10. Manta, O.; Palazzo, M. Transforming Financial Systems: The Role of Time Banking in Promoting Community Collaboration and Equitable Wealth Distribution. *FinTech* **2024**, *3*, 407–423. https://doi.org/10.3390/fintech3030022.

FinTech

Review

Recent Trends in Accounting and Information System Research: A Literature Review Using Textual Analysis Tools

Fábio Albuquerque [1,*] and Paula Gomes Dos Santos [1,2]

[1] ISCAL—Lisbon Accounting and Business School, Instituto Politécnico de Lisboa, 1069-035 Lisbon, Portugal; pasantos@iscal.ipl.pt
[2] COMEGI, Universidades Lusíada, 1300-001 Lisbon, Portugal
* Correspondence: fhalbuquerque@iscal.ipl.pt

Abstract: Accounting has been evolving to follow the latest economic, political, social, and technological developments. Therefore, there is a need for researchers to also include in their research agenda the emerging topics in the accounting area. This exploratory paper selects technological matters in accounting as its research object, proposing a literature review that uses archival research as a method and content analysis as a technique. Using different tools for the assessment of qualitative data, this content analysis provides a summary of those papers, such as their main topics, most frequent words, and cluster analysis. A top journal was used as the source of information, namely *The International Journal of Accounting Information Systems*, given its scope, which links accounting and technological matters. Data from 2000 to 2022 was selected to provide an evolutive analysis since the beginning of this century, with a particular focus on the latest period. The findings indicate that the recent discussions and trending topics in accounting, including matters such as international regulation, the sustainable perspective in accounting, as well as new methods, channels, and processes for improving the entities' auditing and reporting, have increased their relevance and influence, enriching the debate and future perspectives in combination with the use of new technologies. Therefore, this seems to be a path to follow as an avenue for future research. Notwithstanding, emerging technologies as a research topic seem to be slower or less evident than their apparent development in the accounting area. The findings from this paper are limited to a single journal and, therefore, this limitation must be considered in the context of those conclusions. Notwithstanding, its proposed analysis may contribute to the profession, academia, and the scientific community overall, enabling the identification of the state of the art of literature in the technological area of accounting.

Keywords: accounting; literature review; technology; textual analysis; *IJAIS*

Citation: Albuquerque, F.; Dos Santos, P.G. Recent Trends in Accounting and Information System Research: A Literature Review Using Textual Analysis Tools. *FinTech* **2023**, 2, 248–274. https://doi.org/10.3390/fintech2020015

Academic Editors: Otilia Manta, Mohammed K. A. Kaabar, Eglantina Hysa, Ovidiu Folcuţ and Anuradha Iddagoda

Received: 8 March 2023
Revised: 7 April 2023
Accepted: 10 April 2023
Published: 12 April 2023

1. Introduction

Accounting, as an applied social science, requires a constant analysis of the threats and opportunities that emerge, among others, in the political, social, environmental, economic, and legal contexts, which, in turn, are interconnected. The difficulty of adequacy and monitoring the developments associated with educational institutions' advent of new technologies has been stressed by literature [1]. It has also been demonstrated that research in accounting needs to evolve and follow contemporary trends that are present not only in the technological environment but also in other areas, including those related to other scientific fields [2]. Accounting research, according to Kaplan [3], has neglected topics of interest, presenting them as too rigid, cautious, and conservative. Additionally, scholars have identified a greater difficulty in publishing in this area compared to other areas of business, in general [4].

Although the definition of accounting has evolved, this is not reflected in the understanding of accounting as a social and moral practice, but only as a technical one, despite the efforts of academics in this regard over the last four decades [5]. Research is thus an essential element for understanding the new forms of management in the so-called digital economy, as well as identifying the new skills and instruments that professionals must have to remain relevant and able to add value to the work they develop [6].

This paper performs a literature review (bibliometric analysis) of a top journal in accounting information systems (AIS) as a target, namely *The International Journal of Accounting Information Systems* (*IJAIS*). Papers released from 2000 to 2022 were gathered, aiming to present an evolutionary analysis of the recent trends in different areas of accounting research, with a particular focus on the latest period (from 2020 to 2022). Therefore, this paper's content analysis provides an overview of the main topics from the investigations covered by this journal over this period. Using different tools based on textual analysis, this exploratory paper offers a summary of the themes covered by those papers through different tools available for the assessment of qualitative data, such as their main topics, most frequent words, and cluster analysis. Their impacts and possible relationships are also included in this context.

Based on the methodology proposed, this paper may contribute to the literature by providing an overall perspective of the latest two decades of accounting literature in the technological field through a methodological approach that can be used in future investigations. To this point, topics considered as future avenues are discussed as opportunities in different fields for researchers. Research gaps in the literature are pointed out, which may be relevant for educational and professional practice in accounting. Consequently, this paper can contribute to professionals, academia, and the scientific community overall, enabling the identification of the state of the art in the accounting research area.

More specifically, the evidence found in this paper suggests the increasing use of emerging technologies in accounting and auditing in the latest years, with new research being developed through experimental and case studies. This can be seen as an open opportunity for researchers, academia, and practitioners since the gap between their different technological development levels, as stressed by the literature [1], may be reduced through closer projects and collaborations. The idea of a more conservative approach in accounting research [2–5] also appears to be mitigated in recent years through the findings from this paper that suggest the inclusion of a more diverse set of topics in the scope of the developed research in accounting. This is evidenced either by integrating trending topics, such as sustainability matters–also known as nonfinancial information or environmental, social and governance (ESG) issues–or by linking accounting as applied social science with other different social scientific areas, such as sociology and psychology from its perspective.

Literature reviews on the so-called emerging technologies in accounting have increased during the latest years, covering different periods, journals, and themes under assessment. For instance, research can be found on specific topics such as the use and implications of blockchains in accounting and auditing [7–10]. Moreover, specific accounting areas have also been selected for this purpose, such as the research by Mugwira [11] on auditing regarding internet-related technologies or neurosciences in accounting by Tank and Farrell [12].

Wider research on the use of technologies in accounting was performed by Kumar [13], Kroon et al. [14] and Chiu et al. [15]. Despite the focus by Kumar [13] on the research released in *IJAIS*, as well as the inclusion of this journal in the scope of the analysis performed by Kroon et al. [14] and Chiu et al. [15], those bibliometric analyses do not cover the latest period proposed in this paper. Therefore, considering this gap and the newest challenges accounting has been facing, it seems relevant to assess what issues and topics have been released by a top journal focused on the use of technologies in this area.

The structure of this paper is as follows: The next section provides the objectives and the methodology used, also reviewing the literature as previously proposed, and the third discusses the findings, also suggesting future avenues for similar research in this field and presenting its main limitations.

2. Literature Analysis

This section summarizes the papers published in the selected journal. It is divided into two subsections. The first provides an overview of the basic materials and methods proposed for the papers' analyses. The next one reports the results from the literature review.

2.1. Materials and Methods

This paper uses a qualitative and exploratory approach based on the archival research method and content analysis as a technique. The content within the abstract of papers released in the *IJAIS* was selected as the object of analysis since it represents a top accounting journal dedicated to information systems matters in this area. Those papers were gathered from the Scopus database by 30 September 2022.

Based on the information available on the Scopus website, "the *IJAIS* publishes thoughtful, well-developed papers that examine the rapidly evolving relationship between accounting and information technology (IT). Papers may range from empirical to analytical, from practice-based to the development of new techniques but must be related to problems facing the integration of accounting and IT. The journal addresses (but will not limit itself to) the following specific issues: control and auditability of information systems; management of IT; artificial intelligence research in accounting; development issues in accounting and information systems; human factors issues related to IT; development of theories related to IT; methodological issues in IT research; information systems validation; human-computer interaction research in AIS".

The *IJAIS* is classified as a Q1 journal in 2021, with a SCImago Journal Rank (SJR) of 1.52, based on the Scopus criteria for best quartile classification in accounting. It has been published since 2000 by Elsevier Inc, which has its head office in the Netherlands. Therefore, the data cover papers released from 2000 onwards, which allows the assessment of research since the beginning of this century, which, therefore, provides an overview of the last 22 years of research in AIS. Further reasons for selecting this journal include its comparatively higher Scopus ranking among journals that do not include any other terms besides the purposed field of analysis (information systems).

The searching process in Scopus was restricted to those papers with available abstracts for assessment. No additional criteria were applied besides the period and the selected journal. Consequently, no other terms or expressions were used as the key searching term for the papers selected. At the end of this process, 364 papers were gathered from Scopus.

The exploratory analysis performed in this paper provides a breakdown for three distinct periods: from 2000 to 2009, from 2010 to 2019, and, finally, from 2020 to 2022. The first two periods were selected to identify the differences, through a comparative analysis, between the topics from the papers released for the two initial decades of this century. The last, despite being shorter than the previous ones, was particularly proposed to focus the assessment on the trending topics found in the same source.

Textual analysis tools available on NVIVO and {L}exos were used as complementary materials for the main data assessment in this paper. The choice between the two has considered the availability of each tool and the most informative and easily readable information in each context and proposed analysis.

Two main sets of textual analyses are performed, as follows:

(i) The identification of the most frequent terms, which includes the presentation of illustrative word clouds;
(ii) The main set of topics and subtopics from the papers gathered, which includes a complementary diagram of a cluster analysis.

The {L}exos was used to provide the word clouds images underlying the most frequent words (i), while the software NVIVO is used for the analysis of the main set of topics and subtopics (ii).

Regarding the identification of the most frequent terms (i), some words must be previously classified as "stop words" since they have no meaning for research purposes and, consequently, must be removed from the analysis. Since {L}exos has no list of stop words by default, the NVIVO first suggestion was used as a reference for this purpose. The software provides a set of predefined stop words in different languages (for this case, English was used), which includes the most common prepositions, particles, interjections, unions, adverbs, pronouns, modal verbs, as well as the different forms of common verbs, such as the verbs to be, to have, and similar. The "by default" set of stop words can also be adjusted by users, i.e., included or excluded by users, depending on the purposes of a given analysis.

In this sense, this paper uses the reference list of stop words from NVIVO, as well as frequent "linking words" considered in research papers with no particular meaning for the proposed analysis, such as "paper", "study", "work", "sample", "focus", "aim", "purpose", "contribution", "relevance", "objective", "propose", "study", "effects", impacts", "evidence", "higher", "lower", "significant", and similar ones. Therefore, the complete list of stop words was then included in {L}exos, a freely available website, and two different word clouds from {L}exos were performed by each period under assessment to illustrate the most frequent terms found.

Furthermore, the main set of topics and subtopics, as well as a cluster analysis (ii), were performed using NVIVO. This software uses an automatic process to find the main topics and respective subtopics, as well as the possible relationships (similarities) between them through cluster analysis. The Pearson correlation coefficient is used to identify the similarities, which are indicated by blue lines, with thicker lines highlighting stronger levels.

A review of the papers selected is presented in the following subsection.

2.2. Results

This subsection is dedicated to the analysis of the papers published in the *IJAIS* from 2000 to 2022, also considering the three comparative periods proposed. Table 1 presents a summary of the papers selected by period and their textual characteristics, based on information provided by {L}exos. A first synthesis of the textual characteristics of papers by period is therefore provided, including the terms occurring once, the total number of terms, the distinct number of terms and vocabulary density.

Table 1. Summary of the textual characteristics of papers selected by period.

Journal	Period	Number of Papers	Number of Terms Occurring Once	Total Number of Terms	Distinct Number of Terms	Vocabulary Density
IJAIS (N = 364)	2000–2009	133	1477	10,870	3045	0.28
	2010–2019	174	1643	13,969	3512	0.251
	2020–2022	57	1059	5161	1935	0.375

The figures in Table 1 show a trend for an increasing number regarding the indicators provided, which is also valid for the last three-year period since it already indicates approximately one-third of the figures for the same indicators published in the previous one. The vocabulary density is an exception, however, as the figures decreased from the first to the second period. It is worthwhile to notice that the figures for the distinct number of terms and vocabulary density regarding the last (shortest) period cannot be compared with the previous ones.

Figure 1 presents a summary of the number of papers and the number of citations published in *IJAIS* over the three periods under assessment. The ratio between the number of citations and the number of papers is also provided as a measure of the average impact of papers by period (average citations per period). Notwithstanding, it should be stressed, again, that the discernible distance between the periods under assessment is expected, considering that the most recent periods may have a relative disadvantage when it comes to citations since, usually, older papers have more opportunities to receive citations.

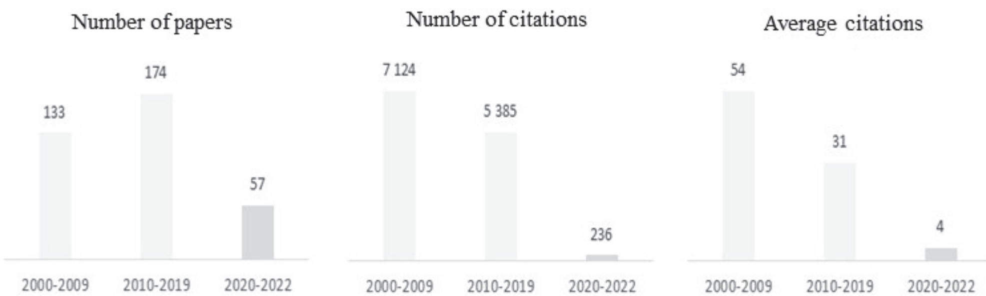

Figure 1. Summary of the number of papers and citations by periods in the *IJAIS*.

Figure 1 shows that the number of papers has increased over the period, conversely to the number of citations, which tends to be more noticeable for the last period, as expected.

Among the 25 papers with more than 100 citations in *IJAIS*, only 7 were published in the second period of analysis, with the most cited paper reaching 202 citations [16]. This is followed by Lee et al. [17], which has 194 citations, with the remaining reaching a maximum of 130 citations [18]. These papers include diverse themes, including the use of dashboards to assess performance management, partial least squares path modelling in accounting research, or business analytics and ERP in management accounting. On the other hand, the most cited paper for the first period [19], on ERP implementation, had a maximum of 437 citations, which is followed by two papers with more than 300 citations [20,21]. The oldest is also focused on ERP but from the perspective of its financial impacts, whereas the most recent covers business intelligence as a topic of emerging technologies.

The findings are presented in the next subsubsections, with a breakdown by period.

2.2.1. Results for the First Period (2000 to 2009)

A recurrent theme during the first period (2000 to 2009) was the use and implementation of AIS, in general, and enterprise resource planning (ERP) including papers developed as literature reviews (e.g., [19,20,22–32]).

Furthermore, studies on IT governance practices and models, in general, and the resource-event-agent (REA) model can also be identified (e.g., [33–35]). There are also analyses related to performance, integrity, risks, success factors, obstacles, or challenges associated with implementing technologies in different areas of accounting that relate to the previous themes, some of them discussing the advantages and disadvantages of outsourcing (e.g., [36–42]).

Other topics emerged or gained prominence during the period, namely the analyses related to the following topics:

i. The dissemination of information via the Internet, such as web reporting, e-commerce models, or web-based business or services (e.g., [43–48]);
ii. The use, implementation, and implications of continuous auditing or continuous monitoring (for instance, [49,50]);
iii. The use or implementation of languages or taxonomies based on Extensible Markup Language (XML) or Extensible Business Reporting Language (XBRL), sometimes also linked to previous themes (e.g., [49,51–53]);
iv. The implementation of internal control system models in the IT area, such as control objectives for information and related technology (COBIT), the relevance of IT certification, such as WebTrust, and also the topics from the Information Systems Audit and Control Association (ISACA) curricula (for instance, [54–56]);
v. Finally, although less incipient in this period, some studies on the emerging technologies from the beginning of this century, such as neural networks (e.g., [57]), or business intelligence (e.g., [21]).

Following, Figure 2 provides the word clouds for this period to illustrate the most common words.

Figure 2. Word clouds from the papers in the *IJAIS* (from 2000 to 2009).

From Figure 2, terms such as "accounting", "information", and "systems", as well as "companies", "organization", "firm", and, "enterprise", are associated with others such as "implementing", "process", "design" or "development", as well as "effectiveness", "performance", "management", "knowledge", "organizational", which indicate the prevalence of studies mostly dedicated to AIS and ERP, also included in the list.

The previous terms along with others such as "audit", "auditors" or "auditing", "risk", "assurance" and "continuous" probably highlight studies related to continuous auditing. Lastly, the terms "disclosure", "electronic" and "corporate" may refer to studies on continuous reporting, e-reporting and corporate websites as a new channel for information disclosures by companies. Conversely, topics such as XML, XBRL, internal control models in IT, or the use or implementation of emerging technologies appear to be less prominent in this first period.

The terms "web" and "trust" also evidence the inclusion of this topic within the papers published in this first period of analysis in the *IJAIS*.

Therefore, to strengthen the previous indications, a global prominence of research on "AIS", and the "ERP", as well as those related to them, can be found for this period, regardless of the exceptions provided above, mostly related to the processes associated with the audit and reporting areas in general, including issues on risk, security, and internet developments.

Figure 3 provides the topics automatically codified as the most relevant from the textual analysis for this first period.

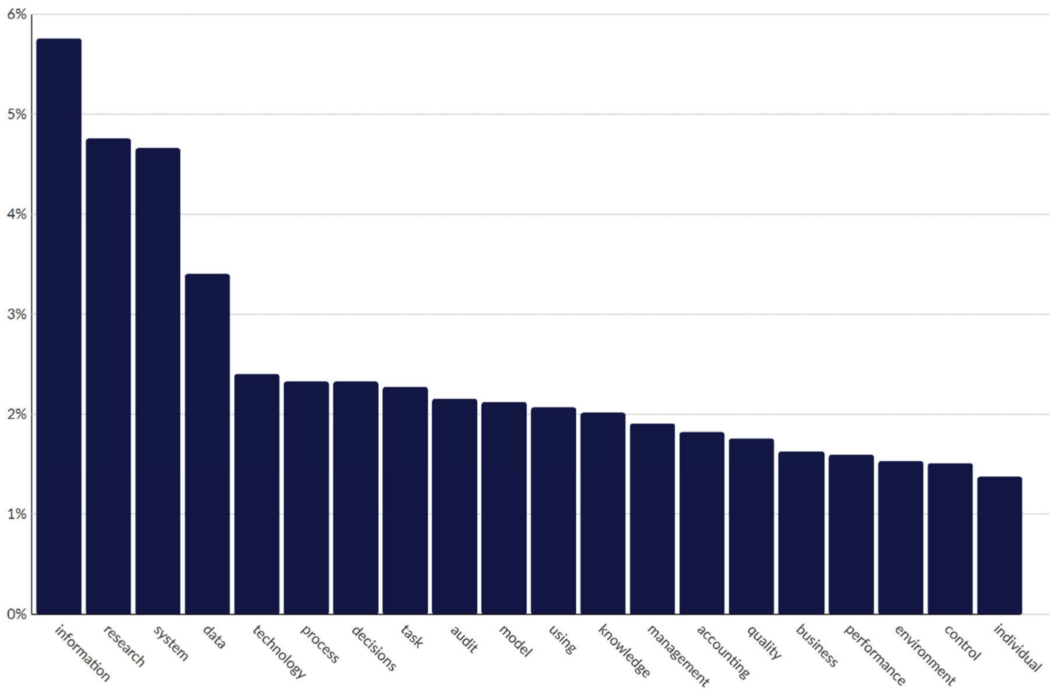

Figure 3. Topics automatically found from the papers in the *IJAIS* (from 2000 to 2009).

Figure 3 shows the 20 most relevant topics that were automatically codified according to their frequencies in a different set of expressions found in papers from this period. The topics "information", "research", "system" and "data" are the most prominent, with the first three having more than 4% of relative importance. Other relevant topics not listed in Figure 3, despite being identified as relevant topics, include "design", "effectiveness" and "structure". Below, the words highlighted in bold identify those topics which are commonly shared (cross-references) among those 20 most relevant, as a useful procedure to identify the focus of researchers in this period:

1. **Accounting**: accounting academics, accounting data points, accounting information, **accounting knowledge, accounting research productivity, accounting system design, accounting systems research, accounting tasks**, database accounting, **differentiating accounting systems**, financial accounting literature, leading accounting, managerial accounting perspective, **quality accounting publication**;
2. **Audit**: audit automation constructs, audit committees, audit documentation, audit engagement risk, audit opinion, audit trail, audit work, auditing education, auditing literature, computer-assisted auditing techniques, continuous audit, **current audit environment**, specific auditing concerns, various audit domains;
3. **Business**: business clients, **business information**, business operations, business organizations, **business process diagrams**, **business process level**, **business process modelling conventions**, business world, Canadian business units, everyday business communications, extensible business, strategic business planning, web-based business;
4. **Control**: control group, control objectives, control relationships, **designing control systems**, external controls, **hierarchical control structures**, informal controls, internal control, international control guideline, proper control procedures, using control charts;

5. **Data**: **accounting data points**, **data quality**, data streams, data warehouses, electronic data interchange, financial data, including data flow diagrams, **normal form data structure**, numerical data increases, secondary data analysis, site data, specific data, spending data, underlying data trends, **unnormalized data structure**, using data;
6. **Decisions**: bonus allocation decisions, **decision aid research**, decision aid use, decision aids, decision facilitation, **decision process**, investment decisions, **management decision models**, multiple decision, novice decision makers, operational decisions, repetitive choice decisions, repetitive valuation decisions, user decisions;
7. **Environment**: alternative environments, continuous reporting environment, **current audit environment,** external environment, manufacturing environments, traditional reporting environment, virtual team environment;
8. **Individual**: individual characteristics, individual decision-makers, individual determinants, individual faculty members, individual faculty productivity, individual level, individual provider attributes, individual units, judging individuals, perceiving individuals;
9. **Information**: **accounting information**, **advanced information technology**, **business information**, **computer-supported information systems**, corporate reporting information, decision-making information, emerging information needs, emerging information technologies, financial reporting information, financial statement information, future-oriented information, **human information processing, important information processing mechanism**, information age, information content, information integrity attributes, information load, information location, information requests, information security, **information system designs**, **information systems research**, informationally equivalent, inter-organizational information sharing, **low information quality seal**, **management information systems**, **management information value chain**, nonfinancial information, online information, open information sharing, output information, preliminary information, **specific information technology**, **supporting information technology**, varied information, vast information source;
10. **Knowledge**: **accounting knowledge**, additional knowledge, causing knowledge acquisition, **expert-like knowledge structures**, feedback impacts knowledge acquisition, filtering knowledge, improving knowledge workers, **knowledge management focus**, **knowledge management practices**, **knowledge management system**, procedural knowledge;
11. **Management**: **cost management systems, effective management**, hybrid manager profile, impression management, **knowledge management focus, knowledge management practices, knowledge management system, management decision models, management information systems, management information value chain**, senior managers, top management support;
12. **Model**: **business process modelling conventions**, conceptual model, contingency model, enterprise modelling, er model, **management decision models**, mathematical model, **research model**, residual income valuation model, **task circumplex model**, theoretical model;
13. **Performance**: firm performance, **managerial end-user performance**, organisational performance, organizational performance, performance evaluation, performance outcomes, subsequent decision-making performance, superior performance, **task performance**, traditional performance measures;
14. **Process**: assurance process, **business process diagrams, business process level, business process modeling conventions**, decision process, event process chains, extensive sample selection process, **human information processing, important information processing mechanism**, little processing, process level risk assessment, processing view, production processes, stable processes, standard development process;
15. **Quality**: **data quality**, disseminating quality, **low information quality seal**, **quality accounting publication**, quality measurement component, quality outlets, quality perspective, service quality, **system quality**;

16. **Research**: **accounting research productivity**, **accounting systems research**, additional research, ais research, attitudinal ambivalence research, case research, current research work, decision aid research, development research, empirical research, field research, future research, **information systems research**, little research, past research, previous research, prior research, recent research, research community, research domain, research findings, research hypotheses, research instrument, research issues, research method opportunities, **research model**, research propositions, **research prototype system**, research questions, research survey, rich research opportunities, various research methods;
17. **System: accounting system design, accounting systems research**, alternative measurement systems, automated record system, **computer-supported information systems, cost management systems**, current system, **designing control systems, differentiating accounting systems, electronic audit-work paper system**, enterprise systems implementation, **expert system groups, expert system types, expert system users, information system designs, information systems research,** key system components, **knowledge management system, management information systems**, medical record system, **research prototype system**, successful system, system acceptance, system acquisition, **system design alternatives, system effectiveness**, system implementation changes, system integration, system outputs, **system quality**, system transformation, system usage, **systems design** scenarios, tertiary assurance system, work systems;
18. **Task**: **accounting tasks**, brainstorming tasks, complex tasks, decision-making tasks, financial tasks, optimisation tasks, querying tasks, simple tasks, **specific design tasks**, task accuracy, task characteristics, **task circumplex model**, task completion, task force, **task performance**, task requirements, task routineness;
19. Technology: advanced information technology, emerging information technologies, emerging technologies, learning technology, specific information technology, supporting information technology, technological advances, technological determinism, technological discourse, technology complexities, technology features, technology fit, technology medium;
20. **Use: auditor use**, continued use, decision aid use, **expert system users**, user acceptance, **user decisions**, user requests, user satisfaction, using activity, **using control charts**, **using data**, using eighty-nine, using paper methods.

The results suggest the prominence of research in AIS dedicated to improving the information (e.g., through its design, quality, structure, and easier visualisation) for management (internal) purposes (e.g., knowledge, effectiveness, and support for decision-makers), which is the traditional investigation line in this area. On the other hand, the topic of "individual" (the 20th one) was the exclusive case for which no relationships were found. Furthermore, additional topics also deserve references within the different topics, such as continuous audit, continuous reporting, web-based businesses, virtual teams, and extensible business (e.g., XBRL). Finally, emerging technologies can also be found as a general reference but with no significant level of specific pieces of evidence regarding topics currently associated with this concept.

Finally, Figure 4 presents the cluster analysis performed to illustrate the relationship between the topics and subtopics for this first period.

The cluster analysis shown in Figure 4 indicates the link between AIS and data management for businesses and control purposes (i.e., information for the decision-making process), which underlies the papers in this period, as highlighted in the aforementioned analysis. Moreover, the emergence of continuous auditing and reporting in this period is also evident.

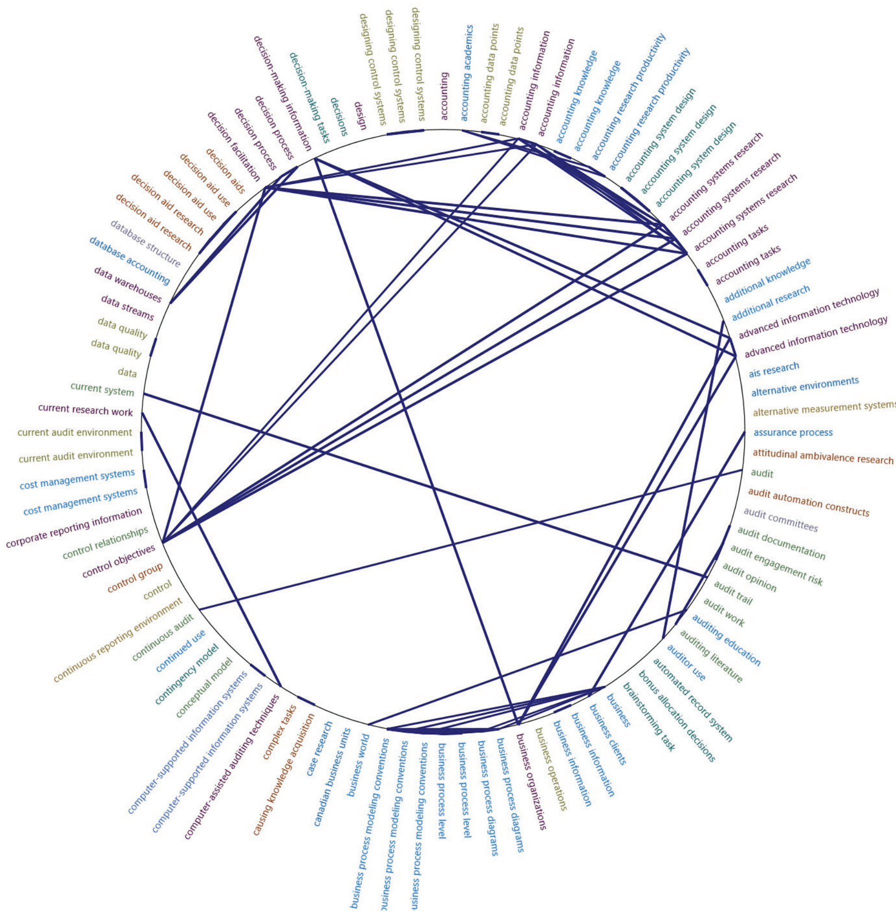

Figure 4. Cluster analysis for the papers in the *IJAIS* (from 2000 to 2009).

2.2.2. Results for the Second Period (2010 to 2019)

Regarding the second period of analysis (2010 to 2019), it can also be observed that AIS and ERP remain relevant topics (e.g., [58–67]), despite sharing their relative importance. The AIS has been the subject of a significant number of studies developed during this period, including additional literature reviews and critical perspectives. Likewise, one of the most cited papers, presenting the same methodological perspective, is the only study identified on dashboard use [16]. Notwithstanding, studies in the following areas gained greater prominence over those initiated in the previous period:

i. Continuous auditing or continuous monitoring (e.g., [68–72]);
ii. Languages or taxonomies based on XML (less expressive) or XBRL, in a more expressive number than those found in the previous period (e.g., [73–80]);
iii. Business intelligence or business analytics (mostly) (e.g., [19,81–83]);
iv. Artificial intelligence, data analytics, big data treatment, and the use of machine learning and data mining techniques (mostly), which are sometimes associated with previous themes and, in many cases, dedicated to the definition of processes related to the detection of fraud, misreporting or tax evasion (e.g., [84–92]);
v. Cloud computing (e.g., [67,93–95]);
vi. Blockchain-based technologies, which are mostly evidenced at the end of this decade (for instance, [96,97]).

In addition to the areas most linked to emerging technologies, studies are identified in more generic areas of process management or IT infrastructure, in terms of processes, governance, associated risks, and value added, among others, also including studies on the use of outsourcing or, later in this decade, on cybersecurity issues (e.g., [98–106]). Moreover, topics such as e-commerce or the dissemination of financial information over the Internet, although existing, have less profusion in this period (e.g., [107]). The first studies on the use of social media and online communities, on the other hand, appeared as an emerging topic in this period (e.g., [108,109]). It is also from this period, albeit residually, studies based on nonfinancial information as a source of data, such as sustainability reports or integrated reporting (e.g., [110]), appeared.

Figure 5 presents the word clouds to illustrate the most common words for this second period.

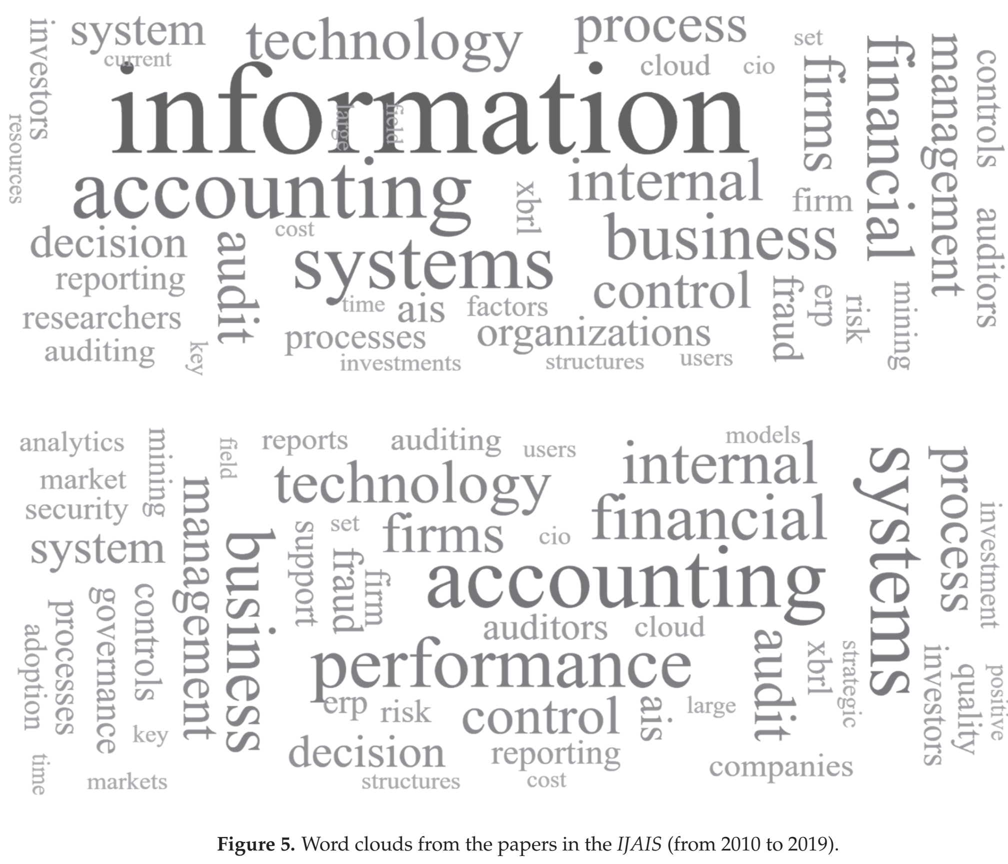

Figure 5. Word clouds from the papers in the *IJAIS* (from 2010 to 2019).

Figure 5 shows new terms usually classified as emerging technologies, such as "XBRL", "mining" and "cloud". In addition, studies related to fraud detection, sometimes associated with the use of data mining-based technologies, also play an important role, as evidenced by the identification of the term "fraud". On the other hand, the issues of continuous auditing and outsourcing of resources do not seem to be among the most important compared to the previous period, although they are also present in this decade.

Finally, in the context of the more traditional issues, such as topics related to business and IT architecture or computer security, also emerge, as evidenced by the greatest relevance of terms such as "business", "process" and "control", as well as the emergence of new terms in this set, such as "governance" and "security".

Following, Figure 6 presents the topics automatically codified as the most relevant from the textual analysis for this second period.

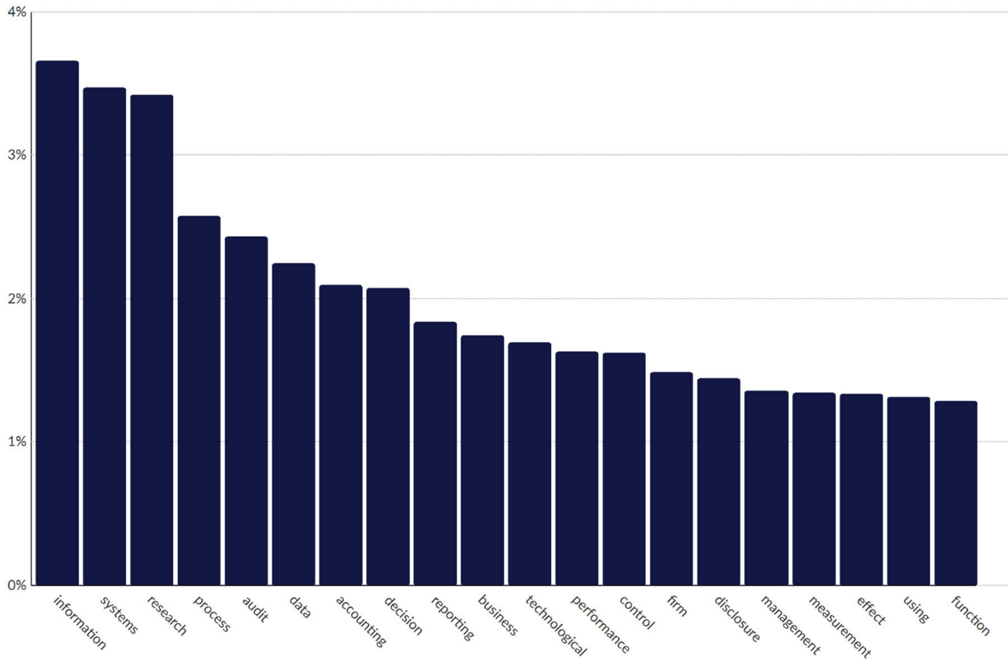

Figure 6. Topics automatically found from the papers in the *IJAIS* (from 2010 to 2019).

Based on the same procedure performed before, Figure 6 shows the 20 most relevant topics. In comparison to the previous period, and despite commonly sharing the three most relevant topics, none of them reached the 4% of relative importance found earlier. Some topics emerge as novelties in this period, such as "reporting", "disclosure", "measurement", "firm" and "function". The set of topics is significantly higher and diversified in this second period, totaling 55 concepts, which include, for instance, "data mining", "experimental", "fraud", "governance", "investors", "market", "risk", "security", "standards", "statements", "trading", and "value". This is also evident in Figure 6 by the set of topics for which the relative importance found is lower than 2% for this period (12 versus 8 for the previous period). Then, the 20 most relevant and the relationships between them and of the automatic topics found, highlighted in bold, are presented below:

1. **Accounting**: 129 accounting students, accounting benefits, accounting domains, **accounting information systems academics**, **accounting information systems field**, accounting journals, accounting literature, **accounting processes**, accounting publications, **accounting researchers**, **accounting standards**, annual bank account balances, especially management accounting, **firm accounting performance, outsourcing accounting functions**;
2. **Audit**: audit analytics, audit arena, **audit fraud brainstorming**, **audit process**, **audit standards**, **audit support systems**, audit team, auditing literature, budgeted audit hours, chief audit executives, computer audit specialist, continuous auditing methodology, **current audit practice**, financial audits, **internal audit function**, internal auditing department, prior year audit, **reduced audit fee increases**, **small audit firms**, **traditional audit paradigm**;
3. **Business**: business networks, business operations, **business process agility**, **business process standards, business value research**, computing-related business objectives, **existing business processes**, extensible business, hindering business efforts, **in-**

termediate business processes, **overall business performance**, **reporting business information**;

4. **Control**: control compliance, control issues, corrective controls, effective controls, ineffective controls, **informal management control systems**, internal control deficiencies, internal control environment, internal control overrides, **internal control reporting requirements**, internal control weakness, internal control weaknesses, it-related controls;
5. Data: applying data mining techniques, corporate data, data analysis tool, data patterns, descriptive data mining approach, descriptive data mining strategy, financial data, global data ecosystem, journal entry data sets, out-of-sample data, panel data, perceptive field survey data, precise data values, prediction data mining techniques, process-level data, procurement data, proprietary data, quantitative data, researching journal entry data mining, semi-monthly data, soft copy data, tagged data, using data;
6. **Decisions**: compared decisions, deception detection decision aid, decision aid reliability, decision aid reliance behavior, decision aids, decision problems, **decision processes**, decision trees, **experimental decision aid research spans**, **governance decision making**, optimal decision, outsourcing decision, reliance decision;
7. **Disclosure**: **cybersecurity disclosure guidance**, **cybersecurity risk disclosure**, disclosure credibility, disclosure role, environmental disclosures, extensive disclosure, **financial statement disclosures**, improving disclosure timeliness, issuing video disclosures, unauthorized disclosure;
8. **Effective**: brainstorming effectiveness, compromising regulation effectiveness, detrimental effect, differential effect, **effective controls**, halo effect, **information environment effects**, interactive effect, mean effects, positive effect, profound effect;
9. **Firm**: aggregate firm level, appointing firms, durable goods industry firms, **firm accounting performance**, firm productivity, firm profitability, **firm value**, firm years, registered firms, **small audit firms**, **superior firm performance**, threatened firms;
10. **Function**: bi-planning functionality, **bi-reporting functionality**, incompatible functions, **internal audit function**, outsourcing accounting functions;
11. **Information: accounting information systems academics, accounting information systems field, bank trading information systems**, capturing context information, chief information officer, deceptive information, detail-tagged footnote information, **financial reporting information, health information technology expenses**, information asymmetry, information environment effects, **information quality**, information release, **information security risk management, information systems professionals, information systems researchers, information technology literature, information technology outsourcing**, integrating information, **performance measurement information**, qualitative information, **recent high-profile information security breach incidents, reporting business information, risk information increases**, supplemental information displays, ™ **information processing costs, user satisfaction measure information system success, using information**;
12. **Management**: bank management, cloud management committee, entail managers, **environmental management approach, especially management accounting, informal management control systems, information security risk management**, management assertions, management support, managing expectations, resource management;
13. **Measures**: measuring spreadsheet infusion, perceptual measures, **performance measurement capabilities, performance measurement information, quality measures**, quantitative measure, **strategic performance measurement system**, subjective measures, **user satisfaction measure information system success**;
14. **Performance**: average performance, **firm accounting performance, firm-level performance**, future performance goals, **internal process-level performance**, organizational performance, **overall business performance, performance measurement capabilities, performance measurement information, strategic performance measurement system, superior firm performance**, supply chain performance;

15. **Process: accounting processes,** assurance process, **audit process, business process agility, business process standards**, close process, **decision processes**, estimation process, **existing business processes**, implementation processes, **intermediate business processes**, labor process, manual process, natural language processing, order fulfilment processes, process efficiency, **process level,** strategic erm processes, ™ **information processing costs**, work processes;
16. **Reporting**: annual reports, digital reporting, discretionary reporting, **financial reporting information, financial reporting systems, internal control reporting requirements**, internet reporting, **reporting business information**, reporting language, reporting timeliness, required reporting deadlines, **standard reports, traditional business-to-government reporting**;
17. **Research**: artificial intelligence research, broad research streams, **business value research**, collaborative design research, **experimental decision aid research spans**, **expert systems research**, future research, multi-method research, potential research, prior research, research discipline, research environments, research methodology, research perspectives, research program, **research quality**, **research settings**, **researching journal entry data mining**, right research, **traditional research classification**;
18. **System**: 43 expert systems, **accounting information systems academics, accounting information systems field**, accounting-related expert systems papers, **audit support systems**, automated systems, **bank trading information systems**, computer-mediated communication system, **decision-aid system**, enterprise resource planning systems adoption, enterprise systems results, **expert system publications, expert systems research, financial reporting systems, incentive systems, informal management control systems, information systems professionals, information systems researchers**, manual systems, restrictive systems, **strategic performance measurement system, system quality**, transparent system, **user satisfaction measure information system success**;
19. **Technological: health information technology expenses, information technology literature, information technology outsourcing**, supporting technologies, **technological competence**, technological domain, technological solutions, technology dominance;
20. **Using**: emergent use, managerial use, media use, **practice use**, spreadsheet use, **user satisfaction measure information system success, using activity theory, using data**, using a hospital, **using information**, using responses.

The results above stressed the issues related to reporting and disclosure, particularly those prepared under audit and financial standards. Furthermore, governance matters, risk and cybersecurity, as well as different perspectives of performance assessments, are topics that can be easily found in the pieces of evidence above. Finally, conversely to the previous period, emerging technologies can be more easily exemplified from the references found in the topics above through the terms such as artificial intelligence and data mining.

Finally, Figure 7 presents the cluster analysis performed to illustrate the relationship between the topics and subtopics for this second period.

When compared to the same analysis performed for the previous period, Figure 7 indicates a lower level of relationships between the topics and subtopics underlying the papers in this period. Moreover, emerging technologies such as artificial intelligence and data mining, as well as a more diversified set of topics on auditing and information systems in general, are also highlighted.

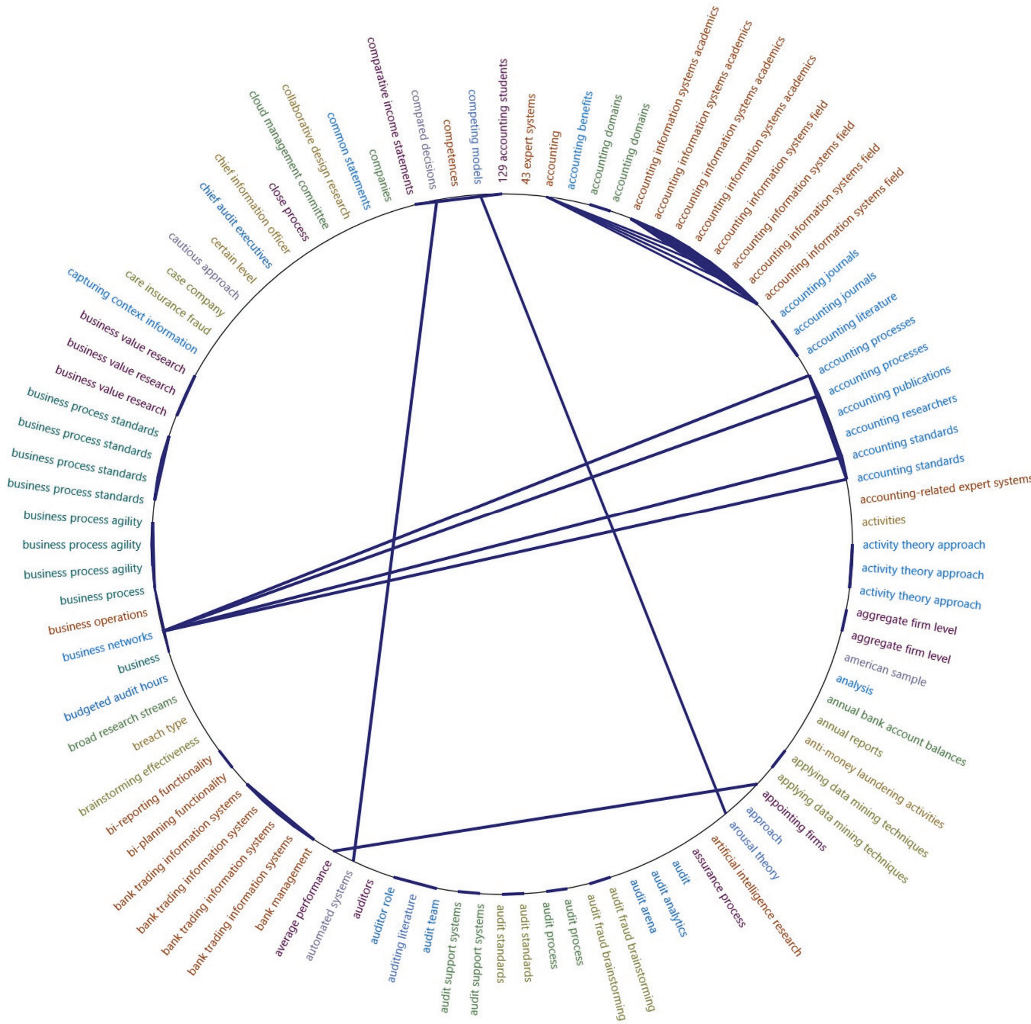

Figure 7. Cluster analysis for the papers in the *IJAIS* (from 2010 to 2019).

2.2.3. Results for the Latest Period (2020 to 2022)

Regarding the last period of publications in the *IJAIS*, studies on the so-called emerging technologies that started at the end of the last decade have followed. Furthermore, it can be seen a lower development of the traditional topics from the earlier periods, such as the use of AIS and ERP (e.g., [111–113]) or the control and management of IT infrastructures (e.g., [114,115]). Those newest studies seem to offer a wider variety of perspectives that address issues such as blockchain-based technologies (e.g., [116–119]), which include crypto-assets or cybersecurity issues (e.g., [120–125]). Less numerous, though available, are also studies on social media (e.g., [126,127]).

As for the topics of emerging technologies consolidated in the last decade, there is still opportunity for the various topics that have been previously explored, such as continuous auditing or continuous monitoring, data analytics, big data, machine learning, artificial intelligence, and cloud computing (e.g., [128–137]).

Although not new, studies can also be found that link different topics in a single research, namely the study by Zhang et al. [137], which addresses the issue of continuous monitoring using machine learning and interactive visualisation of data. Another example is the research by Alzamil et al. [138], which uses text-mining tools to assess financial information published on social networks. Finally, it is important to notice the existence of a single study on the COVID-19 pandemic [139] and the development observed in studies that use nonfinancial information as a source of information, such as sustainability reports or integrated reporting (e.g., [130,140]).

Figure 8 provides the word clouds to illustrate the most common words for this last period.

Figure 8. Word clouds from the papers in the *IJAIS* (from 2020 to 2022).

Furthermore, “cybersecurity”, “breach” and “blockchain” arise among the most common terms found in this period, replacing topics such as “XBRL” as emerging topics from the previous one. On the other hand, differences in the relative frequencies of terms such as “control” and “quality”, together with the evidence of traditional ones, such as “reports”, “reporting” and “decision-making”, also indicate new approaches for the research developed in this period, in comparison to the previous ones.

Therefore, this latest three-year period seems to have a more diversified range of topics on emerging technologies, methods, and approaches in accounting research.

Following, Figure 9 presents the topics automatically codified as the most relevant from the textual analysis for this last period.

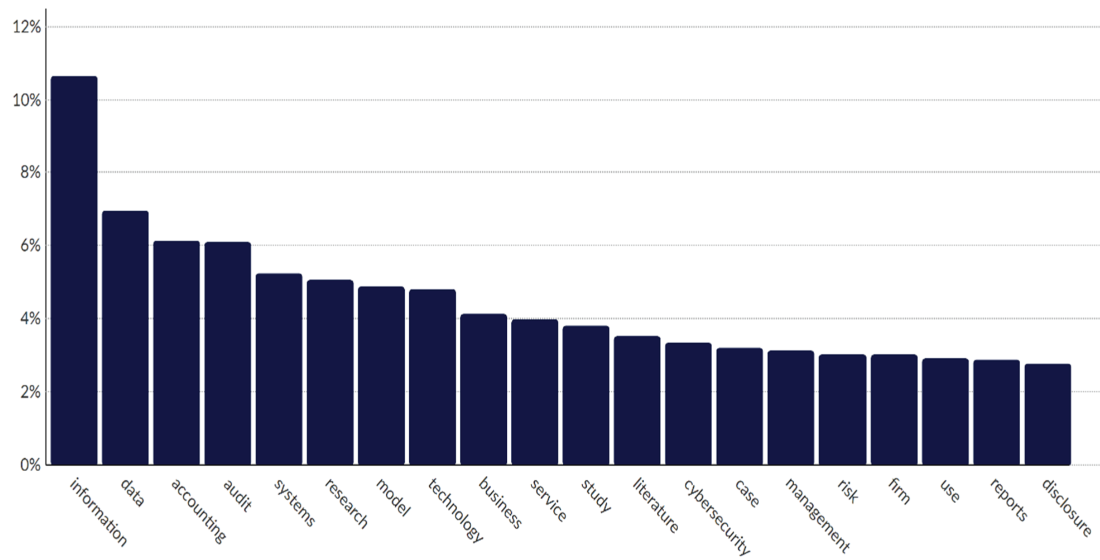

Figure 9. Topics automatically found from the papers in the *IJAIS* (from 2020 to 2022).

Figure 9 shows that the gap between the topic "information", which is kept as the most relevant, is amplified in this last period. Despite being the shortest period under assessment, 31 topics were automatically identified, including, for instance, "blockchain", "effects", "factors", "internal control", "material weakness", "process", "quality", "tax", and "theory", besides those found in Figure 8. Below, the 20 most relevant, highlighted in bold, are listed, based on the same procedures as used before:

1. **Accounting**: 136 accounting professionals, accounting context, **accounting data, accounting fraud data mining literature, accounting fraud detection models, accounting information systems case study, accounting information systems scholars, accounting literature**, aggregated accounting numbers, cloud-based client accounting, **developing accounting information systems**, different accounting standards, highest-ranked accounting journals, laggard accounting systems, **management accounting**, professional accounting bodies, recent accounting fraud theory, robust account;
2. **Audit**: **4 audit firms**, asset-related audits, audit conclusions, audit fee premiums, audit framework, audit hours, audit personnel, audit practice, audited entity, auditing parties, auditing profession, computer-assisted audit tools, contemporary audit standards, continuous audit procedures, **cybersecurity audit effectiveness**, digital audit evidence, financial statement audits, **improving audit quality**, increasing audit productivity, **internal control audit work**, manual audit procedures, recurring audit deficiencies, relevant audit standards, reliable audit evidence;
3. **Business**: business digitization, **business information technology intensity**, business model transformation indices, business operations, **business processes**, business professionals, business rules, general business descriptions, increasing business competition, strategic business partner role;
4. **Case**: accounting information systems case study, compelling use case, in-depth case study, participatory case study, specific case, various use cases;
5. **Cybersecurity**: 52 cybersecurity comment letters, **cybersecurity audit effectiveness**, cybersecurity breach incidents, cybersecurity incidents, **cybersecurity risk disclosure practices**, **cybersecurity risk disclosure trends**, organizational cybersecurity risk exposure, overall cybersecurity risks, **proprietary cybersecurity information**, regarding cybersecurity;

6. **Data**: **accounting data**, **accounting fraud data mining literature**, available data, big data capabilities, **big data technologies**, climate data, collected data, data analytics, data breach, **data processing integrity**, **data quality research**, data standards, data visualization software, financial data, general ledger data, interactive data visualization, interview data, legal-entity data segmentation, novel data analysis technique, novel data mining technique, real-life data, social media data, textual data, unstructured data, **using data**;
7. **Disclosures**: corporate disclosures, cryptocurrency disclosures, **cybersecurity risk disclosure practices**, **cybersecurity risk disclosure trends**, disclosure location, **firm disclosures**, remediation disclosures;
8. **Firms**: **4 audit firms**, adopting firm, **firm disclosures**, firm resource, firm samples, firm size, firm tenure, incentivizing client firms, Korean-listed firms;
9. **Information: accounting information systems, accounting information systems case study, accounting information systems scholars, agricultural information systems**, budget information, **business information technology intensity**, clarifying information, **developing accounting information systems**, existing information systems, **information content, information dissemination, information overload, information processing capabilities, information quality, information systems discipline, information systems theories, information technology experts, integrated information systems, personal information management capabilities**, private information, **proprietary cybersecurity information**, qualitative information, quantitative information, social responsibility information, specific value information, text information;
10. **Literature**: **accounting fraud data mining literature**, **accounting literature**, current literature, existing literature, extensive literature review, **natural language processing literature**, prior literature, research literature, systematic literature review;
11. **Management: cyber risk management effectiveness, cyber risk management maturity, knowledge management research, management accountants, management accounting, management reporting**, personal information management capabilities, supply chain management, top management commitment, top management support, workflow management;
12. **Model**: **accounting fraud detection models**, **business model transformation indices**, developed models, digital maturity model, filed model, **force field model**, model performance, predictive models, proposed model, research model, theoretical model, **wave theory life cycle model**;
13. **Reporting**: financial reporting, **management reporting**, report length, social responsibility reports, unique reporting requirements;
14. **Research**: answering research questions, **data quality research**, design science research contribution, empirical research, extending research, future research, **knowledge management research**, prior research, recent research, research initiative, **research literature**, **research model**, research studies;
15. **Risk: cyber risk management effectiveness, cyber risk management maturity, cybersecurity risk disclosure practices, cybersecurity risk disclosure trends, organizational cybersecurity risk exposure, overall cybersecurity risks**, regulation risks, risk assessment;
16. **Service**: assurance services, consumer services, payment services, service components, **service quality**, shared service mode;
17. **Study: accounting information systems case study**, cross-sectional field study, existing studies, **in-depth case study**, longitudinal study, **multi-case study approach, participatory case study, research studies**;
18. **System: accounting information systems, accounting information systems case study, accounting information systems scholars, agricultural information systems, developing accounting information systems, enterprise resource planning system design agenda, existing information systems, information systems discipline, in-**

formation systems theories, integrated information systems, intelligent systems, laggard accounting systems, system quality, system usage;
19. **Technology**: above-mentioned technologies, **big data technologies, blockchain technology applications, blockchain technology solutions, business information technology intensity**, computer technology, emerging technology adoption, **information technology experts**, learning technologies, ledger technology, past technology experience, technological advancements, technological developments, trending technology;
20. **Use**: **compelling use case**, **cost-effective use**, decision-making use, **effective use**, organizational use, user satisfaction, **using data**, using DevOps, using propensity score, **various use cases**.

From the most relevant topics or subtopics found for this period, distinctive characteristics can be highlighted, as follows:

- A more diversified set of subtopics within the topics found;
- The increasing relevance of matters regarding social responsibility, climate, and budgetary information;
- A more evident link, from the subtopics, identified, between accounting and other social sciences through the consideration or inclusion of a wide-ranging of explanatory factors, such as "individual factors", "environmental factors", "organizational complexity factors", "psychological factors", and "social-psychological factors";
- A diverse set of underlying theories and research methods used, particularly those focusing on case and experimental studies, as well as literature reviews (for this reason, "case", "study", and "literature" appears as novelties within the most relevant topics, besides those previously found, such as "research" and "model");
- Besides general references to "emergent technologies" or "trending technologies", the most significant number of indications on specific uses of those tools as precise topics or subtopics, for instance, "blockchain", "crypto assets" or "cryptocurrencies", "intelligent systems", "cloud-based accounting", "big data", "data analytics", "data mining, "learning technologies", and "natural language";
- "Risk", "cybersecurity" and "tax" are included in the set of main topics, which demonstrates the growing relevance of those topics (the latter as a particular novelty for this period).

Finally, Figure 10 presents the cluster analysis performed to illustrate the relationship between the topics or subtopics for this latest period.

Figure 10 shows a most diversified set of topics or subtopics and relationships, as well as a particular increase in case studies and literature reviews, which may indicate the prominence of those research methods in this latest period, as discussed before. Regardless of the relevance of the traditional topics in AIS research, the figure also highlights the relevance of usual topics included in the concept of emerging technologies, such as big data, cloud computing, cryptocurrencies and blockchain, added to those found in previous periods (for instance, data mining, continuous audit and cybersecurity).

The following section discusses the main findings, presenting the main limitations and proposing prospects for further research in accounting.

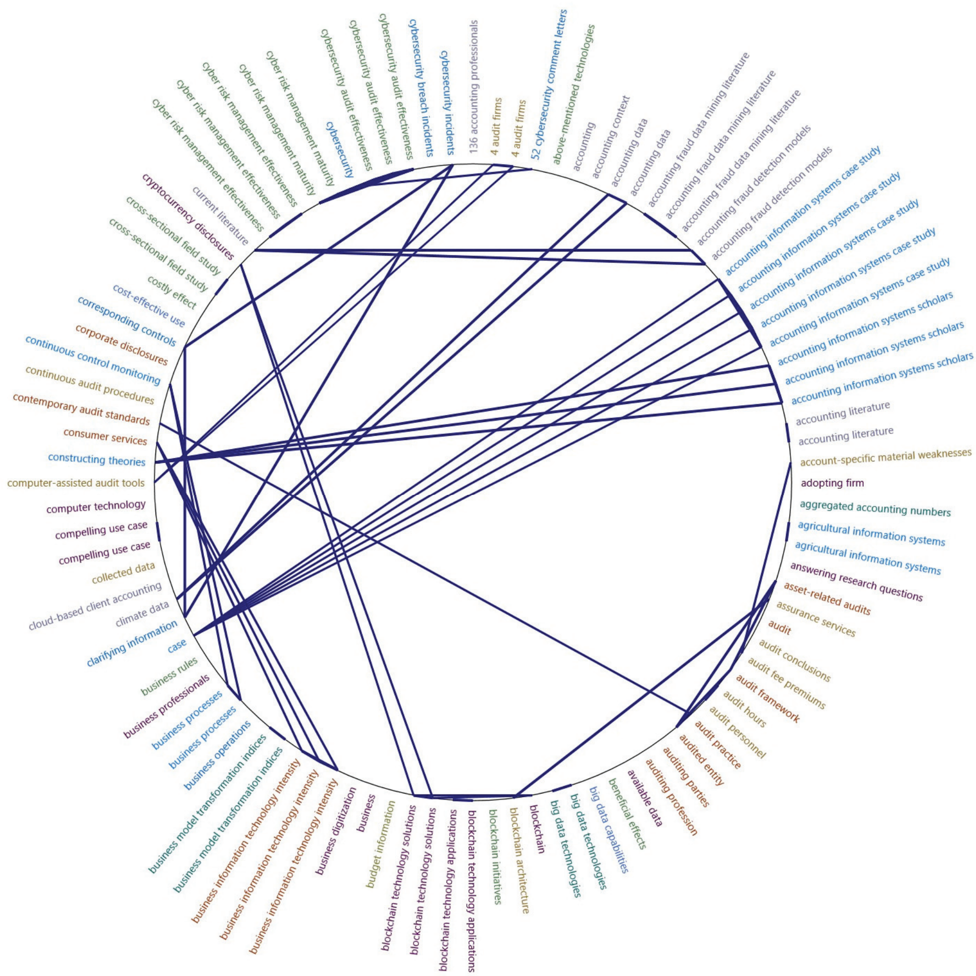

Figure 10. Cluster analysis for the papers in the *IJAIS* (from 2020 to 2022).

3. Discussion

This paper selected one top journal in accounting, which is specifically dedicated to the use of technologies in accounting, to assess the research topics published and their evolution over this century (from 2000 to 2022). For this purpose, the analysis compares three distinct periods, namely the first two decades and the last three years. The latest period is particularly used as a proxy for the recent trends in accounting research.

The findings indicate that trending topics in accounting have increased their relevance and influence, enriching the debate and future perspectives for professionals, academics, and researchers in this area through the combined use of new technologies. This aspect is also stressed by Kroon et al. [14], who concluded that the assessment of their impacts on the accounting profession is scarce, suggesting that future research should improve the empirical analysis of their contributions to open innovation.

In this context, it is worthwhile to mention that professionals, academics, and researchers have highlighted the difficulty of adequacy and monitoring the developments in the accounting profession and education due to new topics and technological advancements. Authors argue that accounting research needs to evolve and follow contemporary trends in reporting, regulation, work methods, social and political trends, as well as the technological environment, with a stronger connection between professionals, academia, and researchers (e.g., [1–3]). Therefore, following such challenges, and keeping up with their needs and demands are relevant matters for different subjects. Collaborations between academia and professionals have been suggested by authors to reduce the gap between the different areas of accounting impacts (e.g., [11]).

Despite the relative openness of the journals to new topics, which were identified, the findings also indicate a certain resilience of traditional themes, even when new methodologies and trending topics are applied. As a reference, the most cited papers from the first period seem to indicate that the underlying research themes remain. Furthermore, accounting research tends to incorporate new topics at relatively slow rates or in later stages than day-to-day practice, technical discussions, technological impacts, or regulation issues. This can be potentially explained by the necessary time to collect and assess data that underlies the different research methods in accounting. Notwithstanding, this might contribute to the feeling that accounting research has not been following the recent advances seen in the accounting profession.

In the first decade of this millennium, the initial focus on the AIS, which included the Internet and its potential resources (web-based services and reporting on the Internet), and related technologies, such as the ERP, was replaced. New challenges in accounting took place and then research was dedicated to new topics such as innovative ways of recording transactions and events, new business models, more efficient and effective methods for processing information, and, finally, new value chains, channels, and methods for disseminating useful information to a wider number of users. Then, the newest research appeared with a more diverse scope, covering new trends in accounting reporting overall, which includes new requirements, methods, and reporting channels, such as social media, as well as the different uses, risks, and benefits of emerging technologies for reporting and fraud detection. Case studies seem to be a relevant research method in the latest period assessed, mitigating a gap in the accounting area highlighted, for instance, by Kroon et al. [14].

Therefore, literature has added increasingly sophisticated data sources and analysis technologies, based on artificial intelligence, machine learning processes, big data, business intelligence, data mining, and data analytics, only to name the most recurrent ones. Despite the existence of literature reviews on the so-called emerging technologies, bibliometric studies on recent trends in AIS for the latest years have not yet been identified at this stage. Notwithstanding, the findings from this research are aligned with those recently released by Kumar [13], Kroon et al. [14], and Chiu et al. [15], which demonstrate a still broad potential for exploration of research in emerging technologies in accounting.

Manetti et al. [141], in this sense, highlight the potential use of emerging technologies to develop new paths for accounting. Furthermore, Kumar [13] identified a relative absence of research on specific areas, such as tax, governmental and nonprofit accounting. Notwithstanding, the findings from this paper, which identify an increasing relevance of studies on tax issues, particularly from the evidence of the latest period, should be highlighted. Moreover, the latest research has been incorporating and linking emerging technologies with trending topics in accounting, such as sustainability (nonfinancial information) reporting and other areas within social sciences. The latter includes research that uses psychology and sociology knowledge to amplify the scope of studies aiming to understand the different factors that may affect human behaviours, particularly when facing data assessment and decision-making processes.

Regardless of the shreds of evidence from this paper, the overall conclusions indicate that there is still an abundant scope for the development of research and use of emerging technologies in the accounting profession and education, which can be even broader from the perspective of accounting as a social science with an applied nature. In this context, its application in neurosciences, proposed by Tank and Farrell [12], is an example of a still-open challenge in accounting.

3.1. Research Limitations

The analysis performed in this paper, despite covering a relevant period, is limited to a single journal. Therefore, this limitation must be considered in the context of those conclusions, given that the decisions taken by its editorial board over this period may be seen as a relevant and subjective factor of neither measurable nor visible influence.

Additionally, the analysis was restricted to the abstracts found in those papers and, consequently, assumes the overall quality of the contents included in this piece of information. This limitation allows the assessment of a more relevant number of papers, despite only providing an overview of their contents. Exploring further sections would provide a more in-depth analysis of the papers' contents. Nonetheless, the decision making by researchers must consider the balance between the costs and the benefits of the analysis, considering its objectives and the level of information to be assessed.

Finally, as a qualitative approach, this research has a more particular and unavoidable constraint related to the judgments that should be made by research over the different steps of the analysis processes. The use of textual analysis tools may mitigate this limitation, but it necessarily remains, for instance during the choice of the most proper stop words for the analysis of the most frequent words.

3.2. Future Avenues in Accounting and Information System Research

Despite its limitation, this research may provide a relevant contribution to various interested parties in the accounting area, including academic members and professionals, as it identifies an overall perspective of the evolution trends and recent topics under discussion in this field.

The issues identified as trending topics can be seen as new sources of themes for researchers, and the results of these investigations can be reverted to benefits for academia and, consequently, professionals in the accounting area. The challenges professionals face needs to be monitored by researchers and educational institutions since it is crucial to include information technologies as a basic subject of curricula content for professional success. Additionally, professional associations can be of great usefulness whenever deficiencies or constraints are identified, as they possess the resources or can exert political pressure to overcome them.

Currently, the development of innovative research has also been combining the newest available data sources for data collection, technological methods for data assessment, and the so-called trending topics in accounting. Those topics include not only matters on international regulation and the sustainable perspective in accounting, such as the environmental, social and governance issues, but also new methods, channels and processes for improving the entities' auditing and reporting. Therefore, this seems to be a path to follow as an avenue for future research in accounting.

As an avenue to develop a literature review on AIS research and to go beyond the textual analysis proposed in this paper, we suggest the use of innovative tools, based on emerging technologies, that cover a more diversified set of journals dedicated to the use of new technologies in different accounting areas.

Author Contributions: This study was conceptualized, developed, written, and revised by F.A. and P.G.D.S. equally. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Instituto Politécnico de Lisboa (IPL/2022/REPUK RAINE_ISCAL).

Data Availability Statement: The data source used for this research was collected from the Scopus database, freely available information to researchers. Nonetheless, for any questions or requests regarding the outputs from this paper, please contact the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Islam, M.A. Future of Accounting Profession: Three Major Changes and Implications for Teaching and Research. Business Reporting, International Federation of Accountants (IFAC). 2017. Available online: https://eprints.qut.edu.au/104070/ (accessed on 4 December 2022).
2. Christensen, J. Accounting in 2036: A Learned Profession. *Account. Rev.* **2018**, *93*, 387–390. [CrossRef]
3. Kaplan, R.S.; Robert, S.; Dzuranin, A.C.; Mălăescu, I.; Janvrin, D.J.; Wood, D.A.; Malsch, B.; Salterio, S.E.; Power, M.K.; Gendron, Y.; et al. Accounting Scholarship that Advances Professional Knowledge and Practice. *Account. Rev.* **2011**, *86*, 367–383. [CrossRef]
4. Al-Adeem, K.R. Who decides what is publishable? Empirical Study on the Influence of a Journal's Editorial Board on the Observed Paradigm Shift in US Academic Accounting Research. *North Am. Account. Stud.* **2019**, *2*, 1–21. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4127109 (accessed on 13 December 2022).
5. Carnegie, G.; Parker, L.; Tsahuridu, E. It's 2020: What is Accounting Today? *Aust. Account. Rev.* **2021**, *31*, 65–73. [CrossRef]
6. Moll, J.; Yigitbasioglu, O. The role of internet-related technologies in shaping the work of accountants: New directions for accounting research. *Br. Account. Rev.* **2019**, *51*, 100833. [CrossRef]
7. Silva, R.; Inácio, H.; Marques, R.P. Blockchain implications for auditing: A systematic literature review and bibliometric analysis. *Int. J. Digit. Account. Res.* **2022**, *22*, 163–192. [CrossRef]
8. Bellucci, M.; Bianchi, D.C.; Manetti, G. Blockchain in accounting practice and research: Systematic literature review. *Meditari Account. Res.* **2022**, *30*, 121–146. [CrossRef]
9. Secinaro, S.; Mas, F.D.; Brescia, V.; Calandra, D. Blockchain in the accounting, auditing and accountability fields: A bibliometric and coding analysis. *Account. Audit. Account. J.* **2022**, *35*, 168–203. [CrossRef]
10. Lardo, A.; Corsi, K.; Varma, A.; Mancini, D. Exploring blockchain in the accounting domain: A bibliometric analysis. *Account. Audit. Account. J.* **2022**, *35*, 204–233. [CrossRef]
11. Mugwira, T. Internet Related Technologies in the auditing profession: A WOS bibliometric review of the past three decades and conceptual structure mapping. *Rev. Contab.* **2022**, *25*, 201–216. [CrossRef]
12. Tank, A.K.; Farrell, A.M. Is Neuroaccounting Taking a Place on the Stage? A Review of the Influence of Neuroscience on Accounting Research. *Eur. Account. Rev.* **2022**, *31*, 173–207. [CrossRef]
13. Kumar, S.; Marrone, M.; Liu, Q.; Pandey, N. Twenty years of the International Journal of Accounting Information Systems: A bibliometric analysis. *Int. J. Account. Inf. Syst.* **2020**, *39*, 100488. [CrossRef]
14. Kroon, N.; Alves, M.; Martins, I. The Impacts of Emerging Technologies on Accountants' Role and Skills: Connecting to Open Innovation—A Systematic Literature Review. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 163. [CrossRef]
15. Chiu, V.; Liu, Q.; Muehlmann, B.; Baldwin, A.A. A bibliometric analysis of accounting information systems journals and their emerging technologies contributions. *Int. J. Account. Inf. Syst.* **2019**, *32*, 24–43. [CrossRef]
16. Yigitbasioglu, O.M.; Velcu, O. A review of dashboards in performance management: Implications for design and research. *Int. J. Account. Inf. Syst.* **2012**, *13*, 41–59. [CrossRef]
17. Lee, L.; Petter, S.; Fayard, D.; Robinson, S. On the use of partial least squares path modeling in accounting research. *Int. J. Account. Inf. Syst.* **2011**, *12*, 305–328. [CrossRef]
18. Appelbaum, D.; Kogan, A.; Vasarhelyi, M.; Yan, Z. Impact of business analytics and enterprise systems on managerial accounting. *Int. J. Account. Inf. Syst.* **2017**, *25*, 29–44. [CrossRef]
19. Bradford, M.; Florin, J. Examining the role of innovation diffusion factors on the implementation success of enterprise resource planning systems. *Int. J. Account. Inf. Syst.* **2003**, *4*, 205–225. [CrossRef]
20. Poston, R.; Grabski, S. Financial impacts of enterprise resource planning implementations. *Int. J. Account. Inf. Syst.* **2001**, *2*, 271–294. [CrossRef]
21. Elbashir, M.Z.; Collier, P.A.; Davern, M.J. Measuring the effects of business intelligence systems: The relationship between business process and organizational performance. *Int. J. Account. Inf. Syst.* **2008**, *9*, 135–153. [CrossRef]
22. Baldwin, A.A.; Morris, B.W.; Scheiner, J.H. Where do AIS researchers publish? *Int. J. Account. Inf. Syst.* **2000**, *1*, 123–134. [CrossRef]
23. Daigle, R.J.; Arnold, V. An analysis of the research productivity of AIS faculty. *Int. J. Account. Inf. Syst.* **2000**, *1*, 106–122. [CrossRef]
24. Nicolaou, A.I. A contingency model of perceived effectiveness in accounting information systems: Organizational coordination and control effects. *Int. J. Account. Inf. Syst.* **2000**, *1*, 91–105. [CrossRef]
25. Nicolaou, A.I. Quality of postimplementation review for enterprise resource planning systems. *Int. J. Account. Inf. Syst.* **2004**, *5*, 25–49. [CrossRef]
26. Hunton, J.E.; Lippincott, B.; Reck, J.L. Enterprise resource planning systems: Comparing firm performance of adopters and nonadopters. *Int. J. Account. Inf. Syst.* **2003**, *4*, 165–184. [CrossRef]
27. Ismail, N.A.; King, M. Firm performance and AIS alignment in Malaysian SMEs. *Int. J. Account. Inf. Syst.* **2005**, *6*, 241–259. [CrossRef]
28. Nicolaou, A.I.; Bhattacharya, S. Organizational performance effects of ERP systems usage: The impact of post-implementation changes. *Int. J. Account. Inf. Syst.* **2006**, *7*, 18–35. [CrossRef]
29. Boulianne, E. Revisiting fit between AIS design and performance with the analyzer strategic-type. *Int. J. Account. Inf. Syst.* **2007**, *8*, 1–16. [CrossRef]

30. Grabski, S.V.; Leech, S.A. Complementary controls and ERP implementation success. *Int. J. Account. Inf. Syst.* **2007**, *8*, 17–39. [CrossRef]
31. O'Leary, D. On the relationship between citations and appearances on "top 25" download lists in the International Journal of Accounting Information Systems. *Int. J. Account. Inf. Syst.* **2008**, *9*, 61–75. [CrossRef]
32. Vasarhelyi, M.A.; Alles, M.G. The "now" economy and the traditional accounting reporting model: Opportunities and challenges for AIS research. *Int. J. Account. Inf. Syst.* **2008**, *9*, 227–239. [CrossRef]
33. Geerts, G.L.; McCarthy, W.E. An ontological analysis of the economic primitives of the extended-REA enterprise information architecture. *Int. J. Account. Inf. Syst.* **2002**, *3*, 1–16. [CrossRef]
34. Bowen, P.L.; Cheung, M.-Y.D.; Rohde, F.H. Enhancing IT governance practices: A model and case study of an organization's efforts. *Int. J. Account. Inf. Syst.* **2007**, *8*, 191–221. [CrossRef]
35. Dowling, C.; Leech, S. Audit support systems and decision aids: Current practice and opportunities for future research. *Int. J. Account. Inf. Syst.* **2007**, *8*, 92–116. [CrossRef]
36. Kang, H.; Bradley, G. Measuring the performance of IT services: An assessment of SERVQUAL. *Int. J. Account. Inf. Syst.* **2002**, *3*, 151–164. [CrossRef]
37. Bhattacharya, S.; Behara, R.S.; Gundersen, D.E. Business risk perspectives on information systems outsourcing. *Int. J. Account. Inf. Syst.* **2003**, *4*, 75–93. [CrossRef]
38. Bedard, J.C.; Jackson, C.; Ettredge, M.L.; Johnstone, K.M. The effect of training on auditors' acceptance of an electronic work system. *Int. J. Account. Inf. Syst.* **2003**, *4*, 227–250. [CrossRef]
39. Boritz, J.E. IS practitioners' views on core concepts of information integrity. *Int. J. Account. Inf. Syst.* **2005**, *6*, 260–279. [CrossRef]
40. Bradley, J. Management based critical success factors in the implementation of Enterprise Resource Planning systems. *Int. J. Account. Inf. Syst.* **2008**, *9*, 175–200. [CrossRef]
41. Curtis, M.B.; Payne, E.A. An examination of contextual factors and individual characteristics affecting technology implementation decisions in auditing. *Int. J. Account. Inf. Syst.* **2008**, *9*, 104–121. [CrossRef]
42. Beasley, M.; Bradford, M.; Dehning, B. The value impact of strategic intent on firms engaged in information systems outsourcing. *Int. J. Account. Inf. Syst.* **2009**, *10*, 79–96. [CrossRef]
43. Ettredge, M.; Richardson, V.J.; Scholz, S. The presentation of financial information at corporate Web sites. *Int. J. Account. Inf. Syst.* **2001**, *2*, 149–168. [CrossRef]
44. Kaplan, S.E.; Nieschwietz, R.J. A Web assurance services model of trust for B2C e-commerce. *Int. J. Account. Inf. Syst.* **2003**, *4*, 95–114. [CrossRef]
45. Marston, C.; Polei, A. Corporate reporting on the Internet by German companies. *Int. J. Account. Inf. Syst.* **2004**, *5*, 285–311. [CrossRef]
46. Bonsón, E.; Escobar, T. Digital reporting in Eastern Europe: An empirical study. *Int. J. Account. Inf. Syst.* **2006**, *7*, 299–318. [CrossRef]
47. Cormier, D.; Ledoux, M.-J.; Magnan, M. The use of Web sites as a disclosure platform for corporate performance. *Int. J. Account. Inf. Syst.* **2009**, *10*, 1–24. [CrossRef]
48. Kim, H.-J.; Mannino, M.; Nieschwietz, R.J. Information technology acceptance in the internal audit profession: Impact of technology features and complexity. *Int. J. Account. Inf. Syst.* **2009**, *10*, 214–228. [CrossRef]
49. Murthy, U.S.; Groomer, S. A continuous auditing web services model for XML-based accounting systems. *Int. J. Account. Inf. Syst.* **2004**, *5*, 139–163. [CrossRef]
50. Alles, M.; Brennan, G.; Kogan, A.; Vasarhelyi, M.A. Continuous monitoring of business process controls: A pilot implementation of a continuous auditing system at Siemens. *Int. J. Account. Inf. Syst.* **2006**, *7*, 137–161. [CrossRef]
51. Debreceny, R.; Gray, G.L. The production and use of semantically rich accounting reports on the Internet: XML and XBRL. *Int. J. Account. Inf. Syst.* **2001**, *2*, 47–74. [CrossRef]
52. Premuroso, R.F.; Bhattacharya, S. Do early and voluntary filers of financial information in XBRL format signal superior corporate governance and operating performance? *Int. J. Account. Inf. Syst.* **2008**, *9*, 1–20. [CrossRef]
53. Bonsón, E.; Cortijo, V.; Escobar, T. Towards the global adoption of XBRL using International Financial Reporting Standards (IFRS). *Int. J. Account. Inf. Syst.* **2009**, *10*, 46–60. [CrossRef]
54. Lord, A.T. ISACA model curricula 2004. *Int. J. Account. Inf. Syst.* **2004**, *5*, 251–265. [CrossRef]
55. Tuttle, B.; Vandervelde, S.D. An empirical examination of CobiT as an internal control framework for information technology. *Int. J. Account. Inf. Syst.* **2007**, *8*, 240–263. [CrossRef]
56. Boulianne, E.; Cho, C.H. The rise and fall of WebTrust. *Int. J. Account. Inf. Syst.* **2009**, *10*, 229–244. [CrossRef]
57. Calderon, T.G.; Cheh, J.J. A roadmap for future neural networks research in auditing and risk assessment. *Int. J. Account. Inf. Syst.* **2002**, *3*, 203–236. [CrossRef]
58. Sutton, S.G. A research discipline with no boundaries: Reflections on 20years of defining AIS research. *Int. J. Account. Inf. Syst.* **2010**, *11*, 289–296. [CrossRef]
59. Granlund, M. Extending AIS research to management accounting and control issues: A research note. *Int. J. Account. Inf. Syst.* **2011**, *12*, 3–19. [CrossRef]
60. Kallunki, J.-P.; Laitinen, E.K.; Silvola, H. Impact of enterprise resource planning systems on management control systems and firm performance. *Int. J. Account. Inf. Syst.* **2011**, *12*, 20–39. [CrossRef]

61. Guan, J.; Levitan, A.S.; Kuhn, J.R. How AIS can progress along with ontology research in IS. *Int. J. Account. Inf. Syst.* **2013**, *14*, 21–38. [CrossRef]
62. Kanellou, A.; Spathis, C. Accounting benefits and satisfaction in an ERP environment. *Int. J. Account. Inf. Syst.* **2013**, *14*, 209–234. [CrossRef]
63. Bradford, M.; Earp, J.B.; Grabski, S. Centralized end-to-end identity and access management and ERP systems: A multi-case analysis using the Technology Organization Environment framework. *Int. J. Account. Inf. Syst.* **2014**, *15*, 149–165. [CrossRef]
64. Gray, G.L.; Chiu, V.; Liu, Q.; Li, P. The expert systems life cycle in AIS research: What does it mean for future AIS research? *Int. J. Account. Inf. Syst.* **2014**, *15*, 423–451. [CrossRef]
65. Ruivo, P.; Oliveira, T.; Neto, M. Examine ERP post-implementation stages of use and value: Empirical evidence from Portuguese SMEs. *Int. J. Account. Inf. Syst.* **2014**, *15*, 166–184. [CrossRef]
66. Hutchison, P.D.; Daigle, R.J.; George, B. Application of latent semantic analysis in AIS academic research. *Int. J. Account. Inf. Syst.* **2018**, *31*, 83–96. [CrossRef]
67. Alles, M. Examining the role of the AIS research literature using the natural experiment of the 2018 JIS conference on cloud computing. *Int. J. Account. Inf. Syst.* **2018**, *31*, 58–74. [CrossRef]
68. Hunton, J.E.; Mauldin, E.; Wheeler, P.; Libby, D.; Libby, J. RETRACTED: Continuous monitoring and the status quo effect. *Int. J. Account. Inf. Syst.* **2010**, *11*, 239–252. [CrossRef]
69. Chan, D.Y.; Vasarhelyi, M. Innovation and practice of continuous auditing. *Int. J. Account. Inf. Syst.* **2011**, *12*, 152–160. [CrossRef]
70. Vasarhelyi, M.; Alles, M.; Kuenkaikaew, S.; Littley, J. The acceptance and adoption of continuous auditing by internal auditors: A micro analysis. *Int. J. Account. Inf. Syst.* **2012**, *13*, 267–281. [CrossRef]
71. Rikhardsson, P.; Dull, R. An exploratory study of the adoption, application and impacts of continuous auditing technologies in small businesses. *Int. J. Account. Inf. Syst.* **2016**, *20*, 26–37. [CrossRef]
72. Jans, M.; Hosseinpour, M. How active learning and process mining can act as Continuous Auditing catalyst. *Int. J. Account. Inf. Syst.* **2019**, *32*, 44–58. [CrossRef]
73. Srivastava, R.P.; Kogan, A. Assurance on XBRL instance document: A conceptual framework of assertions. *Int. J. Account. Inf. Syst.* **2010**, *11*, 261–273. [CrossRef]
74. Henderson, D.; Sheetz, S.D.; Trinkle, B.S. The determinants of inter-organizational and internal in-house adoption of XBRL: A structural equation model. *Int. J. Account. Inf. Syst.* **2012**, *13*, 109–140. [CrossRef]
75. O'Riain, S.; Curry, E.; Harth, A. XBRL and open data for global financial ecosystems: A linked data approach. *Int. J. Account. Inf. Syst.* **2012**, *13*, 141–162. [CrossRef]
76. Heravi, B.R.; Lycett, M.; de Cesare, S. Ontology-based standards development: Application of OntoStanD to ebXML business process specification schema. *Int. J. Account. Inf. Syst.* **2014**, *15*, 275–297. [CrossRef]
77. Dhole, S.; Lobo, G.J.; Mishra, S.; Pal, A.M. Effects of the SEC's XBRL mandate on financial reporting comparability. *Int. J. Account. Inf. Syst.* **2015**, *19*, 29–44. [CrossRef]
78. Chou, C.-C.; Chang, C.; Peng, J. Integrating XBRL data with textual information in Chinese: A semantic web approach. *Int. J. Account. Inf. Syst.* **2016**, *21*, 32–46. [CrossRef]
79. Chou, C.-C.; Hwang, N.-C.R.; Wang, T.; Debreceny, R. The topical link model-integrating topic-centric information in XBRL-formatted reports. *Int. J. Account. Inf. Syst.* **2018**, *29*, 16–36. [CrossRef]
80. Abdolmohammadi, M.J.; DeSimone, S.M.; Hsieh, T.-S.; Wang, Z. Factors associated with internal audit function involvement with XBRL implementation in public companies: An international study. *Int. J. Account. Inf. Syst.* **2017**, *25*, 45–56. [CrossRef]
81. Peters, M.D.; Wieder, B.; Sutton, S.G.; Wakefield, J. Business intelligence systems use in performance measurement capabilities: Implications for enhanced competitive advantage. *Int. J. Account. Inf. Syst.* **2016**, *21*, 1–17. [CrossRef]
82. Sutton, S.G.; Holt, M.; Arnold, V. "The reports of my death are greatly exaggerated"—Artificial intelligence research in accounting. *Int. J. Account. Inf. Syst.* **2016**, *22*, 60–73. [CrossRef]
83. Rikhardsson, P.; Yigitbasioglu, O. Business intelligence & analytics in management accounting research: Status and future focus. *Int. J. Account. Inf. Syst.* **2018**, *29*, 37–58. [CrossRef]
84. Debreceny, R.S.; Gray, G.L. Data mining journal entries for fraud detection: An exploratory study. *Int. J. Account. Inf. Syst.* **2010**, *11*, 157–181. [CrossRef]
85. Jans, M.; Lybaert, N.; Vanhoof, K. Internal fraud risk reduction: Results of a data mining case study. *Int. J. Account. Inf. Syst.* **2010**, *11*, 17–41. [CrossRef]
86. Gray, G.L.; Debreceny, R.S. A taxonomy to guide research on the application of data mining to fraud detection in financial statement audits. *Int. J. Account. Inf. Syst.* **2014**, *15*, 357–380. [CrossRef]
87. Alles, M.; Gray, G.L. Incorporating big data in audits: Identifying inhibitors and a research agenda to address those inhibitors. *Int. J. Account. Inf. Syst.* **2016**, *22*, 44–59. [CrossRef]
88. Amani, F.A.; Fadlalla, A.M. Data mining applications in accounting: A review of the literature and organizing framework. *Int. J. Account. Inf. Syst.* **2017**, *24*, 32–58. [CrossRef]
89. Chen, Y.-J.; Wu, C.-H.; Li, H.-Y.; Chen, H.-K. Enhancement of fraud detection for narratives in annual reports. *Int. J. Account. Inf. Syst.* **2017**, *26*, 32–45. [CrossRef]
90. Rahimikia, E.; Mohammadi, S.; Rahmani, T.; Ghazanfari, M. Detecting corporate tax evasion using a hybrid intelligent system: A case study of Iran. *Int. J. Account. Inf. Syst.* **2017**, *25*, 1–17. [CrossRef]

91. Werner, M. Financial process mining—Accounting data structure dependent control flow inference. *Int. J. Account. Inf. Syst.* **2017**, *25*, 57–80. [CrossRef]
92. Baader, G.; Krcmar, H. Reducing false positives in fraud detection: Combining the red flag approach with process mining. *Int. J. Account. Inf. Syst.* **2018**, *31*, 1–16. [CrossRef]
93. Prasad, A.; Green, P.; Heales, J. On governance structures for the cloud computing services and assessing their effectiveness. *Int. J. Account. Inf. Syst.* **2014**, *15*, 335–356. [CrossRef]
94. Prasad, A.; Green, P. Governing cloud computing services: Reconsideration of IT governance structures. *Int. J. Account. Inf. Syst.* **2015**, *19*, 45–58. [CrossRef]
95. Yigitbasioglu, O.M. External auditors' perceptions of cloud computing adoption in Australia. *Int. J. Account. Inf. Syst.* **2015**, *18*, 46–62. [CrossRef]
96. Wang, Y.; Kogan, A. Designing confidentiality-preserving Blockchain-based transaction processing systems. *Int. J. Account. Inf. Syst.* **2018**, *30*, 1–18. [CrossRef]
97. McCallig, J.; Robb, A.; Rohde, F. Establishing the representational faithfulness of financial accounting information using multiparty security, network analysis and a blockchain. *Int. J. Account. Inf. Syst.* **2019**, *33*, 47–58. [CrossRef]
98. Yao, L.J.; Liu, C.; Chan, S.H. The influence of firm specific context on realizing information technology business value in manufacturing industry. *Int. J. Account. Inf. Syst.* **2010**, *11*, 353–362. [CrossRef]
99. Prasad, A.; Heales, J. On IT and business value in developing countries: A complementarities-based approach. *Int. J. Account. Inf. Syst.* **2010**, *11*, 314–335. [CrossRef]
100. Heidari, F.; Loucopoulos, P. Quality evaluation framework (QEF): Modeling and evaluating quality of business processes. *Int. J. Account. Inf. Syst.* **2014**, *15*, 193–223. [CrossRef]
101. Lunardi, G.L.; Becker, J.L.; Maçada, A.C.G.; Dolci, P.C. The impact of adopting IT governance on financial performance: An empirical analysis among Brazilian firms. *Int. J. Account. Inf. Syst.* **2014**, *15*, 66–81. [CrossRef]
102. Brocke, J.V.; Braccini, A.M.; Sonnenberg, C.; Spagnoletti, P. Living IT infrastructures—An ontology-based approach to aligning IT infrastructure capacity and business needs. *Int. J. Account. Inf. Syst.* **2014**, *15*, 246–274. [CrossRef]
103. Cullinan, C.P.; Zheng, X. Outsourcing accounting information systems: Evidence from closed-end mutual fund families. *Int. J. Account. Inf. Syst.* **2015**, *17*, 65–83. [CrossRef]
104. Li, H.; No, W.G.; Wang, T. SEC's cybersecurity disclosure guidance and disclosed cybersecurity risk factors. *Int. J. Account. Inf. Syst.* **2018**, *30*, 40–55. [CrossRef]
105. Asatiani, A.; Apte, U.; Penttinen, E.; Rönkkö, M.; Saarinen, T. Impact of accounting process characteristics on accounting outsourcing—Comparison of users and non-users of cloud-based accounting information systems. *Int. J. Account. Inf. Syst.* **2019**, *34*, 100419. [CrossRef]
106. Chen, Y.-J.; Liou, W.-C.; Wu, J.-H. Fraud detection for financial statements of business groups. *Int. J. Account. Inf. Syst.* **2019**, *32*, 1–23. [CrossRef]
107. Cho, C.H.; Roberts, R.W. Environmental reporting on the internet by America's Toxic 100: Legitimacy and self-presentation. *Int. J. Account. Inf. Syst.* **2010**, *11*, 1–16. [CrossRef]
108. Demek, K.C.; Raschke, R.L.; Janvrin, D.J.; Dilla, W.N. Do organizations use a formalized risk management process to address social media risk? *Int. J. Account. Inf. Syst.* **2018**, *28*, 31–44. [CrossRef]
109. Wilkin, C.L.; Campbell, J.; Moore, S.; Simpson, J. Creating value in online communities through governance and stakeholder engagement. *Int. J. Account. Inf. Syst.* **2018**, *30*, 56–68. [CrossRef]
110. Blackburn, N.; Brown, J.; Dillard, J.; Hooper, V. A dialogical framing of AIS–SEA design. *Int. J. Account. Inf. Syst.* **2014**, *15*, 83–101. [CrossRef]
111. Robalo, R.C.; Moreira, J.A. The influence of power strategies in AIS implementation processes. *Int. J. Account. Inf. Syst.* **2020**, *39*, 100487. [CrossRef]
112. Weber, R. Taking the ontological and materialist turns: Agential realism, representation theory, and accounting information systems. *Int. J. Account. Inf. Syst.* **2020**, *39*, 100485. [CrossRef]
113. Huh, B.G.; Lee, S.; Kim, W. The impact of the input level of information system audit on the audit quality: Korean evidence. *Int. J. Account. Inf. Syst.* **2021**, *43*, 100533. [CrossRef]
114. Zhen, J.; Xie, Z.; Dong, K. Impact of IT governance mechanisms on organizational agility and the role of top management support and IT ambidexterity. *Int. J. Account. Inf. Syst.* **2021**, *40*, 100501. [CrossRef]
115. Plant, O.H.; van Hillegersberg, J.; Aldea, A. Rethinking IT governance: Designing a framework for mitigating risk and fostering internal control in a DevOps environment. *Int. J. Account. Inf. Syst.* **2022**, *45*, 100560. [CrossRef]
116. Alles, M.; Gray, G.L. "The first mile problem": Deriving an endogenous demand for auditing in blockchain-based business processes. *Int. J. Account. Inf. Syst.* **2020**, *38*, 100465. [CrossRef]
117. Vincent, N.E.; Skjellum, A.; Medury, S. Blockchain architecture: A design that helps CPA firms leverage the technology. *Int. J. Account. Inf. Syst.* **2020**, *38*, 100466. [CrossRef]
118. Søgaard, J.S. A blockchain-enabled platform for VAT settlement. *Int. J. Account. Inf. Syst.* **2021**, *40*, 100502. [CrossRef]
119. Yen, J.-C.; Wang, T. Stock price relevance of voluntary disclosures about blockchain technology and cryptocurrencies. *Int. J. Account. Inf. Syst.* **2021**, *40*, 100499. [CrossRef]

120. Gao, L.; Calderon, T.G.; Tang, F. Public companies' cybersecurity risk disclosures. *Int. J. Account. Inf. Syst.* **2020**, *38*, 100468. [CrossRef]
121. Chandra, A.; Snowe, M.J. A taxonomy of cybercrime: Theory and design. *Int. J. Account. Inf. Syst.* **2020**, *38*, 100467. [CrossRef]
122. Slapničar, S.; Vuko, T.; Čular, M.; Drašček, M. Effectiveness of cybersecurity audit. *Int. J. Account. Inf. Syst.* **2022**, *44*, 100548. [CrossRef]
123. Blakely, B.; Kurtenbach, J.; Nowak, L. Exploring the information content of cyber breach reports and the relationship to internal controls. *Int. J. Account. Inf. Syst.* **2022**, *46*, 100568. [CrossRef]
124. Hsieh, S.-F.; Brennan, G. Issues, risks, and challenges for auditing crypto asset transactions. *Int. J. Account. Inf. Syst.* **2022**, *46*, 100569. [CrossRef]
125. Wang, T.; Yen, J.-C.; Yoon, K. Responses to SEC comment letters on cybersecurity disclosures: An exploratory study. *Int. J. Account. Inf. Syst.* **2022**, *46*, 100567. [CrossRef]
126. Saxton, G.D.; Guo, C.; Saxton, G.D.; Guo, C. Social media capital: Conceptualizing the nature, acquisition, and expenditure of social media-based organizational resources. *Int. J. Account. Inf. Syst.* **2020**, *36*, 100443. [CrossRef]
127. Amin, M.H.; Mohamed, E.K.; Elragal, A. CSR disclosure on Twitter: Evidence from the UK. *Int. J. Account. Inf. Syst.* **2021**, *40*, 100500. [CrossRef]
128. Wilkin, C.; Ferreira, A.; Rotaru, K.; Gaerlan, L.R. Big data prioritization in SCM decision-making: Its role and performance implications. *Int. J. Account. Inf. Syst.* **2020**, *38*, 100470. [CrossRef]
129. Pei, D.; Vasarhelyi, M.A. Big data and algorithmic trading against periodic and tangible asset reporting: The need for U-XBRL. *Int. J. Account. Inf. Syst.* **2020**, *37*, 100453. [CrossRef]
130. Bonsón, E.; Lavorato, D.; Lamboglia, R.; Mancini, D. Artificial intelligence activities and ethical approaches in leading listed companies in the European Union. *Int. J. Account. Inf. Syst.* **2021**, *43*, 100535. [CrossRef]
131. Ma, D.; Fisher, R.; Nesbit, T. Cloud-based client accounting and small and medium accounting practices: Adoption and impact. *Int. J. Account. Inf. Syst.* **2021**, *41*, 100513. [CrossRef]
132. Yoon, K.; Liu, Y.; Chiu, T.; Vasarhelyi, M.A. Design and evaluation of an advanced continuous data level auditing system: A three-layer structure. *Int. J. Account. Inf. Syst.* **2021**, *42*, 100524. [CrossRef]
133. Geerts, G.L.; O'Leary, D.E. V-Matrix: A wave theory of value creation for big data. *Int. J. Account. Inf. Syst.* **2022**, *47*, 100575. [CrossRef]
134. Jun, S.Y.; Kim, D.S.; Jung, S.Y.; Jun, S.G.; Kim, J.W. Stock investment strategy combining earnings power index and machine learning. *Int. J. Account. Inf. Syst.* **2022**, *47*, 100576. [CrossRef]
135. Perdana, A.; Lee, H.H.; Koh, S.; Arisandi, D. Data analytics in small and mid-size enterprises: Enablers and inhibitors for business value and firm performance. *Int. J. Account. Inf. Syst.* **2021**, *44*, 100547. [CrossRef]
136. Zhang, C.; Cho, S.; Vasarhelyi, M. Explainable Artificial Intelligence (XAI) in auditing. *Int. J. Account. Inf. Syst.* **2022**, *46*, 100572. [CrossRef]
137. Zhang, G.; Atasoy, H.; Vasarhelyi, M.A. Continuous monitoring with machine learning and interactive data visualization: An application to a healthcare payroll process. *Int. J. Account. Inf. Syst.* **2022**, *46*, 100570. [CrossRef]
138. Alzamil, Z.; Appelbaum, D.; Nehmer, R. An ontological artifact for classifying social media: Text mining analysis for financial data. *Int. J. Account. Inf. Syst.* **2020**, *38*, 100469. [CrossRef]
139. Lin, H.; Hwang, Y. The effects of personal information management capabilities and social-psychological factors on accounting professionals' knowledge-sharing intentions: Pre and post COVID-19. *Int. J. Account. Inf. Syst.* **2021**, *42*, 100522. [CrossRef]
140. Monteiro, A.P.; Vale, J.; Leite, E.; Lis, M.; Kurowska-Pysz, J. The impact of information systems and non-financial information on company success. *Int. J. Account. Inf. Syst.* **2022**, *45*, 100557. [CrossRef]
141. Manetti, G.; Bellucci, M.; Oliva, S. Unpacking dialogic accounting: A systematic literature review and research agenda. *Account. Audit. Account. J.* **2021**, *34*, 250–283. [CrossRef]

FinTech

MDPI

Essay

Enterprise Financialization and Technological Innovation: An Empirical Study Based on A-Share Listed Companies Quoted on Shanghai and Shenzhen Stock Exchange

Tao Zhu and Xinyu Sun *

School of Economics, Henan University, Kaifeng 475000, China
* Correspondence: 104753210111@henu.edu.cn

Abstract: In recent years, the growth rate of China's real industry has slowed down while the financial industry has entered a phase of rapid development. Driven by the profit-seeking motive of capital, real enterprises tend to carry out financial investments, and the degree of corporate financialization has been rising. This paper selects A-share listed enterprises in Shanghai and Shenzhen from 2009 to 2020 as research samples to study the impact of corporate financialization on technological innovation and the mediating effect of financing constraints from the perspective of financial asset holding. The study found that the financialization of enterprises' crowding out effect on technological innovation has led to the phenomenon of "turning from real to virtual". We also found that the crowding-out effect had experienced lag. This conclusion still held when we controlled for endogeneity. The heterogeneity analysis showed that the financialization of non-state-owned enterprises had an excessive inhibitory effect on technological innovation, and the financialization of enterprises in eastern China has had a remarkable inhibitory effect on technological innovation. The influence mechanism analysis showed how financing constraints played a crucial mediating role in corporate financialization inhibiting technological innovation, and corporate financialization has inhibited technological innovation by exacerbating financing constraints. Based on this research, we propose targeted suggestions to prevent the excessive financialization of enterprises on both government and enterprise levels.

Keywords: corporate financialization; technological innovation; financing constraints; asset allocation

Citation: Zhu, T.; Sun, X. Enterprise Financialization and Technological Innovation: An Empirical Study Based on A-Share Listed Companies Quoted on Shanghai and Shenzhen Stock Exchange. *FinTech* **2023**, *2*, 275–293. https://doi.org/10.3390/fintech2020016

Academic Editors: Otilia Manta, Mohammed K. A. Kaabar, Eglantina Hysa, Ovidiu Folcuţ and Anuradha Iddagoda

Received: 18 February 2023
Revised: 18 April 2023
Accepted: 20 April 2023
Published: 23 April 2023

1. Introduction

China's real economy is currently in the process of transformation and upgrading, while innovation has become the crucial driving force of national economic development. Enterprises have successively enhanced their innovation consciousness and technology innovation capability. However, China's traditional economic growth is faced with problems such as overcapacity, high investment costs, and a lack of core technologies. These problems have led to a repeated reduction in returns on investment in the manufacturing industry and declining market demand. Compared with the traditional manufacturing industry, it has become an indisputable fact that the rapid development of the financial industry could create an excessive profit rate. The income of financial investment made by non-financial enterprises exceeds the income of entity investment. Driven by the profit-seeking motive of capital, industrial capital has been withdrawn from the real economy and begun to continuously pour into the financial industry, bringing higher yields, which could lead to the uneven distribution of corporate assets, ignoring the development of main businesses, accelerating the expansion of the virtual economy, and eventually resulting in the phenomenon of "from the real to the virtual" [1]. According to the statistics of the CSMAR database, the financial assets held by Chinese real enterprises were approximately 1.04 billion RMB in 2008, while the financial assets held by Chinese real enterprises reached 3.28 billion RMB in 2020 [2]. The financialization of enterprises has a crucial impact on enterprise innovation activities and brings a mass of challenges to the innovation and development of real enterprises. From a macro perspective, the economy is the body, while finance is the bloodline. Technological innovation and the high-quality development of the real economy need the "reservoir effect" of financial assets. From a micro perspective, the excessive financialization of enterprises affects the overall uneven distribution of resources, which produces a "crowding out effect" on the technological innovation of enterprises.

The report of the 19th National Congress of the Communist Party of China clearly stated that it is indispensable to "deepen the reform of the financial system, enhance the ability of financial services to the real economy, and guard the bottom line of not occurring systemic financial risks". At present, the Chinese economy has shifted from a stage of high-speed growth to a stage of high-quality development. Preventing the real economy from pursuing real development is the foundation for high-quality economic development. The Fifth Plenary Session of the 19th Central Committee of the Communist Party of China pointed out that it is imperative to "adhere to the core position of innovation in the overall situation of modernization, improve the technological innovation ability of enterprises, and accelerate the construction of a prosperous country in science and technology". Scientific and technological innovation accelerates the transformation of the economy from "quantitative development" to "qualitative development", which plays a crucial role in the transformation of an economic development mode. Therefore, the country is supposed to put scientific and technological innovation in the core position of overall national development. The 14th Five-Year Plan emphasized how "the government ought to maintain the proportion of the manufacturing sector as basically stable and consolidate and strengthen the foundation of the real economy". Promoting and strengthening the development of the real economy has been an indispensable task in China's economic construction since entering the new era. Scientific and technological innovation is the engine for real enterprises to achieve high-quality economic development. These policy directions show that the country attaches great importance to enterprise financialization and enterprise technological innovation.

Corporate financialization and technological innovation have always been popular research areas in the field of corporate finance. Their research value is ponderable. The purpose of this paper is to explore whether the financialization of real enterprises has a "reservoir effect" or "crowding out effect" for the financialization of enterprise technological innovation and whether the phenomenon of enterprise financialization can alleviate the financing constraint of technological innovation or intensify the financing constraint of technological innovation. Through the research of this paper, first of all, we aim to deepen an understanding of enterprise financialization at the micro level, explore the financial reasons for a lack of internal innovation power of enterprises, and correctly understand the current economic boom of "moving from the real to the virtual". Secondly, we clarify the intermediary role of financing constraints, promote financial financing efficiency, and strengthen their innovation input. Third, we aim to guide enterprises to rationally allocate financial assets and prevent the negative impact of excessive financialization. Fourthly, we provide ideas for the government to formulate macroeconomic policies and achieve high-quality economic development.

The subsequent content of this paper is arranged as follows. The second part is the literature review. The third part includes the theoretical analysis and research hypotheses. The fourth part is the research design, including sample selection, variable selection, and a description and benchmark model construction. The fifth part is the empirical analysis, including descriptive statistical analysis, benchmark model regression analysis, heterogeneity analysis, impact mechanism analysis, and robustness test. The sixth part details the conclusions and policy recommendations.

2. The Literature Review

The concept of enterprise financialization was put forward in the 1990s. Domestic and foreign scholars have studied much on the issue of enterprise financialization. Foreign scholars have defined financialization from both macro and micro perspectives. From a macro perspective, Palley (2007) pointed out that financialization refers to the process in which the proportion of financial markets, financial institutions, and financial activity participate in an economy that is gradually increasing [3]; From a micro perspective, Krippner (2005) believed that enterprise financialization referred to the asset allocation of entity enterprises that tend to make financial investment profits, and no longer make profits through the production and sales of traditional main business 23 [4]. Regarding the measurement of corporate financialization, Demir (2007) used relevant indicators, such as the proportion of financial assets held by enterprises to measure the financialization of enterprises. Domestic scholars have expanded the measurement of enterprise financialization [5]. Zhang et al. (2016) and Liu (2017) used the holding share of enterprise financial assets to measure the financialization of enterprises from a broad level and measure the profit channel of enterprises from a narrow level [6,7].

With the transformation of economic growth momentum, the relationship between enterprise financialization and enterprise innovation has attracted the attention of academic circles. At present, the academic circle has not reached an agreement on the research of whether enterprise financialization should promote or inhibit enterprise technological innovation. According to its action direction, the influence of corporate financialization on technology innovation can be divided into two studies: the promoting effect and the inhibitory effect. Scholars with a view of promotion believe that corporate financial asset allocation is based on preventive reserve motivation. By allocating financial assets to facilitate liquidity ability, enterprises can increase their financing channels so they can realize funds in a timely manner when facing external economic uncertainty. These financial assets guarantee the development of real enterprises. The appropriate financialization of enterprises can alleviate financing constraints to a certain extent. The profits obtained by enterprises from financial channels can smooth the funds needed for their production, investment, and operation, provide financial support for the technological innovation of enterprises, and help to enhance the innovation ability of enterprises and improve the profitability of entities. Bonfiglioli (2008) showed that corporate financialization enabled enterprises to obtain more investment returns, alleviate the problem of corporate financing constraints to a certain extent, create more profits for enterprises, and promote enterprise innovation investment [8]. Xu et al. (2019) discussed the impact of enterprise financialization on technological innovation from the perspectives of innovation input and innovation performance. It was found that the current financialization mainly showed a “pulling effect” on enterprise innovation. When the profitability of an enterprise was weak, the financialization of enterprises showed a “crowding out effect” on innovation investment [9]. Yang et al. (2019) found that the short-term financial investment of some idle funds of enterprises could increase the liquidity of enterprise assets, realize the preservation and appreciation of capital, and provide a financial guarantee for enterprises’ investment in technological innovation and R&D. Scholars who hold the view of an inhibitory effect believe that financial investment is based on speculative profit-seeking motivation. The principal-agent theory makes enterprise ownership and management separate. Based on their own interests, the management of an enterprise invests funds in the financial sector with a high short-term yield, thus attracting capital from the entity investment [10]. Under the condition of limited resources, the financialization of enterprises affects the overall resource allocation. If enterprises use too many resources for financial assets investment, it not only shifts the business focus but also affects the innovation input. Seo et al. (2012) believed that non-financial companies investing too much of their assets in financial investment could crowd out resources for technological innovation and lead to a lack of sufficient funds for technological innovation and development [11]. Trivedi (2014) found that although the financialization of enterprises improves the financial returns of speculators, it could not improve the mismatch of financial assets, and it would also affect the efficiency of industrial investment [12]. Gleadle et al. (2014) found that the financialization of real enterprises significantly reduced investment in R&D and innovation in the current period, and the profit of enterprise financial channels inhibited technological innovation [13]. Kliman et al. (2015) analyzed changes in the financial asset structure of American listed companies and found that modern enterprises are more inclined to invest in long-term securities with weak liquidity so as to obtain higher returns [14]. Davis (2016) believed that with the transformation of the external financing structure of enterprises, the growth of financial profits and the financial profits of financial market payment could reflect the financialization tendency to some extent and lead to a decrease in corporate entity investment [15]. Cupertino et al. (2019) found that excessive financial investment made the enterprise lack enough funds to carry out product research and development innovation, thus inhibiting its technological innovation output [16]. Zhuang et al. (2022) took Chinese micro-enterprises as a research object, which showed that the main purpose of financial investment by Chinese enterprises was profit pursuit rather than precautionary savings. Fintech development aggravated the profit-seeking motivation of capital, promoted the financial investment of enterprises, and aggravated the problem of "moving from real to virtual" [17]. Xie et al. (2014) used listed company data to empirically examine the impact of manufacturing financialization on technological innovation. It was found that the excessive financialization of the manufacturing industry inhibited the ability of technological innovation. The government regulation intensified the negative impact of corporate financialization on innovation [18]. Du et al. (2017) showed that the "crowding out effect" of enterprise financialization was greater than the "reservoir effect". The income brought by financial investment did not alleviate the future underinvestment of enterprises but reduced the innovation ability of enterprises and weakened the development of the real economy [19]. Dong et al. (2021) used a sample of non-financial listed companies from 2009 to 2019 for empirical analysis. It was found that the financialization degree of enterprises had a crowding-out effect on technological innovation investment. The impact of financialization suitability on innovation investment showed a "U" dynamic transformation. If the enterprise financialization deviated from the optimal degree, it had an evidently negative impact on the enterprise innovation investment [20].

By combing the relevant literature, we found that, first of all, domestic and foreign scholars measured financialization based on different perspectives and generally measured financialization at the micro level. Secondly, domestic and foreign scholars continued to study and discuss the relationship between enterprise financialization and innovation. However, there is no consensus on the relationship between financialization and technological innovation. A number of studies have attributed the motivation of enterprise financial investment to preventive reserve motivation and speculative profit-seeking motivation. Regarding research on the influence of enterprise financialization on enterprise technological innovation, enterprise financialization could promote or inhibit enterprise technological innovation.

The main contributions of this paper are as follows: first, this paper, from the enterprise technology innovation R&D perspective, analyzes the relationship between enterprise financialization and innovation. Based on enterprise property rights and the regional financial development level, we expanded the heterogeneity analysis. This paper broadened the research fields related to enterprise financialization and innovation, helped enterprises to have a clearer understanding of the substantial impact of enterprise financialization on innovation, encouraged enterprises to actively innovate in theory and data, improved the motivation and enthusiasm of enterprise independent innovation, and provided theoretical and practical thinking for enterprises to make relevant decisions. Second, this paper adopted the intermediary effect model. By focusing on the intermediary role of financing constraints, the systematic relationship between enterprise financialization, financing constraints and technological innovation was clarified, and the internal influence transmission mechanism of financialization on technological innovation was defined. It expanded the research scope of the impact of enterprise financialization on innovation, provided empirical evidence at the micro level for enterprise financialization on technological innovation, helped enterprises to deeply combine a financial asset allocation plan with enterprise innovation strategy, and had certain reference values for the problem of "turning from real to virtual" being faced by the government.

3. Theoretical Analysis and Research Hypothesis

3.1. Enterprise Financialization and Enterprise Technology Innovation

Enterprise investment refers to the use of funds that are held by an enterprise in order to obtain an expected return proportional to the risk within a certain period of time. Traditional finance believes that investors' investment behavior is rational; they accurately process the information obtained based on a perfect market mechanism and maximize utility as an investment goal when making investment decisions. However, the actual investment behavior of enterprises cannot be consistent with theoretical assumptions. Factors such as the asymmetry of investment market information, the adjustment of government financial policies, changes in financial market demand, an enterprise's own operating conditions, and the ability to allocate resources may all lead to the alienation of enterprise investment behavior. The financialization problem of "turning from real to virtual" in China is the result of the joint effect of the financial sector's influence on economic policy, economic growth, economic returns, and the joint effect of many micro-enterprises' financial investment behavior.

Due to the high liquidity and facilitated liquidity of financial assets, the allocation of financial assets by enterprises has the role of "reservoir" of funds, which has a positive impact on enterprise technological innovation. On the one hand, enterprise financialization can play a partially defensive role. Enterprises form part of the idle funds for short-term financial investment, increase the income of corporate financial investment, promote the liquidity of enterprise assets, and achieve the preservation and appreciation of capital. To a certain extent, financialization can prevent a shortage of funds when enterprises face the impact of an external environment so as to promote the long-term development of enterprises and make better technological innovation. The process of enterprise financialization is equivalent to a capital reservoir. The profit of financial investment improves the investment capacity of enterprise entities and increases the capital of enterprise technological innovation. On the other hand, compared with the real economy sector, a return on the investment of the financial industry is very ponderable, and the benefits brought about by financial investment are much higher than the benefits of the real economy. More experienced non-financial enterprises invest idle funds in the capital market for re-lending business. Financial investment improves the overall profitability of non-financial enterprises. Enterprises have the ability to carry out innovative activities and indirectly promote enterprise technological innovation investment.

Due to the cash flow competition between different investments, there is an alternative relationship between corporate financial investment and physical investment, and financialization has a "crowding out effect" on the technological innovation of enterprises. On the one hand, according to the principal-agent theory, the interests of the owners and managers of a company are not completely consistent in the context of the separation of ownership and management rights. Due to a high investment cost, a lack of core technology, and other problems, the profits of the real economy continue to decline, while the income of financial assets shows a continuous growth trend. The existence of the profit-seeking motive of capital makes the management of enterprises invest more capital resources in the financial field when the uncertainty of the macroeconomic environment increases. Non-financial enterprises choose to use more idle funds for financial investment, which crowds out the resources of enterprises for technological innovation, making the funds invested by enterprises in technological innovation and development obviously insufficient before inhibiting the level of technological innovation of enterprises. On the other hand, from the perspective of enterprise liquidity management, the holding of certain liquid assets by enterprises is a crucial guarantee to maintain normal production and timely respond to external uncertain shocks. Enterprise innovation and R&D itself have the characteristics of poor liquidity, a long return on the investment period, and many uncertainties in the cycle. Innovation R&D investment is irreversible, investment risk is large, and the technological innovation R&D process also has a certain risk of failure, which intensifies the cautiousness of enterprises for the innovation investment behavior. Financial asset allocation has the characteristics of a short investment cycle and facilitates liquidity and a high return on investment. Although enterprises need to bear investment risks, non-financial enterprises tend to choose financial assets to invest in under liquidity management. There is an obvious crowding out on the relationship between technological innovation investment and financial asset investment.

To sum up, there are two views on the impact of enterprise financialization on enterprise technological innovation. Whether enterprise financialization has a positive or negative effect on enterprise technological innovation has not yet been determined. Based on the above theoretical analysis, this paper puts forward the following hypotheses:

Hypothesis H1a: *Corporate financialization promotes enterprise technological innovation, and there is a reservoir effect.*

Hypothesis H1b: *Corporate financialization inhibits enterprise technological innovation and has a crowding-out effect.*

3.2. Heterogeneity Analysis of the Impact of Enterprise Financialization on Enterprise Technology Innovation

Will the impact of enterprise financialization on enterprise technological innovation vary depending on the nature of enterprise property rights? Compared with the central and western regions, the level of financial development in the eastern region is high; therefore, is the impact on the financialization of entity enterprises in the eastern region on technological innovation more obvious than that of entity enterprises in the central and western regions? This paper analyzes the heterogeneity from two aspects: the nature of enterprise property rights and the financial development level of the region where the enterprise is located.

From the perspective of the nature of enterprise property rights, China's economy has long been composed of two economic sectors with different property rights, including state-owned enterprises and non-state-owned enterprises. The nature of the property rights of enterprises is different, their financial asset allocation is different, and the impact of enterprise financialization on technological innovation may be different. Specifically, state-owned enterprises have large, fixed assets and the stable development of their main business. They have institutional and policy financing advantages, which can obtain sufficient funds at a lower cost. In the case of a high return on investment in financial assets, state-owned enterprises are more inclined to make financial investments based on the profit motive of capital. State-owned enterprises have a high degree of correlation with government departments. Due to the constraints of traditional production and operation methods and the insufficient analysis of market information, state-owned enterprises usually have low technological innovation efficiency and lack continuous investment in research and development. Compared with state-owned enterprises, non-state-owned enterprises have smaller assets, and they usually face greater difficulties in transaction costs and financing constraints, from which it is difficult to obtain sufficient funds to support production through direct financing. However, the technological innovation capabilities of non-state-owned enterprises and the investment in technological innovation R&D are generally higher than those of state-owned enterprises. Therefore, the financialization of enterprises may have a greater impact on the technological innovation of non-state-owned enterprises.

From the perspective of the financial development level of the region where the enterprise is located, China's regional economic development level has long shown a pattern of being high in the east and low in the west. The financial development level of the region where the enterprise is located is different, and the impact of financialization on technological innovation may be different. Since the reform and opening up, the total economic volume of the eastern region has maintained a leading position, and the financial industry has been actively developed. The development of the financial market has been more perfect, and the degree of information asymmetry between commercial banks, securities companies, and other financial institutions and enterprise development has been small. Therefore, non-financial enterprises in the eastern region can choose more financial investment products, and they are more inclined to invest in financial assets to obtain an income. The impact of financialization on enterprise technological innovation is more obvious than that of enterprises in the central and western regions.

Based on the above theoretical analysis, the impact of enterprise financialization on enterprise technological innovation may be heterogeneous due to the nature of enterprise property rights and the different levels of financial development in the regions where enterprises are located. This paper puts forward the following hypotheses:

Hypothesis H2: *The impact of enterprise financialization on enterprise technological innovation is heterogeneous in two aspects: the nature of enterprise property rights and the financial development level of the region where the enterprise is located.*

3.3. Analysis of the Influence Mechanism of Enterprise Financialization on Enterprise Technological Innovation

Due to the uncertainty and information asymmetry of innovation, innovation activities easily fall into external financing constraints. In the financial market led by banks, the R&D investment of Chinese enterprises faces more serious financing constraints. The influence mechanism of enterprise financialization on enterprise technology innovation this paper analyzes the influence mechanism from the perspective of an enterprise financing constraint.

There are usually two channels for enterprises to carry out technological innovation: first, enterprises adopt mergers and acquisitions to incorporate the emerging technologies of the acquirer into enterprises. Second, enterprises obtain patented technologies through independent research and development. Enterprises through the above two channels for technological innovation have a great demand for funds. Relying only on internal funds is not enough to support enterprise technological innovation; therefore, enterprises have to support technological innovation through external financing. Studies have shown that the risk of technological innovation R&D is relatively high. Compared with other investment activities of enterprises, technological innovation plays a more prominent role in the context of financing constraints.

On the one hand, when enterprises make profits from financial channels, they may partially alleviate the financing constraints of enterprises and play a role in the capital reservoir for technological innovation. This is mainly reflected in the fact that financialization alleviates information asymmetry. The main reason for the high use cost of external funds in R&D activities is that external investors have difficulty obtaining enterprise R&D information. Entity enterprises participate in external financial institutions in the form of financial investment, which has close contact with financial institutions to disclose research and development information and reduce the financing pressure on innovation activities. Second, financialization sends a good signal. Financial investment helps companies to make considerable profits in the short term and improve their return on assets. At the same time, it is also conducive for enterprises to create a good public image, obtain the affirmation of financial analysts, and enhance the confidence of external investors. Third, financialization ensures sufficient endogenous funds. The internal financing of an enterprise is superior to external financing. The financial assets invested by enterprises can be quickly realized to adjust the level of capital, ensure sufficient internal capital of enterprises, effectively improve external financing pressure, and resist the risk of innovation.

On the other hand, corporate financialization hinders the development of innovation activities by intensifying the financing pressure on enterprises. This is mainly reflected in the policy constraints. In 2017, the China Securities Regulatory Commission (CSRC) issued a Q&A on Issuance Supervision-Regulatory Requirements on Guiding and Regulating the

Financing Behavior of Listed Companies, which clearly stated that "when a non-financial listed company applied for refinancing, in principle, there shall be no financial investment such as holding a large amount of trading financial assets and financial assets with a long period of time at the end of the recent period, lending money to others, entrusted wealth management, etc.". It is stated that when enterprises make large-scale financial investments, they are subject to capital market financing constraints [21]. The second concept this is reflected in is limited to bank financing. From the perspective of bank credit financing, banks review the repayment ability and loan purpose of enterprises when conducting credit approval. Companies that invest too much money in the virtual economy rather than developing their main business make banks think there is a "false prosperity." Banks and other financial institutions reduce lending to enterprises that generate excessive financial investment, which increases the degree of financing constraints on enterprises. The deepening of financing constraints faced by enterprises reduces their technological innovation and development activities.

Judging from the above analysis, corporate financialization has had a significant impact on innovations by alleviating or exacerbating financing constraints. From this, we made the following assumptions:

Hypothesis H3a: *Corporate financialization strengthens the promoting effect or reduces the inhibitory effect of innovation by alleviating financing constraints.*

Hypothesis H3b: *Corporate financialization reduces the promoting effect or strengthens the inhibitory effect of innovation by intensifying financing constraints.*

4. Research Design

4.1. Sample Selection

In this paper, Shanghai and Shenzhen A-share listed companies from 2009 to 2020 were selected as the study samples. In order to ensure the accuracy of the research data, the following data were screened: firstly, we eliminated ST, * ST, and financial industry-listed companies so as to avoid the impact of the investment nature of financial companies on research results. Secondly, we eliminated the listed companies with missing relevant research data to avoid the impact of incomplete data on the regression results. Finally, we treat all variables with Winsorize at the 99% and 1% levels to avoid the impact of sample extremes and outliers on empirical results. After the screening, we finally retained 17,536 sample data. The investment in technological innovation and financial data of listed companies used in the empirical analysis were all from the CSMAR database.

4.2. Variable Selection and Description

4.2.1. Dependent Variable

Starting from the financial investment behavior of enterprises, this paper discusses the impact of corporate financialization on enterprise technological innovation. According to the proposed research hypothesis, this paper measures the level of technological innovation from the perspective of technological innovation R&D investment (Rd). By referring to the research of Yang et al. (2017) and Kong et al. (2017), the total R&D investment of the enterprises was measured by a natural logarithmic value [22,23].

4.2.2. Independent Variable

This paper defines enterprise financialization as the corresponding financial asset allocation behavior of enterprises. Referring to the research of Peng et al. (2018), based on the corporate balance sheet data, we measured the degree of corporate financialization by the ratio of the financial assets held by the enterprises to the total assets of the enterprises[Fin] [24]. The financial assets held by an enterprise consist of seven parts: monetary funds, trading financial assets, net investment real estate, net financial assets available for sale, net investments held to maturity, net dividends receivable, and net interest receivable.

Considering that the financialization of enterprises may have a lagging impact on enterprise technological innovation, we referred to the research of Duan et al. (2021) and used the proportion of financial assets held by enterprises (L_Fin) in the previous year to measure the degree of enterprise financialization and conduct a test of lag impact [25]. Referring to the research of Peng et al. (2022), we removed the net investment real estate and net investment from holding to maturity on the basis of the proportion of corporate finance in the original independent variable, generated a new independent variable enterprise financialization (Fin1), re-measured the proportion of corporate financial assets, and tested the robustness of alternative independent variables [2].

4.2.3. Control Variables

Referring to the research of Gu et al. (2018), we selected the following variables that may affect the technological innovation of enterprises as control variables. The size of the enterprise (Size) was measured by the natural logarithmic value of the total assets in the enterprise. Enterprise growth capacity (Growth) was measured by the ratio of the growth of the enterprise's operating income to the total operating income of the previous year. The Return on Total Assets (Roa) can be measured by the ratio of net profit to the share of total assets. Financial leverage (leverage) is measured by the ratio of the total liabilities in the enterprise to the owner's equity. Board structure (Board) is measured by the ratio of the number of independent directors to the number of directors. Equity concentration (Holder) is measured by the shareholding ratio of the largest shareholder [26].

4.2.4. Mediation Variable

Referring to the research of Xie et al. (2011), we selected an enterprise financing constraint (Fc) as the intermediary variable between enterprise financialization and enterprise technological innovation. The enterprise financing constraint was measured by the absolute value of the SA index, the larger absolute value, and a higher degree of the enterprise financing constraint [27], Table 1.

Table 1. Description of variables.

Variable Category	Variable Name	Notation	Definitions and Explanations
Dependent variable	Technological innovation R&D investment	Rd	Ln (Total investment in R&D)
Independent variable	The proportion of corporate financial assets	Fin	Enterprises hold financial assets/total assets
		L_Fin	The proportion of financial assets held by enterprises in the previous year
Control variables	Enterprise size	Size	Ln (total assets)
	Enterprise growth ability	Growth	Operating revenue growth/total revenue of last year
	return on total assets	Roa	Net profit/total assets
	financial leverage	Leverage	Total liabilities/owner's equity
	Board structure	Board	Number of independent directors/total number of Board of Directors
	Equity concentration	Holder	The largest shareholder shareholding ratio
Mediation variable	Enterprise financing constraints	Fc	Measured by the absolute values of the SA index $SA = -0.737 \times Size + 0.043 \times Size^2 - 0.04 \times Age$

4.3. *Benchmark Model Construction*

In order to evaluate the impact of enterprise financialization on technological innovation, a measurement model was constructed as follows:

$$Rd_{it} = \alpha_0 + \alpha_1 Fin_{it} + \alpha_k control_{it} + id_i + year_t + \varepsilon_{it} \quad (1)$$

$$Rd_{it} = \mu_0 + \mu_1 L\_Fin_{it} + \mu_k control_{it} + id_i + year_t + \varepsilon_{it} \quad (2)$$

Model (1) takes the investment in technological innovation R&D as the dependent variable and the proportion of financial assets held by enterprises in the total assets as the independent variable. Model (2) takes the investment in technological innovation R&D as the dependent variable and the proportion of financial assets held by enterprises in the previous year as the independent variable to test the delayed impact of corporate financialization on technological innovation. *I* represents the first enterprise in the sample. *T* is the year. Coefficient α_1 indicates the influence of enterprise technology innovation. If coefficient α_1 is significantly positive, the enterprise financialization promotes enterprise technological innovation, which assumes that H1a is verified. If coefficient α_1 is significantly negative, enterprise financialization suppresses enterprise technology innovation, which assumes H1b to be verified. *k* represents the *k* th control variable. The control represents all the control variables, including enterprise size, enterprise growth ability, return on total assets, financial leverage, board structure, and equity concentration. Id_i represents individual fixed effect. $Year_t$ represents time fixed effect. ε_{it} represents random disturbance term.

5. Empirical Analysis

5.1. Descriptive Statistical Analysis

Table 2 shows the descriptive statistics of the main variables. According to Table 2, the dependent variable enterprise technology innovation R&D average was very close to the median, with a minimum of 11.603 and a maximum of 22.357. These data show that there are different degrees of difference in the technological innovation R&D investment level of China's non-financial listed companies, and the degree of importance to technological innovation R&D investment varied greatly among enterprises. The average variable enterprise financialization was 0.041, which shows the enterprises holding financial assets of total assets of 4.1%. It had a minimum of 0 and a maximum of 0.520, which shows that China's non-financial listed companies' financial investment occupies an important position. The difference in financial asset allocation was obvious. Some companies tended to have a high position allocation of financial assets, and enterprise financialization and enterprise technology innovation-related issues were very necessary. For the relevant control variables, the difference between the mean value and the median of the most controlled variables was small, which indicates that the relevant control variables were valued within a reasonable range.

Table 2. Descriptive statistics for the main variables.

Variables	Obs	Mean	Median	SD	Min	Max
Rd	17536	17.830	17.844	1.559	11.603	22.357
Fin	17536	0.041	0.012	0.072	0.000	0.520
L_Fin	12738	0.037	0.011	0.065	0.000	0.488
Size	17536	6.127	5.925	1.297	3.745	10.484
Growth	17536	−0.330	−0.106	7.264	−83.827	41.532
Roa	17536	0.051	0.046	0.050	−0.329	0.239
Leverage	17536	0.900	0.610	0.908	0.021	6.751
Board	17536	0.375	0.333	0.054	0.250	0.571
Holder	17536	34.534	32.590	14.792	8.010	75.250

Table 3 shows the results of Pearson's correlation test for the main variable. As we can see from Table 3, the negative relationship between enterprise financialization and enterprise technology innovation variables is negative, which initially supports the H1b hypothesis proposed above. The correlation coefficients between most variables are significant, and the absolute value of the correlation coefficient between variables is basically less than 0.5, indicating that there was no serious collinearity among the variables studied in this paper.

Table 3. Association tests for the primary variables.

	Rd	Fin	Size	Growth	Roa	Leverage	Board	Holder
Rd	1							
Fin	−0.069 ***	1						
Size	0.513 ***	−0.063 ***	1					
Growth	−0.00600	0.00600	0.00500	1				
Roa	0.062 ***	0.068 ***	−0.097 ***	0.402 ***	1			
Leverage	0.138 ***	−0.125 ***	0.536 ***	−0.055 ***	−0.328 ***	1		
Board	0.037 ***	0.039 ***	0.025 ***	0.00100	−0.00200	0.017 ***	1	
Holder	0.026 ***	−0.038 ***	0.190 ***	0.053 ***	0.108 ***	0.095 ***	0.066 ***	1

Note: The numbers in the table are the correlation coefficient between the relevant variables, *** is significant at 1% levels, respectively.

5.2. Benchmark Regression Results

Table 4 shows the benchmark regression results of the impact of corporate financialization on corporate technological innovation. Column (1) shows the estimated results of the impact of corporate financialization on R&D investment in technological innovation in the current period. After controlling for the individual effect and time effect, the regression coefficient of the independent variable *Fin* was −0.521, which was significantly negative at the 1% level. The data indicate that corporate financialization has an obvious inhibitory effect on technological innovation R&D investment. The financial investment of enterprises occupies the resources of technological innovation investment, and the higher the degree of corporate financialization, the less the enterprise invested in technological innovation research and development. This regression result verifies hypothesis H1b proposed above. Column (2) shows the regression results of the influence of corporate financialization on the one-stage lag of R&D investment in technological innovation. The regression coefficient of the independent variable *L_Fin* was −0.461, which was also significantly negative at the 1% level. The data indicate how corporate financialization had a lagging inhibitory effect on corporate technological innovation R&D investment.

Table 4. Benchmark regression results.

Variables	(1) Rd	(2) Rd
Fin	−0.521 ***	
	(−4.20)	
L_Fin		−0.461 ***
		(−3.41)
Size	0.716 ***	0.735 ***
	(23.61)	(21.68)
Leverage	−0.092 ***	−0.091 ***
	(−3.81)	(−3.19)
Growth	−0.005 ***	−0.004 ***
	(−5.07)	(−4.06)
Roa	1.108 ***	0.743 ***
	(5.62)	(3.69)
Holder	0.002	0.002
	(1.10)	(0.80)
Board	−0.468 **	−0.325 *
	(−2.44)	(−1.67)
Observations	16995	12266
R^2	0.894	0.918
id FE	Yes	Yes
year FE	Yes	Yes

Note: Robust t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.3. Heterogeneity Analysis

Based on the heterogeneity theoretical analysis of the influence of enterprise financialization on enterprise technological innovation, the research samples were divided into the following groups: first, according to the property rights of enterprises, the research samples were divided into state-owned enterprises and non-state-owned enterprises. Second, according to the financial development level of the region where the enterprises were located, the research samples were divided into enterprises in the western region, enterprises in the central region, and enterprises in the eastern region. We used the above subsamples separately for benchmark regression.

Table 5 shows the results of subsample regression according to the property rights of enterprises. It can be seen from Table 5 that the financialization of both state-owned enterprises and non-state-owned enterprises had a crowding-out effect on technological innovation's R&D input, but there were certain differences in the significance of negative effects. Column (1) is the regression result of the influence of financialization on the state-owned enterprises of a technological innovation R&D input. Column (2) is the regression result of the influence of financialization on non-state-owned enterprises and technological innovation R&D input. As can be seen from the estimated coefficient of the independent variable *Fin*, state-owned enterprises and non-state-owned enterprises were more motivated by capital profit-seeking financial asset allocation. Since non-state-owned enterprises have stronger technological innovation abilities and a higher innovation efficiency than state-owned enterprises, the negative effect of enterprise financialization on enterprise technological innovation input was significant at the 1% level.

Table 5. Subsample regression according to the nature of enterprise property rights.

Variables	**(1)** **Rd**	**(2)** **Rd**
Fin	−0.461	−0.385 ***
	(−1.09)	(−3.22)
Size	0.810 ***	0.721 ***
	(10.35)	(22.81)
Leverage	−0.028	−0.112 ***
	(−0.70)	(−3.52)
Growth	−0.003	−0.006 ***
	(−1.38)	(−5.65)
Roa	1.601 ***	1.056 ***
	(2.88)	(5.18)
Holder	−0.002	0.003
	(−0.42)	(1.12)
Board	0.048	−0.788 ***
	(0.14)	(−3.75)
Observations	5248	11667
R^2	0.896	0.900
id FE	Yes	Yes
year FE	Yes	Yes

Note: brackets t statistics, *** $p < 0.01$.

Table 6 shows the results of sub-sample regression according to the financial development level of the region where the enterprises are located. As can be seen from Table 6, with different financial development levels in the regions where enterprises were located, the crowding out effect of financialization on technological innovation R&D investment of enterprises was different. Column (1) shows the regression results of the influence of enterprise financialization on enterprise technological innovation R&D investment in western China. Column (2) shows the regression results of the influence of enterprise financialization on enterprise technological innovation R&D investment in central China. Column (3) shows the regression result of the influence of enterprise financialization on enterprise technological innovation R&D investment in eastern China. Due to the relatively low level of financial development in central and western regions, the negative effect of corporate financialization on technological innovation R&D investment was relatively small. The financial development level of the eastern region was relatively high. The eastern region has financing convenience and rich types of financial products, and enterprises tend to use part of the capital to invest in financial assets so as to obtain higher investment returns. Therefore, financial enterprises in the eastern region have a significant negative impact on investment in technological innovation, research, and development.

Table 6. Regression of samples according to the financial development level of the region where the enterprise is located.

	(1)	(2)	(3)
Variables	**Rd**	**Rd**	**Rd**
Fin	−0.246	−0.427	−0.499 ***
	(−0.44)	(−1.28)	(−3.68)
Size	0.663 ***	0.838 ***	0.706 ***
	(7.21)	(10.23)	(20.90)
Leverage	−0.144 **	−0.075	−0.085 ***
	(−2.08)	(−1.15)	(−3.01)
Growth	−0.003	−0.007 ***	−0.004 ***
	(−1.13)	(−3.25)	(−3.83)
Roa	1.396 *	1.220 **	1.010 ***
	(1.73)	(2.27)	(4.76)
Holder	−0.001	0.008	0.001
	(−0.13)	(1.32)	(0.42)
Board	−0.113	−0.661	−0.497 **
	(−0.19)	(−1.31)	(−2.27)
Observations	1942	2484	12515
R^2	0.878	0.886	0.900
id FE	Yes	Yes	Yes
year FE	Yes	Yes	Yes

Note: brackets t statistic, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

To sum up, the influence of enterprise financialization on enterprise technology innovation has heterogeneity in both the nature of enterprise property rights and the financial development level in the region where the enterprise is located, which verifies hypothesis H2.

5.4. Impact Mechanism Analysis

5.4.1. Construction of the Mediation Effect Model

Benchmark regression analysis verified that there was a negative correlation between firm financialization and firm technological innovation. If so, how does firm financialization affect technological innovation? Based on the analysis of the influence mechanism of corporate financialization on corporate technological innovation mentioned above, this paper chose the enterprise financing constraint as the intermediary variable between enterprise financialization and enterprise technological innovation. The following mediation effect model was constructed by referring to the step-by-step method proposed by Baron and Kenny (1986) to test the mediation effect [28]:

$$Rd_{it} = a_0 + a_1 Fin_{it} + a_k control_{it} + id_i + year_t + \varepsilon_{it} \tag{3}$$

$$Fc_{it} = b_0 + b_1 Fin_{it} + b_k control_{it} + id_i + year_t + \varepsilon_{it} \tag{4}$$

$$Rd_{it} = c_0 + c_1 Fin_{it} + c_2 Fc_{it} + c_k control_{it} + id_i + year_t + \varepsilon_{it} \tag{5}$$

Rd_{it} is the technological innovation R&D input of the dependent variable. Fin_{it} is the proportion of the financial assets of the dependent variable. Fc_{it} is the financing constraint of the intermediary variable. By referring to the mediation effect test process proposed by Wen et al. (2014), the regression coefficient a_1 of Fin in Equation (3) was observed to test whether enterprise financialization had a significant impact on enterprise technological innovation. We observed the regression coefficient b_1 of Fin in Equation (4) to test whether corporate financialization had a significant impact on financing constraints. We observed the regression coefficient c_1 of Fin in Equation (5) and tested whether corporate financialization and financing constraints had a significant impact on corporate technological innovation [29]. When coefficient a_1 was significant, and if coefficient b_1 and coefficient c_2 were both significant, this indicated that corporate financing constraints were playing an intermediary role between corporate financialization and corporate technological innovation. In this case, when coefficient c_1 was not significant, it indicated that corporate financing constraints had a complete intermediary effect between corporate financialization and corporate technological innovation. When the coefficient c_1 was significant, if the symbols of b_1*c_2 and c_1 were the same, then corporate financing constraints had a partial mediating effect between corporate financialization and corporate technological innovation. If the symbols of b_1*c_2 and c_1 were different, then corporate financing constraints had a masking effect between corporate financialization and corporate technological innovation.

5.4.2. Estimation Results of the Mediation Effect Model

Table 7 shows the regression results of the mediation effect model. Column (2) is listed as the regression result of the independent variable *Fin* on the intermediate variable *Fc*. Coefficient b_1 was significantly positive at the 1% level, which indicates that financial investment intensifies corporate financing constraints, making it more difficult for enterprises to achieve external financing. Column (3) is listed as the regression result of the dependent variable *Rd* on the independent variable Fin and intermediate variable *Fc*. When both coefficients c_1 and c_2 were significantly negative, it indicated that the intensification of corporate financing constraints significantly inhibited corporate technological innovation. When the symbols of b_1*c_2 and c_1 were the same, it indicated that corporate financing constraints had an intermediary effect between corporate financialization and corporate technological innovation. By comparing the regression coefficient of the independent variable Fin in column (1) and column (3), it could be seen that after the addition of the intermediate variable *Fc*, the inhibitory effect of corporate financialization on R&D investment in corporate technological innovation decreased, indicating that corporate financing constraints bore part of the intermediary effect between corporate financialization and corporate technological innovation, and corporate financialization behavior intensified financing constraints to a certain extent and inhibited the technological innovation of enterprises. The above analysis verifies hypothesis H3b.

Table 7. Results of the mediation affect model regression.

Variables	(1) Rd	(2) Fc	(3) Rd
Fin	−0.521 ***	0.064 ***	−0.467 ***
	(−4.20)	(5.63)	(−3.76)
Fc			−0.849 ***
			(−3.47)
Size	0.716 ***	0.206 ***	0.891 ***
	(23.61)	(49.19)	(13.89)
Leverage	−0.092 ***	0.003	−0.090 ***
	(−3.81)	(1.21)	(−3.74)
Growth	−0.005 ***	−0.000 **	−0.005 ***
	(−5.07)	(−2.06)	(−5.18)
Roa	1.108 ***	0.004	1.112 ***
	(5.62)	(0.27)	(5.62)
Holder	0.002	−0.001 ***	0.001
	(1.10)	(−4.02)	(0.73)
Board	−0.468 **	−0.000	−0.468 **
	(−2.44)	(−0.01)	(−2.47)
Observations	16995	16995	16995
R^2	0.894	0.987	0.895
id FE	Yes	Yes	Yes
year FE	Yes	Yes	Yes

Note: brackets t statistic, *** $p < 0.01$, ** $p < 0.05$.

5.5. Robustness Test

5.5.1. Replace the Independent Variables

In order to more comprehensively measure the impact of firm financialization on firm technological innovation, in the robustness test part, the independent variables were replaced first. On the one hand, considering the particularity of the real estate industry in China's economic development, the domestic companies listed in the financial assets investment cycle were usually shorter than the real estate investment cycle; real estate investment was recognized by most Chinese investors' capital value, so the entity enterprise asset allocation in real estate investment might not be entirely for speculative motives. On the other hand, the net investment held by enterprises to maturity usually had a long-term nature. The long-term financial investment made by enterprises could be based on their long-term development strategy, which does not belong to the short-term speculative behavior of enterprises. In the robustness test, the net investment real estate and net hold-to-maturity investment were removed from the calculation formula of the original independent variable corporate financial assets ratio (Fin) to generate a new independent variable corporate financial assets ratio (Fin1). This was measured by the ratio of the sum of monetary funds, trading financial assets, net financial assets available for sale, net dividends receivable, and net interest receivable to the total assets of the enterprise. Table 8 shows the regression result for replacing independent variables. After replacing independent variables, the regression coefficient of independent variable Fin1 was −0.394, which was significantly negative at the 1% level. The data indicate that enterprise financialization still has a significant negative impact on enterprise technological innovation R&D investment and that the negative effect also has a lag. This test remained consistent with the original conclusion. The robustness of the original conclusion is proved.

Table 8. Results of regression of replacement independent variables.

Variables	(1) Rd	(2) Rd
Fin1	−0.394 ***	
	(−3.26)	
L_Fin1		−0.324 **
		(−2.34)
Size	0.719 ***	0.738 ***
	(23.65)	(21.69)
Leverage	−0.093 ***	−0.092 ***
	(−3.84)	(−3.22)
Growth	−0.005 ***	−0.004 ***
	(−5.12)	(−4.10)
Roa	1.121 ***	0.748 ***
	(5.69)	(3.71)
Holder	0.002	0.002
	(1.12)	(0.83)
Board	−0.469 **	−0.325 *
	(−2.44)	(−1.67)
Observations	16995	12266
R^2	0.894	0.917
id FE	Yes	Yes
year FE	Yes	Yes

Note: brackets t statistic, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.5.2. Sample Subinterval Estimation

Considering the US subprime crisis in 2008 and the subsequent "four trillion investment" policy, this may have had a sustained impact on the financial investment and technological innovation of Chinese non-financial enterprises. In order to exclude the impact of special events on the research conclusions, sample data from two years after the subprime crisis were excluded from the robustness test. In other words, we excluded the sample data from 2009 and 2010 for sample sub-interval estimation. Table 9 shows the regression results of the sample subinterval. After removing the sample data in 2009 and 2010, corporate financialization still had a significant negative impact on corporate technological innovation R&D investment, and the negative effect still had a lag. This test remains consistent with the original conclusion. The robustness of the original conclusion was proved.

Table 9. Results of sample subinterval regression.

Variables	(1) Rd	(2) Rd
Fin	−0.483 ***	
	(−4.08)	
L_Fin		−0.457 ***
		(−3.51)
Size	0.744 ***	0.741 ***
	(25.08)	(21.58)
Leverage	−0.106 ***	−0.087 ***
	(−4.19)	(−2.92)
Growth	−0.004 ***	−0.004 ***
	(−4.97)	(−3.91)
Roa	0.947 ***	0.693 ***
	(5.12)	(3.55)
Holder	0.001	0.002
	(0.73)	(0.85)
Board	−0.334 *	−0.278
	(−1.80)	(−1.44)
Observations	15951	11974
R^2	0.911	0.922
id FE	Yes	Yes
year FE	Yes	Yes

Note: brackets t statistic, *** $p < 0.01$, * $p < 0.1$.

5.5.3. Instrumental Variable

Since there may be endogenous problems caused by the reverse causality between the variables of corporate financial investment and technological innovation R&D level. In order to better mitigate the impact of endogenous problems, an instrumental variable method (two-stage least square method) was used in this paper to reduce the impact of endogenous problems. Referring to the research of Wang et al. (2017), we considered the investment income for the enterprise foreign investment income, including the enterprise during a certain period of the accounting foreign investment dividend income, bond interest income, and those associated with other units of profits. Its main enterprise's internal financial asset allocation level and enterprise technology innovation research and development activities would not have a direct impact on the enterprise's technological innovation and R&D input [30]. It can satisfy the correlation and exogeneity hypothesis of instrumental variables well. In this paper, the ratio of investment income to operating income (Inv) was selected as an instrumental variable to solve the endogenous bias caused by reverse causation, and the endogeneity test was conducted by using the two-stage least square method.

Table 10 shows the estimation results after regression using the two-stage least square method. The regression results of the first stage show that the regression coefficient of the instrumental variable Inv and independent variable Fin was 0.405 and had a positive significance at the 1% level. The test value of the Kleibergen-Paap rk Wald F statistic was 347.946. If the value was much larger than 10, it indicated that the tool variable Inv was recognizable and not weak. The regression results of the second stage showed that the regression coefficient of the independent variable Fin and dependent variable Rd was −14.856, which was still significantly negatively correlated at the level of 1%. This test is consistent with the original regression results, which could more effectively weaken the effect of endogeneity.

Table 10. Results of regression with the instrumental variable method.

Variables	(1) First Stage Fin	(2) Second Stage Rd
Inv	0.405 ***	
	(0.013)	
Fin		−14.856 ***
		(0.741)
Size	−0.001 ***	0.757 ***
	(0.000)	(0.011)
Growth	−0.000 **	−0.014 ***
	(0.000)	(0.002)
Roa	0.048 ***	4.065 ***
	(0.012)	(0.289)
Leverage	−0.007 ***	−0.407 ***
	(0.001)	(0.018)
Board	0.056 ***	1.739 ***
	(0.010)	(0.233)
Holder	−0.000 **	−0.012 ***
	(0.000)	(0.001)
Constant	0.030 ***	13.713 ***
	(0.005)	(0.109)
Kleibergen-Paap rk Wald F		347.946
Observations	17536	17536

Note: brackets t statistic, *** $p < 0.01$, ** $p < 0.05$.

6. Conclusions

This paper empirically examines the impact of corporate financialization on corporate technological innovation based on the panel data of listed A-share enterprises in Shanghai and Shenzhen from 2009 to 2020. First of all, this paper tested the influence of enterprise financialization on technological innovation with a two-way fixed effect model. Secondly, the paper analyzed heterogeneity from the nature of the enterprise's property rights and the level of financial development in the region where the enterprise was located. Finally, the paper tested the mediation effect of financing constraints through the three-step method of the mediation effect. The research results were as follows: first, enterprise financialization has a significant crowding out effect on investment in enterprise technological innovation. The larger scale of financial assets allocated by enterprises, the more serious crowding-out effect on enterprise R&D innovation, and the crowding out effect has lag. Second, the heterogeneity analysis showed that compared with state-owned enterprises, the financialization of non-state-owned enterprises had a greater crowding effect on enterprise technological innovation. Compared with the central and western regions, the level of financial development was higher, and the negative effect of enterprise financialization on enterprise technological innovation was greater. Third, the analysis of the influence mechanism further showed that there is some intermediary effect between financing constraint and enterprise financialization and enterprise technology innovation. The excessive allocation of financial assets increases the external financing constraints of enterprises and, thus, inhibits technological innovation.

Combining the findings of this paper, policy recommendations can be put forward at both government and enterprise levels. From the government level, first of all, the government should deepen the reform of the financial industry system to serve real economic development. The gradual overcapacity of the real economy and the high profits of the financial sector are important reasons for the influx of Chinese real enterprises into the financial sector. The development of the financial industry should serve the development of the real economy rather than squeezing out real investment. On the one hand, the government should further promote supply-side structural reform, optimize the environment for financial development, promote the combination of an effective market and the competent government, and give full play to the role of the financial market as a "reservoir". On the other hand, the government should encourage the development of the real economy, promote the transformation of the real industry into a dynamic force, build innovation platforms for enterprises, help them carry out technological innovation activities, actively promote the establishment of a modern industrial system with scientific and technological innovation as its core competitiveness, deepen the reform of the institutional mechanism for the protection of intellectual property rights, and stimulate the vitality of the main body of market innovation. Secondly, the government should improve the efficiency of financial services and improve the financing difficulties of enterprises. According to the conclusion, the deepening of the financialization of enterprises could aggravate financing constraints and seriously restrict the innovation and development of enterprises. Therefore, on the one hand, the government should optimize the financing structure, increase the financing channels of real enterprises, and solve the financing difficulties of small and medium-sized enterprises. On the other hand, the government should increase policy support for real enterprises, adopt policies such as industrial support or tax incentives to alleviate the financing difficulties faced by enterprise innovations, ensure resource investment in enterprise innovation activities, and achieve high-quality economic development. Finally, the government should strengthen the supervision of financial market investment and build a financial monitoring mechanism for enterprises. The government should strictly control the scale of the financial asset allocation of enterprises, curb the unlimited expansion of capital, pay attention to prevent financial risks, build a multi-tiered financial regulatory system, identify the problem of "moving from real to virtual" in the process of economic operations, and create a good business environment for real enterprises.

At the enterprise level, enterprises should establish the correct sense of management and formulate a long-term sustainable development strategy. Enterprises should base themselves on the development of their main business, make reasonable non-productive investments according to their own development needs, and avoid the impulse of financial investment. Entity enterprises should pay attention to capital innovation, technology innovation research and development achievements as an important indicator of management performance appraisal, where the incentive management of more enterprise asset allocations in technology innovation research, and development investment can reduce manage excessive financial investment, avoid excessive financialization problems, guaranteeing the advancement of technological innovation and achieving high-quality development. Secondly, enterprises should establish and improve the internal risk management system and cope with financial investment and the technological innovation between each link to establish a comprehensive risk identification and management system. This can better predict, evaluate and control the risk of enterprise financial investment and technological innovation, minimize the risks faced by enterprises, and enhance the foundation of enterprise technological innovation.

Author Contributions: Conceptualization, T.Z. and X.S.; methodology, T.Z.; software, X.S.; validation, T.Z. and X.S.; formal analysis, X.S.; investigation, T.Z.; resources, T.Z.; data curation, X.S.; writing—original draft preparation, X.S.; writing—review and editing, T.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zhong, H.M. The impact of enterprise financialization on innovation investment. *Economist* **2021**, *2*, 92–101.
2. Peng, L.; Zhan, H.R.; Wen, W. Financialization of entity enterprises and enterprise technology innovation—Experiential evidence from non-financial listed companies. *Economist* **2022**, *4*, 58–69.
3. Palley, T.I. Financialization: What it is and Why it Matters. *Soc. Sci. Electron. Publ.* **2007**, *26*, 9–15. [CrossRef]
4. Krippner, G.R. The financialization of the American economy. *Socio-Econ. Rev.* **2005**, *3*, 173–208. [CrossRef]
5. Demir, F. The Rise of Rentier Capitalism and the Financialization of Real Sectors in Developing Countries. *Rev. Radic. Political Econ.* **2007**, *39*, 351–359. [CrossRef]
6. Zhang, C.S.; Zhang, B.T. The mystery of the decline of Chinese industrial investment rate: The perspective of economic financialization. *Econ. Res.* **2016**, *51*, 32–46.
7. Liu, G.C. Financial asset allocation and enterprise R & D and innovation: 'squeeze out' or 'squeeze in'. *Stat. Study* **2017**, *34*, 49–61.
8. Bonfiglioli, A. Financial Intergration, Productivity and Capital Accumulation. *J. Int. Econ.* **2008**, *76*, 337–355. [CrossRef]
9. Xu, S.; Liu, D.C. Empirical study on the impact of enterprise financialization on technological innovation. *Sci. Res. Manag.* **2019**, *40*, 240–249.
10. Yang, S.L.; Niu, D.Y.; Liu, D.L.; Wang, Z.H. Financialization of entity enterprises, analyst focus and internal innovation driving force. *Manag. Sci.* **2019**, *32*, 3–18.
11. Seo, H.J.; Kim, H.S.; Kim, Y.C. Financialization and the Slowdown in Korean Firm' R&D Investment. *Asian Econ. Pap.* **2012**, *11*, 35–49.
12. Trivedi, S.R. Financialisation and accumulation: A firm-level study in the Indian context. *Procedia Econ. Financ.* **2014**, *11*, 348–359. [CrossRef]
13. Gleadle, P.; Parris, S.; Shipman, A.; Simonetti, R. Restructuring and innovation in pharmaceuticals and biotechs: The impact of financialisation. *Crit. Perspect. Account.* **2014**, *25*, 67–77. [CrossRef]
14. Kliman, A.; Williams, S.D. Why 'Financialisation' Hasn't Depressed US Productive Investment. *Camb. J. Econ.* **2015**, *39*, 67–92. [CrossRef]
15. Davis, L.E. Identifying the 'Financialization' of the Non Financial Corporation in the U.S. Economy: A Decomposition of Firm-Level Balance Sheets. *J. Post Keynes. Econ.* **2016**, *39*, 115–141. [CrossRef]
16. Cupertino, S.; Consolandi, C.; Vercelli, A. Corporate Social Performance, Financialization, and Real Investment in U.S. Manufacturing Firms. *Sustainability* **2019**, *11*, 1836. [CrossRef]
17. Zhuang, X.D.; Wang, R.Z. Fintech, corporate financial investment motivation and the problem of 'moving from real to virtual'—The empirical evidence based on the micro data of Chinese enterprises. *South. Econ.* **2023**, *401*, 90–109.
18. Xie, J.Z.; Wang, W.T.; Jiang, Y. Financialization of manufacturing industry, government control and technological innovation. *Econ. Dyn.* **2014**, *11*, 78–88.
19. Du, Y.; Zhang, H.; Chen, J.Y. The impact of financialization on the future development of the main business of real enterprises: Promote or inhibit. *China's Ind. Econ.* **2017**, *12*, 113–131.
20. Dong, L.; Chen, X.F. The influence of enterprise financialization on innovation investment from the perspective of suitability. *Res. Local Financ.* **2021**, *7*, 77–88.
21. Gu, H.F.; Zhang, H.H. Enterprise financialization, financing constraints and enterprise innovation—The regulatory role of monetary policy. *Contemp. Econ. Sci.* **2020**, *42*, 74–89.
22. Yang, G.C.; Liu, J.; Lian, P.; Rui, M. Tax-cut incentives, R & D manipulation, and R & D performance. *Econ. Res.* **2017**, *52*, 110–124.
23. Kong, D.M.; Xu, M.L.; Kong, G.W. Internal compensation gap and innovation. *Econ. Res.* **2017**, *52*, 144–157.
24. Peng, Y.C.; Huang, Z.G. The causes and governance of economic 'transition from real to virtual': Understanding the financial system reform of the 19th National Congress. *World Econ.* **2018**, *41*, 3–25.
25. Duan, J.S.; Zhuang, X.D. Financial investment behavior and enterprise technology innovation—Motivation analysis and empirical evidence. *Ind. Econ. China* **2021**, *1*, 155–173.
26. Gu, X.Y.; Chen, Y.G.; Pan, S.Y. Economic policy uncertainty and innovation—Is based on the empirical analysis of listed companies in China. *Econ. Res.* **2018**, *53*, 109–123.
27. Xie, W.M.; Fang, H.X. Financial development, financing constraints and enterprise R & D investment. *Financ. Res.* **2011**, *5*, 171–183.
28. Baron, R.M.; Kenny, D.A. The Moderator-mediator Variabel Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *J. Personal. Soc. Psychol.* **1986**, *51*, 1173–1182. [CrossRef]
29. Wen, Z.L.; Ye, B.J. Analysis of mediation effects: Methods and model development. *Adv. Psychol. Sci.* **2014**, *22*, 731–745. [CrossRef]
30. Wang, H.J.; Cao, Y.Q.; Yang, Q.; Yang, Z. The financialization of entity enterprises or suppresses enterprise innovation—Based on the experience of China's listed manufacturing companies. *Nankai Manag. Rev.* **2017**, *20*, 155–166.

FinTech

Article

Impact of the COVID-19 Pandemic on Cryptocurrency Markets: A DCCA Analysis

Dora Almeida [1,2], Andreia Dionísio [1], Paulo Ferreira [1,2,3,*] and Isabel Vieira [1]

[1] CEFAGE, IIFA—Center for Advanced Studies in Management and Economics, University of Évora, 7004-516 Évora, Portugal; dora.almeida@uevora.pt (D.A.); andreia@uevora.pt (A.D.); impvv@uevora.pt (I.V.)
[2] VALORIZA—Research Centre for Endogenous Resource Valorization, Polytechnic Institute of Portalegre, 7300-555 Portalegre, Portugal
[3] Department of Economic Sciences and Organizations, Polytechnic Institute of Portalegre, 7300-555 Portalegre, Portugal
[*] Correspondence: pferreira@ipportalegre.pt

Abstract: Extraordinary events, regardless of their financial or non-financial nature, are a great challenge for financial stability. This study examines the impact of one such occurrence—the COVID-19 pandemic—on cryptocurrency markets. A detrended cross-correlation analysis was performed to evaluate how the links between 16 cryptocurrencies were changed by this event. Cross-correlation coefficients that were calculated before and after the onset of the pandemic were compared, and the statistical significance of their variation was assessed. The analysis results show that the markets of the assessed cryptocurrencies became more integrated. There is also evidence to suggest that the pandemic crisis promoted contagion, mainly across short timescales (with a few exceptions of non-contagion across long timescales). We conclude that, in spite of the distinct characteristics of cryptocurrencies, those in our sample offered no protection against the financial turbulence provoked by the COVID-19 pandemic, and thus, our study provided yet another example of 'correlations breakdown' in times of crisis.

Keywords: contagion; COVID-19; cryptocurrencies; detrended cross-correlation analysis; detrended cross-correlation analysis correlation coefficient; integration

Citation: Almeida, D.; Dionísio, A.; Ferreira, P.; Vieira, I. Impact of the COVID-19 Pandemic on Cryptocurrency Markets: A DCCA Analysis. *FinTech* **2023**, *2*, 294–310. https://doi.org/10.3390/fintech2020017

Academic Editor: David Roubaud

Received: 10 April 2023
Revised: 12 May 2023
Accepted: 18 May 2023
Published: 24 May 2023

1. Introduction

The Bitcoin (BTC), created in 2008 by Satoshi Nakamoto, was the first cryptocurrency. Thousands have been launched since then, promoting the astonishing growth of cryptocurrency markets in terms of capitalization, negotiation volumes, and prices [1–3]. Cryptocurrencies are a relevant set of global financial assets [4], attracting investors' interest due to their distinctive features (e.g., blockchain technology, decentralization, scarcity, high returns, low correlations with traditional assets, and susceptibility to speculative bubbles). Inter alia, the attention of academics and policymakers has also been attracted by these markets' potential instability and contagion risks [5–7]. Several studies focusing on cryptocurrencies have assessed herding behavior [8], co-explosivity [9], contagions [10], interdependence [11], co-movements [12], information flows, and links with other financial assets [13–15].

Globalization has promoted the interdependence of financial markets and institutions [16], thus enhancing the probability of financial contagions, especially in periods of turmoil. Both financial and non-financial shocks may promote financial contagions, and the risks posed by episodes such as natural disasters and pandemics are an emerging line of research [17,18]. The COVID-19 pandemic is one such distressing phenomenon. It has impacted financial and real markets across the world, provoking a range of effects that often elicit comparison with the effects of the global financial crisis of 2008 [19,20]. The pandemic impacted daily market returns around the globe, froze economic activity, spiked uncertainty, endangered global financial stability [21,22], reduced income, disrupted transportation, services, and manufacturing industries, raised unemployment, and affected other major economic variables [23,24]. However, such an extreme event provides an opportunity to study return spillovers among cryptocurrencies during highly uncertain and stressful periods. The links established in cryptocurrency markets during these phases are of special interest to investors and portfolio managers as they are directly related to return and volatility spillovers (i.e., contagions), and are relevant for risk management and portfolio diversification strategies [3].

The literature contains several different methodologies to assess financial contagions. Distinct crisis contexts have also been assessed (see [25]). To ensure conceptual and methodological coherence, various contagion definitions have been adopted (for example, [26–28]). In this study, we follow the precedent set by [26], which defines contagion as "a significant increase in cross-market linkages after a shock to one country (or group of countries)" [26] (p. 2223). In light of such a definition, a contagion would be considered a significant increase in correlation levels between cryptocurrencies due to the COVID-19 pandemic. On the contrary, if in a given cut-off moment, no significant increase in correlations is detected, there is no contagion (although there may be interdependence). In this study, we considered 31 December 2019 as the cut-off moment, based on the date when the World Health Organization was notified about the first cases of the disease, which made the information about COVID-19 publicly available for investors (see, for instance, [29–33]).

Several researchers have analyzed interdependence, dynamic linkages, comovements, and risk connectedness among major cryptocurrencies (e.g., [1,3,7,11,12], among others). Most of these studies are limited to a relatively small number of cryptocurrencies, usually the three or four with the highest market capitalization (where BTC is always included—see, for example, [34–38]). Evaluations are also often focused on the relationships between each cryptocurrency and BTC. Here, we try to improve knowledge of the behavior of cryptocurrency markets by using a larger set of 16 cryptocurrencies (doubling the number analyzed in [33]) in our evaluation of integration and contagions in cryptocurrency markets in the context of the COVID-19 pandemic.

To detect and measure cross-correlations, contagions, and efficiency in various stock markets, previous studies have used detrended cross-correlation analysis (DCCA) and DCCA, together with detrended fluctuation analysis (DFA) (e.g., [39–41]). We followed this methodological approach and estimated the DCCA correlation coefficient (ρDCCA) and its variation $\Delta\rho$DCCA (our measure of contagion) before and after 31 December 2019. The adopted approach allows the identification of possible non-linearities among variables, which are not accounted for when estimating simpler linear correlation coefficients. All possible pairs of cryptocurrencies in our sample were assessed, with the objective of providing more information about these markets' complex dynamics.

Our study expands upon the existing literature in four ways. First, it focuses on a real shock that has severely affected financial markets [42] and that has challenged risk and management activities [20]. Second, as we analyzed both periods before and after the beginning of the COVID-19 pandemic, we provide new evidence concerning cryptocurrency markets' behavior when the global financial system is disturbed by a real extreme shock. Third, it provides evidence of integration and contagions occurring between cryptocurrencies emanating from a health crisis rather than a financial one. Fourth, it employs a methodology that not only accounts for nonlinearities, but also allows for an assessment of a contagion across different timescales; thus, it produces information on its short- and long-run impacts, which is relevant because the effects across shorter and longer timescales may differ.

The remainder of the paper is organized as follows. Section 2 presents a brief literature review, and it provides recent empirical evidence of contagions in cryptocurrency markets. In Section 3, we present both the data and methodology, with results shown and discussed in Section 4, and Section 5 concludes.

2. Brief Literature Review

In this section, we briefly review the most relevant literature for our assessment (i.e., that examine co-movements between cryptocurrency markets, and between them and other financial markets).

The level of financial integration is of great relevance in international finance as it impacts, for example, diversification strategies, risk management, and the design of regulation. Integration has been enhanced by financial deregulation and liberalization, and also by technological progress [43]. One relevant sign of increasing market integration is the rising correlations across them (see, among others, [44]). Given its potential positive and negative real effects (for example, regarding positive effects, enhanced economic growth and welfare; conversely, regarding negative effects, increased risk of contagions), it is relevant to assess how individual financial markets relate to each other.

Cryptocurrencies have been considered a relevant part of the global financial market [4] and are increasingly included in investors' portfolios. It is thus important to analyze the co-movements between cryptocurrencies, as well as those between the cryptocurrency markets and other markets. One interesting feature that distinguishes the study of cryptocurrencies from those of other assets is that, given the former's short history, observing the structural organizational process of markets from their inception is possible.

A vast amount of the literature examines links between cryptocurrencies. Such studies include, for example, Granger causality tests, GARCH-based models, wavelets, and cointegration analyses. Before the outbreak of the COVID-19 pandemic, several features of the cryptocurrency markets' behavior were explored (e.g., interdependence, dynamic linkages, or co-movements). However, the analyses were performed using samples containing a small number of cryptocurrencies and using BTC as a benchmark. For example [10], using DCCA, based on a sample between July 2016 and May 2019, analyzed the evidence that a contagion from BTC had transferred to the other considered cryptocurrencies. Except for the USDT, the authors found evidence of a contagion being present in all the cryptocurrencies analyzed. Although Ref. [45] used a different approach by making use of copula functions, it found similar results. Using coherence and cross-wavelet transform techniques, Ref. [46] studied the connection between BTC and five other major cryptocurrencies, identifying co-movements in the time–frequency space, with the main relationships occurring between BTC and Dash, Monero (XMR), Ripple (XRP), a lagged relationship with Ethereum (ETH), and out-of-phase movements with Litecoin (LTC). Ref. [47] considered five leading and liquid cryptocurrencies, using a sample from 2016 to 2018, and it investigated the dynamics of their multiscale interdependence. The authors identified high levels of dependence on a daily frequency scale, and a contagion with its origins in XRP and ETH.

The spillovers of returns and/or volatilities between cryptocurrencies were evaluated inter alia by [7,48–53]. According to [45], BTC was the dominant contributor to return and volatility spillovers, contrary to [49], which found tight and time-varying volatility spillovers, but not with BTC as the leading contributor. Shared leadership between the BTC and LTC was also identified by [50], with ETH as the main net receiver. This evidence was corroborated by [51], which also highlighted the relevant links between these cryptocurrencies and various others. Conversely, Ref. [7] concluded that BTC, EHT, and LTC are the main net transmitters of volatility spillovers, with the short-term risk spillovers being stronger (in comparison to the medium- and long-term ones). These authors also found evidence of larger negative spillovers than positive ones, thus contradicting [52]. Although they identified ETH and XRP as the main receivers of negative-return shocks, it was also possible to make conclusions regarding very weak positive-return spillovers for Dash and ETH. Higher market capitalization cryptocurrencies exhibited leadership in terms of volatility spillover. Refs. [53,54] found evidence of frequent structural breaks, which were more relevant for larger cryptocurrencies, and small cryptocurrencies' exhibited volatility spillover leadership. The diversity of these results justifies the interest in further and deeper assessments.

As the COVID-19 pandemic spread, it affected stock markets worldwide, thus justifying the assessment of its contagion effects on other financial markets. The pandemic is a shock with no financial origin; this contrasts with, for example, the US subprime crisis of 2007/2008 or the Euro area sovereign debt crisis of 2010/2011. However, this non-financial disturbance caused turmoil in financial markets [55], increased uncertainty, and panicked investors [56], with significant price falls in several markets. Both financial and real markets have suffered the consequences of the pandemic [57,58], and for the first time in their short life, cryptocurrency markets were also impacted by the global shock [59].

Several studies assessed the effects of the COVID-19 pandemic on the cryptocurrency markets (see [60–66], among others). Results have identified significant changes in co-movement patterns and in correlations during the pandemic period. Moreover, they also showed the more influential role of altcoins during the crisis period compared with pre-pandemic times, changes in the structure of the cryptocurrency networks, and the intensification of the information flows between cryptocurrencies which simultaneously occurred with the abrupt fall in stock markets; this could warn of the possibility of contagions, and thus, increases in systematic risk.

The relationships between cryptocurrencies with several conventional assets, such as currencies, stock markets, or even commodities, were also analyzed during the pandemic (e.g., [20,61,67]), with mixed results. It is possible to find evidence of high symmetric dependence between cryptocurrencies during normal market conditions and an asymmetric one in bearish and bullish market conditions, negative dependence between cryptocurrencies and gold, thus indicating possible diversification opportunities for these assets during the pandemic, a low positive dependence between cryptocurrencies and gold under normal market conditions, low dynamic conditional correlations with other financial assets in stable periods, and weak or negative volatility dynamics before the pandemic, which became positive during the health crisis for the most assessed assets.

Evidence is also mixed regarding cryptocurrencies' hedge and safe haven properties. Although the results in [20] indicate that gold and cryptocurrencies can be used for hedge or diversification purposes across all timescales, Refs. [20,30,35,36], for example, concluded that BTC does not act as a hedge in periods of financial turmoil (such as the COVID-19 period). On the other hand, Ref. [37] suggests that BTC is a safe haven investment.

When analyzing the impact of the pandemic using multiscale cross-correlations among the cryptocurrency markets and several other assets, Refs. [68,69] estimated the generalized DCCA coefficient. Although they did not find significant cross-correlations in 2018 and 2019 between cryptocurrencies and other assets, this changed in 2020, when the cryptocurrency markets appeared to have become more connected with other financial markets. Ref. [69] also concluded that during the turbulent periods of the COVID-19 pandemic, cryptocurrencies were strongly cross-correlated, although the higher levels of cross-correlation were registered with other assets (the latter were, however, less independent among themselves). As the pandemic became a more normal feature of everyday life, cross-correlations between cryptocurrencies and other markets tended to decrease.

The effect of the pandemic on connectedness, returns, and volatility spillovers between cryptocurrencies was also analyzed (e.g., [21,68–73]). These studies provide evidence of several spillovers in both regimes, but also structural changes in spillovers in late 2018 and early 2020. There were also stronger cross-correlations between cryptocurrency markets during the COVID-19 pandemic. Results suggest that cryptocurrencies acted as net receivers and transmitters of shocks during the COVID-19 pandemic, and that this event enhanced the spillovers and increased the integration of cryptocurrency markets.

The dynamic properties of cryptocurrency markets are still not fully identified and understood [69]. One of the reasons for this is that most past research focused almost exclusively on BTC, or at most, on the four or five most important cryptocurrencies [74]. Samples of the main cryptocurrencies were used in most studies that focused on contagion, interdependence, or integration in cryptocurrency markets (e.g., [75]). Most of these studies evaluated the relationships between those cryptocurrencies and BTC. The other possible links between the other cryptocurrencies have been explored less. To fill these gaps in the literature, we considered a sample of 16 cryptocurrencies and evaluated relationships between all possible pairs.

The COVID-19 pandemic is an interesting subject for an analysis of contagion. Its outbreak can be clearly identified, in contrast with other well-researched sources of financial contagion, for which there were various probable turmoil catalysts. For instance, there were various underlying causes for the 2007–08 subprime crisis, thus making it difficult to pinpoint exactly what provoked the crisis, and it created some noise in the assessment of contagion. Furthermore, most analyses evaluate financial contagions when the source of contagion is also of a financial nature; however, as cryptocurrencies' trading volumes attained record levels during the pandemic, an evaluation of possible variations in terms of integration levels and contagion, which were provoked by this real shock, is also of academic and practical interest.

When assessing these issues, and given that the variables of interest tend to exhibit non-linearities [76,77], this paper uses the DCCA and a variation of the ρDCCA. This approach produces new insights into these markets' reactions to a global non-financial shock, and it allows analyses across different timescales, thus providing more detailed information on the structure of correlations. The obtained results are useful given that there are distinct preferences depending on the investment time horizon. Furthermore, the DCCA is robust in terms of evaluating power-law cross-correlations between two series regardless of their (non) stationarity (e.g., [78]).

3. Data and Methods

To perform the empirical analysis, we used the closing daily prices of 16 cryptocurrencies, with a market capitalization of more than a billion dollars, on 7 March 2020; on that date, 94% of the total market capitalization of all the cryptocurrencies were available in the used database (i.e., 263,364,575,633 USD). Furthermore, according to [66], the less well-known and less capitalized a cryptocurrency is, the less liquid and less reliable its related data are, thus justifying the use of cryptocurrencies with high market capitalization levels. We used an open-source database (https://coinmarketcap.com, accessed on 31 January 2021), which is considered to be an appropriate database with which to conduct research [79]. The sample selection considered various degrees of market capitalization and different underlying business models for cryptocurrencies. Due to data availability constraints, the time series of the different cryptocurrencies had distinct starting dates. Aiming to preserve all the possible information contained within each time series, all data available before the cut-off moment (31 December 2019) were considered. All time series ended by 30 January 2021 (details in Table 1). Cryptocurrencies' daily returns were calculated as $r_{i,t} = \ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right)$, where $r_{i,t}$ is the return of cryptocurrency i at period t, and $P_{i,t}$ and $P_{i,t-1}$ are the prices at time t and $t-1$, respectively.

Our main goal was to analyze how cryptocurrency markets behaved before and after the onset of the COVID-19 pandemic. More specifically, we evaluated the co-movements during the pre-crisis period (up to 31 December 2019) and during the crisis period (from this cut-off date until 30 January 2021), thus allowing us to make conclusions regarding integration, contagion, or independence, in accordance with the adopted definition of contagion (see [26]), as well as the studies of [41] or [80]. The non-linearity of data makes the use of classic linear approaches inappropriate; thus, the evaluation of a contagion between cryptocurrencies is based on the DCCA (commonly used in the finance literature, see for example [81–84]), the ρDCCA, and variations thereof. DCCA does not require that the analyzed series are stationary, and it allows the establishment of cross-correlations (contagion effects) in both regimes by directly using the properties of the moments of the series (either linear or nonlinear relationships). Consequently, there is no sample reduction, and all original observations are used (an advantage, especially when the number of observations is not very high).

Table 1. Sample Description.

	Cryptocurrency		Start Date	Market Capitalization (USD)	
1	Bitcoin	BTC	29 April 2013	162,684,945,903	61.77%
2	Ethereum	ETH	7 August 2015	26,164,459,704	9.93%
3	Ripple	XRP	4 August 2013	26,164,459,704	9.93%
4	Bitcoin Cash	BCH	23 July 2017	6,059,789,428	2.30%
5	Bitcoin SV	BSV	9 November 2018	4,290,029,659	1.63%
6	Tether	USDT	25 February 2015	4,643,212,805	1.76%
7	Litecoin	LTC	29 April 2013	3,889,681,824	1.48%
8	EOS	EOS	1 July 2017	3,366,250,140	1.28%
9	BinanceCoin	BNB	25 July 2017	3,138,663,736	1.19%
10	Tezos	XTZ	2 October 2017	2,103,907,641	0.80%
11	ChainLink	LINK	20 September 2017	1,520,607,569	0.58%
12	Cardano	ADA	1 October 2017	1,268,987,677	0.48%
13	Stellar	XLM	5 August 2014	1,183,231,787	0.45%
14	TRON	TRX	13 September 2017	1,136,886,287	0.43%
15	Monero	XMR	21 May 2014	1,143,443,765	0.43%
16	Huobi Token	HT	3 February 2018	1,063,188,577	0.40%
		Total		249,821,746,206	94.86%

Note: (i) Table shows basic information, such as each cryptocurrency's starting date and market capitalization (in value and percentage) on 7 March 2020; (ii) The total market capitalization on 7 March 2020, of all the cryptocurrencies available on the database, was USD 263,64,575,633.

The DCCA approach was first proposed by [85] to evaluate long-term power-law cross-correlations between two time series of equal lengths N. It is a generalization of the DFA, proposed by [86], to a context where interest lies in the study of the joint behavior of two distinct time series of equal lengths N. DCCA produces results for different timescales through the detrended covariance function, $F^2_{\text{DCCA}}(n)$. In this study, the DFA is not applied directly, but the DFA exponent values are used to calculate the ρDCCA.

In accordance with DFA, if there is a long-range correlation between two time series, then $F_{\text{DCCA}} \sim n^{\lambda}$ with $\lambda = (\alpha_{\text{DFA}} + \alpha'_{\text{DFA}})/2$ [87]. Although the λ exponent allows quantification of the long-range power-law correlation and identification of seasonality, it does not quantify the level of identified cross-correlations [88]. To obtain such a quantification (with the DFA and DCCA approaches), it is thus necessary to use the ρDCCA, proposed by [87].

According to [89], the ρDCCA is obtained using two time series, x_k and y_k, with equal lengths N (k represents two equidistant observations), starting with the integration of those time series in order to obtain two new ones $x_t = \sum_{k=1}^{t} x_k$ and $y_t = \sum_{k=1}^{t} y_k$, with $t = 1, 2, \ldots, N$. Then, both integrated time series are divided into $(N - n)$ overlapping boxes of equal lengths n, with $4 \leq n \leq N/4$. Subsequently, the local trend of each box, $\widetilde{x}_t$ and $\widetilde{y}_t$, is calculated by a least-squares fit of each series. The detrended series are obtained by subtracting each trend from their original values. The detrended covariance of the residuals for a specific box is then calculated as:

$$f^2_{\text{DCCA}}(n) = \frac{1}{n-1} \sum_{k=i}^{i+n} \left(x_t - \widetilde{x}_t \right) \left(y_t - \widetilde{y}_t \right) \quad (1)$$

The next step is to obtain the new covariance function, which is given by the average of all $(N - n)$ overlapping boxes (i.e., $F^2_{\text{DCCA}}(n) = \frac{1}{N-n} \sum_{i=1}^{N-n} f^2_{\text{DCCA}}\Big)$.

Finally, the ρDCCA is calculated as:

$$\rho\text{DCCA}(n) = \frac{F^2_{\text{DCCA}}(n)}{F_{\text{DFA}\{x\}}(n) F_{\text{DFA}\{y\}}(n)} \quad (2)$$

This cross-correlation coefficient depends on the timescale (i.e., the box length, n) and on the size of the series, N. Based on Monte Carlo simulations, Ref. [90] tested this coefficient and compared it with the linear correlation coefficient. Regarding its efficiency, the study concluded that it displays the desirable properties of a correlation coefficient; indeed, it is composed of values between -1 and 1 ($-1 \leq \rho$DCCA ≤ 1, see [91] for a full description of the coefficient's properties). Thus, the interpretation is straightforward: if ρDCCA $= 0$, there is no cross-correlation; if ρDCCA $= 1$ or ρDCCA $= -1$, there is perfect cross-correlation, or perfect anti cross-correlation, respectively.

The ρDCCA values are an indicator of the presence of cross-correlations [92], and they capture the level of market integration [44]. To examine the statistical significance of ρDCCA (identifying the critical values), and to test the null hypothesis for ρDCCA (classical test), Ref. [92] proposed a set of procedures that we followed in order to empirically confirm the existence of cross-correlation between time series. However, as we wanted to assess the (non)existence of contagions in cryptocurrency markets during the pandemic, we considered two periods (before and after the onset of the pandemic), and thus, in accordance with [93], we calculated the $\Delta\rho$DCCA as:

$$\Delta\rho\text{DCCA}(n) \equiv \rho^{after}_{\text{DCCA}}(n) - \rho^{before}_{\text{DCCA}}(n) \tag{3}$$

where, $\rho^{after}_{\text{DCCA}}(n)$ and $\rho^{before}_{\text{DCCA}}(n)$ represent the detrended cross-correlation coefficients, before and after the onset of the pandemic, respectively.

By considering the values displayed by the relevant coefficients before and after the cut-off moment, $\Delta\rho\text{DCCA}(n)$ allows us to make conclusions based on the possible contagion effects of the pandemic on cryptocurrency markets. Thus, if $\Delta\rho\text{DCCA}(n) > 0$, the correlation coefficients increased in the period after the cut-off moment and there are cross-correlation effects; thus, in accordance with [26], there is evidence of contagion. If $\Delta\rho\text{DCCA}(n) < 0$, the correlation coefficients have decreased in the period after the cut-off moment, and dependence between markets declined.

The null and alternative hypotheses used to assess the significance of $\Delta\rho\text{DCCA}(n)$ are:

$$\begin{array}{c} H_0 : \Delta\rho\text{DCCA}(n) = 0,\ the\ differences\ are\ not\ significant \\ H_1 : \Delta\rho\text{DCCA}(n) \neq 0,\ the\ differences\ are\ significant \end{array} \tag{4}$$

The significance of $\Delta\rho\text{DCCA}(n)$ is assessed using the critical values proposed by [89,94] for 90%, 95%, and 99%.

4. Results and Discussion

4.1. Descriptive Statistics

Table 2 presents the descriptive statistics of the cryptocurrencies' returns. To assess the stationarity of these series, a standard Augmented Dickey–Fuller (ADF) test was performed (using the StataSE 15® (64-bit) software, from StataCorp LLC, Lakeway Drive, College Station, TA, USA). The test's H_0 was rejected in all cases, thus suggesting that the examined series of returns are all stationary (results not shown, but available upon request).

As the volatility of the series of returns did not increase (and in fact, decreased) after 31 December 2019, we conclude that the onset of the COVID-19 pandemic did not significantly change the cryptocurrencies' behavior. As the number of observations is not constant across periods, such evidence should be considered carefully. For most cryptocurrencies, mean returns are positive and close to zero. With the exceptions of Bitcoin SV (BSV) and Binance Coin (BNB), mean returns increased after 31 December 2019.

BSV has shown the highest average return before the pandemic crisis, as well as the lowest average return and the highest volatility during the health crisis. Regarding skewness, it was positive in the pre-crisis period (except for BTC and USDT) and negative during the crisis period (except for BSV, USDT, and Stellar (XLM)); this is in accordance with [33,60], meaning that during the first period, there was a higher probability of large positive return variations than negative ones, which could be a sign of increased sensitivity to the effects of the pandemic. In contrast, during the second period, negative returns were more frequent, thus reflecting the turmoil and uncertainty provoked by the pandemic. Regarding kurtosis, high values (i.e., leptokurtic distributions) were observed in both periods, thus suggesting that the returns do not follow a normal distribution; this is consistent with the existence of fat-tails, a well-known stylized fact in financial markets. This is also a justification for using nonlinear, rather than linear, techniques. Although the USDT is a stable cryptocurrency (pegged to the USD), it exhibited an extremely high kurtosis value before 31 December 2019. Shortly after it was launched in 2014, questions were raised concerning whether its issuer was setting aside enough collateral to maintain the dollar peg. The issuing company started reporting its reserves in 2017, due to mounting investors' doubts. This could be an explanation for the high kurtosis observed in this cryptocurrency during the first period that was assessed. According to a report examining June 2018 by Freeh Sporkin & Sullivan, LLP, after that date, all tethers in circulation were fully backed by USD reserves. This could be an explanation for the alignment of the kurtosis values of the USDT with those of the other cryptocurrencies in our sample during the second analyzed period.

Table 2. Descriptive Statistics of Cryptocurrencies' Returns.

Cryptocurrency	Before 31 December 2019				After 31 December 2019			
	Mean	**Stdev.**	**Skewness**	**Kurtosis**	**Mean**	**Stdev.**	**Skewness**	**Kurtosis**
BTC	0.0016	0.0427	−0.1527	10.7409	0.0039	0.0414	−3.4812	44.5290
ETH	0.0024	0.0714	−3.4274	74.6109	0.0060	0.0551	−2.5411	29.9171
XRP	0.0015	0.0727	2.0756	32.9133	0.0021	0.0660	−0.3960	26.4318
BCH	−0.0008	0.0794	0.6179	10.4098	0.0018	0.0603	−1.8145	24.2868
BSV	0.0008	0.0901	0.8643	19.9132	0.0015	0.0814	2.8755	46.5471
USDT	−0.0001	0.0211	−12.2749	829.3628	0.0000	0.0055	0.1522	37.9746
LTC	0.0009	0.0645	1.7163	28.5632	0.0030	0.0540	−1.5536	16.3358
EOS	0.0010	0.0827	2.2245	27.6377	0.0030	0.0545	−2.0790	22.8957
BNB	0.0055	0.0787	1.3888	15.1944	0.0003	0.0502	−3.3523	38.3843
XTZ	−0.0004	0.0751	0.1255	10.5396	0.0019	0.0634	−2.1090	24.3520
LINK	0.0027	0.0812	0.7048	7.1339	0.0065	0.0711	−1.4227	18.0953
ADA	0.0003	0.0792	2.9094	29.3140	0.0061	0.0623	−1.1089	14.6842
XLM	0.0015	0.0754	2.0089	19.6020	0.0050	0.0668	1.6195	21.9256
TRX	0.0023	0.0963	2.1343	19.3240	0.0022	0.0545	−2.2636	24.9947
XMR	0.0016	0.0703	0.6497	9.6001	0.0029	0.0509	−2.4056	26.4712
HT	0.0009	0.0518	0.6165	7.6063	0.0021	0.0431	−3.5911	49.8863

Notes: (i). Stdev represents the standard deviation; ii. Before the cut-off moment, there exists a different number of observations between series (as detailed in Table 1), but after the cut-off moment, all the series have a similar number of observations (396).

4.2. $\Delta\rho$DCCA *Analysis*

Our goal is to analyze correlations in cryptocurrency markets before and after the COVID-19 pandemic crisis and to make conclusions on the types of observed relations. We thus compared the ρDCCA before and after the cut-off moment, estimated the $\Delta\rho\text{DCCA}(n)$, and assessed whether there were significant correlation changes between the two periods.

As mentioned above, the statistical significance of $\Delta\rho\text{DCCA}(n)$ is tested using the critical values proposed by [89,94] for 90%, 95%, and 99%. Figure 1 depicts the lower (LL_99%) and upper (UL_99%) critical values (due to their proximity to zero, they are practically imperceptible). If the estimated $\Delta\rho\text{DCCA}(n)$ values are outside the referred limits (LL and UL), the correlation is statistically significant, and if positive, it can be interpreted, according to [10,26], as evidence of a contagion. Conversely, if the estimates lie within the critical values, the variation between correlations is not significant. In accordance with [44], a positive value for $\Delta\rho\text{DCCA}(n)$ can also be interpreted as an increase in integration between markets.

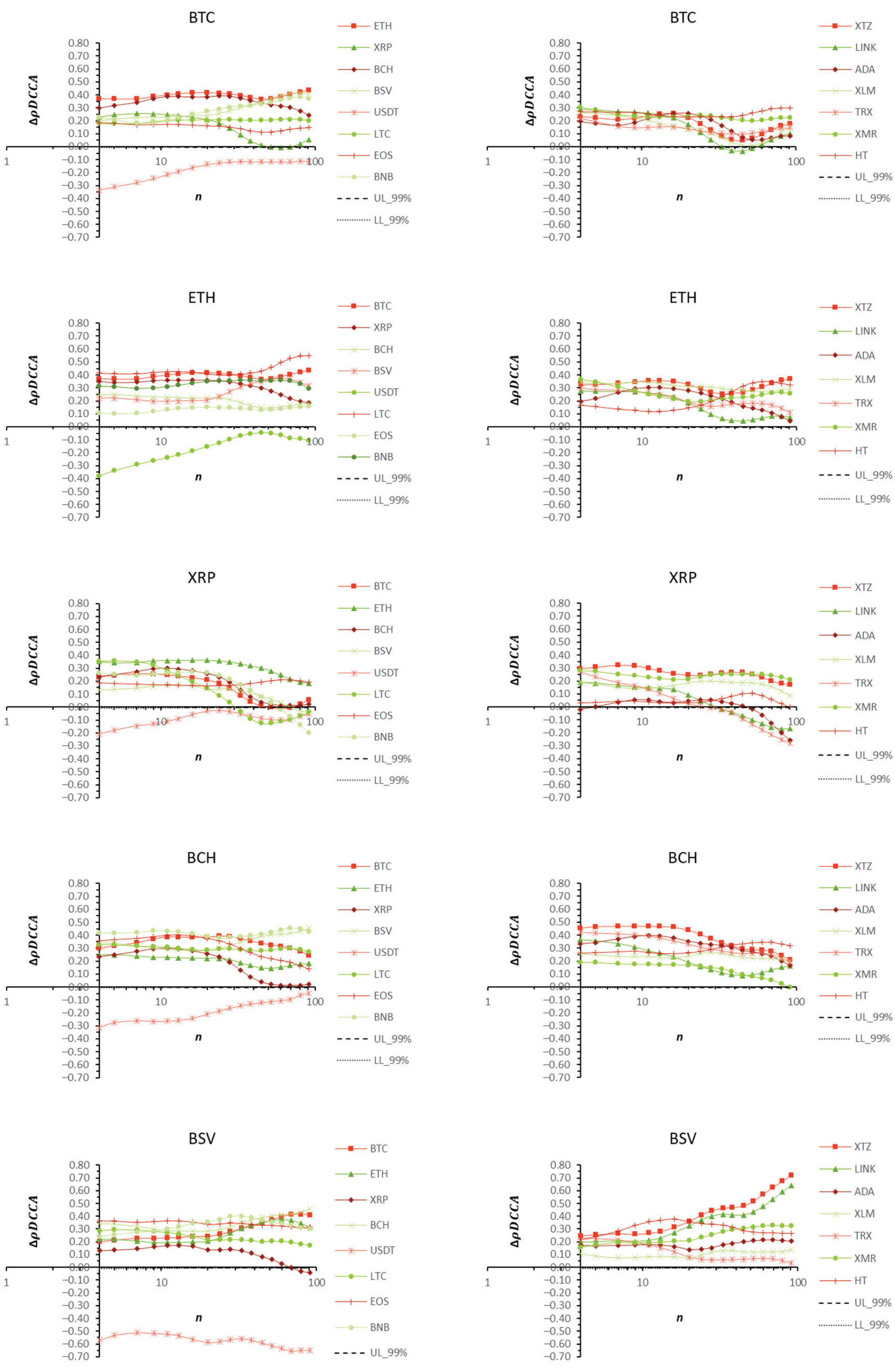

Figure 1. *Cont.*

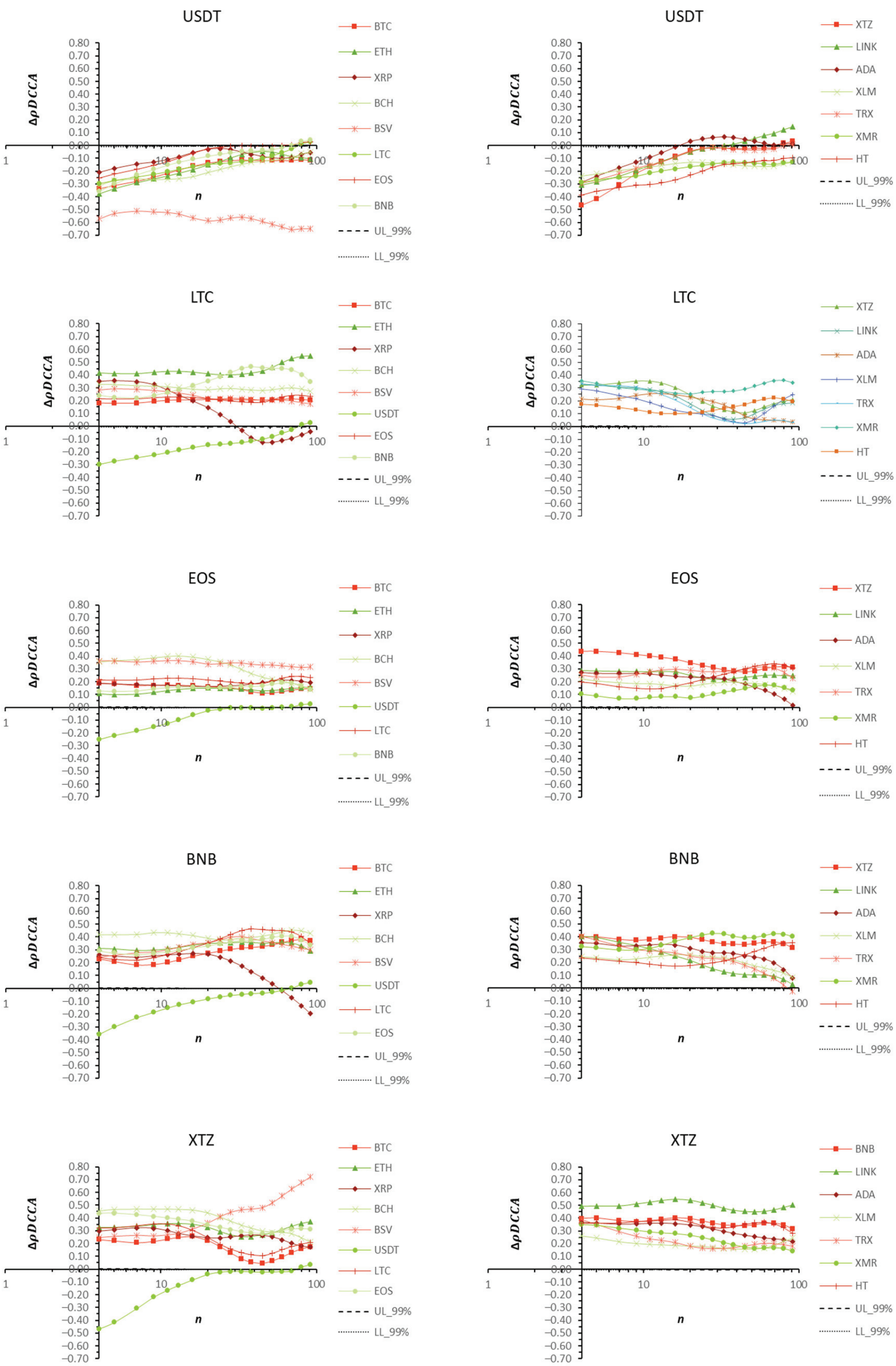

Figure 1. *Cont.*

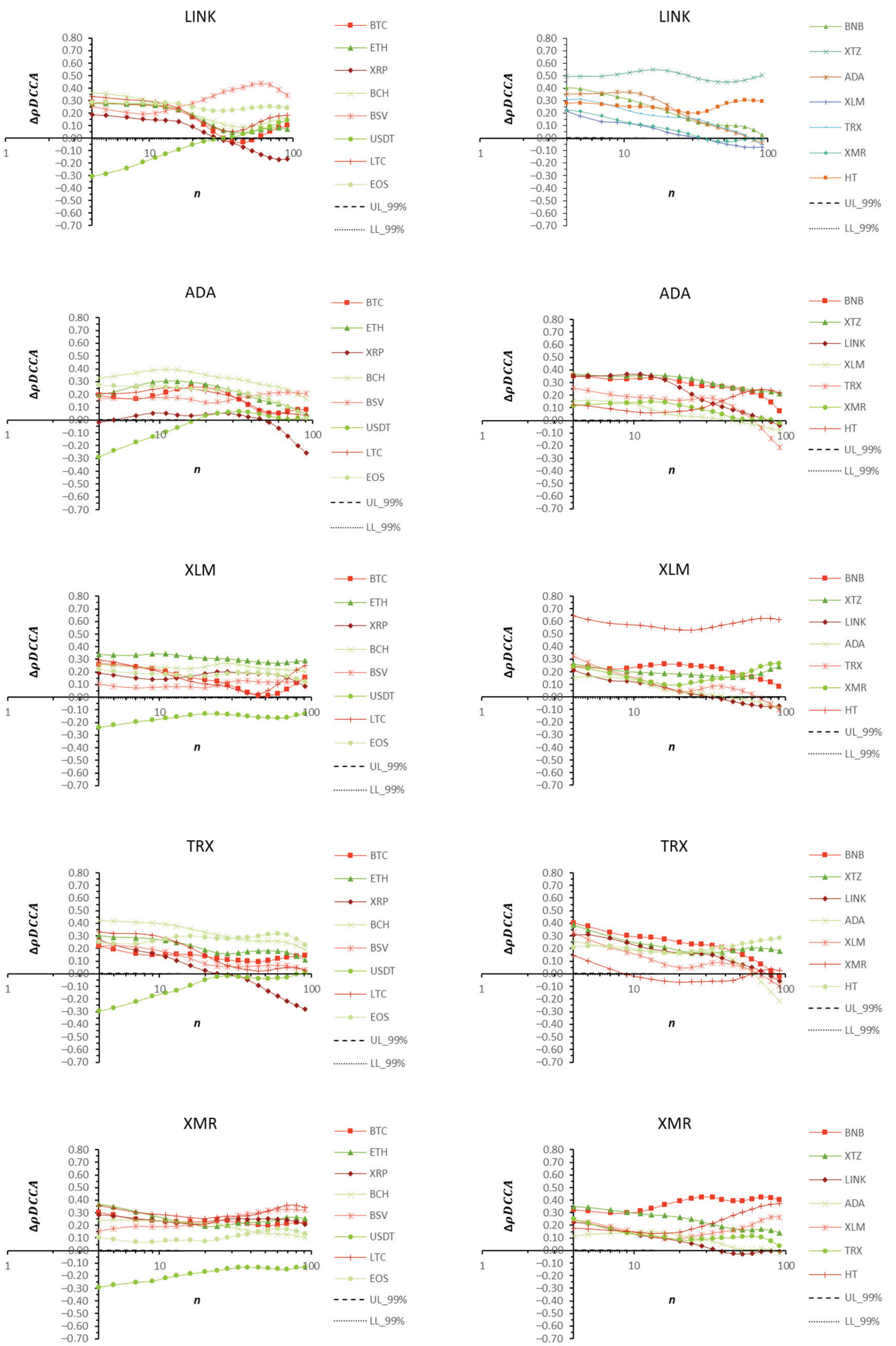

Figure 1. *Cont.*

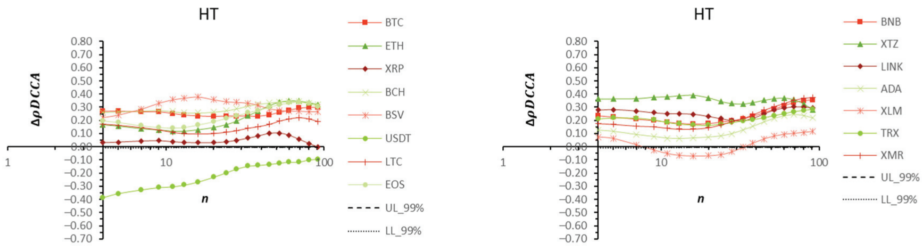

Figure 1. $\Delta\rho$DCCA for each cryptocurrency in the title of each graph with the remaining cryptocurrency markets as a function of n (days). Note: UL and LL are the upper and lower critical values, respectively, and are used to assess the statistical significance of $\Delta\rho\text{DCCA}(n)$. If the estimated values are outside/inside both critical values, the variation in correlation is statistically significant/not significant, respectively. A statistically significant and positive variation in correlation may be interpreted as evidence of contagion and of increased market integration.

During the pandemic period, there was a statistically significant increase in the correlation coefficients (as can be seen by a $\Delta\rho\text{DCCA}(n) > 0$) for most of the analyzed cryptocurrencies (the only exception was USDT); this contrasts, for example, with [20,95]. The statistically significant increase in the correlation coefficients between the majority of cryptocurrencies may indicate that the respective markets are integrated (contradicting, for example, [20]), and thus, that there was an increase in systemic risk. Stronger integration was found between the XTZ market and the remaining cryptocurrency markets, as well as between BSV and the other markets (as can be seen by the higher values of the $\Delta\rho\text{DCCA}(n)$).

In accordance with [10], for short timescales, the null hypothesis of $\Delta\rho\text{DCCA}(n) = 0$ was rejected in all cases and $\Delta\rho\text{DCCA}(n) > 0$ (except for USDT), thus suggesting that there is evidence of contagion (corroborating the findings in [47]) and highlighting the contribution of this study. Thus, the crisis caused by the COVID-19 pandemic seems to have affected cryptocurrency markets, increasing integration (in accordance with [33,60,69], among others) and suggesting that movements in one cryptocurrency reflect movements in other cryptocurrencies.

For long timescales, although there continues to be evidence of a statistically significant absence of contagion between most cryptocurrencies and USDT (given $\Delta\rho\text{DCCA}(n) < 0$ and statistically significant) there is statistically significant evidence of contagion between LTC, EOS, BNB, XTZ, LINK, ADA, TRX, and the USDT. Despite rejecting the null hypothesis for most cryptocurrencies, some contradictory evidence exists (with $\Delta\rho\text{DCCA}(n) < 0$). For instance, there is a statistically significant absence of contagion between: i. XRP and LTC, BNB, BSV, TRX, LINK and ADA; ii. BNB and TRX; iii. LINK and the XLM, XMR, TRX, and ADA; iv. ADA and XLM, XMR and TRX; v. XLM and TRX; and vi. HT and XLM. These results contrast with those of [47].

The assessed cryptocurrencies thus appear to have mostly suffered short-term effects caused by the COVID-19 pandemic, possibly due to investor panic and as a reflex due to a lack of connection with the real economy (see [34]). The distinct behavioral patterns of both short and long timescales suggest that investors need to constantly update their positions (short vs. long) and consider the distinct preferences for different time horizons when building investment portfolios.

ETH, LTC, XTZ, and HT markets display the highest levels of integration with the other cryptocurrency markets in our sample.

5. Conclusions

Extraordinary events, regardless of their financial or non-financial nature, usually challenge the stability and alter the structure of financial markets. In this study, we assessed the impacts of a real shock—the COVID-19 pandemic—on cryptocurrency markets. We used the DCCA approach to examine how relationships within a set of 16 cryptocurrencies were affected by this pandemic. More specifically, market integration and contagions were evaluated by comparing the cross-correlation coefficients (ρDCCA) between all possible pairs of cryptocurrencies in our sample, before and after the onset of the COVID-19 crisis.

This analysis produced a multi-timescale perspective of the links established between the analyzed cryptocurrencies. We found out that correlation levels generally increased from the pre-crisis period to the crisis period, thus suggesting that there was a contagion during the pandemic that affected the cryptocurrency markets across both short and long timescales. This means that investors changed their behavior at the onset of the COVID-19 pandemic, leading to greater connectedness in the cryptocurrency markets (this does not corroborate the results of other studies, for example, [3]). Exceptions to this general conclusion are USDT (across short timescales) and XRP and USDT (across long timescales). This result hints that these cryptocurrencies could have safe-haven properties in periods of turmoil in the cryptocurrency markets.

Considering that a positive variation in ρDCCA indicates that there was an increase in market integration, the analysis also shows, in accordance with [20,33,60,69], that cryptocurrency markets became more integrated after the onset of the pandemic. This means that, as a whole, they became more exposed to the effects of shocks, thus providing yet another example of the so-called correlations breakdown (i.e., that diversification becomes more difficult, precisely when it is more necessary). This evidence leads us to conclude that the analyzed cryptocurrency markets are neither immune to non-financial shocks affecting the global economy, nor independent from the global financial system.

Our results contribute to improving knowledge concerning the behavior of cryptocurrencies in times of stress, in this case, during the emergence of a pandemic. They are thus of use for investors, helping them to make more informed investment decisions that consider the time-varying nature of the structure of dependence between cryptocurrencies. The evidence for different levels of integration between cryptocurrencies across different timescales and periods has practical implications for investors during their decision-making processes, regarding portfolio diversification, risk management, and trading and hedging strategies.

The study is also useful for academics who are interested in how non-financial shocks impact financial integration, and how they provoke contagion in financial markets. Furthermore, this study may also assist policy makers and regulators who are in charge of anticipating potential triggers of cryptocurrency market instability, or who are attempting to reduce these markets' vulnerabilities and minimize the spread of risk and uncertainty across them. Our results point out a high risk of contagion during times of stress. Thus, policy makers involved in regulating the cryptocurrency markets should consider this empirical evidence when defining future policy measures. Furthermore, as cryptocurrency markets are interconnected and are also linked with other markets (e.g., [30]), this study highlights that regulatory oversight and monitoring are needed to prevent, for example, financial instability and systemic risk.

Overall, the study provides valuable information about the interconnectedness of cryptocurrencies and the role that real crises play in shaping such links, and thus, it should be considered by all agents interested in investing, studying, or regulating these markets.

In the last decade, as cryptocurrency markets have grown and gained relevance, regulators and environmentalists have intensified debates on the massive power consumption of the mining process and its adverse impact on ecosystems and climate change. Several studies found an increasing degree of interconnectedness between cryptocurrencies and other financial assets and also within cryptocurrencies. Our results corroborate the results of some previous studies that focus upon the interconnectedness between cryptocurrency markets. Considering this integration, and the Environmental, Social, and Governance (ESG) sustainability concerns that emerged from the Paris Agreement of 2015, cryptocurrency markets can play an important role in achieving ESG goals by promoting sustainable investments and via the integration of sustainable practices into their operating models.

As this is an innovative research area, where few studies have analyzed the ESG perspective, with regard to cryptocurrencies (see, for instance [96–98]), there is an urgent need to study cryptocurrency investments from the perspective of ESG investments. We intend to develop such a study as part of our future research (using, for example, the recently created cryptocurrency environmental attention (ICEA) index in [99]) in order to help the environmentally concerned investors who are willing to include crypto assets in their portfolio while contributing to the achievement of the ESG goals.

The different number of observations for each time series before 31 December 2019 could be a limitation of our study.

Author Contributions: Conceptualization, A.D., D.A., I.V. and P.F.; Data curation, A.D. and D.A.; Formal Analysis, A.D. and D.A.; Investigation, D.A.; Methodology, A.D., D.A., I.V. and P.F.; Project Administration, A.D. and D.A.; Resources, D.A.; Software, A.D., D.A. and P.F.; Supervision, A.D., I.V. and P.F.; Validation, A.D., D.A., I.V. and P.F.; Visualization, A.D., D.A., I.V. and P.F.; Writing—original draft, A.D., D.A., I.V. and P.F.; Writing—review and editing, A.D., D.A., I.V. and P.F. All authors have read and agreed to the published version of the manuscript.

Funding: Andreia Dionísio, Dora Almeida, Isabel Vieira, and Paulo Ferreira are pleased to acknowledge financial support from Fundação para a Ciência e a Tecnologia (grant UIDB/04007/2020). Dora Almeida and Paulo Ferreira also acknowledges the financial support of Fundação para a Ciência e a Tecnologia (grant UIDB/05064/2020).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Kumar, A.; Iqbal, N.; Mitra, S.K.; Kristoufek, L.; Bouri, E. Connectedness among major cryptocurrencies in standard times and during the COVID-19 outbreak. *J. Int. Financ. Mark. Inst. Money* **2022**, *77*, 101523. [CrossRef]
2. Leirvik, T. Cryptocurrency returns and the volatility of liquidity. *Financ. Res. Lett.* **2021**, *44*, 102031. [CrossRef]
3. Giannellis, N. Cryptocurrency market connectedness in COVID-19 days and the role of Twitter: Evidence from a smooth transition regression model. *Res. Int. Bus. Financ.* **2022**, *63*, 101801. [CrossRef]
4. Gajardo, G.; Kristjanpoller, W.D.; Minutolo, M. Does Bitcoin exhibit the same asymmetric multifractal cross-correlations with crude oil, gold and DJIA as the Euro, Great British Pound and Yen? *Chaos Solitons Fractals* **2018**, *109*, 195–205. [CrossRef]
5. Bouri, E.; Shahzad, S.J.H.; Roubaud, D.; Kristoufek, L.; Lucey, B. Bitcoin, gold, and commodities as safe havens for stocks: New insight through wavelet analysis. *Q. Rev. Econ. Financ.* **2020**, *77*, 156–164. [CrossRef]
6. Neto, D. Are Google searches making the Bitcoin market run amok? A tail event analysis. *N. Am. J. Econ. Financ.* **2021**, *57*, 101454. [CrossRef]
7. Mensi, W.; Al-Yahyaee, K.H.; Al-Jarrah, I.M.W.; Vo, X.V.; Kang, S.H. Does volatility connectedness across major cryptocurrencies behave the same at different frequencies? A portfolio risk analysis. *Int. Rev. Econ. Financ.* **2021**, *76*, 96–113. [CrossRef]
8. Vidal-Tomás, D.; Ibáñez, A.M.; Farinós, J.E. Herding in the cryptocurrency market: CSSD and CSAD approaches. *Financ. Res. Lett.* **2019**, *30*, 181–186. [CrossRef]
9. Bouri, E.; Shahzad, S.J.H.; Roubaud, D. Co-explosivity in the cryptocurrency market. *Financ. Res. Lett.* **2019**, *29*, 178–183. [CrossRef]
10. Ferreira, P.; Pereira, É. Contagion Effect in Cryptocurrency Market. *J. Risk Financ. Manag.* **2019**, *12*, 115. [CrossRef]
11. Le, T.H.; Do, H.X.; Nguyen, D.K.; Sensoy, A. COVID-19 pandemic and tail-dependency networks of financial assets. *Financ. Res. Lett.* **2021**, *38*, 101800. [CrossRef]
12. Kristoufek, L. Tethered, or Untethered? On the interplay between stablecoins and major cryptoassets. *Financ. Res. Lett.* **2021**, *43*, 101991. [CrossRef]
13. Park, S.; Jang, K.; Yang, J.-S. Information flow between bitcoin and other investment assets. *Phys. Stat. Mech. Appl.* **2021**, *566*, 1116. [CrossRef]
14. Mensi, W.; Rehman, M.U.; Maitra, D.; Al-Yahyaee, K.H.; Sensoy, A. Does bitcoin co-move and share risk with Sukuk and world and regional Islamic stock markets? Evidence using a time-frequency approach. *Res. Int. Bus. Financ.* **2020**, *53*, 101230. [CrossRef]
15. Huynh, T.L.D.; Shahbaz, M.; Nasir, M.A.; Ullah, S. Financial modelling, risk management of energy instruments and the role of cryptocurrencies. *Ann. Oper. Res.* **2020**, *313*, 47–75. [CrossRef]

16. Calvo, G.A.; Mendoza, E.G. Rational contagion and the globalization of securities markets. *J. Int. Econ.* **2000**, *51*, 79–113. [CrossRef]
17. Lee, K.-J.; Lu, S.-L.; Shih, Y. Contagion Effect of Natural Disaster and Financial Crisis Events on International Stock Markets. *J. Risk Financ. Manag.* **2018**, *11*, 16. [CrossRef]
18. Nguyen, D.T.; Phan, D.H.B.; Ming, T.C.; Nguyen, V.K.L. An assessment of how COVID-19 changed the global equity market. *Econ. Anal. Policy* **2021**, *69*, 480–491. [CrossRef]
19. Aslam, F.; Aziz, S.; Nguyen, D.K.; Mughal, K.S.; Khan, M. On the efficiency of foreign exchange markets in times of the COVID-19 pandemic. *Technol. Forecast. Soc. Chang.* **2020**, *161*, 120261. [CrossRef]
20. Mensi, W.; El Khoury, R.; Ali, S.R.M.; Vo, X.V.; Kang, S.H. Quantile dependencies and connectedness between the gold and cryptocurrency markets: Effects of the COVID-19 crisis. *Res. Int. Bus. Financ.* **2023**, *65*, 101929. [CrossRef]
21. Shahzad, S.J.H.; Bouri, E.; Kang, S.H.; Saeed, T. Regime specific spillover across cryptocurrencies and the role of COVID-19. *Financ. Innov.* **2021**, *7*, 5. [CrossRef] [PubMed]
22. Ullah, S. Impact of COVID-19 Pandemic on Financial Markets: A Global Perspective. *J. Knowl. Econ.* **2022**, *13*, 0123456789. [CrossRef]
23. Khan, A.; Khan, N.; Shafiq, M. The Economic Impact of COVID-19 from a Global Perspective. *Contemp. Econ.* **2021**, *15*, 64–75. [CrossRef]
24. Pak, A.; Adegboye, O.A.; Adekunle, A.I.; Rahman, K.M.; McBryde, E.S.; Eisen, D.P. Economic Consequences of the COVID-19 Outbreak: The Need for Epidemic Preparedness. *Front. Public Health* **2020**, *8*, 241. [CrossRef] [PubMed]
25. Seth, N.; Panda, L. Financial contagion: Review of empirical literature. *Qual. Res. Financ. Mark.* **2018**, *10*, 15–70. [CrossRef]
26. Forbes, K.J.; Rigobon, R. No Contagion, Only Interdependence: Measuring Stock Market Comovements. *J. Financ.* **2002**, *57*, 2223–2261. [CrossRef]
27. Bae, K.-H.; Karolyi, G.A.; Stulz, R. A New Approach to Measuring Financial Contagion. *Rev. Financ. Stud.* **2003**, *16*, 717–763. [CrossRef]
28. Davidson, S.N. Interdependence or contagion: A model switching approach with a focus on Latin America. *Econ. Model.* **2020**, *85*, 166–197. [CrossRef]
29. Yousaf, I.; Ali, S. The COVID-19 outbreak and high frequency information transmission between major cryptocurrencies: Evidence from the VAR-DCC-GARCH approach. *Borsa Istanb. Rev.* **2020**, *20*, S1–S10. [CrossRef]
30. Corbet, S.; Larkin, C.; Lucey, B. The contagion effects of the COVID-19 pandemic: Evidence from gold and cryptocurrencies. *Financ. Res. Lett.* **2020**, *35*, 101554. [CrossRef]
31. Akhtaruzzaman; Boubaker, S.; Nguyen, D.K.; Rahman, M.R. Systemic risk-sharing framework of cryptocurrencies in the COVID–19 crisis. *Financ. Res. Lett.* **2022**, *47*, 102787. [CrossRef] [PubMed]
32. James, N.; Menzies, M.; Chan, J. Changes to the extreme and erratic behaviour of cryptocurrencies during COVID-19. *Phys. A Stat. Mech. Appl.* **2021**, *565*, 125581. [CrossRef] [PubMed]
33. Assaf, A.; Charif, H.; Demir, E. Information sharing among cryptocurrencies: Evidence from mutual information and approximate entropy during COVID-19. *Financ. Res. Lett.* **2022**, *47*, 102556. [CrossRef]
34. Caferra, R.; Vidal-Tomás, D. Who raised from the abyss? A comparison between cryptocurrency and stock market dynamics during the COVID-19 pandemic. *Financ. Res. Lett.* **2021**, *43*, 101954. [CrossRef] [PubMed]
35. Conlon, T.; Corbet, S.; McGee, R.J. Are cryptocurrencies a safe haven for equity markets? An international perspective from the COVID-19 pandemic. *Res. Int. Bus. Financ.* **2020**, *54*, 101248. [CrossRef] [PubMed]
36. Bouri, E.; Tiwari, A.K.; Roubaud, D. Does Bitcoin hedge global uncertainty? Evidence from wavelet-based quantile-in-quantile regressions. *Financ. Res. Lett.* **2017**, *23*, 87–95. [CrossRef]
37. Goodell, J.W.; Goutte, S. Co-movement of COVID-19 and Bitcoin: Evidence from wavelet coherence analysis. *Financ. Res. Lett.* **2021**, *38*, 101625. [CrossRef]
38. Yarovaya, L.; Matkovskyy, R.; Jalan, A. The effects of a 'black swan' event (COVID-19) on herding behavior in cryptocurrency markets. *J. Int. Financ. Mark. Inst. Money* **2021**, *75*, 101321. [CrossRef]
39. da Silva, M.F.; Pereira, J.D.A.L.; Filho, A.M.D.S.; de Castro, A.P.N.; Miranda, J.G.V.; Zebende, G.F. Quantifying cross-correlation between Ibovespa and Brazilian blue-chips: The DCCA approach. *Phys. A Stat. Mech. Appl.* **2015**, *424*, 124–129. [CrossRef]
40. Ma, P.; Li, D.; Li, S. Efficiency and cross-correlation in equity market during global financial crisis: Evidence from China. *Phys. A Stat. Mech. Appl.* **2016**, *444*, 163–176. [CrossRef]
41. Mohti, W.; Dionísio, A.; Vieira, I.; Ferreira, P. Financial contagion analysis in frontier markets: Evidence from the US subprime and the Eurozone debt crises. *Phys. A Stat. Mech. Appl.* **2019**, *525*, 1388–1398. [CrossRef]
42. Zhang, Y.; Hamori, S. Do news sentiment and the economic uncertainty caused by public health events impact macroeconomic indicators? Evidence from a TVP-VAR decomposition approach. *Q. Rev. Econ. Financ.* **2021**, *82*, 145–162. [CrossRef]
43. Cho, S.; Hyde, S.; Nguyen, N. Time-varying regional and global integration and contagion: Evidence from style portfolios. *Int. Rev. Financ. Anal.* **2015**, *42*, 109–131. [CrossRef]
44. Ferreira, P. Portuguese and Brazilian stock market integration: A non-linear and detrended approach. *Port. Econ. J.* **2017**, *16*, 49–63. [CrossRef]
45. Tiwari, A.K.; Adewuyi, A.O.; Albulescu, C.T.; Wohar, M.E. Empirical evidence of extreme dependence and contagion risk between main cryptocurrencies. *N. Am. J. Econ. Financ.* **2019**, *51*, 101083. [CrossRef]

46. Mensi, W.; Rehman, M.U.; Al-Yahyaee, K.H.; Al-Jarrah, I.M.W.; Kang, S.H. Time frequency analysis of the commonalities between Bitcoin and major Cryptocurrencies: Portfolio risk management implications. *N. Am. J. Econ. Financ.* **2019**, *48*, 283–294. [CrossRef]
47. Qureshi, S.; Aftab, M.; Bouri, E.; Saeed, T. Dynamic interdependence of cryptocurrency markets: An analysis across time and frequency. *Phys. A Stat. Mech. Its Appl.* **2020**, *559*, 125077. [CrossRef]
48. Koutmos, D. Return and volatility spillovers among cryptocurrencies. *Econ. Lett.* **2018**, *173*, 122–127. [CrossRef]
49. Yi, S.; Xu, Z.; Wang, G.-J. Volatility connectedness in the cryptocurrency market: Is Bitcoin a dominant cryptocurrency? *Int. Rev. Financ. Anal.* **2018**, *60*, 98–114. [CrossRef]
50. Ji, Q.; Bouri, E.; Lau, C.K.M.; Roubaud, D. Dynamic connectedness and integration in cryptocurrency markets. *Int. Rev. Financ. Anal.* **2019**, *63*, 257–272. [CrossRef]
51. Sensoy, A.; Silva, T.C.; Corbet, S.; Tabak, B.M. High-frequency return and volatility spillovers among cryptocurrencies. *Appl. Econ.* **2021**, *53*, 4310–4328. [CrossRef]
52. Kakinaka, S.; Umeno, K. Asymmetric volatility dynamics in cryptocurrency markets on multi-time scales. *Res. Int. Bus. Financ.* **2022**, *62*, 101754. [CrossRef]
53. Canh, N.P.; Wongchoti, U.; Thanh, S.D.; Thong, N.T. Systematic risk in cryptocurrency market: Evidence from DCC-MGARCH model. *Financ. Res. Lett.* **2019**, *29*, 90–100. [CrossRef]
54. Huynh, T.L.D.; Nasir, M.A.; Vo, X.V.; Nguyen, T.T. "Small things matter most": The spillover effects in the cryptocurrency market and gold as a silver bullet. *N. Am. J. Econ. Financ.* **2020**, *54*, 101277. [CrossRef]
55. Guo, H.; Zhao, X.; Yu, H.; Zhang, X. Analysis of global stock markets' connections with emphasis on the impact of COVID-19. *Phys. A Stat. Mech. Appl.* **2021**, *569*, 125774. [CrossRef]
56. Szczygielski, J.J.; Brzeszczyński, J.; Charteris, A.; Bwanya, P.R. The COVID-19 storm and the energy sector: The impact and role of uncertainty. *Energy Econ.* **2021**, *109*, 105258. [CrossRef] [PubMed]
57. Li, Z.; Wang, Y.; Huang, Z. Risk Connectedness Heterogeneity in the Cryptocurrency Markets. *Front. Phys.* **2020**, *8*, 243. [CrossRef]
58. McKibbin, W.; Fernando, R. The Global Macroeconomic Impacts of COVID-19: Seven Scenarios Warwick. *Asian Econ. Pap.* **2021**, *20*, 1–21. [CrossRef]
59. Naeem, M.A.; Bouri, E.; Peng, Z.; Shahzad, S.J.H.; Vo, X.V. Asymmetric efficiency of cryptocurrencies during COVID19. *Phys. A Stat. Mech. Appl.* **2021**, *565*, 125562. [CrossRef]
60. Katsiampa, P.; Yarovaya, L.; Zięba, D. High-frequency connectedness between Bitcoin and other top-traded crypto assets during the COVID-19 crisis. *J. Int. Financ. Mark. Inst. Money* **2022**, *79*, 101578. [CrossRef]
61. Sui, X.; Shi, G.; Hou, G.; Huang, S.; Li, Y. Impacts of COVID-19 on the Return and Volatility Nexus among Cryptocurrency Market. *Complexity* **2022**, *2022*, 5346080. [CrossRef]
62. Balcilar, M.; Ozdemir, H.; Agan, B. Effects of COVID-19 on cryptocurrency and emerging market connectedness: Empirical evidence from quantile, frequency, and lasso networks. *Phys. A Stat. Mech. Appl.* **2022**, *604*, 127885. [CrossRef]
63. Nguyen, A.P.N.; Mai, T.T.; Bezbradica, M.; Crane, M. The Cryptocurrency Market in Transition before and after COVID-19: An Opportunity for Investors? *Entropy* **2022**, *24*, 1317. [CrossRef] [PubMed]
64. Yarovaya, L.; Zięba, D. Intraday volume-return nexus in cryptocurrency markets: Novel evidence from cryptocurrency classification. *Res. Int. Bus. Financ.* **2022**, *60*, 101592. [CrossRef]
65. Rubbaniy, G.; Khalid, A.A.; Samitas, A. Are Cryptos Safe-Haven Assets during COVID-19? Evidence from Wavelet Coherence Analysis. *Emerg. Mark. Financ. Trade* **2021**, *57*, 1741–1756. [CrossRef]
66. García-Medina, A.; Hernández, J.B.C. Network analysis of multivariate transfer entropy of cryptocurrencies in times of turbulence. *Entropy* **2020**, *22*, 760. [CrossRef]
67. Maghyereh, A.; Abdoh, H. COVID-19 and the volatility interlinkage between bitcoin and financial assets. *Empir. Econ.* **2022**, *63*, 2875–2901. [CrossRef]
68. SDrozdz; Kwapień, J.; Oświecimka, P.; Stanisz, T.; Watorek, M. Complexity in economic and social systems: Cryptocurrency market at around COVID-19. *Entropy* **2020**, *22*, 1043. [CrossRef]
69. Kwapień, J.; Wątorek, M.; Drożdż, S. Cryptocurrency market consolidation in 2020–2021. *Entropy* **2021**, *23*, 1674. [CrossRef]
70. Raza, S.A.; Shah, N.; Guesmi, K.; Msolli, B. How does COVID-19 influence dynamic spillover connectedness between cryptocurrencies? Evidence from non-parametric causality-in-quantiles techniques. *Financ. Res. Lett.* **2021**, *47*, 102569. [CrossRef]
71. Naeem, M.A.; Qureshi, S.; Rehman, M.U.; Balli, F. COVID-19 and cryptocurrency market: Evidence from quantile connectedness. *Appl. Econ.* **2022**, *54*, 280–306. [CrossRef]
72. Yousaf, I.; Ali, S. Discovering interlinkages between major cryptocurrencies using high-frequency data: New evidence from COVID-19 pandemic. *Financ. Innov.* **2020**, *6*, 45. [CrossRef] [PubMed]
73. Özdemir, O. Cue the volatility spillover in the cryptocurrency markets during the COVID-19 pandemic: Evidence from DCC-GARCH and wavelet analysis. *Financ. Innov.* **2022**, *8*, 12. [CrossRef] [PubMed]
74. Bariviera, A.F.; Merediz-Solà, I. Where do we stand in cryptocurrencies economic research? A survey based on hybrid analysis. *J. Econ. Surv.* **2021**, *35*, 377–407. [CrossRef]
75. Wątorek, M.; Kwapień, J.; Drożdż, S. Multifractal Cross-Correlations of Bitcoin and Ether Trading Characteristics in the Post-COVID-19 Time. *Futur. Internet* **2022**, *14*, 215. [CrossRef]
76. Bouri, E.; Gupta, R.; Roubaud, D. Herding behaviour in cryptocurrencies. *Financ. Res. Lett.* **2018**, *29*, 216–221. [CrossRef]

77. Dimpfl, T.; Peter, F.J. Group transfer entropy with an application to cryptocurrencies. *Phys. A Stat. Mech. Appl.* **2019**, *516*, 543–551. [CrossRef]
78. Wang, G.-J.; Xie, C.; Chen, S.; Yang, J.-J.; Yang, M.-Y. Random matrix theory analysis of cross-correlations in the US stock market: Evidence from Pearson's correlation coefficient and detrended cross-correlation coefficient. *Phys. A Stat. Mech. Appl.* **2013**, *392*, 3715–3730. [CrossRef]
79. Vidal-Tomás, D. Which cryptocurrency data sources should scholars use? *Int. Rev. Financ. Anal.* **2022**, *81*, 102061. [CrossRef]
80. Pericoli, M.; Sbracia, M. A Primer on Financial Contagion. *J. Econ. Surv.* **2003**, *17*, 571–608. [CrossRef]
81. Pal, D.; Mitra, S.K. Interdependence between crude oil and world food prices: A detrended cross correlation analysis. *Phys. A Stat. Mech. Appl.* **2018**, *492*, 1032–1044. [CrossRef]
82. Costa, N.; Silva, C.; Ferreira, P. Long-Range Behaviour and Correlation in DFA and DCCA Analysis of Cryptocurrencies. *Int. J. Financ. Stud.* **2019**, *7*, 51. [CrossRef]
83. Ferreira, P.; Dionisio, A. Revisiting Covered Interest Parity in the European Union: The DCCA Approach. *Int. Econ. J.* **2015**, *29*, 597–615. [CrossRef]
84. Guedes, E.; Dionísio, A.; Ferreira, P.J.; Zebende, G.F. DCCA cross-correlation in blue-chips companies: A view of the 2008 financial crisis in the Eurozone. *Phys. A Stat. Mech. Appl.* **2017**, *479*, 38–47. [CrossRef]
85. Podobnik, B.; Stanley, H.E. Detrended Cross-Correlation Analysis: A New Method for Analyzing Two Nonstationary Time Series. *Phys. Rev. Lett.* **2008**, *100*, 084102. [CrossRef]
86. Peng, C.-K.; Buldyrev, S.V.; Havlin, S.; Simons, M.; Stanley, H.E.; Goldberger, A.L. Mosaic organization of DNA nucleotides. *Phys. Rev. E* **1994**, *49*, 1685–1689. [CrossRef]
87. Zebende, G. DCCA cross-correlation coefficient: Quantifying level of cross-correlation. *Phys. A Stat. Mech. Appl.* **2011**, *390*, 614–618. [CrossRef]
88. Zebende, G.; Filho, A.M. Cross-correlation between time series of vehicles and passengers. *Phys. A Stat. Mech. Appl.* **2009**, *388*, 4863–4866. [CrossRef]
89. Guedes, E.F.; Brito, A.A.; Oliveira Filho, F.M.; Fernandez, B.F.; de Castro AP, N.; da Silva Filho, A.M.; Zebende, G.F. Statistical test for ΔρDCCA cross-correlation coefficient. *Phys. A Stat. Mech. Appl.* **2018**, *501*, 134–140. [CrossRef]
90. Kristoufek, L. Measuring correlations between non-stationary series with DCCA coefficient. *Phys. A Stat. Mech. Appl.* **2014**, *402*, 291–298. [CrossRef]
91. Zhao, X.; Shang, P.; Huang, J. Several Fundamental Properties of DCCA Cross-Correlation Coefficient. *Fractals* **2017**, *25*, 1750017. [CrossRef]
92. Podobnik, B.; Jiang, Z.-Q.; Zhou, W.-X.; Stanley, H.E. Statistical tests for power-law cross-correlated processes. *Phys. Rev. E* **2011**, *84*, 066118. [CrossRef] [PubMed]
93. da Silva, M.F.; Pereira, J.D.A.L.; Filho, A.M.D.S.; de Castro, A.P.N.; Miranda, J.G.V.; Zebende, G.F. Quantifying the contagion effect of the 2008 financial crisis between the G7 countries (by GDP nominal). *Phys. A Stat. Mech. Appl.* **2016**, *453*, 1–8. [CrossRef]
94. Guedes, E.F.; Brito, A.A.; Oliveira Filho, F.M.; Fernandez, B.F.; de Castro AP, N.; da Silva Filho, A.M.; Zebende, G.F. Statistical test for ΔρDCCA: Methods and data. *Data Brief* **2018**, *18*, 795–798. [CrossRef] [PubMed]
95. Almeida, D.; Dionísio, A.; Vieira, I.; Ferreira, P. COVID-19 Effects on the Relationship between Cryptocurrencies: Can It Be Contagion? Insights from Econophysics Approaches. *Entropy* **2023**, *25*, 98. [CrossRef]
96. Yamey, G.; Schäferhoff, M.; Aars, O.K.; Bloom, B.; Carroll, D.; Chawla, M.; Dzau, V.; Echalar, R.; Gill, I.S.; Godal, T.; et al. Financing of international collective action for epidemic and pandemic preparedness. *Lancet Glob. Heal.* **2017**, *5*, e742–e744. [CrossRef]
97. Smith, S.S. ESG & Other Emerging Technology Applications. In *Blockchain Artificial Intelligence and Financial Services*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 175–191.
98. Laboure, M.; Müller, M.H.; Heinz, G.; Singh, S.; Köhling, S. Cryptocurrencies and CBDC: The Route Ahead. *Glob. Policy* **2021**, *12*, 663–676. [CrossRef]
99. Wang, Y.; Lucey, B.; Vigne, S.A.; Yarovaya, L. An index of cryptocurrency environmental attention (ICEA). *China Financ. Rev. Int.* **2022**, *12*, 378–414. [CrossRef]

FinTech

Article

Unlocking the Potential of Blockchain Technology in the Textile and Fashion Industry

Sunhilde Cuc

Department of Textiles, Leather and Industrial Management, University of Oradea, 1 Universitatii Street, 410087 Oradea, Romania; sunhilde_cuc@yahoo.com

Abstract: The textile and fashion industry is on the brink of a major disruption, and blockchain technology (BT) presents a promising solution that could transform the industry by facilitating supply chain transparency, traceability, and sustainability. This article explores the potential of BT in the textile and fashion industry, with a focus on its current applications and potential impact. Using case studies and analyzing all announced blockchain projects from January 2017 to January 2023, we examine the diversity of blockchain applications across different aspects of the textile and fashion industry, including smart contracts and payment processing, supply chain tracking, sustainability applications, and customer engagement. The findings suggest an increasing number of companies are adopting BT, and that BT has the potential to revolutionize the T and F industry by creating a more transparent and efficient supply chain, reducing fraud and counterfeiting, and increasing customer confidence in products. We also identified the challenges and difficulties that may arise during the implementation of BT. This article contributes to the literature on BT in the textile and fashion industry, providing critical insights into its potential impact.

Keywords: blockchain technology (BT); textile and fashion industry; smart contracts; supply chain traceability; sustainability

Citation: Cuc, S. Unlocking the Potential of Blockchain Technology in the Textile and Fashion Industry. *FinTech* **2023**, *2*, 311–326. https://doi.org/10.3390/fintech2020018

Academic Editor: David Roubaud

Received: 18 April 2023
Revised: 17 May 2023
Accepted: 18 May 2023
Published: 24 May 2023

1. Introduction

The textile and fashion industry has experienced significant growth in recent years, with its global sales reaching a total of 2.14 trillion USD in 2022. Of this amount, 1.53 trillion USD can be attributed to apparel sales [1], while the remaining 610.91 billion USD can be attributed to textile sales worldwide [2]. The term "textile and fashion industry" is employed in the present paper to refer to the broader economic sector encompassing both textile and apparel manufacturing, as well as the fashion design and retail sectors. This terminology recognizes the interconnectedness and interdependence of these various industries and their profound impact on the global economy and society. By utilizing this broader terminology, we seek to more accurately assess the potential applications of blockchain technology within this multifaceted industry. Specifically, we aim to elucidate the ways in which blockchain's distributed ledger system could be leveraged to enhance the efficiency, security, and transparency of various operations within the textile and fashion industry. As the industry continues to expand, it is increasingly important to ensure the sustainability, transparency, and traceability of the supply chain. The rapidly evolving digital economy has placed the traditional textile and fashion industry at the forefront of global dynamic change, creating a landscape characterized by volatility, velocity, variety, complexity, and dynamism [3]. As a result, there is a growing need for digital solutions to address these challenges [4,5]. Blockchain technology has been identified as a potential solution to these challenges because it can provide a secure and immutable record of transactions and data [5–7].

1.1. Blockchain Technology (BT)

A lot of research has been conducted in both industry and academia to explore the potential and usefulness of blockchain technology (BT) in various application areas [6–8]. Recently, blockchain technology (BT) has become more widely known and has sparked enthusiasm in many industries, including the textile and fashion industry, due to its potential to improve business processes.

A "blockchain", as the name suggests, is in its simplest terms a "chain" of previously validated "blocks" of transactions, a decentralized database that stores data securely and encrypted in a distributed public ledger. Cryptography is the practice of safeguarding data by encoding it in order to prevent unauthorized access in an environment where security is not assured [6,7]. BT utilizes cryptography to protect the system's integrity by using advanced cryptographic algorithms. These algorithms allow for the secure identification of participants, confidential transactions, and verifiable transaction authenticity. Cryptographic keys are used to sign transactions, ensuring that each participant has validated them and preventing third-party impersonation. Transactions are encrypted and digitally signed so that no part can be altered without being rejected by others in the blockchain. Blocks are added that reference the previous block through a cryptographic signature, forming a chain of blocks [6]. That ensures the trustworthiness of transactions or smart contracts, making them unalterable. It is also known as distributed ledger technology [8–10].

The concept of blockchain was first introduced in 2008, and since then it has been constantly developing [9]. Even though blockchain was born with the advent of Bitcoin, it is no longer limited to cryptocurrencies [10,11]. Today, it has a remarkable effect in many other areas of distributed applications and has achieved significant success in the realms of finance, business, industry, politics, and society. Its features, such as the distribution of data storage among separate nodes and the utilization of consensus algorithms, provide immutability and transparency and eliminate the requirement for a central authority, thus making blockchain technology reliable [8,10,11].

In banking and finance, blockchain offers a secure and efficient way to carry out international payments, enhance capital markets, simplify trade finance, facilitate secure peer-to-peer transactions, and combat money laundering [12–14]. From an industrial standpoint, researchers have observed the possibility of blockchain applications in the supply chain across various industries [15], including textiles and fashion [16,17].

The integration of digital currencies, smart contracts, and distributed data storage through blockchain technology is enabling the emergence of novel decentralized structures, such as decentralized autonomous organizations, which are regulated by source codes to determine their governance structure [18].

Recent research [19] has revealed that 44 of the top 100 public companies by market capitalization across six major sectors are actively utilizing BT. The technology, media, and telecom sector is leading the way, with 36% of these companies belonging to this sector, including Meta (NASDAQ: META), Salesforce (NYSE: CRM), Adobe (NASDAQ: ADBE), Verizon (NYSE: VZ), and Nvidia (NASDAQ: NVDA). The consumer and retail (20%) and basic materials and industrials (20%) sectors are also represented, with participants such as UPS (NYSE: UPS), PayPal (NASDAQ: PYPL), Visa (NYSE: V), Walmart (NYSE: WMT), McDonald's (NYSE: MCD), and Nike (NYSE: NKE). Despite occasional setbacks caused by regulatory and macroeconomic hurdles, the blockchain and cryptocurrency industry is continuing to grow in adoption and use cases among large global institutional players.

Of the 100 companies in the global top 100, 63% are from the United States, while 12% are from China (including the Hong Kong Special Administrative Region). Not all of these companies are actively utilizing blockchain technology; however, 86 of them are actively pursuing blockchain-related solutions for their business needs [19] (Figure 1).

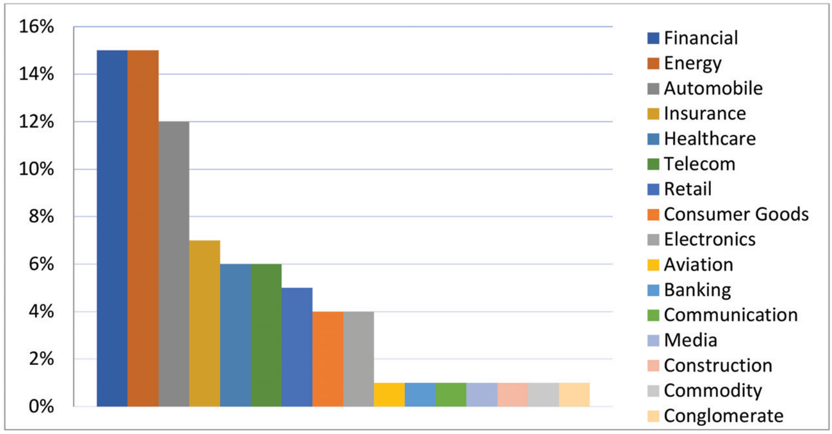

Figure 1. Blockchain adoption among Fortune 100 in 2022.

Contrary to popular belief, blockchain technology (BT) is not in the public domain like the Internet; instead, it is patentable, and many of the newer blockchain platforms have been patented. In 2021, 25.2 billion USD of venture capital was allocated to blockchain startups worldwide, representing a 713% increase from 3.1 billion USD in 2020. Global venture funding for blockchain and crypto companies achieved a new peak of 26.8 billion USD in 2022, mainly due to a strong first half. However, as the year progressed, the crypto winter combined with macroeconomic pressures caused three consecutive quarters of decreases in funding and transactions [20].

There has been considerable focus on the swift advancement of blockchain technology (BT) in the application, particularly among academics. Scholars are dedicating a great deal of study to the topic of blockchain. Despite the rapidly increasing popularity and interest in this technology, there is limited knowledge regarding the current application and utilization of blockchain in the textile and fashion industry.

1.2. Textile and Fashion Industry

Fashion is one of the most influential industries in the world, playing a major role in the global economy. It is a major contributor to the world economy, and if it were to be ranked alongside individual countries' GDP, the global fashion industry would be the seventh-largest economy in the world [21]. The textile and fashion industry is characterized by geographically dispersed production and rapid market-driven changes, providing employment opportunities to millions of workers worldwide, particularly for women. Around the world, one out of every six workers is employed in the apparel industry, and women make up 80% of the workforce in the supply chain. Due to the scale and profile of workers employed, the sector has the potential to make a significant contribution to economic and social development. Approximately 3000 billion textile and garment companies are entering the market daily [22].

Textiles and clothing is a diverse sector that plays an integral role in the global manufacturing industry, with a value of more than 2.14 trillion USD and employing over 75 million people worldwide [1,2]. In Europe alone, it employs 1.7 million people and generates a turnover of EUR 166 billion [23]. The sector has seen remarkable growth over the past decades, and the forecast is also optimistic. The global apparel market experienced a gradual increase in revenue from 2015 to 2020, when the coronavirus (COVID-19) pandemic had a significant impact on retail. In 2022, the revenue of this market was estimated to be 1.53 trillion USD, and it is projected to reach nearly 2 trillion USD by 2027 [24]. The global textile market has exhibited a growth from USD 573.22 billion in 2022 to USD 610.91 billion in 2023, corresponding to a compound annual growth rate (CAGR) of 6.6%. This growth has been interrupted by the Russia–Ukraine war, which has significantly impeded global economic recovery from the COVID-19 pandemic, particularly in the short term. The hostilities have resulted in economic sanctions being imposed on various countries, as well as a sharp increase in commodity prices and supply chain disruptions, leading to inflation across goods and services and impacting many markets worldwide. Despite these challenges, the textile market is expected to expand to USD 755.38 billion by 2027, reflecting a CAGR of 5.5% [2]. The revenue data of the textile and apparel market worldwide from 2015 to 2027, presented in Figure 2, have been collected from sources [2,24], as indicated in their own presentation.

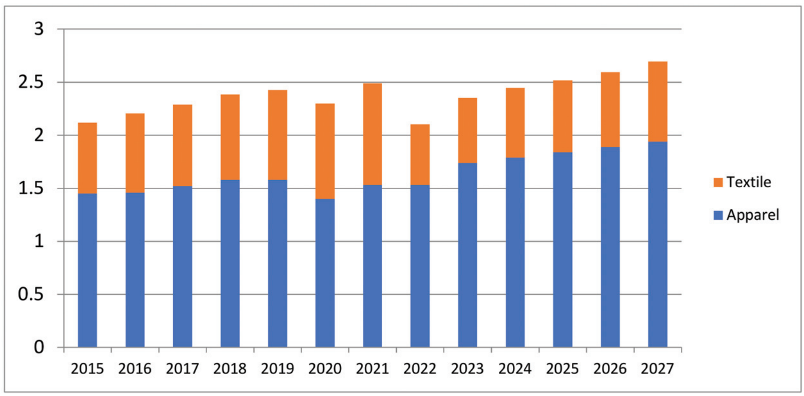

Figure 2. Revenue of the textile and apparel market worldwide from 2015 to 2027 [2,24].

The configuration of the textile and fashion supply network varies in terms of complexity, geographical spread, and size. A wide range of natural (e.g., cotton, wool, silk) and synthetic fibers (e.g., nylon, polyester, rayon, etc.) are used in garment production. Despite the geographical dispersion of the industry and the diversity of materials used, five main value-adding stages are evident in most textile and apparel supply chains: (1) raw material sources (e.g., farm, forest, fiber plant, etc.); (2) textile companies (e.g., fiber producers; spinners; fabric makers); (3) garment manufacturers (e.g., designing, cutting, sewing, ironing, etc.); (4) export network (e.g., intermediaries as trading entities and logistics providers involved in buying, selling, and transporting textile and apparel products across the principal value-adding activities and/or carrying out specific processing activities); and (5) brands and retailers (see Figure 3) (adapted from [25]).

Depending on the specific product being offered, the production chain can differ significantly, emphasizing one aspect over the other. For example, the luxury fashion industry is distinct from the mass-produced apparel retail industry. Luxury ensembles and accessories are often exclusively designed and manufactured for special orders, such as couture houses, and luxury brands often control the design and quality of their products by owning the entire supply chain or opting for the most reliable manufacturer [26]. The mass-produced apparel and retail industry, on the other hand, comprises the most affordable-fashion brands and labels, which operate on a different supply chain model compared with luxury brands [27]. Fashion brands that target mass-produced apparel aim to manufacture products at the lowest cost to increase their profit margin. Thus, the potential application of BT in the luxury segment can be used to create a crypto-legal structure of endogenous protective laws administered through a decentralized system of self-executing smart contracts which can fill the gap in the existing intellectual property regime. This can deter counterfeiting, while the mass production sector, so-called fast fashion, can enhance efficiencies and ensure cost savings through the use of smart contracts and secure payment.

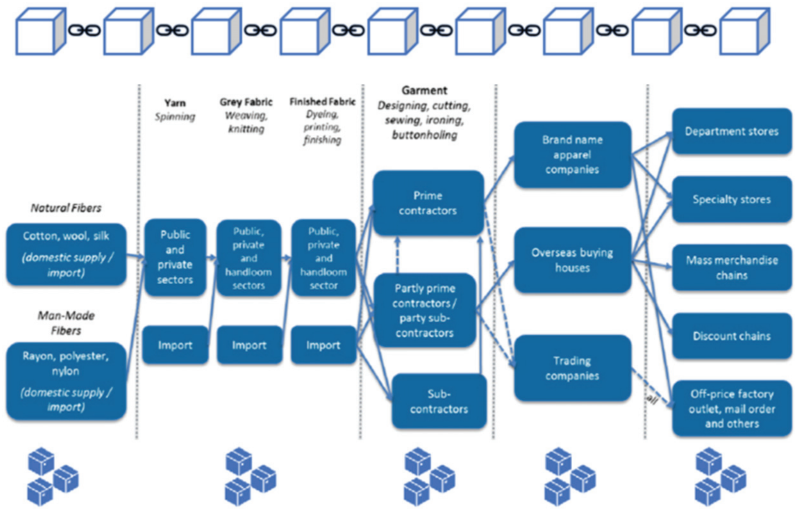

Figure 3. Integration of blockchain technology in the textile and fashion supply chain.

Fashion companies that can adapt to increasing complexity by revising their operating models and altering their strategies for supply chains, sales channels, and digital marketing will be best positioned to withstand such a competitive market [21].

Even though BT has been implemented in several industries [28,29], the literature on the subject indicates that no sufficient attention was paid to adopting blockchain in the textile and fashion industry. In the last period, blockchain has been increasingly considered for various applications in the textile and fashion industry, ranging from smart contracts, supply chain tracking operations [30], and supply chain management [31], to product authentication and payment processing. However, evidence from practice is still scarce regarding why, where, and how organizations seek to apply this technology in their supply chain [16].

This study lays the foundation for further theoretical perspectives and empirical research to investigate the characteristics of the textile and fashion industry and the importance of various types of blockchain applications in the supply chain.

2. Materials and Methods

The application of blockchain technology (BT) in different industries continues to develop, with an increasing number of blockchain projects being announced. To achieve our research aim, we focused on analyzing announced blockchain projects across the textile and fashion industries from January 2017 to January 2023. To capture the diversity of blockchain applications across different contexts of this complex sector, we examined the following aspects: smart contracts, payment processing, and supply chain tracking including product authentication, sustainability application, and customer engagement.

The selection of the textile and apparel industry for this research was based on several factors. Firstly, the sector is rapidly advancing in its experimentation with blockchain technology [32]. Secondly, the supply chain configuration, product, and business process characteristics vary significantly across this industry, as do the regulatory regimes and market requirements under which they operate [33,34]. Thirdly, it is one of the most challenging sectors for sustainable development, with numerous social and environmental issues [35,36]. Furthermore, the industry is highly fragmented and globalized, and production, shipping, and logistics is a major sector responsible for managing material flows across complex and global supply chains and is subject to various regulations, business processes, and management requirements.

This paper presents two distinct applications of blockchain technology (BT) in the textile and fashion industry. In the first part, we will discuss smart contracts, the connection between blockchain and them, and the potential impact of smart contracts on the textile and fashion industry. The second part will focus on the use of blockchain in the supply chain in the textile and fashion industry. It will emphasize BT's impact on the complex production chain, and two aspects of industry interest will be highlighted: product authenticity tracking and blockchain benefits and barriers in the sustainable supply chain. In the third section, we review the reported blockchain applications in the textile and apparel industries and provide a synthesis of the main projects adopted by companies in the textile and fashion industry. Finally, we briefly conclude the study.

This research will employ data collection and data analysis methods to further explore these issues. A comprehensive review of data from media sources and the practical literature was conducted to gain an understanding of the use of BT within the textile and fashion industry. The sources for this research were accessed through multiple databases, including Google Scholar, ScienceDirect, IEEE, Emerald, and Scopus, to minimize any potential bias in selection [37].

3. Results

3.1. Smart Contracts

With the rapid advancement of artificial intelligence, which has significantly advanced and improved computational law, smart contracts have once again become a focus of attention. Faced with massive changes in consumer behavior and disrupted supply chains due to the COVID-19 pandemic, the textile and fashion industry quickly adapted by accelerating digitization and facilitating the adaptation to online sales strategies, the implementation of smart contracts, and the establishment of secure payment processes [38]. Smart contracts have become popular recently in diverse industries, such as insurance, energy, real estate, financial services, health care, entertainment, etc. [39,40].

Although blockchain technology is being explored in many areas, the utilization of smart contracts is one of the most significant features of blockchain applications [40,41], allowing for the execution of trusted transactions without the need for third-party intermediaries.

Smart contracts are not exclusively linked to blockchain technology; they are often referred to using a variety of terms, such as "Digital Contract", "Smart Legal Contract", or "Smart Contract Code". Generally, all definitions of smart contracts involve some form of automated, self-executing transaction [40–42]. A smart contract is a piece of code stored on the blockchain that runs automatically when certain conditions and rules are met. It encodes a business agreement between two parties, which is then verified and signed by them before being uploaded to the network and does not require a lawyer to be involved.

These contracts are created to guarantee that the terms of the agreement will be followed without having to go to court. When the terms and conditions are met, the smart contract will automatically execute and carry out the tasks it was programmed to do, such as releasing funds, making payments, and transferring assets. Automation takes away the need for humans to make decisions when it comes to carrying out the contract, regardless of the outcome. This is achieved through the implementation of cryptographic hashes, digital signatures, consensus algorithms, timestamps, and incentive policies, thus enabling peer-to-peer transactions in a distributed environment without the need for mutual trust.

A variety of interpretations of smart contracts have been suggested. One of the first definitions of a smart contract presents it as "a set of promises, specified in digital form, including protocols by which the parties fulfill these promises" [42]. Generally speaking, smart contracts can be defined as computer programs that enforce the terms and conditions of a particular agreement or contract between two or more parties on a blockchain using software codes and computational infrastructure. By definition, a contract is a legally enforceable agreement, and in the case of smart contracts, the agreement will be enforced not by public law enforcement, but by the terms and mechanisms established within the contract itself. A smart contract does not need to be enforced by a government, but it can help prevent misunderstandings between people. It is a way to ensure that all parties involved in a deal fulfill their obligations [43]. Scholars classify smart contracts into two categories based on their legality: strong and weak [44]. Weak smart contracts can be altered without any additional cost, while strong smart contracts cannot be modified or the cost of modification is too high to be practical. Traditional law enforcement cannot intervene in the execution of strong smart contracts, regardless of whether it is performed by a third party or a judge.

Ref. [45] proposed a taxonomy of smart contracts into five categories, which describe their intended application domain.

- Financial contracts that manage, gather, or distribute money as a preeminent feature; certify the ownership of a real-world asset, endorse its value, and keep track of trades or implement crowdfunding services; gather money from investors in order to fund projects; provide an insurance on setbacks that are digitally provable.
- Notary contracts that exploit the immutability of the blockchain to store some data persistently, and in some cases to certify their ownership and provenance, or allow users to write the hash of a document on the blockchain so that they can prove document existence and integrity; associate users with addresses in order to certify their identity.
- Game contracts which implement games of chance or skills (e.g., Lottery).
- Wallet contracts that handle keys, send transactions, manage money, and deploy and watch contracts in order to simplify the interaction with the blockchain.
- Library contracts that implement general-purpose operations to be used by other contracts.

There are a growing number of smart contract platforms available, each with its own unique features that make it suitable for certain applications. The top smart contract platforms in 2023 include Ethereum (or Ether or ERC-20), widely considered to be the best general-use smart contract platform that can be used for everything from ICOs to facilitating smart contract use with almost any kind of decentralized application; Hyperledger Fabric, established by the Linux Foundation in December 2015; NEM, launched on 31 March 2015 [46]; Stellar, one of the oldest smart contract platforms founded in 2014; Waves, launched in June 2016, an opensource platform designed to facilitate token operations; Solana, developed in 2017 to address issues faced by the Ethereum platform; Avalanche; Polkadot; Algorand, and more.

Some fashion brands that use the Ethereum platform for smart contracts include Nike, Adidas, Puma, Burberry, Gucci, Prada, Louis Vuitton, and Versace.

3.2. Traceability and Tracking of Textile and Fashion Supply Chain

Blockchain technologies can be used for traceability and tracking in the supply chain in a variety of areas. Traceability involves tracing the origin of a product or material, while tracking involves tracking the current location and status of a product or material. Traceability can be used to ensure that the product or material is from a known, trusted source and that it has been handled correctly, while tracking can be used to monitor the product or material in real time and ensure that it is delivered to the correct destination in a timely manner.

The academic literature concerning the utilization of blockchain in the supply chain began to appear only in 2016 [47,48]. Among the initial studies, scholars explored the potential of blockchain in service systems by enabling the sharing of information and the collaborative production of value in a reliable and transparent environment [49].

The traceability of the textile and fashion industry is becoming increasingly important as consumers demand greater transparency regarding the origin, history, components, and perceived quality of the products they purchase. Additionally, traceability can help to reduce the environmental impact of the industry by providing information on the sustainability of the production process and ensuring that workers in the supply chain are treated fairly and their rights are respected. From an industry perspective, traceability can help to improve the efficiency of the production process and reduce costs, as well as identify potential problems and take corrective action to prevent them from occurring again. Furthermore, traceability can help to ensure that the products meet the required standards and that the quality is consistent. Finally, traceability can help to protect the industry from counterfeiting and other fraudulent activities.

Blockchain technology can be used to track the entire supply chain from raw materials to finished products [16,50,51]. As presented in the introduction, the textile and fashion industry is mainly composed of heterogeneous small- and medium-sized companies, which are often highly specialized in certain processes, forming global supply chains for the entire range of activities, from sourcing raw materials to delivering finished products to customers. Among the factors that tend to increase its complexity, the large number of raw materials used in the preparation of fibers and the diversity of manufacturing steps necessary to obtain them can be highlighted. All these factors make traceability almost impossible [52].

Figure 3 presents that in the T&C supply chain, the upstream partners take the raw materials in various forms as inputs from the suppliers. They perform various operations to create the final product, which is then passed on to the next supply chain partner. This process is repeated by various supply chain partners until the product is supplied to the retailer. Consequently, much information is generated at each stage of the supply chain that needs to be collected and managed properly. This information is a crucial part of the supply chain, and each partner must work to control its flow and protect confidential information. All the information can be recorded, but only essential information should be shared on the distributed ledger. Traceability and tracking are key elements of supply chain management in the textile industry, with traceability referring to the ability to track the movement of a product or material throughout the supply chain, and tracking referring to the monitoring of specific attributes or characteristics of a product or material. The importance of these factors lies in their ability to ensure transparency and accountability in the supply chain, enabling companies to identify and address issues such as unethical labor practices, environmental violations, and product quality concerns. Table 1 presents a list of the factors related to tracking and traceability in the textile and fashion supply chain as identified in the literature [16,47,48,51,52].

Table 1. Tracking and traceability factors.

Tracking Factors	Traceability Factors
Location of material sources	Origin of raw materials
Processes undergone by the raw material	Source of products
Quality of raw material	Compliance with standards
Location of goods	Manufacturing location
Production and delivery dates	Certification of quality Quantity of finished products
Payment tracking	Fraud prevention
Product authenticity	Counterfeiting prevention
Timelines for delivery	Processing data
Cost of production	Environmental impact of production processes
Shipping status	Circular economy issues

The utilization of blockchain technology in supply chain management is widely recognized, as it securely records and stores all transaction data of stakeholders in the supply chain. Due to the intricate nature of supply chains often being used to conceal the source, tracking, and legitimacy of fashion and textiles, the use of BT makes supply chain information more transparent and the distribution of information more equitable. Blockchain has the potential to significantly influence supply chain management, its related processes, and the governing structures associated with them [53]. Long and intricate supply chains can be tracked with relative ease and efficiency by recording essential data in the blockchain throughout the product's journey from the source of raw materials to the manufacturer to the customer. Using BT to interconnect distributed ledgers, databases, and stakeholders in the supply chain can improve effectiveness and guarantee cost and time savings, and also allows manufacturers to monitor the quality of their products and ensure that they are meeting customer expectations. The literature has yielded essential traceability information for the textile and clothing supply chain, which should be stored and accessible to any stakeholder. This information has been divided into four categories: product, quality, process, and social–environmental [52].

3.2.1. Brand Authentication

The utilization of blockchain to deter counterfeiting has been acknowledged in certain industries, such as the food [54], automotive [55,56] pharmaceutical [57,58], and fashion industries [59–61]. One of the major challenges faced by the fashion industry is the influx of counterfeit products in the marketplace. The issue of counterfeit goods has become a major concern for governments, economists, and business leaders. According to the Organization for Economic Cooperation and Development (OECD), the value of counterfeit and pirated products worldwide was estimated to be around USD 1 trillion in 2013 and is projected to reach nearly 3 Trillion USD by 2022 [62]. The value of counterfeit and pirated goods seized by customs globally was estimated to be USD 509 billion, up from USD 461 billion in 2013, representing 2.5% of world trade. In 2019, imports of counterfeit and pirated products into the EU amounted to as much as EUR 119 billion (USD 134 billion), which represents up to 5.8% of EU countries' imports [63]. The European Union experienced an increase from 5% to 6.8% of imports from non-EU countries. As these figures do not incorporate domestically produced and circulated knock-off goods or pirated digital products distributed online, the actual amount of counterfeiting and piracy is thought to be much higher. Mainland China and Hong Kong were the primary producers of these fake goods, with the United Arab Emirates, Turkey, Singapore, Thailand, and India also contributing substantially. The United States suffered the most economic losses due to counterfeiting, followed by France, Italy, Switzerland, and Germany [64].

Blockchain technology is used to authenticate textile products by creating a digital record of the product's origin, production process, and distribution. This record is used to track the product throughout its lifecycle, ensuring that it is genuine and has not been tampered with. Whenever members of the supply chain upload data concerning a product, it is stored in the blockchain network in a perpetual state. Distinctly different from traditional software-based tracking systems, the blockchain network is not managed by a single entity; instead, the information is located in a decentralized database that is shared among numerous nodes. All of the information is encrypted separately, meaning that any alterations to the data must be accepted by the remaining nodes in the network—an endeavor that a perpetrator of fraud would find difficult, if not impossible, to accomplish. On a practical level, blockchain technology simplifies the process of identifying cases of fraud. With a permanent record of textile and fashion products that traverse the supply chain, companies are able to compare real-world items to their digital counterparts. Any discrepancies between the two will immediately alert companies to possible issues. Additionally, blockchain technology can be used to store product information such as size, color, and fabric type, allowing customers to easily verify the authenticity of the product. This helps to reduce counterfeit products and protect the brand's reputation. In order to drive innovation in the blockchain space and create a platform for collaboration and knowledge sharing, and to develop the applications of blockchain technology and raise the standards of luxury, Aura Blockchain Consortiu was created in April 2021 [64]. This is a collective of leading companies, (e.g., LVMH, Prada Group, and Cartier) universities, and research institutions that are working together to develop and deploy blockchain-based solutions. The consortium is focused on developing and deploying blockchain technology to create a secure and trusted digital infrastructure for businesses and governments [65]. LVMH, the French luxury goods conglomerate, who owns over 70 luxury fashion brands, including names such as Dior, Fendi, Givenchy, Kenzo, and Celine, has implemented a blockchain-based solution in partnership with Microsoft and ConsenSys to verify the authenticity of its luxury products. The solution enables customers to scan a QR code on the product using their smartphone, which then verifies the product's authenticity on the blockchain.

The advantages of traceability extend beyond the company–consumer relationship, creating trust and transparency between members of the supply chain, including companies and their suppliers and distributors.

3.2.2. Blockchain and Sustainability Issues

Scholars have conducted exploratory studies into the potential of blockchain technology to facilitate sustainability initiatives [66]. Researchers have assessed the advantages and drawbacks of integrating blockchain into sustainable supply chains [59]. From a sustainability and corporate image standpoint, it is becoming increasingly necessary to trace the effects of production on society, the environment, and the economy, which has made blockchain a focal point in providing a deeper level of understanding and assurance of operations. The textile and fashion industry has become a focus of media scrutiny regarding sustainability and circular economy issues; however, obtaining accurate data remains difficult due to the globalization of fashion supply chains and the historically limited attention paid to lifecycle sustainability issues in comparison with other industries [67,68]. In the past, many companies have experienced damage to their corporate image due to the revelation of a corrupt supply chain that included forced labor, armed conflict, or toxic emissions. Blockchain could be a barrier to such activities, as the technology would need to include data points that are specifically designed to identify these malicious practices. In 2022, the Swedish company TrusTrace launched its new blockchain-based solution for supply chain traceability, TrusTrace Certified Material Compliance, in an effort to combat misinformation and improve transparency and traceability within the fashion industry. This solution is an extension of the existing product traceability and supply chain transparency platform, and it is intended to be a comprehensive one-stop shop for material compliance. Early input into developing the platform has been provided by major sports brands such as Adidas, Decathlon, and Filippa K, in line with their ambitious sustainability goals for the coming years [69].

3.2.3. Customer Engagement

Blockchain technology can also be used to enhance customer engagement in the textile and fashion industry. Customers are increasingly demanding transparency and sustainability from brands [31], and blockchain technology can provide a platform for delivering this information. For example, a blockchain-enabled platform could enable customers to track the environmental impact of a product throughout its lifecycle, from raw material extraction to disposal. This would enable customers to make more informed purchasing decisions and incentivize companies to improve their sustainability practices. For example, The Fabricant, a Netherlands-based digital fashion house, has launched a blockchain-enabled platform called "Immaterial", which allows customers to purchase and own digital fashion items as non-fungible tokens (NFTs). For NFTs, it partnered with Vogue and Diesel. The platform uses BT to ensure its customers of the ownership and authenticity of digital fashion items [70].

The information presented in the article is summarized in Table 2, which outlines the successful adoption of blockchain technology (BT) by various organizations and companies. The table provides examples of the areas of application and the corresponding solutions adopted by these entities.

Table 2. Examples of Organizations and Companies Successfully Utilizing Blockchain Technology: Areas of Application and Solutions Adopted (2017–2023).

Area of Application	Example Company or Association	Solution	Source
Smart contracts	LVMH	+Accept cryptocurrency as payment	[71]
	Gucci		[72]
	Philipp Plein		[72]
	Adidas		[73]
	Inditex (Zara)		[74]
Supply Chain Management	UK Fashion and Textile Association (UKFT)	Enabling product traceability and improving transparency in the supply chain	[75,76]
	AURA Consortium	Is supporting the first global blockchain solution dedicated to the luxury goods industry, promoting the use of a single global blockchain platform open to all luxury brands to provide consumers with additional transparency and traceability	[64,65]
	Arianee Consortium	Is a decentralized, opensource protocol that leverages blockchain technology to create unique digital identities for luxury goods, including fashion items. The Arianee protocol enables brands and retailers to track the ownership, provenance, and authenticity of high-end fashion products throughout their lifecycle.	[77]
	The Woolmark Company	Tracking the origin of wool fibers from farm to fashion to ensure that the wool fibers are ethically sourced and traceable.	[78]
	Lenzing Group	Tracing products across the supply chain (manmade cellulose fibers)	[79,80]
	Chargeurs Luxury Materials	Ensuring product quality, sustainability and traceability across the supply chain (wool)	[81]
	Gucci	Tracing products across the supply chain	[82]
	LVMH	Tracing products across the supply chain	[75,76]
	Stella McCartney	Collaboration with Bolt Threads and Evrnu to create a "regenerated" cashmere sweater made from recycled materials, tracked using a blockchain platform	[83]
	H&M	Implementation of a blockchain-based system for tracking and sharing information about suppliers and their sustainability practices	[84]
	C&A	Tracing organic cotton from the farm to the ginning process, with a plan to extend it to the consumers	[85]
	Inditex (Zara)	Data securitization and tracing products across the supply chain	[86]
	Levi Strauss & Co.	Levi Strauss & Co. started testing the blockchain version of the Worker Well-being survey with SHINE to better understand if, in fact, "what's good for workers is also good for business".	[87]
	Adidas	Supply chain traceability for sustainable materials	[69,88]
	Decathlon	Supply chain traceability for sustainable materials	[87,88]
	Nike Inc.	Supply Chain Data Collection Tracking and verifying the movement of cotton fiber across the supply chain	[89,90]
Brand Authentication	LVMH Prada	Blockchain-based solution in partnership with Microsoft and ConsenSys for verifying the authenticity of luxury products (AURA platform)	[64,91]
	HUGO BOSS	In collaboration with ASTRATUM create Tracey, a blockchain-based system to monitor items in their supply chain and validate their genuineness	[91]

Table 2. *Cont.*

Area of Application	Example Company or Association	Solution	Source
Customer Engagement	The Fabricant	Is a Netherlands-based digital fashion house that has launched a blockchain-enabled platform called "Immaterial", which allows customers to purchase and own digital fashion items as non-fungible tokens (NFTs) For NFTs, it partnered with Vogue and Diesel The platform uses BT to ensure its customers that the ownership and authenticity of digital fashion items are transparent and immutable	[70]
	Levi Strauss & Co.	Pilot project using blockchain technology to enable customers to scan a QR code on their jeans and access information about the production process, materials used, and sustainability practices	[87]
	Nike Inc.	Launched a digital community and experience hub and a home for virtual creations and products	[92,93]
	Christian Dior	Uses blockchain for their loyalty programs	[94]

4. Conclusions

After examining the potential of BT in the textile and fashion business ecosystems, several conclusions can be drawn:

- Transformational Potential: BT has the potential to revolutionize the textile and fashion industry by creating a more transparent and efficient supply chain. This transformation can improve traceability, reduce fraud and counterfeiting, and instill greater customer confidence in purchased products.
- Infrastructure for Enhanced Connectivity: BT provides a robust infrastructure that facilitates the connection of intricate networks and databases in the industry. This enables simultaneous and irreversible updates across all interconnected databases, streamlining processes and allowing for automation where necessary.
- Collaborative Adoption for Success: Successful implementation of BT in the textile and fashion industry relies on collaboration between different stakeholders. Manufacturers, suppliers, retailers, and consumers must work together to establish a unified blockchain network that effectively tracks and verifies product authenticity.
- Efficiency and Cost Savings: The adoption of BT offers the potential for increased efficiency and cost savings in supply chain management. Through streamlined processes, reduced paperwork, and the elimination of intermediaries, operational efficiency is enhanced, leading to tangible cost benefits.
- Sustainability and Transparency: BT contributes to improved sustainability by fostering transparency in supply chain practices. The ability to verify ethical and sustainable practices empowers consumers to make informed choices, promotes responsible production and consumption, and supports sustainability initiatives in the industry.

While significant benefits can be achieved through BT implementation, it is important to acknowledge and address the challenges that accompany it. Technical limitations, regulatory issues, and concerns over data privacy and security need to be carefully considered and overcome [95]. The successful adoption of BT in the textile and fashion industry necessitates thoughtful examination of these challenges, as well as close collaboration among various actors, including designers, manufacturers, retailers, and policymakers. By working together, these stakeholders can overcome obstacles and fully realize the potential benefits of BT adoption.

Further research is required to fully comprehend the extent to which blockchain contributes to sustainability initiatives. Additionally, potential risks associated with implementing BT should be taken into account to ensure that its utilization is beneficial for the environment.

In conclusion, the adoption of BT in the textile and fashion industry offers substantial benefits for all stakeholders involved. By leveraging its potential, such as increased efficiency, cost savings, improved sustainability, and enhanced supply chain transparency, the industry can thrive. However, it is imperative to address the challenges at hand, including data privacy concerns and potential disruptions to the workforce, through close collaboration among stakeholders. By doing so, the textile and fashion industry can fully harness the transformative power of BT.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Available on request.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Smith, P. Global Apparel Market—Statistics & Facts (15 February 2023). Available online: https://www.statista.com/topics/5091/apparel-market-worldwide/ (accessed on 11 May 2023).
2. Textile Global Market Report 2023 (January 2023). Available online: https://www.thebusinessresearchcompany.com/report/textile-global-market-report (accessed on 11 May 2023).
3. Berg, A. How Current Global Trends Are Disrupting the Fashion Industry. McKinsey & Company. 2022. Available online: https://www.mckinsey.com/industries/retail/our-insights/how-current-global-trends-are-disrupting-the-fashion-industry (accessed on 11 May 2023).
4. Periyasami, S.; Periyasamy, A.P. Metaverse as future promising platform business model: Case study on fashion value chain. *Businesses* **2022**, *2*, 527–545. [CrossRef]
5. Yousefi, S.; Tosarkani, B.M. An analytical approach for evaluating the impact of blockchain technology on sustainable supply chain performance. *Int. J. Prod. Econ.* **2022**, *246*, 108429. [CrossRef]
6. Al-Jaroodi, J.; Mohamed, N. Blockchain in industries: A survey. *IEEE Access* **2019**, *7*, 36500–36515. [CrossRef]
7. Monrat, A.A.; Schelén, O.; Andersson, K. A survey of blockchain from the perspectives of applications, challenges, and opportunities. *IEEE Access* **2022**, *7*, 117134–117151. [CrossRef]
8. Blockchain-Internet Security. Available online: https://www.internetsociety.org/issues/blockchain/ (accessed on 12 February 2023).
9. Davidson, S.; De Filippi, P.; Potts, J. Blockchains and the economic institutions of capitalism. *J. Inst. Econ.* **2018**, *14*, 639–658. [CrossRef]
10. Nakamoto, S. Bitcoin: A Peer-to-Peer Electronic Cash System. 2009. Available online: https://git.dhimmel.com/bitcoin-whitepaper/ (accessed on 12 February 2023).
11. Upadhyay, N. Demystifying blockchain: A critical analysis of challenges, applications and opportunities. *Int. J. Inf. Manag.* **2020**, *54*, 102120. [CrossRef]
12. Osmani, M.; El-Haddadeh, R.; Hindi, N.; Janssen, M.; Weerakkody, V. Blockchain for next generation services in banking and finance: Cost, benefit, risk and opportunity analysis. *J. Enterp. Inf. Manag.* **2021**, *34*, 884–899. [CrossRef]
13. Vučinić, M.; Luburić, R. Fintech, risk-based thinking and cyber risk. *J. Cent. Bank. Theory Pract.* **2022**, *11*, 27–53. [CrossRef]
14. Gorkhali, A.; Chowdhury, R. Blockchain and the evolving financial market: A literature review. *J. Ind. Integr. Manag.* **2022**, *7*, 47–81. [CrossRef]
15. Idrees, S.M.; Aijaz, I.; Jameel, R.; Nowostawski, M. Exploring the Blockchain Technology: Issues, Applications and Research Potential. *Int. J. Online Biomed. Eng.* **2021**, *17*, 48–69. [CrossRef]
16. Agrawal, T.K.; Kumar, V.; Pal, R.; Wang, L.; Chen, Y. Blockchain-based framework for supply chain traceability: A case example of textile and clothing industry. *Comput. Ind. Eng.* **2021**, *154*, 107130. [CrossRef]
17. Ahmed, W.A.H.; MacCarthy, B.L. Blockchain in the supply chain—A comprehensive framework for theory-driven research. *Digit. Bus.* **2022**, *2*, 100043. [CrossRef]
18. Wu, B. Comprehensive Overview and Analysis of Blockchain Use Cases in Many Industries, DC WEB. MAKERS (April 2019). Available online: https://www.blockchain.dcwebmakers.com/blog/comprehensive-overview-and-analysis-of-blockchain-use-cases-in-many-industries.html (accessed on 20 January 2023).
19. Blockdata—The Top 100 Public Companies Using Blockchain in 2022. Available online: https://www.blockdata.tech/blog/general/the-top-100-public-companies-using-blockchain-in-2022 (accessed on 23 March 2023).
20. State of Blockchain 2022 Report. Available online: https://www.cbinsights.com/research/report/blockchain-trends-2022/ (accessed on 27 February 2023).
21. McKinsey, The State of Fashion 2023 Holding onto Growth as Global Clouds Gather. Available online: https://www.mckinsey.com/industries/retail/our-insights/state-of-fashion (accessed on 22 February 2023).

22. Fashion Industry Statistics: The 4th Biggest Sector is Way More than Just about Clothing. Available online: https://fashinnovation.nyc/fashion-industry-statistics/ (accessed on 22 February 2023).
23. Textiles and Clothing in the EU. Available online: https://single-market-economy.ec.europa.eu/sectors/fashion/textiles-and-clothing-industries_en (accessed on 22 February 2023).
24. Smith, P. Global Revenue of the Apparel Market 2014–2027. 2022. Available online: https://www.statista.com/forecasts/821415/value-of-the-global-apparel-market (accessed on 22 February 2023).
25. Martin, M. Global Supply Chains: Deciding the Way Forward. 2015. Available online: https://www.supplychain247.com/article/global_supply_chains_deciding_the_way_forward (accessed on 22 February 2023).
26. Jestratijevic, I.; Rudd, N.A.; Uanhoro, J. Transparency of sustainability disclosures among luxury and mass-market fashion brands. *J. Glob. Fash. Mark.* **2020**, *11*, 99–116. [CrossRef]
27. Badhwar, A.; Islam, S.; Tan, C.S.L. Exploring the potential of blockchain technology within the fashion and textile supply chain with a focus on traceability, transparency, and product authenticity: A systematic review. *Front. Blockchain* **2023**, *6*, 7. [CrossRef]
28. Bodkhe, U.; Tanwar, S.; Parekh, K.; Khanpara, P.; Tyagi, S.; Kumar, N.; Alazab, M. Blockchain for industry 4.0: A comprehensive review. *IEEE Access* **2020**, *8*, 79764–79800. [CrossRef]
29. Chen, Y.; Lu, Y.; Bulysheva, L.; Kataev, M.Y. Applications of blockchain in industry 4.0: A review. *Inf. Syst. Front.* **2022**. [CrossRef]
30. Liu, X.; Yang, Y.; Jiang, Y.; Fu, Y.; Zhong, R.Y.; Li, M.; Huang, G.Q. Data-driven ESG assessment for blockchain services: A comparative study in textiles and apparel industry. *Resour. Conserv. Recycl.* **2023**, *190*, 106837. [CrossRef]
31. Yadlapalli, A.; Rahman, S. Blockchain Technology in Apparel Supply Chains. In *Sustainable Approaches in Textiles and Fashion: Consumerism, Global Textiles and Supply Chain*; Springer Nature: Singapore, 2022; pp. 63–83. [CrossRef]
32. Lim, M.K.; Li, Y.; Wang, C.; Tseng, M.-L. A literature review of blockchain technology applications in supply chains: A comprehensive analysis of themes, methodologies and industries. *Comput. Ind. Eng.* **2021**, *154*, 107133. [CrossRef]
33. Silvestre, R.M. Portugal's Position on the Opportunities of Blockchain and 3D Technology in the Footwear Industry Value-Chain. Ph.D. Thesis, Universidade NOVA de Lisboa, Lisboa, Portugal, 2020.
34. Yu, S. Application of blockchain-based sports health data collection system in the development of sports industry. *Mob. Inf. Syst.* **2021**, *2021*, 4663147. [CrossRef]
35. Sandhiya, R.; Boopika, A.M.; Akshatha, M.; Swetha, S.V.; Hariharan, N.M. Future of fashion industry: Sustainable fashion using blockchain. *Blockchain 3.0 Sustain. Dev.* **2021**, *10*, 145. [CrossRef]
36. Jraisat, L.; Jreissat, M.; Upadhyay, A.; Kumar, A. Blockchain technology: The role of integrated reverse supply chain networks in sustainability. In *Supply Chain Forum: An International Journal*; Taylor & Francis: London, UK, 2022; pp. 1–14. [CrossRef]
37. Ellram, L.M.; Tate, W.L. The use of secondary data in purchasing and supply management (P/SM) research. *J. Purch. Supply Manag.* **2016**, *22*, 250–254. [CrossRef]
38. Chen, Y. How blockchain adoption affects supply chain sustainability in the fashion industry: A systematic review and case studies. *Int. Trans. Oper. Res.* **2023**. [CrossRef]
39. Hewa, T.; Ylianttila, M.; Liyanage, M. Survey on blockchain based smart contracts: Applications, opportunities and challenges. *J. Netw. Comput. Appl.* **2021**, *177*, 102857. [CrossRef]
40. Cohn, A.; West, T.; Parker, C. Smart after all: Blockchain, smart contracts, parametric insurance, and smart energy grids. *Geo. L. Tech. Rev.* **2016**, *1*, 273.
41. Bocek, T.; Stiller, B. Smart contracts–blockchains in the wings. In *Digital Marketplaces Unleashed*; Springer: Berlin/Heidelberg, Germany, 2017; pp. 169–184.
42. Szabo, N. Smart Contracts: Building Blocks for Digital Markets. 1996. Available online: https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html (accessed on 22 May 2022).
43. Hornyák, O.; Alkhoury, G.F. Smart contracts in the automotive industry. In *Vehicle and Automotive Engineering 3: Proceedings of the 3rd VAE2020, Miskolc, Hungary 3*; Springer: Singapore, 2021; pp. 148–157. [CrossRef]
44. Raskin, M. The law and legality of smart contracts. *Geo. L. Tech. Rev.* **2016**, *1*, 305.
45. Bartoletti, M.; Pompianu, L. An empirical analysis of smart contracts: Platforms, applications, and design patterns. In *Financial Cryptography and Data Security: FC 2017 International Workshops, WAHC, BITCOIN, VOTING, WTSC, and TA, Sliema, Malta, April 7, 2017, Revised Selected Papers 21, 2017*; Springer International Publishing: Berlin/Heidelberg, Germany, 2017; pp. 494–509. [CrossRef]
46. Davies, A. What Are the 5 Best Smart Contract Platforms for 2023? Available online: https://www.devteam.space/blog/what-are-the-5-best-smart-contract-platforms-for-2022/ (accessed on 22 March 2023).
47. Seebacher, S.; Schüritz, R. Blockchain technology as an enabler of service systems: A structured literature review. In *Exploring Services Science: 8th International Conference, IESS 2017, Rome, Italy, 24–26May 2017, Proceedings 8*; Springer International Publishing: Berlin/Heidelberg, Germany, 2017; pp. 12–23. [CrossRef]
48. Venkatesh, V.G.; Kang, K.; Wang, B.; Zhong, R.Y.; Zhang, A. System architecture for blockchain based transparency of supply chain social sustainability. *Robot. Comput.-Integr. Manuf.* **2020**, *63*, 101896. [CrossRef]
49. Chowdhury, N.R.; Chowdhury, P.; Paul, S.K. Sustainable practices and their antecedents in the apparel industry: A review. *Curr. Opin. Green Sustain. Chem.* **2022**, *37*, 100674. [CrossRef]
50. Lacity, M.C. Addressing key challenges to making enterprise blockchain applications a reality. *MIS Q. Exec.* **2018**, *17*, 201–222.

51. Wamba, S.F.; Queiroz, M.M. Blockchain in the operations and supply chain management: Benefits, challenges and future research opportunities. *Int. J. Inf. Manag.* **2020**, *52*, 102064. [CrossRef]
52. Bullón Pérez, J.J.; Queiruga-Dios, A.; Gayoso Martínez, V.; Martín del Rey, Á. Traceability of ready-to-wear clothing through blockchain technology. *Sustainability* **2020**, *12*, 7491. [CrossRef]
53. Schmidt, C.G.; Wagner, S.M. Blockchain and supply chain relations: A transaction cost theory perspective. *J. Purch. Supply Manag.* **2019**, *25*, 100552. [CrossRef]
54. Bechtsis, D.; Tsolakis, N.; Bizakis, A.; Vlachos, D. A blockchain framework for containerized food supply chains. *Comput. Aided Chem. Eng.* **2019**, *46*, 1369–1374. [CrossRef]
55. Gîrbacia, F.; Voinea, D.; Boboc, R.; Duguleană, M.; Postelnicu, C.C. Toward blockchain adoption for the automotive industry. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2022; Volume 1220, p. 012026. [CrossRef]
56. Balachander, S.; Murugan, A. Assessing the feasibility of Blockchain Technology in Automotive Industry. In Proceedings of the 2022 IEEE 9th Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), Prayagraj, India, 2–4 December 2022; pp. 1–6. [CrossRef]
57. Haq, I.; Esuka, O.M. Blockchain technology in pharmaceutical industry to prevent counterfeit drugs. *Int. J. Comput. Appl.* **2018**, *180*, 8–12. [CrossRef]
58. Saxena, N.; Thomas, I.; Gope, P.; Burnap, P.; Kumar, N. Pharmacrypt: Blockchain for critical pharmaceutical industry to counterfeit drugs. *Computer* **2020**, *53*, 29–44. [CrossRef]
59. Thanasi-Boçe, M.; AL-Issa, N.; Ali, O. Combating Luxury Counterfeiting Through Blockchain Technology. In *Blockchain Technologies in the Textile and Fashion Industry*; Springer Nature: Singapore, 2022; pp. 1–16. [CrossRef]
60. Hemantha, Y. Embracing block chain technology in supply chain to combat counterfeiting luxury and fashion brands. *Asian J. Manag.* **2022**, *13*, 145–150.
61. Chen, C.-L.; Shang, X.; Tsaur, W.-J.; Weng, W.; Deng, Y.-Y.; Wu, C.-M.; Cui, J. An Anti-Counterfeit and Traceable Management System for Brand Clothing with Hyperledger Fabric Framework. *Symmetry* **2021**, *13*, 2048. [CrossRef]
62. Bremer, C. Trade in Fake Goods Is Now 3.3% of World Trade and Rising. 2019. Available online: https://www.oecd.org/governance/trade-in-fake-goods-is-now-33-of-world-trade-and-rising.htm (accessed on 12 March 2023).
63. OECD. Global Trade in Fakes. 2021. Available online: https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/reports/2021_EUIPO_OECD_Report_Fakes/2021_EUIPO_OECD_Trate_Fakes_Study_FullR_en.pdf (accessed on 12 March 2023).
64. Luxury Groups and Brands Together for a Greater Good (April 2021). Available online: https://auraluxuryblockchain.com/about (accessed on 12 March 2023).
65. A Revolution in the Luxury Industry. 2021. Available online: https://auraluxuryblockchain.com/ (accessed on 12 March 2023).
66. Treiblmaier, H. Combining Blockchain Technology and the Physical Internet to Achieve Triple Bottom Line Sustainability: A Comprehensive Research Agenda for Modern Logistics and Supply Chain Management. *Logistics* **2019**, *3*, 10. [CrossRef]
67. Zhang, A.; Zhong, R.Y.; Farooque, M.; Kang, K.; Venkatesh, V.G. Blockchain-based life cycle assessment: An implementation framework and system architecture. *Resour. Conserv. Recycl.* **2020**, *152*, 104512. [CrossRef]
68. Peters, G.; Li, M.; Lenzen, M. The need to decelerate fast fashion in a hot climate—A global sustainability perspective on the garment industry. *J. Clean. Prod.* **2021**, *295*, 126390. [CrossRef]
69. Adidas Adopts Blockchain Solution TrusTrace for Sustainable Materials (March 2022). Available online: https://www.ledgerinsights.com/adidas-adopts-blockchain-solution-trustrace-for-sustainable-materials/ (accessed on 12 March 2023).
70. Blockchain Fashion House the Fabricant Raises $14m to Cloth Metaverse Avatars (April 2022). Available online: https://www.ledgerinsights.com/blockchain-fashion-house-the-fabricant-raises-14m-metaverse-avatars/ (accessed on 11 May 2023).
71. Chargeurs. Chargeurs Luxury Materials Increases the Marketing Clout of Its Organica Precious Fiber-Labeled Wool Thanks to RWS Certification. 2018. Available online: https://www.chargeurs.com/wp-content/uploads/2019/05/13-2018.12.03-Chargeurs-Luxury-Materials-increases-the-marketing-clout-of-its-Organica-Precious-Fiber-labeled-wool-thanks-to-RWS-certification.pdf (accessed on 11 May 2023).
72. The Use of Smart Contracts in the Fashion Industry: Gucci Case Study. Blockchain Council. Available online: Blockchain-council.org/blockchain/the-use-of-smart-contracts-in-the-fashion-industry-gucci-case-study/ (accessed on 11 May 2023).
73. Adidas Announces Its First Cryptocurrency Initiative with Coinbase and the Sandbox. Available online: https://www.cryptoknowmics.com/news/adidas-announces-its-first-cryptocurrency-initiative-with-coinbase-and-the-sandbox (accessed on 11 May 2023).
74. Smart Contracts: What Are They and How Can They Help Your Business? Inditex. 2019. Available online: https://www.inditex.com/en/smart-contracts-what-are-they-and-how-can-they-help-your-business (accessed on 20 March 2023).
75. Blockchain in the Fashion Industry: What You Need to Know. UKFT. Available online: https://www.ukft.org/insights/blockchain-in-the-fashion-industry-what-you-need-to-know/ (accessed on 20 March 2023).
76. Blockchain: A New Way of Doing Business in the Fashion Industry. UKFT. Available online: https://www.ukft.org/insights/blockchain-a-new-way-of-doing-business-in-the-fashion-industry/ (accessed on 22 March 2023).
77. Our Enterprise-Ready Solutions. Available online: https://www.arianee.com/newsroom (accessed on 22 March 2023).
78. Available online: https://www.wool.com/news/australian-wool-innovation-launches-blockchain-traceability-initiative/ (accessed on 26 March 2023).

79. Lenzing Introduces Blockchain-Enabled Traceability Platform. Available online: https://www.lenzing.com/newsroom/press-releases/press-release/new-level-of-transparency-in-the-textile-industry-lenzing-introduces-blockchainenabled-traceability-platform (accessed on 12 March 2023).
80. Lenzing Presented First Blockchain Pilot Project at Hong Kong Fashion Summit. 2019. Available online: https://www.tencel.com/b2b/news-and-events/lenzing-presented-first-blockchain-pilot-project-at-hong-kong-fashion-summit (accessed on 12 March 2023).
81. Outstanding Wool at the Forefront of Traceability. Available online: https://www.chargeurs.com/les-metiers/luxury-materials/the-wool/?lang=en (accessed on 12 March 2023).
82. Gucci Leverages Blockchain Technology to Track Luxury Goods. Blockchain News, 17 March 2020. Available online: www.the-blockchain.com/2020/03/17/gucci-leverages-blockchain-technology-to-track-luxury-goods/ (accessed on 11 May 2023).
83. Stella McCartney Teams up with Google Cloud. 2019. Available online: https://hmgroup.com/news/hm-group-expands-partnership-with-textilegenesis/https://www.ecotextile.com/2019051624314/materials-production-news/stella-mccartney-teams-up-with-google-cloud.html (accessed on 17 February 2023).
84. H&M Group Expands Partnership with TextileGenesis. (April, 2022). Available online: https://hmgroup.com/news/hm-group-expands-partnership-with-textilegenesis/ (accessed on 11 May 2023).
85. Fashion for Good. Successfully Tracing Organic Cotton with Innovative Technologies. 2019. Available online: https://fashionforgood.com/our_news/successfully-tracing-organic-cotton-with-innovative-technologies (accessed on 11 May 2023).
86. Seifert, R.W.; Markoff, R. RFID: Yesterday's Blockchain A Cautionary and Hopeful Tale. Available online: https://www.imd.org/research-knowledge/articles/rfid-yesterdays-blockchain/ (accessed on 11 May 2023).
87. A New Way to Measure Worker Well-Being. Available online: https://www.levistrauss.com/2019/01/24/new-way-measure-worker-well/ (accessed on 11 May 2023).
88. Adidas and Parley for the Oceans Join Forces to Create a Sustainable Future with Blockchain Technology. Adidas. Available online: www.adidas.com/us/parley-blockchain-technology (accessed on 12 March 2023).
89. Nike Implements Blockchain for Supply Chain Data Collection. Available online: https://www.rfidlabel.com/2022/07/nike-implements-blockchain-for-supply-chain-data-collection/ (accessed on 11 May 2023).
90. Nike and ConsenSys Join Forces to Develop Blockchain Solutions for Manufacturing and Supply Chain Transparency. ConsenSys. 2019. Available online: www.consensys.net/blog/nike-and-consensys-join-forces-to-develop-blockchain-solutions-for-manufacturing-and-supply-chain-transparency/ (accessed on 12 March 2023).
91. Prada Launches Blockchain Platform to Track Luxury Goods. (29 June 2020). Available online: https://www.forbes.com/sites/billybambrough/2020/06/29/prada-launches-blockchain-platform-to-track-luxury-goods/#3c8d8e7a4f4b (accessed on 11 April 2023).
92. Nike Launches. SWOOSH, a New Digital Community and Experience. Available online: https://about.nike.com/en/newsroom/releases/nike-launches-swoosh-a-new-digital-community-and-experience (accessed on 11 April 2023).
93. Hackling, C. Blockchain: Unlocking The Value Chain for Better Traceability. 2019. Available online: https://globalfashionagenda.com/blockchain-unlocking-the-value-chain-for-better-traceability-2/# (accessed on 11 April 2023).
94. Luxury Brands Are Still Embracing Blockchain For Loyalty and Product Authentication Programs. 2021. Available online: https://www.enmodemagazine.com/luxury-brands-are-still-embracing-blockchain-for-loyalty-and-product-authentication-programs/ (accessed on 11 April 2023).
95. Iansiti, M.; Lakhani, K.R. The truth about blockchain. *Harv. Bus. Rev.* **2017**, *95*, 118–127.

FinTech

Article

Digital Economy under Fintech Scope: Evidence from African Investment

Sonia Kherbachi

LRMTQ, FSECSG, University of Bejaia, Bejaia 06000, Algeria;
sonia.kherbachi@univ-bejaia.dz or soniakherbachi@gmail.com

Abstract: The digital economy has revolutionized industries worldwide, prompting companies to invest in digital technologies to enhance productivity and profitability. However, the successful implementation of these technologies hinges on employees' perceptions and satisfaction with the digital infrastructure. This paper aims to explore the impact of digital technology satisfaction on overall job satisfaction within the fintech domain. Drawing from the User-Task-Technology fit framework, it investigates the interplay between digital technology satisfaction, job satisfaction, and work-life balance. By aligning technology with task requirements and individual user needs, organizations can foster a positive work environment and improve firm performance. The study employs Principal Component Analysis (PCA) to identify key requirements for the digital economy in a digital environment. Furthermore, it addresses two research questions related to the selection of variables representing sustainability dimensions and evaluating dependency in digital economy projects under a fintech scope. The findings highlight the importance of digital technology satisfaction in driving employee job satisfaction and overall work experience. Ultimately, this research contributes to a deeper understanding of the factors influencing the digital economy and offers insights for managers and organizations seeking to optimize their digital transformation strategies. The study concludes by exploring the digital economy in the context of healthcare services in Africa, specifically focusing on the initiatives led by the World Bank.

Keywords: digital economy; job satisfaction; work-life balance; finTech; User-Task-Technology fit; Principal Component Analysis (PCA); sustainability

Citation: Kherbachi, S. Digital Economy under Fintech Scope: Evidence from African Investment. *FinTech* **2023**, *2*, 475–483. https://doi.org/10.3390/fintech2030027

Academic Editor: David Roubaud

Received: 24 May 2023
Revised: 7 July 2023
Accepted: 12 July 2023
Published: 14 July 2023

1. Introduction

The digital economy has significantly accelerated digital transformation across various industries, including agriculture, industry, and services. This transformation has had a profound impact on the development of these sectors. In order to capitalize on the opportunities presented by the digital economy, companies are increasingly investing in digital technologies to empower their employees and drive profitability [1].

When organizations establish a digital infrastructure, it becomes imperative to consider how employees perceive these digital technologies. This perception is closely linked to several important aspects, such as work-environment satisfaction [1], job satisfaction [2], job involvement [3], firm performance [4], and work-life balance [5]. Employee satisfaction is widely recognized as a critical outcome in the digital workplace. Companies assess job satisfaction as it is closely associated with performance ratings based on factors such as individual productivity improvement, error reduction, absenteeism, turnover, and more.

Fintech can improve both financial stability and access to services [6]. According to Hanaysha [7], there exists a strong correlation between satisfaction with digital technology and job satisfaction regarding access to services. In the digital era, where digital platforms have permeated almost all industries, the experience of using these technologies has become an integral part of employees' overall work experience. When employees are satisfied with the digital technology they use, they are better equipped to adapt to the ever-changing work conditions imposed by the digital landscape, ultimately leading to enhanced job satisfaction [8].

Therefore, it can be inferred that satisfaction with digital technology has the potential to positively influence overall job satisfaction relying on Fintech scopes, as depicted in Figure 1.

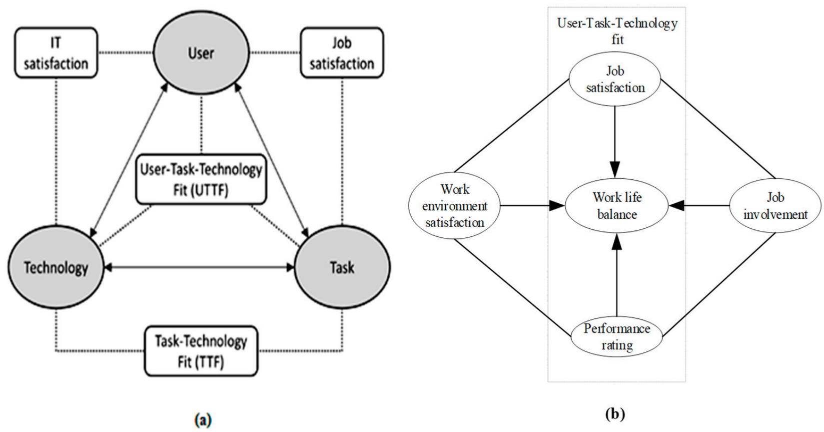

Figure 1. The research framework of digital economy under fintech scope adopted from the research framework from User-Task-Technology fit (Source: adapted from [1] (p. 343)).

Digital technologies have the capacity to enable employees to handle complex tasks while reducing the burden of tedious and repetitive tasks. Moreover, satisfaction with digital technology can enhance users' sense of control over their work, leading to improved firm performance by generating benefits such as cost savings, increased connectivity, and greater agility and adaptability in complex and competitive environments [9]. To fully leverage the potential of digital technologies and achieve optimal firm performance, it is crucial to align technology with the specific task requirements and the work environment of individual users [10]. Task-technology fit (TTF) refers to the alignment of the tasks performed and the technology utilized [11], while user-task-fit technology extends the TTF theory by considering employees' needs for both immediate task accomplishment and work-environment satisfaction, which contributes to ensuring work-life balance [12] (see Figure 1a). Given that jobs constitute a significant part of people's lives, companies must strive to maintain work-life balance, which is the harmony between job satisfaction and life satisfaction [5], as depicted in Figure 1b.

Building upon these findings, this research aims to make two primary contributions. Firstly, it seeks to identify common factors influencing the digital economy from the perspectives of both managers and employees. Secondly, it aims to illustrate the interrelationships among the requirements of the digital economy. Consequently, this paper addresses the following research questions:

How can variables be selected to represent the three dimensions (social, economic, and environmental) of sustainability in the context of the digital economy?

How can dependency (referring to the evaluation of reliance on external factors, resources and stakeholders) be evaluated at different stages of a digital-economy project under a fintech scope?

To address these questions, this project on healthcare services, supported by the World Bank in Africa, is presented as leveraging fintech solutions and technologies, such as electronic health records, telemedicine platforms, health data analytics, digital payment systems for healthcare services, and digital insurance solutions, in order to drive digital transformation and innovation within the healthcare sector, ultimately improving healthcare service delivery and accessibility. Hence, "Fintech", in the context of the digital economy project supported by the World Bank in Africa, refers to the integration of innovative financial technology solutions within the healthcare sector, aiming to optimize financial management, improve decision-making, and streamline financial transactions through the application of digital tools and platforms. It involves leveraging technology to enhance financial efficiency, transparency, and accessibility in healthcare services. Principal Component Analysis (PCA) is used to identify the key requirements of the digital economy within a digital environment.

The rest of this research paper is planned as follows. After presenting an overview of the digital economy in terms of its social, economic, and environmental dimensions in Section 1, Section 2 presents the research methodology. Section 3 explores the digital economy of healthcare services in Africa led by the World Bank. Section 4 concludes the paper.

2. Materials and Methods

This paper aims to assess the current state of digital-economy development through virtual organized projects. It selects key indicators from three dimensions: economy, social, and environment. The Principal Component Analysis (PCA) method is used to evaluate the quality of the digital economy at two stages of digital transformation, namely the investment and development phases. Additionally, the paper explores the interactions that exist between two phases of the World Bank project. The PCA analysis is conducted on relevant factors derived from World Bank projects in Africa, specifically in the context of healthcare services. The analysis is implemented and performed using the R software.

The primary goal of the World Bank in Africa is to digitize healthcare services. As such, the World Bank develops two types of projects, Investment Project Financing (IN) and Development Policy Loan (AD). It aims to ensure sustainable development through financial investment with blockchain solution (IN) and emphasizes development lending (AD). In this paper, we utilize PCA to illustrate the requirements for AD and IN in the digital transformation process, focusing on three sustainability perspectives: economic (such as costs for technology investment, including software and hardware, and costs for employee training), environmental (including ratings for environmental satisfaction, job satisfaction, and job involvement), and social (evaluating work-life balance and performance ratings). Therefore, a total of ten observed variables were considered, covering 700 categories of healthcare services across Africa.

Table 1 suggests that there are significant differences between actual and forecasted values for various project-related costs and employee-related factors. Here are some observations from the table:

- Project Type: There are two types of projects (F). The World Bank is helping African countries develop their social services by supporting them in digitizing theses services. As such, it develops two types of projects, IN and AD, which aim to guarantee sustainable development and poverty reduction. Most of the investments, with 96.43% of the total projects, relate to the financing of investment projects (IN). However, this shows that certain activities within the projects are in the digitalization phase, while others are in the digital transformation stage.
- Further details about these project types are not available in the table.
- Project Cost: The average project cost is 137,714,386 with a standard deviation of 836,417,787. The *p*-value is less than 2.2×10^{16}, indicating a significant difference between actual and forecasted project costs.
- Hardware, Software, and Total Costs: Similar to project costs, the average costs for hardware, software, and total costs are provided along with their respective standard deviations. The *p*-values for all these variables are less than 2.2×10^{16}, suggesting significant differences between actual and forecasted costs.
- Training Costs: The average training cost is 3,665,771 with a standard deviation of 13,365,251. The *p*-value is less than 2.2×10^{16}, indicating a significant difference between actual and forecasted training costs.

Table 1. Descriptive analysis.

	Var. Type	Mean	Sd	*p*-Value	Obs.
Project type	F	-	-	-	2
DN	N	-	-	-	-
Project cost	N	137,714,386	836,417,787	$<2.2 \times 10^{16}$	700
Hardware	N	5,819,286	37,466,464	$<2.2 \times 10^{16}$	700
Software	N	67,652,629	110,124,388	$<2.2 \times 10^{16}$	700
Total costs	N	72,764,771	112,045,596	$<2.2 \times 10^{16}$	700
Training costs	N	3,665,771	13,365,251	$<2.2 \times 10^{16}$	700
Environment satisfaction	N	2.7085714	1.1261926	$<2.2 \times 10^{16}$	700
Job satisfaction	N	2.7314286	1.1140336	$<2.2 \times 10^{16}$	700
Job involvement	N	2.7171429	0.7216202	$<2.2 \times 10^{16}$	700
Work life balance	N	2.7485714	0.7273018	$<2.2 \times 10^{16}$	700
Performance rating	N	3.1628571	0.3694993	$<2.2 \times 10^{16}$	700

Note: N = Number, F = Factor.

3. Results

This paper investigates three models that are in line with the two project categories AD and IN. First, PCA considers both categories of projects to analyze the trends of each variable (project cost, hardware, software, training cost, total cost of hardware and software, environment satisfaction, job satisfaction, job involvement, work-life balance, performance rating).

3.1. Model 1: AD and IN

Figure 2 presents a visualization of the ten variables, with some individuals showing a significantly positive coordinate on the axis, while others are represented by a notably negative coordinate (to the left of the graph). This graphical representation highlights the variables that are most effectively captured on the map and contribute to the construction of the Principal Component Analysis (PCA) plan. The figure reveals that the PCA plan is primarily influenced by job satisfaction, training costs, performance rating, and variables with high values, such as software and total costs. Additionally, project cost, work-life balance, and hardware demonstrate a strong correlation.

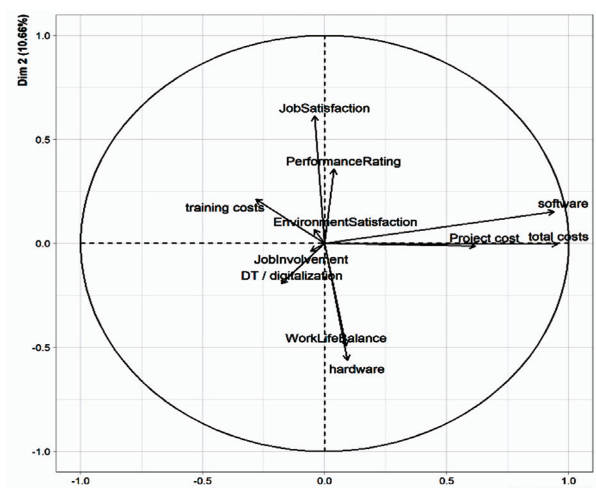

Figure 2. Variables' factor map. Note: This biplot provides information about which variables provide the largest contribution to the component: (1) A high absolute value (towards 1 or −1) indicates that the variable strongly influences the component. Values close to 0 indicate that the variable has a weak influence on the component. (2) The sign of a loading (+ or −) indicates whether a variable and a principal component are positively or negatively correlated.

3.2. Model 2: AD without IN

Based on an estimation of the optimal number of axes for interpretation, it is suggested that one focus the analysis on describing the first axis. Indeed, it exhibits a higher amount of inertia compared to what would be expected from random distributions at the 0.95-quintile level (34.6% versus 26.82%), as depicted in Figure 3.

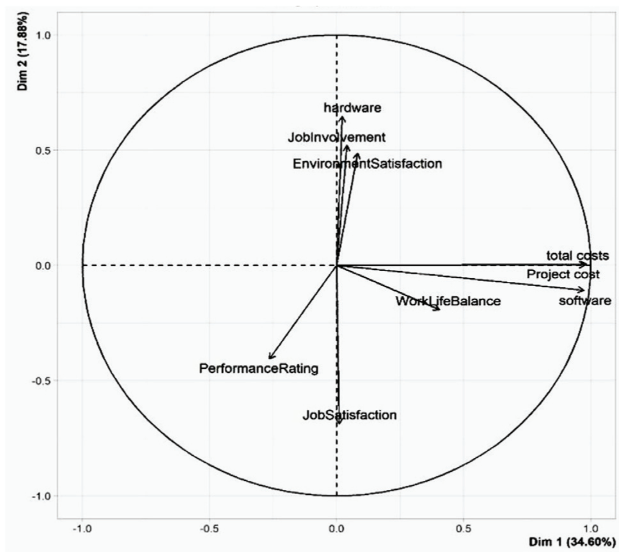

Figure 3. Variables' factor map. Note: This biplot shows the most correlated variables for Development Policy Loan (AD) projects. The objective of the loadings in the biplot is to retrieve more insights on the variation of the features and separability of the classes in relation to the principal component.

In this particular model, the most significant investments are directed towards software and hardware. This emphasis on software and hardware can be attributed to the total costs and project cost dedicated to the development and maintenance of the technology infrastructure.

Note that project-cost, software, and total-cost variables exhibit high correlations with this dimension, with respective correlation coefficients of 0.98, 0.97, and 0.98. These variables can effectively summarize the characteristics of dimension one, as illustrated in Table 2. By focusing on variables such as total costs, project costs, and software, the fintech scope within healthcare services can effectively address cost challenges, optimize project expenditures, and harness the power of technology to deliver innovative and efficient healthcare solutions. Within AD, African healthcare services are, at a digital stage, employing cost-effective strategies, managing project budgets, and leveraging cutting-edge software. The work-life balance came in the second step (showing a correlation coefficient of 0.41), suggesting that there is a tendency for it to be positively associated with economic variables. This implies that prioritizing and promoting a healthy work-life balance for healthcare professionals can have beneficial implications for managing project budgets, optimizing costs, and harnessing the potential of technology within healthcare services.

Table 2. Correlation matrix retrieved from dimension 1 of factor map.

	Correlation	*p*-Value
Total costs	0.9834795	1.414754×10^{18}
Project cost	0.9780937	3.536449×10^{17}
Software	0.9733558	3.284126×10^{16}
Work-life Balance	0.4046043	4.483796×10^{2}

3.3. Model 3: IN witout AD

In this particular model, the focus is on IN projects, where investments of the World Bank are allocated towards technology and employees. This model is reflected in the hierarchical classification of three distinct clusters, as illustrated in Figure 4.

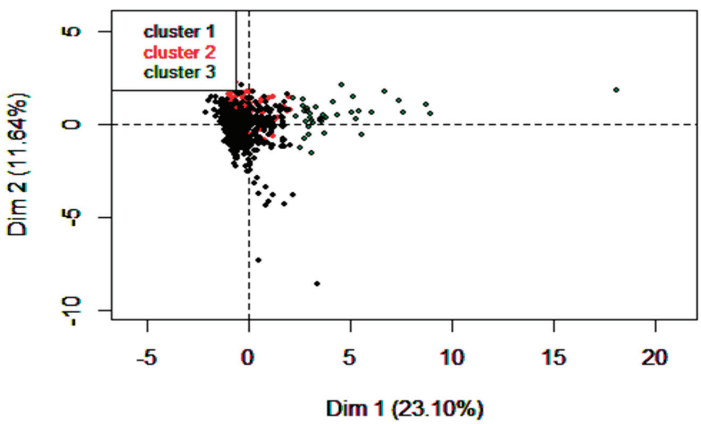

Figure 4. Ascending hierarchical classification of variables. Note: These clusters provide a comprehensive understanding of the World Bank's investment strategy in IN projects, emphasizing the importance of technology, employee training, performance evaluation, and well-being of employees in achieving the desired outcomes and impact in the healthcare services sector.

The first cluster represents the convergence of human capital and technology infrastructure. It includes variables such as training costs and hardware. This cluster underscores the importance of investing in employees' skills and competencies, as well as providing their work in the digital economy. It highlights the significance of empowering employees with the right tools and knowledge to enhance their performance.

The cluster 2 is characterized by the Performance Rating variable. This variable indicates that the World Bank evaluates the outcomes and results of its investments in the healthcare services sector. It serves as a measure of effectiveness and allows the World Bank to track its efforts and assess the impact of its initiatives in improving healthcare services. This cluster reflects the organization's commitment to monitoring and evaluating the success of its investments.

The third cluster comprises variables such as software, total costs, and project cost. It emphasizes the World Bank's focus on equipping healthcare services employees with appropriate work tools and promoting their well-being. The inclusion of software, total-cost, and project-cost variables highlights the organization's commitment to enhancing the digital infrastructure and supporting employees' effectiveness and satisfaction in their work.

4. Discussion and Conclusions

By considering the implications of variables such as job satisfaction, training costs, performance rating, and software and total costs, the fintech scope in healthcare services can thrive within the digital economy. Prioritizing employee satisfaction, investing in training programs, establishing a performance-driven culture, and optimizing software and costs will enable fintech professionals to develop innovative solutions that enhance healthcare delivery, improve patient outcomes, and contribute to the overall digital transformation of the healthcare industry.

The findings in Figure 2 demonstrate that within the fintech scope of the project, job satisfaction emerges as a crucial element, emphasizing the importance of creating a supportive work environment and investing in employee training to drive engagement and the successful implementation of fintech tools. The effective management of training costs ensures that healthcare professionals in Africa possess the necessary skills to leverage and adapt to fintech advancements. A robust performance evaluation system helps measure the impact of fintech solutions and identify areas for improvement. Moreover, optimizing software utilization and managing total costs contribute to a cost-effective implementation and efficient resource allocation. By considering these implications, the World Bank's project can leverage fintech to enhance healthcare service delivery in Africa, fostering improved patient care and contributing to the overall development of the healthcare sector.

As the models 2 and 3 reveal strong dependencies with economic perspectives, the correlation analyses attempt to emphasize the dependency degree between variables within the two types of Word Bank projects AD and IN. Figure 5a,b shows a strong correlation among four variables in terms of social and environmental dimensions of the digital economy in Africa, which is stronger in relation to IN. This situation is mostly explained by the investment of the World Bank in employee training. Additionally, the analyses reveal that the performance rating is less correlated than other variables, which is explained by the fact that the project is still undergoing the digitalization process (see Figure 5c,b).

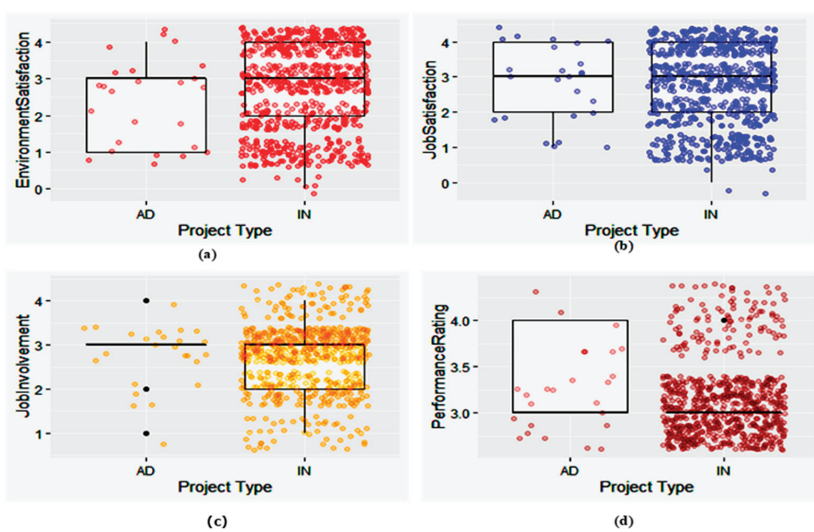

Figure 5. Correlation graphs for AD and IN projects among principle components variables.

The primary objectives of this study are twofold: first, to propose and test an integrated model that enhances and improves the understanding and evaluation of the digital economy in practical settings; and second, to explore the phenomenon of digital transformation and digitalization in Africa within the context of an international corporation under a fintech scope. Additionally, the study aims to extract valuable lessons from empirical findings that can inform and enhance digital economy practices.

To achieve these objectives, the models have identified several key lessons. Firstly, the results emphasize the importance of focusing the evaluation of digital-economy projects on social and environmental aspects, taking into account the interests of stakeholders who have a close involvement in the project. This approach ensures that sustainability considerations are effectively incorporated into the evaluation process.

Secondly, the results highlight the need to differentiate between projects based on their unique goals, objectives, and constraints before evaluating digital transformation and digitalization. By recognizing the specific characteristics of each project, the evaluation process becomes more meaningful and enables a deeper understanding of the implications and outcomes of the digital-economy initiatives.

Finally, practitioners can improve their digital-economy practices and make informed decisions regarding digital transformation and digitalization initiatives under fintech solution in healthcare services.

Furthermore, fintech innovations, such as blockchain-based platforms for secure transactions or digital payment systems, can contribute to greater transparency, efficiency, and accountability within investment projects. These advancements can streamline financial operations and contribute to more reliable performance-rating assessments.

The use of technology enables improved decision-making, ensuring that projects align with social sustainability goals by prioritizing work-life balance and job satisfaction among their workforces. This can be achieved by leveraging digital tools and platforms that facilitate flexible work arrangements, remote collaboration, and employee engagement. By providing a supportive work environment that promotes work-life balance, organizations can enhance employee well-being, job satisfaction, and overall productivity. By prioritizing work-environment satisfaction and providing employees with the necessary tools and resources, organizations can foster a sense of responsibility and engagement in environmental sustainability efforts.

By embracing financial fintech within the digital economy, African organizations can enhance their competitive edge, drive sustainable growth, and navigate the digital landscape more confidently while addressing the economic, social, and environmental dimensions of sustainability. By integrating financial fintech insights, organizations can leverage the power of technology to optimize financial management, improve decision-making, and mitigate risks in investment projects. This integration enables a more comprehensive evaluation framework that encompasses both financial and technological aspects, enhancing the overall understanding and effectiveness of the digital economy in the African context.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Archived dataset analyzed from World Bank project on healthcare services in Africa is available at: https://www.kaggle.com/datasets/soniakh89/fintech-health-service-from-wb-in-africa, accessed on 1 March 2023.

Acknowledgments: The author acknowledges the technical contribution of Naima BENKHIDER (ORCID ID 0000-0001-6518-5163), who helped with technical support related to data visualization.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Wang, W.; Wang, Y.; Zhang, Y.; Ma, J. Spillover of workplace IT satisfaction onto job satisfaction: The roles of job fit and professional fit. *Int. J. Inf. Manag.* **2020**, *50*, 341–352. [CrossRef]
2. Ang, J.; Koh, S. Exploring the relationships between user information satisfaction and job satisfaction. *Int. J. Inf. Manag.* **1997**, *17*, 169–177. [CrossRef]

3. Elias, S.; Barney, C. Age as a moderator of attitude towards technology in the workplace: Work motivation and overall job satisfaction. *Behav. Inf. Technol.* **2012**, *31*, 453–467. [CrossRef]
4. Martínez-Caroa, E.; Cegarra-Navarrob, J.G.; Alfonso-Ruiz, F.J. Digital technologies and firm performance: The role of digital organisational culture. *Technol. Forecast. Soc. Chang.* **2020**, *154*, 119962. [CrossRef]
5. McCloskey, D.W. Finding Work-Life Balance in a Digital Age: An Exploratory Study of Boundary Flexibility and Permeability. *Inf. Resour. Manag. J.* **2016**, *29*, 53–70. [CrossRef]
6. Philippon, T. The Fintech Opportunity. In *NBER Working Papers 22476*; National Bureau of Economic Research, Inc.: Cambridge, MA, USA, 2016. [CrossRef]
7. Hanaysha, J. Examining the Effects of Employee Empowerment, Teamwork, and Employee Training on Organizational Commitment. *Procedia Soc. Behav. Sci.* **2016**, *229*, 298–306. [CrossRef]
8. Dittes, S.; Richter, S.; Richter, A.; Smolnik, S. Toward the workplace of the future: How organizations can facilitate digital work. *Bus. Horiz.* **2019**, *62*, 649–661. [CrossRef]
9. Pagani, M.; Pardo, C. The impact of digital technology on relationships in a business network. *Ind. Mark. Manag.* **2017**, *67*, 185–192. [CrossRef]
10. Lee, H.; Choi, H.; Lee, J.; Min, J.; Lee, H. Impact of IT Investment on Firm Performance Based on Technology IT Architecture. *Procedia Comput. Sci.* **2016**, *91*, 652–661. [CrossRef]
11. Vanduhe, V.; Nat, M.; Hasan, F. Continuance Intentions to Use Gamification for Training in Higher Education: Integrating the Technology Acceptance Model (TAM), Social Motivation, and Task Technology Fit (TTF). *IEEE Access* **2020**, *8*, 21473–21484. [CrossRef]
12. Nam, T. Technology use and work-life balance. *Appl. Res. Qual. Life* **2014**, *9*, 1017–1040. [CrossRef]

FinTech

Article

Quantifying the Economic and Financial Viability of NB-IoT and LoRaWAN Technologies: A Comprehensive Life Cycle Cost Analysis Using Pragmatic Computational Tools

Bernhard Koelmel [1,2,3,*], Max Borsch [4], Rebecca Bulander [1], Lukas Waidelich [1], Tanja Brugger [1], Ansgar Kuehn [1], Matthias Weyer [1], Luc Schmerber [5] and Michael Krutwig [6]

1 School of Engineering, Industrial Engineering, Pforzheim University, 75175 Pforzheim, Germany; rebecca.bulander@hs-pforzheim.de (R.B.); lukas.waidelich@hs-pforzheim.de (L.W.); tanja.brugger@hs-pforzheim.de (T.B.); ansgar.kuehn@hs-pforzheim.de (A.K.); matthias.weyer@hs-pforzheim.de (M.W.)
2 ISM International School of Management, Chair Technology Management, 75007 Paris, France
3 McCoy College of Business, Texas State University, San Marcos, TX 78666, USA
4 Wirtschaftsförderung Nordschwarzwald, 75172 Pforzheim, Germany; max.borsch@nordschwarzwald.de
5 Luc Schmerber, 76199 Karlsruhe, Germany; luc@lucschmerber.com
6 Krumedia GmbH, 76199 Karlsruhe, Germany; michael.krutwig@krumedia.com
* Correspondence: bernhard.koelmel@hs-pforzheim.de or bkoelmel@txstate.edu

Abstract: This paper focuses on quantifying the economic and financial viability of NB-IoT and LoRaWAN technologies, two low-power wide-area network (LPWAN) technologies with unique characteristics that make them suitable for IoT applications. The purpose of this study is to propose a "pragmatic" artifact for performing life cycle cost analysis and demonstrate its application to these technologies. The methodology uses pragmatic computational tools to facilitate the analysis and considers all relevant economic and financial factors, such as operating costs, equipment costs, and revenue potential. The main finding of this study is that Narrow Band-Internet of Things (NB-IoT) and Long Range Wide Area Network (LoRaWAN) technologies have different cost structures and revenue potentials, which may affect their economic and financial viability for different IoT applications. Ultimately, the study concludes that a comprehensive life cycle cost analysis is critical to making informed decisions about technology adoption, and that the proposed methodology can be applied to other IoT technologies to gain insight into their economic and financial viability.

Keywords: financial viability; life cycle cost analysis; LPWAN; pragmatic computational tools; design science research; data-driven decision making

Citation: Koelmel, B.; Borsch, M.; Bulander, R.; Waidelich, L.; Brugger, T.; Kuehn, A.; Weyer, M.; Schmerber, L.; Krutwig, M. Quantifying the Economic and Financial Viability of NB-IoT and LoRaWAN Technologies: A Comprehensive Life Cycle Cost Analysis Using Pragmatic Computational Tools. *FinTech* **2023**, *2*, 510–526. https://doi.org/10.3390/fintech2030029

Academic Editor: David Roubaud

Received: 1 June 2023
Revised: 8 July 2023
Accepted: 15 July 2023
Published: 20 July 2023

1. Introduction

The economic and financial viability of emerging technologies plays a crucial role in the decision-making process for their adoption and implementation. This scientific paper aims to explore the economic and financial viability of Narrow Band-Internet of Things (NB-IoT) and Long Range Wide Area Network (LoRaWAN) technologies for different Internet of Things (IoT) applications within I4.0/I5.0 and Smart City environments. The research question driving this study is: "What is the economic and financial viability of NB-IoT and LoRaWAN technologies for different IoT applications, as assessed through a comprehensive life cycle cost analysis?"

Our hypothesis posits that the economic and financial viability of NB-IoT and LoRaWAN technologies varies based on the specific IoT applications, owing to differences in cost structures and revenue potentials. To test this hypothesis, a comprehensive life cycle cost analysis will be conducted with the help of design science research, taking into account various economic and financial factors, such as operating costs, equipment costs, and revenue potential.

The findings of this research will provide valuable insights into the total cost of ownership of NB-IoT and LoRaWAN technologies, identifying potential areas for cost savings, and facilitating informed decision-making processes regarding their adoption and implementation in diverse IoT applications. Industry 4.0 and the emerging concept of Industry 5.0 have ushered in a new era of technological advancements that are reshaping industries and societies around the world [1]. These transformative technologies, collectively referred to as I4.0/I5.0 technologies, encompass a wide range of digital innovations such as the Internet of Things (IoT), cloud computing, artificial intelligence (AI), robotics, and automation. These technologies hold great promise for revolutionizing various sectors, including manufacturing, healthcare, transportation, and smart city/urban development.

The benefits of I4.0/I5.0 technologies are significant and varied. They enable increased efficiency, productivity, and quality in manufacturing processes, resulting in cost reductions, improved product customization, and faster time to market. In an economic context, these technologies form the backbone of improvement initiatives, enabling stakeholders to optimize resource utilization, improve service delivery, etc.

The adoption of I4.0/I5.0 technologies brings forth socio-economic challenges, including the digital divide, inequality of access, and workforce transformation. Interoperability presents a challenge that necessitates the establishment of standards and protocols for seamless communication and integration among diverse technologies and stakeholders [2]. Privacy and data security are also paramount concerns in the adoption of these technologies. The vast amount of data generated and exchanged raises issues of privacy, data ownership, and cybersecurity. Protecting privacy and implementing robust security measures are essential for building trust.

The adoption of I4.0/I5.0 technologies presents unique challenges, as noted above, but also in terms of financial viability [3], including lifecycle costs that include both upfront investments and operational expenses. This article focuses on evaluating the economic and financial feasibility of NB-IoT and LoRaWAN technologies in light of the challenges associated with the adoption of emerging technologies. This study aims to provide valuable insights into the viability of these technologies by assessing their potential benefits and examining the associated costs. Understanding the economic and financial aspects is crucial for organizations and stakeholders to effectively leverage NB-IoT and LoRaWAN, considering resource allocation and investments. These costs include the cost of implementation, reskilling, and training the workforce to adapt to the new technologies, and developing the infrastructure to support their integration. The lifecycle costs of communication technologies, in particular, are an important area, as they tie up capital over a long period of time. Financial analysis, including life cycle costing, is essential to ensure a comprehensive assessment of the costs and benefits associated with the adoption of a new technology [4]. This paper aims to quantify the economic and financial viability of two promising IoT technologies, NB-IoT and LoRaWAN [5], through a comprehensive life cycle cost analysis using pragmatic computational tools.

The life cycle cost analysis assesses the full range of costs and benefits associated with the deployment of NB-IoT and LoRaWAN technologies, including not only the upfront costs but also the costs associated with operations, maintenance, and disposal [6]. The analysis will provide decision-makers with an understanding of the total cost of ownership of these technologies and identify potential areas for cost savings [7].

Furthermore, this paper argues that financial analysis should accompany technology decisions to ensure that both aspects are addressed for the successful adoption of innovative technologies. In the context of the "not-invented-here" syndrome [8], which hinders good decisions about innovative technologies, a thorough financial analysis becomes critical. The syndrome can lead to the adoption of innovative technologies without proper financial analysis, resulting in inefficient use of resources, high costs, and ultimately, technology adoption failure.

Therefore, this paper proposes a methodology for conducting a life cycle cost analysis of NB-IoT and LoRaWAN technologies to quantify their economic and financial viability [9].

The methodology uses pragmatic computational tools to facilitate the analysis and ensure that it is comprehensive and efficient.

In conclusion, this paper argues that financial analysis is essential for technology adoption decisions, and a comprehensive life cycle cost analysis can facilitate the decision-making process. Furthermore, the proposed methodology can be applied to other IoT technologies to provide valuable insights into their economic and financial viability. Ultimately, this can enable organizations to make informed technology adoption decisions, maximize the benefits of innovative technologies, and minimize financial risks [10].

2. Design Science Research as Scientific Approach

As a research method we employ design science research in developing the artifact "Life Cycle Cost Analysis Using Pragmatic Computational Tools." Design science research as depicted in Figure 1 is a research paradigm that aims to produce innovative solutions to practical problems through the creation of new artifacts, such as models, methods, and tools [11–14]. The relevance cycle in Design Science Research ensures that the designed artifacts address real-world problems, while the rigor cycle ensures the scientific validity and quality of the research process and outcomes. The process involves identifying a problem, developing a solution, and evaluating its effectiveness. The use of design science research in information systems is increasingly popular due to its ability to produce practical and relevant solutions that can be implemented in real-world settings [15].

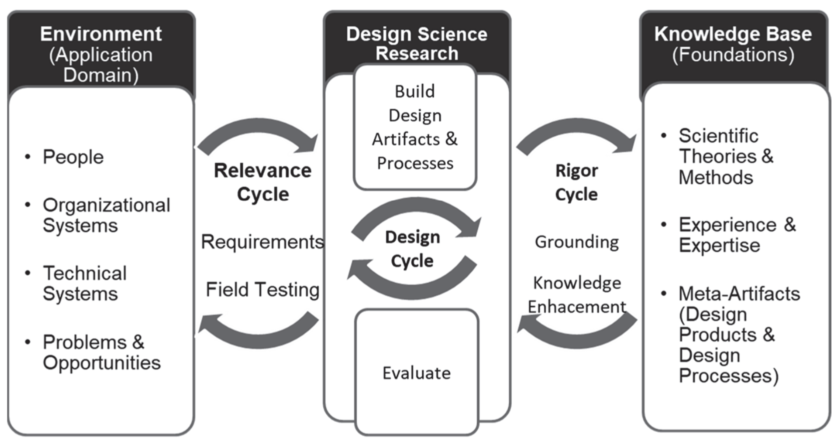

Figure 1. Research Methodology: Design science research; Own illustration, based on [14].

In this context, our artifact seeks to fill a significant research gap by providing a comprehensive life cycle cost analysis tool for IoT technologies such as NB-IoT and LoRaWAN.

Design Science Research (DSR) or design-oriented research is a scientific method that aims to develop practice-oriented solutions to problems or challenges. Design Science Research (DSR) holds significant practical relevance in addressing real-world problems and driving innovation in various domains. Unlike traditional research methods that focus primarily on observing and explaining phenomena, DSR emphasizes the creation of artifacts or solutions that can directly address practical challenges. This practical orientation is crucial, as it allows researchers to bridge the gap between theory and practice, translating theoretical knowledge into tangible outcomes that can be implemented and evaluated. It aims to create new knowledge by developing artifacts, such as models, methods, and tools, that can be applied in real-world settings [16]. The central tenet of DSR is that the development of a novel artifact should be grounded in a problem domain and informed by an understanding of the state of the art in the relevant field. The Design Science Research (DSR) process as shown in Figure 2 encompasses several key steps to address practical problems and develop innovative artifacts [13].

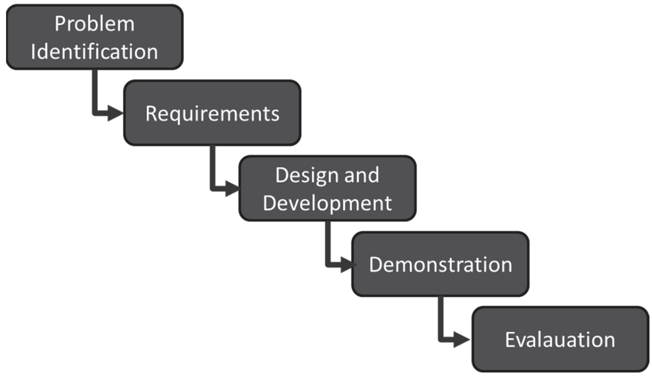

Figure 2. Design Science Research Process; Own illustration, based on [13].

The first step is problem identification, where researchers identify a practical problem grounded in a specific context and informed by the existing literature and practice. Once the problem is identified, the design and development phase begins, leveraging existing knowledge and theory to create an artifact that effectively addresses the identified problem. This phase may involve the creation of new theories or adapting existing theories to a new context.

The subsequent phase focuses on demonstrating the usefulness of the artifact. Researchers showcase how the artifact can be utilized to solve the practical problem identified earlier. This can be achieved through testing in simulated or real-world environments, highlighting how the artifact surpasses existing solutions or practices.

Finally, the effectiveness of the artifact is evaluated. This evaluation employs quantitative or qualitative methods to assess the impact of the artifact on the problem domain. The evaluation aims to provide evidence of the artifact's usefulness while offering insights into its limitations and potential for further development.

By following this structured process, researchers can systematically identify, design, develop, demonstrate, and evaluate artifacts, ensuring their practical applicability and advancing their knowledge in the respective field. This approach enables the generation of valuable insights into the economic, societal, and technological aspects of the artifacts, guiding decision-making processes and promoting continuous improvement.

DSR has been increasingly applied in the field of information systems and has proven to be effective in producing practical solutions to complex problems. This approach has been used to develop a wide range of artifacts, including software systems, decision support tools, and frameworks for guiding practice. DSR differs from traditional research approaches in that it places greater emphasis on the practical relevance of the research results. While traditional research may focus on developing theoretical models and testing them in a controlled setting, DSR seeks to develop solutions that can be implemented in real-world settings and have a measurable impact on practice.

3. State of the Art

3.1. IoT Communication Technologies for the Internet of Things

Low-power wide area networks (LPWANs) have become a popular communication technology for the Internet of Things (IoT) due to their low power consumption and wide coverage area. Two of the most popular LPWAN technologies are LoRaWAN and NB-IoT [17–19].

LoRaWAN (Long Range Wide Area Network) is a wireless communication protocol based on the LoRa modulation technique. LoRaWAN has the ability to communicate over long distances, typically up to 10 km in rural areas and up to 2 km in urban areas. It operates in unlicensed frequency bands, which makes it a cost-effective solution. The LoRaWAN protocol is open-source and has a large community of developers. LoRaWAN is primarily used for battery-powered devices that require low data rates, such as environmental monitoring sensors, smart parking systems, and asset tracking [20,21].

NB-IoT (Narrowband IoT) is a cellular technology designed for IoT devices within 5G cellular networks. It is a standardization effort by the 3GPP and is based on the LTE (Long-Term Evolution) technology. The NB-IoT uses a narrow bandwidth of 200 kHz and can operate in licensed or unlicensed frequency bands. The main advantage of the NB-IoT is its ability to operate in areas with weak signal strengths and in underground locations. It can also support high data rates and has a low latency, making it suitable for applications that require real-time data, such as industrial automation and smart cities [22,23]. Table 1 summarizes the technical properties of LoRaWAN and NB-IoT.

Table 1. Selected properties of LoRaWAN vs. NB-IoT [20–24].

Property	LoRaWAN	NB-IoT
Modulation Technique	LoRa (Chirp Spread Spectrum (CSS))	QPSK (Orthogonal Frequency-Division Multiplexing (OFDM))
Frequency Range	868 MHz, 915 MHz, and 433 MHz	700 MHz, 800 MHz, 900 MHz, and 1.9 GHz
Frequency Bands	Unlicensed	Licensed and unlicensed
Network Topology	Star, Mesh, and Hybrid	Star and Point-to-Point
Coverage Area	10 km (rural), 2 km (urban)	10 km (rural), 1 km (urban)
Battery Life	Up to 10 years	Up to 15 years
Data Rate	0.3–50 kbps	50–250 kbps
Security	AES-128 bit encryption	AES-128 bit encryption
Deployment	Requires a gateway	Cellular network required
Scalability	Can support thousands of nodes	Can support thousands of nodes
Latency	Seconds to minutes	Sub-seconds
Use Cases	Environmental monitoring, smart parking, asset tracking	Industrial automation, smart cities, security and surveillance

One of the main advantages of LoRaWAN is its long-range communication capabilities, which make it suitable for use in cases that require devices to be deployed in remote areas, such as environmental monitoring or asset tracking. Additionally, the unlicensed frequency bands used by LoRaWAN make it a cost-effective solution, as no licensing fees are required. However, the trade-off for this long-range communication is a low data rate and higher latency, which may not be suitable for applications that require real-time data [24].

On the other hand, NB-IoT offers high data rates, low latency, and reliable connectivity in areas with weak signal strengths. Its cellular network infrastructure also provides a level of security and reliability that may not be possible with LoRaWAN. However, the licensing fees and higher deployment costs associated with the NB-IoT may make it less cost-effective than the LoRaWAN for certain applications [24].

In conclusion, both the LoRaWAN and NB-IoT have their advantages and limitations, and the choice between them will depend on the specific requirements of the application. The LoRaWAN is best suited for applications that require long-range communication and low data rates, while NB-IoT is ideal for applications that require real-time data and operate in areas with weak signal strength.

3.2. Assessing Financial Viability of Innovative Technologies

Life cycle costing (LCC) is a method for calculating the total cost of ownership of a product or service over its entire life cycle, from design and development to disposal. It is widely used in the field of advanced technologies, where the high initial cost and long life cycle of products require a comprehensive analysis of the total cost of ownership [25,26].

One of the key benefits of LCC is that it provides a comprehensive view of the costs associated with a product or service. This includes not only the initial purchase price but also the costs of maintenance, repair, and replacement over the life of the product. LCC also takes into account the impact of factors such as energy consumption, environmental impact, and regulatory compliance.

Terotechnology is a related concept that refers to the application of engineering and management principles to optimize the life cycle costs of physical assets. It is based on the idea that the cost of ownership of an asset is not just the initial purchase price, but also the cost of operating, maintaining, and disposing of the asset over its entire life cycle. Terotechnology considers the technical, economic, and social factors that affect the performance of an asset and seeks to optimize the cost-effectiveness of the asset throughout its life cycle [27].

While terotechnology has its merits, LCC is more pragmatic and has a better chance to be used in practice. This is because LCC is a more straightforward and easily understandable approach for calculating the total cost of ownership of a product or service. It is also more widely accepted and used in industry and government, with many organizations requiring LCC analyses as part of their procurement and purchasing processes.

One of the challenges of LCC is the need to gather accurate and reliable data on the costs associated with a product or service over its entire life cycle. This requires a detailed understanding of the product's design, manufacturing process, and operating characteristics, as well as the costs of maintenance, repair, and replacement over time. It also requires an understanding of the external factors that can affect the cost of ownership, such as changes in regulations, energy prices, and environmental policies [25,26].

To overcome these challenges, organizations can use a variety of tools and techniques to gather and analyze data on the life cycle costs of their products or services. These include cost accounting systems, enterprise resource planning (ERP) software, and specialized LCC software tools. These tools can help organizations to identify areas where costs can be reduced and to make more informed decisions about the design, development, and procurement of products and services [26].

Overall, LCC is a valuable approach for assessing the total cost of ownership of advanced technologies. By taking a comprehensive view of the costs associated with a product or service over its entire life cycle, LCC can help organizations to make more informed decisions about the design, development, and procurement of products and services. While terotechnology has its merits, LCC is more pragmatic and has a better chance to be used in practice [25].

3.3. Financial Viability of Selected IoT Communication Technologies

Life cycle costing is a crucial tool for making informed decisions about the economic feasibility of IoT communication technologies. IoT systems are typically composed of numerous devices with diverse functionalities and connectivity options, and estimating the total cost of ownership over the system's life cycle can be complex. Life cycle costing involves evaluating the costs of a system over its entire lifespan, from procurement and deployment to maintenance and disposal, taking into account all relevant cost components. By understanding the full cost profile of a technology, businesses can make more informed decisions about which IoT communication technologies are financially viable and sustainable in the long term. Financial viability is a critical factor in determining the feasibility and success of complex and future-oriented technologies, such as LoRaWAN and NB-IoT. These technologies, with their potential to revolutionize various industries through the Internet of Things (IoT), require a comprehensive evaluation of costs to make informed decisions regarding their adoption and implementation.

One-time costs, including the purchase of hardware and software, play a significant role in assessing the financial viability of these technologies. The initial investment required to acquire the necessary infrastructure, devices, and sensors can be substantial. It is crucial to consider the costs associated with procuring the hardware and software components, as well as any additional customization or integration required for specific applications. Moreover, ongoing maintenance costs should be factored in, as these technologies often require regular updates, bug fixes, and security patches to ensure optimal performance and address emerging challenges.

Recurring costs are equally important to consider when assessing the financial viability of LoRaWAN and NB-IoT. Communication costs form a significant component, as these technologies rely on wireless connectivity to transmit data between devices and platforms. The expenses incurred by the data plans, network subscriptions, and infrastructure maintenance should be evaluated to determine the long-term financial implications of deploying and operating these technologies. Additionally, maintenance costs encompass not only routine maintenance, but also potential repairs or replacements of faulty components over the technology's lifespan. Properly accounting for these recurring expenses is essential for budgeting and ensuring sustained operations.

Operating costs, including energy costs, are another critical aspect of financial viability. LoRaWAN and NB-IoT technologies often involve numerous devices and sensors spread across a network, which consume power to function. The energy consumption associated with these technologies can be substantial, particularly in large-scale deployments. Assessing the energy requirements and estimating the associated costs are vital for understanding the ongoing operational expenses and optimizing energy efficiency.

In addition to the direct costs, the lifelong learning of employees must be considered. With the continuous advancement of technology, it is crucial to ensure that the workforce possesses the necessary skills and knowledge to effectively operate and maintain these complex systems. Investing in employee training, upskilling, and lifelong learning initiatives is crucial to keep pace with the evolving technological landscape. These costs, both in terms of time and resources, need to be factored into the financial evaluation of LoRaWAN and NB-IoT technologies.

It is important to note that the financial viability assessments for complex and future-oriented technologies should not be limited to individual cost components. The holistic evaluation of all costs, including one-time, recurring, and indirect costs, provides a comprehensive understanding of the long-term financial implications. By considering the complete cost spectrum, decision-makers can gain insights into the total cost of ownership and make informed choices regarding the adoption and implementation of these technologies.

As LoRaWAN and NB-IoT technologies continue to evolve and find applications in various sectors, understanding their financial viability is crucial for organizations and stakeholders. Robust financial analysis, encompassing both direct and indirect costs, helps in evaluating the return on investment, optimizing resource allocation, and mitigating financial risks. Moreover, considering the financial viability of these technologies provides valuable insights into their long-term sustainability and enables strategic decision-making for their successful implementation in the ever-changing technological landscape.

Several studies have addressed the life cycle costs of various IoT communication technologies, including LoRaWAN and NB-IoT [28]. A big number of research works conclude that, among the plethora of low-power wide area network (LPWAN) technologies, the cost-effectiveness of IoT is not certain for IoT service solutions.

Another study conducted by the authors in 2020 [29] compared the applicability, including the costs, of LoRaWAN and NB-IoT for industrial applications.

However, it is worth noting that these studies have some limitations. For example, they focused primarily on specific applications and did not consider the impact of the size and scale of the IoT system on life cycle costs. The following table highlights important aspects of the financial viability of NB-IoT and LoRaWAN technologies for IoT applications. Table 2 provides a general overview and comparison of the financial viability aspects between NB-IoT and LoRaWAN technologies for IoT applications. It is important to conduct a comprehensive analysis specific to the use case and context to obtain accurate financial viability assessments.

Table 2. Important aspects of the financial viability of NB-IoT and LoRaWAN technologies for IoT applications.

Aspect	NB-IoT	LoRaWAN
Cost Structures	Higher initial equipment costs Lower operating costs Lower maintenance costs Higher subscription fees	Lower initial equipment costs Higher operating costs Higher maintenance costs Lower subscription fees
Revenue Potential	Limited revenue opportunities Lower potential for direct revenue	Diverse revenue opportunities Potential for direct and indirect revenue streams
Total Cost of Ownership	Relatively higher	Relatively lower
Cost Savings Opportunities	Potential for savings in equipment costs and subscription fees through economies of scale	Potential for savings in maintenance costs and subscription fees through
Decision-making Support	Requires careful evaluation of long-term operational costs and revenue potential long-term operational costs and	Requires consideration of application requirements, scalability, and specific needs

To address these limitations, a holistic approach to life cycle costing is needed, one that takes into account not only the economic but also the environmental and social impacts of IoT communication technologies. While there are some studies that have applied life cycle costing to IoT systems in general, there is currently a lack of a holistic artifact that specifically addresses the economic and financial viability of LoRaWAN and NB-IoT technologies. Such an artifact would provide a comprehensive framework for evaluating the life cycle costs of these technologies, taking into account all relevant cost components. Additionally, it would allow for the comparison of the economic and financial viability of LoRaWAN and NB-IoT across a range of applications and scenarios.

4. Approach to Constructing the Scientific Artifact "Pragmatic Computational Tool" for Calculating the Life Cycle Costs of IoT Devices Based on Design Science Research

The present study aimed to develop a pragmatic computational tool using a design science research (DSR) approach for calculating the life cycle costs of IoT devices based on relevant parameters such as hardware (sensors and gateways), software costs, server costs, personnel-related costs, etc. The first step in the DSR approach was problem identification, which highlighted the lack of a comprehensive tool for life cycle cost analysis of IoT devices. The proposed tool aimed to fill this gap by providing a user-friendly and reliable way to calculate the life cycle costs of IoT devices that could be customized as per users' needs [30].

The design phase involved creating a model of the proposed artifact, which was a computational tool capable of taking various inputs, such as hardware, software, server, and personnel-related costs, and generating outputs, including the total cost of ownership, return on investment, and payback period. The tool was designed to be customizable, which enabled users to tailor the inputs and outputs to suit their specific needs [13].

The next step involved the implementation of the model in the form of a working prototype. The prototype was evaluated to ensure that it met the needs of the stakeholders, which included IoT device manufacturers, system integrators, and end-users. The prototype was evaluated based on its functionality, usability, and usefulness using methods such as user testing, expert reviews, and other forms of feedback [13].

Based on the feedback received, the prototype was refined and improved through an iterative process until it met the needs of the stakeholders. This iterative process of refinement and improvement is a hallmark of DSR. The final product was reliable, user-friendly, and met the needs of the stakeholders [13].

The development of the tool involved problem identification, model creation, implementation, evaluation, refinement, and communication of the results. The proposed tool fills a significant research gap and provides a customizable, user-friendly, and reliable way to calculate the life cycle costs of IoT devices [13–15].

5. Constructing the Scientific Artifact "Pragmatic Computational Tool" for Calculating the Life Cycle Costs of IoT Devices

The "Pragmatic Computational Tool" for calculating the lifetime of IoT devices was built using Microsoft Excel and Google Sheets. These programs are commonly used tools for data analysis, financial modeling, and cost calculations. Decision-makers are likely to already have the necessary skills and familiarity, making the cost calculator more accessible and intuitive for them to use. By using a tool that decision-makers are already familiar with, the learning curve associated with adopting a new software or tool is minimized. The spreadsheet format lends itself well to organizing and structuring the various cost categories and tasks involved in calculating the lifecycle costs of IoT devices.

The tool was designed to provide a practical and user-friendly way to estimate the life cycle costs of IoT devices. The tool uses different categories of costs, including procurement costs, training and usage costs, maintenance costs, disposal costs, and external project costs, to estimate the total cost of ownership (TCO) of an IoT device over its lifetime.

To construct the tool, the first step was to create a worksheet in Excel with different categories of costs as column headers.

Formally, a section consists of a heading, a finer subdivision of the costs, fields for entries, and fields for the calculated costs (c.f. Figure 3).

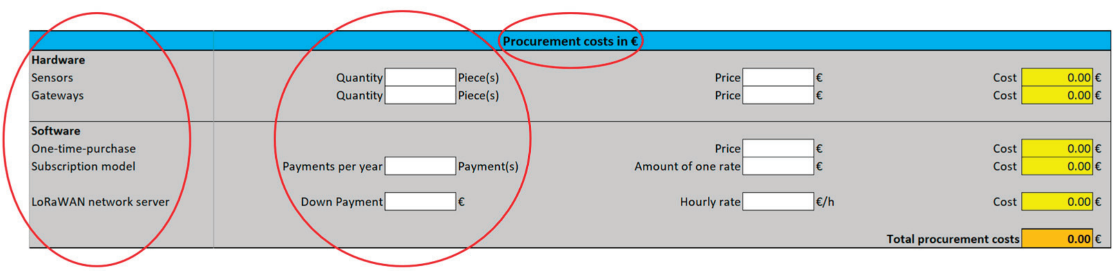

Figure 3. Design of the "Artifact" cost calculator; Own illustration.

The columns are labeled as procurement costs, training and usage costs, maintenance costs, disposal costs, and external project costs. The rows were labeled with specific tasks that are required to maintain and operate the IoT devices. For example, tasks such as hardware and software installation, training and support, device maintenance, disposal, and project management were included. Once the categories and tasks were identified, the next step was to assign cost values to each of them. The costs of a row are always summarized in a yellow field in the right column, and the cost of all lines in a section is displayed in an orange box (c.f. Figure 3).

Visually, the calculator is kept in unobtrusive gray, while the headings are highlighted in light blue. In addition, the color of individual fields varies depending on their meaning, ranging from to be filled in, via calculated automatically, to the sum above everything (c.f. Figure 4).

To make the tool even more user-friendly, symbols were used to represent the different types of costs. For example, a dollar sign (€) was used to indicate procurement costs, a wrench symbol was used to indicate maintenance costs, and a recycle symbol was used to indicate disposal costs (c.f. Figure 5).

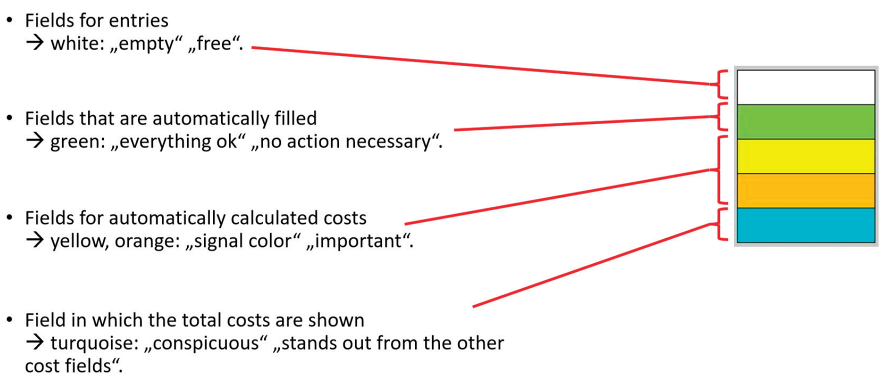

Figure 4. Color scheme of the "Artifact" cost calculator; Own illustration.

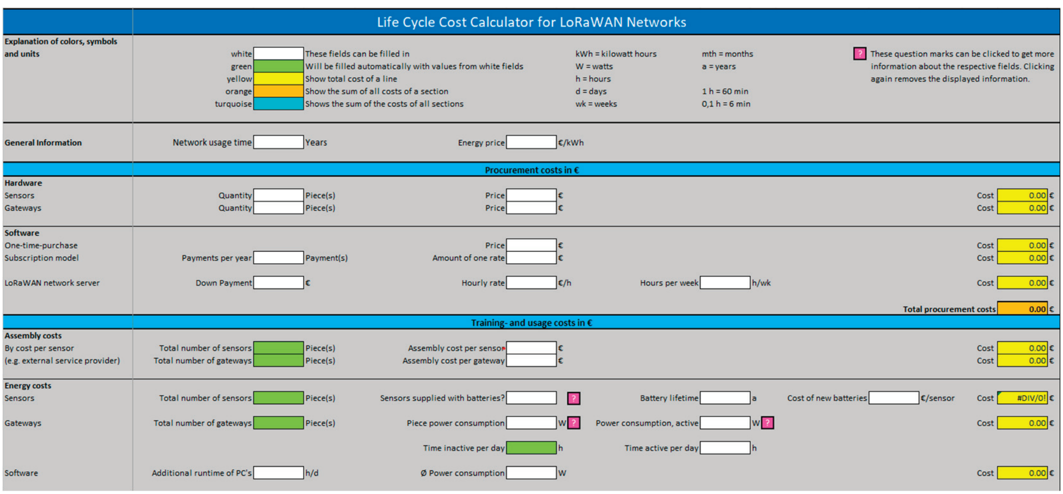

Figure 5. Interface of the Artifeact for the life cycle cost calculator for LoRaWAN; Own illustration.

In addition to assigning costs to each task, the tool also included units of measurement. This helped users understand the scale of the costs associated with each task. Once all the costs were assigned and the tool was complete, it was tested and validated to ensure its accuracy and usability. The tool was tested using different scenarios to determine its effectiveness in estimating the TCO of IoT devices. Feedback was collected from users to identify any areas of improvement, and the tool was updated accordingly.

Due to the different cost structures between IoT devices and gateways, it was necessary to construct separate calculators for each. As such, separate calculations are necessary to accurately estimate the total cost of ownership for each type of device (c.f. Figure 5).

Additionally, external project costs may also differ between IoT devices and gateways. For instance, the installation of gateways may require more specialized expertise and equipment, resulting in higher costs.

Overall, the "Pragmatic Computational Tool" provides a practical and user-friendly way to estimate the life cycle costs of IoT devices. It is easy to use, with well-explained colors, symbols, and units, making it an effective tool for decision-makers in the IoT industry.

6. Validating and Discussing the Scientific Artifact "Pragmatic Computational Tool" for Calculating the Life Cycle Costs of IoT Devices in a Smart City Environment

The evaluation and assessment of an artifact within the framework of design science research necessitate a systematic process, encompassing the establishment of clear evaluation goals, the design of the evaluation methodology, the collection and analysis of relevant data, the interpretation of results, and the reflection on findings to inform iterative improvements [13,14].

The validation of the scientific artifact "Pragmatic Computational Tool" for calculating the life cycle costs of IoT devices was conducted using several use cases from different domains, including smart cities, environmental monitoring, energy management, citizen science, and traffic management. The objective of the validation was to assess the accuracy and usability of the tool in various real-world scenarios and to identify any limitations or areas for improvement [31].

The assessment of the "Pragmatic Computational Tool" for calculating the life cycle costs of IoT devices was conducted using a validation process that involved several use cases from different domains. Out of the fifteen entities contacted, nine participated in the assessment, representing a diverse range of organizations employing either LoRaWAN or NB-IoT communication technologies in their smart city environments.

The assessment encompassed various smart city use cases representing distinct domains, including traffic management, environmental monitoring, citizen science, and energy management. The artifact was evaluated based on its ability to effectively monitor and optimize specific aspects within each domain. For example, in the traffic management domain, the artifact was assessed for its capability to monitor traffic flow, parking availability, and air quality. Similarly, in the environmental monitoring domain, the artifact's performance was evaluated in terms of monitoring air and water quality. The citizen science use case involved assessing the artifact's ability to collect data on weather conditions and noise levels. Lastly, the energy management use case focused on evaluating the artifact's effectiveness in optimizing energy consumption and production in buildings and industrial facilities. Through these assessments, this study aimed to determine the artifact's applicability and effectiveness in addressing the unique challenges and requirements of each domain within the context of smart cities.

In each use case, the tool was used to calculate the life cycle costs of the IoT devices, including procurement costs, training and usage costs, maintenance costs, disposal costs, and external project costs. The tool used different cost assumptions and parameters for each use case depending on the specific requirements and characteristics of the scenario.

The validation of the tool involved several steps, including verifying the accuracy of the calculations, assessing the usability and accessibility of the tool, and analyzing the results to identify any patterns or trends across the different use cases [32].

To verify the accuracy of the calculations, the tool was compared to other established methods for calculating life cycle costs, such as the traditional cost accounting approach and the Total Cost of Ownership (TCO) framework. The results showed that the tool was able to produce accurate and reliable cost estimates for each use case, and that the results were consistent with the results obtained from other methods.

To assess the usability and accessibility of the tool, the tool was evaluated by a group of experts in each use case domain. The experts were asked to evaluate the tool based on several criteria, including ease of use, clarity of instructions, and accessibility of the tool for non-experts. The feedback from the experts was positive, and they found the tool to be user-friendly and intuitive, with clear instructions and a simple interface. Table 3 delivers an overview on the assessment approach for the Pragmatic Computational Tool.

Table 3. Overview on the assessment approach for the Pragmatic Computational Tool.

Assessment Activity Dimension.	Actual Activities
Use Case Selection	Identification of diverse domains: Smart city, environmental monitoring, energy management, citizen science, and traffic management.
Participant Engagement	Contacted 15 entities deploying LoRaWAN or NB-IoT communication technologies in smart city environments, of which 9 participated in the evaluation.
Assessment Objective	Evaluate usefulness, accuracy, usability, and identify areas for improvement.
Validation Steps	Qualitative interaction of results and analysis of results.
Accuracy Verification	Compare tool's calculations with traditional cost accounting and Total Cost of Ownership (TCO) framework.
Usability Evaluation	Expert evaluators assess ease of use, clarity of instructions, and accessibility for non-experts.
Analysis of Results	Identify patterns and trends across different use cases.
Findings and Recommendations	Extract insights and suggestions for tool enhancement based on the assessment outcomes.

For the assessment, a total of 15 entities were initially contacted, representing diverse sectors and domains in the smart city context. Out of these fifteen entities, nine responded and actively participated in the assessment, providing valuable insights into their specific use cases. The assessment involved the utilization of the Pragmatic Computational Tool to calculate the life cycle costs of IoT devices in the domains of traffic management, environmental monitoring, citizen science, and energy management. In addition to using the tool, a qualitative interview approach was adopted to gather in-depth information and perspectives from the participating entities. This combination of quantitative analysis through the tool and qualitative interviews allowed for a comprehensive assessment of the artifacts' effectiveness and applicability in addressing the unique challenges and requirements of each use case within the smart city context.

The assessment results provide valuable insights into the costs associated with using LoRaWAN and NB-IoT technologies in various smart city use cases. The findings indicate that, initially, NB-IoT has lower costs compared to LoRaWAN for a smaller number of installed nodes (up to 5000 nodes). However, as the number of nodes increases beyond this threshold, the cost advantage shifts towards LoRaWAN, making it a more cost-effective option (c.f. Figure 6).

In the specific use cases assessed, it can be observed that for the Citizen Science domain employing LoRaWAN, the costs ranged from 8900 euros for 50 installed nodes to 20,800 euros for 500 nodes. Similarly, in the Traffic Management domain utilizing LoRaWAN, the costs ranged from 14,250 euros for 250 nodes to 100,000 euros for 1800 nodes. The Energy Management use case employing LoRaWAN had costs of 118,000 euros for 5000 nodes.

On the other hand, the Traffic Management use case employing NB-IoT had costs of 1200 euros for 50 nodes, while the Environmental Monitoring use case had costs of 5700 euros for 250 nodes. In the Energy Management use case utilizing NB-IoT, the costs were 119,000 euros for 5000 nodes.

These results indicate that NB-IoT technology initially offers cost advantages for smaller-scale deployments, as it can be integrated into existing cellular networks, resulting in lower hardware and installation costs. However, as the number of nodes increases, LoRaWAN becomes more cost-effective due to the use of lower-cost devices and the ability to support a higher number of nodes per gateway.

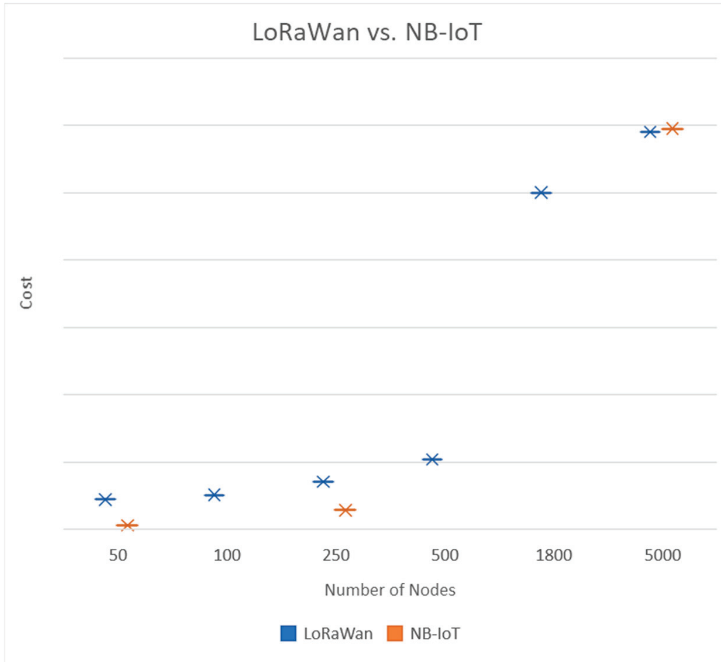

Figure 6. Cost of LoRaWan vs. NB-Iot.

These findings emphasize the importance of considering the scale of the deployment and the specific requirements of the use case when selecting the appropriate communication technology. Decision-makers need to carefully evaluate the cost-performance trade-offs between LoRaWAN and NB-IoT based on factors such as the number of nodes, hardware costs, installation expenses, and long-term maintenance requirements.

Overall, the assessment highlights the cost dynamics between LoRaWAN and NB-IoT, showcasing the advantages of each technology at different scales of deployment. These insights can inform decision-making processes for selecting the most cost-effective communication technology for IoT applications.

The cost performance disparity between the NB-IoT and LoRaWAN in scenarios with fewer sensors can be attributed to several factors. Firstly, LoRaWAN necessitates a workforce with specialized skills to operate and maintain the network, leading to higher labor costs. Additionally, the employment of gateways in LoRaWAN systems contributes to elevated hardware expenses per device. In contrast, NB-IoT offers advantages in terms of cost-efficiency by leveraging existing cellular networks, resulting in lower hardware and installation costs. However, as the number of devices escalates, LoRaWAN emerges as the more cost-effective option due to its utilization of economical devices and the ability to support a higher number of devices per gateway. This underscores the significance of conducting a meticulous analysis of the specific use case and requirements before determining the most suitable IoT communication technology.

Moreover, feedback received from stakeholders further supports the arguments. One recurring response was the preference for LoRaWAN, driven by the desire to have control over the technologies and data while ensuring future-proofing, especially when anticipating a large-scale deployment of nodes. Stakeholders with an IT-oriented perspective expressed enthusiasm for managing a new system, acknowledging that it could become a core competency for their organizations. Conversely, feedback from an NB-IoT use case highlighted the inclination towards NB-IoT to avoid the challenges associated with finding qualified employees, suggesting that the ease of implementation and reduced dependence on specialized personnel was a significant advantage.

These additional arguments emphasize the multi-faceted considerations in selecting the appropriate IoT communication technology. Factors such as control over technologies and data, future scalability, management capabilities, and the availability of qualified employees all play critical roles in the decision-making process. Assessing the specific needs and aligning them with the strengths and limitations of each technology is vital for making informed choices and ensuring successful implementation in various use cases within the smart city context.

7. Assumptions and Limitations

This paper focuses on quantifying the economic and financial viability of NB-IoT and LoRaWAN technologies, which are two low-power wide-area network (LPWAN) technologies with unique characteristics suitable for IoT applications. This study aims to propose an artifact for performing life cycle cost analysis and demonstrate its application to these technologies. The methodology utilizes pragmatic computational tools to facilitate the analysis and considers various economic and financial factors, including operating costs, equipment costs, and revenue potential.

There are assumptions like the development of hardware and the communication costs for NB-IoT and LoRaWAN follow a similar trend over time. However, if the expected costs decrease, the evaluation may shift towards NB-IoT. The costs of employees actively involved in the LoRaWAN implementation are explicitly included.

The main finding of this study indicates that NB-IoT and LoRaWAN technologies have distinct cost structures and revenue potentials, influencing their economic and financial viability for different IoT applications. It concludes that a comprehensive life cycle cost analysis is crucial for informed decision-making regarding technology adoption. Furthermore, the proposed methodology can be applied to other IoT technologies to gain insights into their economic and financial viability.

In terms of future relevance, Design Science Research is particularly suitable for generating practical and impactful research outcomes while ensuring scientific rigor. This research approach will play an increasingly important role in the planning, design, and implementation of innovations and will gain recognition among research methodologies.

Further research is needed to validate the tool in other use cases and to refine the tool to better reflect the specific requirements and characteristics of each scenario. The cost calculators developed for NB-IoT and LoRaWAN aim to provide a quick and efficient way to estimate the expected costs of these networks. The calculators are designed to provide a clear overview of where and in which phase these costs are incurred, as well as to compare the two network types in terms of costs.

This study, however, has certain limitations. It is expected to yield incremental innovations rather than groundbreaking research results, with a focus on improving products, processes, and systems through validation. Additionally, the analysis did not consider other communication technologies. The evaluation of the artifact was conducted with a specific target audience involved in the Smart City domain. It is important to note that the calculators are not intended to evaluate the suitability of a particular technology and should not be used as a substitute for later cost accounting [33]. Additionally, the calculators cannot map all contingencies and special cases that may arise during the implementation and operation of these networks.

Furthermore, certain aspects are not considered in the cost calculators. These include the cost of capital, interest payments, depreciation, inflation/deflation rate, electricity price development, revenue generated by the network (in the case of LoRaWAN), safety aspects, network coverage, and other technical aspects of the networks. Therefore, it is important to use the calculators in conjunction with other tools and resources to fully evaluate the costs and suitability of each network type for a particular use case.

8. Conclusions

In this study, the validation of the "Pragmatic Computational Tool" for estimating the life cycle costs of IoT devices was carried out to assess its utility, reliability, and user-friendliness. The primary objective was to evaluate the economic and financial viability of Narrow Band-Internet of Things (NB-IoT) and Long Range Wide Area Network (LoRaWAN) technologies, both of which are low-power wide-area network (LPWAN) technologies specifically designed for IoT applications. To achieve this, a design science research approach was employed, which involved the development and subsequent evaluation of an artifact capable of performing a comprehensive life cycle cost analysis using practical computational tools.

The evaluation process was designed to provide valuable insights into the total cost of ownership associated with the utilization of NB-IoT and LoRaWAN technologies. By conducting a thorough assessment, this study aimed to identify potential cost-saving opportunities and facilitate informed decision-making processes regarding the adoption and implementation of these technologies in a range of IoT applications. Through this evaluation, the researchers sought to examine the distinct cost structures and revenue potentials associated with NB-IoT and LoRaWAN technologies across various IoT domains.

In the design science research paradigm, employing a limited number of use cases for evaluation is considered a valid approach [14]. This is primarily due to the emphasis on problem-solving and the iterative development process inherent in this research methodology. The focus is on creating innovative solutions and advancing knowledge in specific domains rather than conducting large-scale empirical studies. By analyzing a small number of carefully selected use cases, researchers can generate valuable insights and demonstrate the feasibility, effectiveness, and applicability of the developed artifact in addressing the identified problem.

While expanding the number of use cases and broadening the scope, such as including additional regions, may enhance the tool's acceptance and generate more comprehensive results, such an extension would exceed the scope of the present study. The current research aimed to provide a preliminary assessment of the Pragmatic Computational Tool within a limited number of use cases, showcasing its potential and addressing specific challenges within the examined domains. Further research could explore additional use cases to strengthen the generalizability of the findings and increase the tool's acceptance as a widely applicable cost calculator.

Furthermore, the proposed methodology, utilizing the Pragmatic Computational Tool, holds significant potential for application to other IoT technologies beyond NB-IoT and LoRaWAN. By adapting the tool to different IoT contexts, researchers can gain valuable insights into the economic viability of various technologies, enabling informed decision-making and resource allocation. The tool's flexibility and practicality make it a promising instrument for conducting comprehensive life cycle cost analyses in diverse IoT applications.

In conclusion, the validation of the "Pragmatic Computational Tool" provided favorable results, highlighting its utility, reliability, and user-friendliness in estimating the life cycle costs of IoT devices. The research demonstrated the effectiveness of employing a design science research approach, utilizing a small number of use cases to evaluate the artifact. While the study focused on NB-IoT and LoRaWAN technologies, it is acknowledged that expanding the scope and incorporating additional use cases would enhance the tool's acceptance and applicability. Moreover, the proposed methodology exhibits potential for application to other IoT technologies, thereby facilitating informed decision-making and resource allocation in various IoT domains.

Author Contributions: Conceptualization, B.K., M.B. and M.K.; methodology, B.K. and L.W.; software, M.K.; formal analysis, B.K. and L.S.; investigation, M.B., R.B. and M.W.; resources, B.K. and A.K.; writing—original draft preparation, B.K.; writing—review and editing, B.K., M.B. and T.B.; visualization, M.B.; funding acquisition, L.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is available at Pforzheim University upon request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Raja Santhi, A.; Muthuswamy, P. Industry 5.0 or industry 4.0S? Introduction to industry 4.0 and a peek into the prospective industry 5.0 technologies. *Int. J. Interact. Des. Manuf.* **2023**, *17*, 947–979. [CrossRef]
2. Raja Santhi, A.; Muthuswamy, P. Pandemic, War, Natural Calamities, and Sustainability: Industry 4.0 Technologies to Overcome Traditional and Contemporary Supply Chain Challenges. *Logistics* **2022**, *6*, 81. [CrossRef]
3. Foster, A.D.; Rosenzweig, M.R. Microeconomics of Technology Adoption. *Annu. Rev. Econ.* **2010**, *2*, 395–424. [CrossRef]
4. Chakravarty, A.; Debnath, J. Life Cycle Costing as a Decision Making Tool for Technology Acquisition in Radio-Diagnosis. *Med. J. Armed Forces India* **2015**, *71*, 38–42. [CrossRef] [PubMed]
5. Sinha, R.S.; Wei, Y.; Hwang, S.-H. A Survey on LPWA Technology: LoRa and NB-IoT. *ICT Express* **2017**, *3*, 14–21. [CrossRef]
6. Senthil Kumaran, D.; Ong, S.K.; Tan, R.B.H.; Nee, A.Y.C. Environmental Life Cycle Cost Analysis of Products. *Environ. Manag. Health* **2001**, *12*, 260–276. [CrossRef]
7. Degraeve, Z.; Roodhooft, F. Improving the Efficiency of the Purchasing Process Using Total Cost of Ownership Information: The Case of Heating Electrodes at Cockerill Sambre S.A. *Eur. J. Oper. Res.* **1999**, *112*, 42–53. [CrossRef]
8. Ashton, J.R. Not Invented Here. *J. Epidemiol. Community Health* **2002**, *56*, 481-a. [CrossRef]
9. Breidenbach, D.P. Life Cycle Cost Analysis. In Proceedings of the IEEE National Aerospace and Electronics Conference, Dayton, OH, USA, 22–26 May 1989.
10. Huisman, K.J.M.; Kort, P.M. Strategic Technology Adoption Taking into Account Future Technological Improvements: A Real Options Approach. *SSRN Electron. J.* **2004**, *159*, 705–728. [CrossRef]
11. Carstensen, A.-K.; Bernhard, J. Design Science Research—A Powerful Tool for Improving Methods in Engineering Education Research. *Eur. J. Eng. Educ.* **2019**, *44*, 85–102. [CrossRef]
12. Goecks, L.S.; de Souza, M.; Librelato, T.P.; Trento, L.R. Design Science Research in Practice: Review of Applications in Industrial Engineering. *Gest. Prod.* **2021**, *28*, 5811. [CrossRef]
13. Dresch, A.; Lacerda, D.P.; Antunes, J.A.V., Jr. Design Science Research. In *Design Science Research*; Springer International Publishing: Cham, Switzerland, 2015; pp. 67–102.
14. Hevner, A.; Chatterjee, S. Design Science Research: Looking to the Future. In *Integrated Series in Information Systems*; Springer: Boston, MA, USA, 2010; pp. 261–268.
15. Hevner, A.; Chatterjee, S. Design Science Research in Information Systems. In *Integrated Series in Information Systems*; Springer: Boston, MA, USA, 2010; pp. 9–22.
16. Hatchuel, A.; Le Masson, P.; Reich, Y.; Subrahmanian, E. Design Theory: A Foundation of a New Paradigm for Design Science and Engineering. *Res. Eng. Des.* **2018**, *29*, 5–21. [CrossRef]
17. Shetty, S.H.; Rao, A.; Gatti, R.R. State of the Art Review of IIoT Communication Protocols. In *Transforming the Internet of Things for Next-Generation Smart Systems*; IGI Global: Hershey, PA, USA, 2021; pp. 37–48.
18. Bahashwan, A.A.; Anbar, M.; Abdullah, N.; Al-Hadhrami, T.; Hanshi, S.M. Review on Common IoT Communication Technologies for Both Long-Range Network (LPWAN) and Short-Range Network. In *Advances on Smart and Soft Computing*; Springer: Singapore, 2021; pp. 341–353.
19. Čolaković, A.; Hasković Džubur, A.; Karahodža, B. Wireless Communication Technologies for the Internet of Things. *Sci. Eng. Technol.* **2021**, *1*, 1–14. [CrossRef]
20. Basford, P.J.; Bulot, F.M.J.; Apetroaie-Cristea, M.; Cox, S.J.; Ossont, S.J.J. LoRaWAN for Smart City IoT Deployments: A Long Term Evaluation. *Sensors* **2020**, *20*, 648. [CrossRef]
21. Ertürk, M.A.; Aydın, M.A.; Büyükakkaşlar, M.T.; Evirgen, H. A Survey on LoRaWAN Architecture, Protocol and Technologies. *Future Internet* **2019**, *11*, 216. [CrossRef]
22. Beyene, Y.D.; Jantti, R.; Tirkkonen, O.; Ruttik, K.; Iraji, S.; Larmo, A.; Tirronen, T.; Torsner, A.J. NB-IoT Technology Overview and Experience from Cloud-RAN Implementation. *IEEE Wirel. Commun.* **2017**, *24*, 26–32. [CrossRef]
23. Ratasuk, R.; Vejlgaard, B.; Mangalvedhe, N.; Ghosh, A. NB-IoT System for M2M Communication. In Proceedings of the 2016 IEEE Wireless Communications and Networking Conference Workshops (WCNCW), Doha, Qatar, 3–6 April 2016.

24. Ballerini, M.; Polonelli, T.; Brunelli, D.; Magno, M.; Benini, L. Experimental Evaluation on NB-IoT and LoRaWAN for Industrial and IoT Applications. In Proceedings of the 2019 IEEE 17th International Conference on Industrial Informatics (INDIN, Helsinki, Finland, 22–25 July 2019.
25. Pererva, P.G.; Kosenko, A.P.; Kobielieva, T.A.; Tkachev, M.M.; Tkacheva, N.P. Financial and Technological Leverage in the System of Economic Evaluation of Innovative Technologies. *Financ. Credit Act. Probl. Theory Pract.* **2017**, *2*, 405–413. [CrossRef]
26. Hunkeler, D.; Rebitzer, G. Life Cycle Costing—Paving the Road to Sustainable Development? *Int. J. Life Cycle Assess.* **2003**, *8*, 109–110. [CrossRef]
27. Kelly, A.; Eastburn, K. Terotechnology. A modern approach to plant engineering. *IEE Proc. A Phys. Sci. Meas. Instrum. Manag. Educ. Rev.* **1982**, *129*, 131–136. [CrossRef]
28. Hossain, M.I.; Markendahl, J.I. Comparison of LPWAN Technologies: Cost Structure and Scalability. *Wirel. Pers. Commun.* **2021**, *121*, 887–903. [CrossRef]
29. Ballerini, M.; Polonelli, T.; Brunelli, D.; Magno, M.; Benini, L. NB-IoT versus LoRaWAN: An Experimental Evaluation for Industrial Applications. *IEEE Trans. Ind. Inform.* **2020**, *16*, 7802–7811. [CrossRef]
30. Dimache, A.; Dimache, L.; Zoldi, E.; Roche, T. Life Cycle Cost Estimation Tool for Decision-Making in the Early Phases of the Design Process. In *Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses*; Springer: London, UK, 2007; pp. 455–459.
31. Vaishnavi, V.K. *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*; Auerbach Publications: Boca Raton, FL, USA, 2007.
32. Indulska, M.; Recker, J. Design Science in IS Research: A Literature Analysis. In *Information Systems Foundations: The Role of Design Science*; ANU Press: Canberra, Australia, 2010.
33. Kadusic, E.; Ruland, C.; Hadzajlic, N.; Zivic, N. The factors for choosing among NB-IoT, LoRaWAN, and Sigfox radio communication technologies for IoT networking. In Proceedings of the 2022 International Conference on Connected Systems & Intelligence (CSI), Trivandrum, India, 31 August–2 September 2022. [CrossRef]

FinTech

MDPI

Review

A Bibliometric Analysis of Financial Technology: Unveiling the Research Landscape

Hiranya Dissanayake [1], Catalin Popescu [2,*] and Anuradha Iddagoda [3,*]

1 Department of Accountancy, Faculty of Business Studies and Finance, Wayamba University of Sri Lanka, Lional Jayathilake Mawatha, Kanadulla, Kuliyapitiya 60200, Sri Lanka; hiranya@wyb.ac.lk
2 Department of Business Administration, Petroleum-Gas University of Ploiesti, 100680 Ploiesti, Romania
3 Management Sciences Unit, Department of Mathematics, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda 10250, Sri Lanka
* Correspondence: cpopescu@upg-ploiesti.ro (C.P.); anuradhaiddagoda@sjp.ac.lk (A.I.)

Abstract: This study presents a comprehensive bibliometric analysis of research on financial technology (FinTech) as a methodology. The aim is to unveil the research landscape, trends, and influential factors within this rapidly evolving field. By examining publication records, citation patterns, and thematic maps, valuable insights into the intellectual structure and impact of FinTech research are provided. The analysis highlights the increasing research output and global interest in FinTech, identifies key contributors and knowledge hubs driving the field, and uncovers emerging research themes such as blockchain technology, digital payments, robo-advisors, peer-to-peer lending, and regulatory frameworks. This analysis serves as a roadmap for researchers, industry professionals, and policymakers, offering guidance for navigating the vast body of FinTech research, identifying research gaps, and fostering collaborations to drive innovation in the financial industry. Overall, this bibliometric analysis contributes to a better understanding of the current state of FinTech research and provides valuable insights for future research endeavors and decision-making in the field.

Keywords: FinTech; financial technology; blockchain; financial inclusion; innovation; digital payments

Citation: Dissanayake, H.; Popescu, C.; Iddagoda, A. A Bibliometric Analysis of Financial Technology: Unveiling the Research Landscape. *FinTech* **2023**, *2*, 527–542. https://doi.org/10.3390/fintech2030030

Academic Editor: David Roubaud

Received: 3 June 2023
Revised: 12 July 2023
Accepted: 1 August 2023
Published: 6 August 2023

1. Introduction

Financial Technology, commonly known as FinTech, has emerged as a transformative force in the financial industry, revolutionizing traditional banking, payments, investment, and other financial services. As the FinTech sector continues to grow rapidly, it becomes increasingly important to understand the research landscape surrounding this dynamic field. According to Kawai et al. [1], who serves as the General Secretary of the International Association of Insurance Supervisors, a member organization of the Financial Stability Board, a working definition of "FinTech" can be described as a technologically facilitated financial innovation that encompasses new business models, applications, processes, and products. The implementation of FinTech has the potential to significantly affect financial markets, institutions, and the overall provision of financial services.

Financial technology (FinTech) is acknowledged as a highly significant advancement within the financial sector and is rapidly progressing, fueled by factors such as the sharing economy, favorable regulations, and advancements in information technology [2]. FinTech holds the potential to revolutionize the financial industry by reducing expenses, enhancing the standard of financial services, and fostering a more inclusive and resilient financial environment.

At the same time, the utilization of internet and automated information processing has sparked innovation in the financial industry, resulting in cost savings, enhanced efficiency, speed, creativity, adaptability, and overall improvement in business processes [3].

FinTech empowers consumers to manage independently their assets by offering automated platforms that utilize robo-advisors and operate on specific algorithms [4]. These platforms enable individuals to take control of their finances and make informed decisions.

FinTech leverages big data analytics to gain deeper insights into consumer behaviors, needs, and demands, enabling the development of optimal solutions. This capability, previously the domain of big data and cloud technology companies, now resides within the realm of FinTech [5].

The banking industry has experienced a significant impact from internet technology. From the perspective of banks, online banking offers a range of potential benefits, including reduced operational costs, access to real-time managerial information, improved internal communication, enhanced convenience in interacting with both existing and potential customers, and the provision of value-added services such as access to professional financial management expertise [6].

On the other hand, the emergence of e-finance and mobile technology for financial companies, following the global financial crisis in 2008, paved the way for FinTech innovation. This progress was marked by the integration of e-finance innovation, internet technology, social networking services, social media, artificial intelligence, and big data analytics. FinTech encompasses six distinct business models: insurance services, crowdfunding, payment systems, lending platforms, wealth management solutions, and capital markets initiatives [7].

The history of technological innovation in the financial sector commenced with the introduction of checks as a payment method in 1945. This was followed by the Bank of America's creation of the first credit card in 1958, and the emergence of ATMs for facilitating financial transactions in 1967. Debit cards were subsequently introduced as transaction tools. In the 1990s, the advent of the internet led to the launch of internet banking services. In the 2000s, FinTech advancements such as mobile payments and crowdfunding were introduced. These milestones highlight the rapid growth of the FinTech industry, underscoring the need to review prior research in order to capture the evolution of financial services [8].

Also, the literature review findings revealed that FinTech research encompassed various business processes, including payments, risk management and investment, financing through crowdfunding and P2P lending, market aggregators, as well as cryptocurrency and blockchain technology. Among these, the most prevalent research theme centered on the adoption of FinTech itself [9].

Simultaneously, we have observed the emergence of individual FinTech startups that have started to capture specific segments of the financial services value chain and enhance their efficiency. Although FinTech has experienced substantial growth in recent years, it still needs to demonstrate its long-term viability, particularly in markets experiencing a downturn, to establish itself as a sustainable phenomenon [10].

FinTech has evolved as a continuous process, wherein finance and technology have advanced in tandem, giving rise to a multitude of incremental and disruptive innovations. These innovations include internet banking, mobile payments, crowdfunding, peer-to-peer lending, and online identification [11].

In terms of innovation, a significant number of FinTech advancements have focused on incremental enhancements, such as optimizing existing business processes through the utilization of mature technologies like mobile phone cameras for mobile payment solutions. Simultaneously, innovations have also affected various facets of FinTech, including the introduction of new services such as chatbots, artificial intelligence-based advisory services, and mobile bank accounts [12].

FinTech solutions are currently offered not only by traditional banks and insurance companies but also by non-banks and non-insurers as providers of financial services. Moreover, the evolution of FinTech has demonstrated a shift in focus from intra-organizational solutions to customer-centric approaches such as business-to-customer (B2C), customer-to-customer (C2C), and provider-oriented business-to-business (B2B) inter-organizational models [13–16].

Presently, the financial industry is undergoing a profound transformation, marked by the emergence of innovative FinTech products that are challenging traditional banking offerings across various areas, including payments and investment advice. Blockchain technology, in particular, is revolutionizing numerous conventional banking services by providing enhanced transaction security, faster money transfers, and reduced costs on both domestic and global scales.

The disruptive nature of FinTech innovation has the potential to reshape the entire financial landscape in the coming years. As with any disruptive force, the true impact of FinTech innovations will become increasingly apparent as the market evolves. This section examines six key challenges faced by both FinTech startups and traditional financial institutions during this era of disruptive innovation: investment management, customer management, regulation, technology integration, security and privacy, and risk management [7]. The growth of the FinTech market has resulted in the introduction of innovative solutions that significantly enhance the customer experience by offering a wide range of efficient and diverse financial services [17].

The combination of the global financial crisis in 2008 and the integration of modern technological advancements, including social media, artificial intelligence (AI), and data analytics, propelled FinTech to emerge as a new paradigm. The FinTech ecosystem (FE) encompasses five interconnected elements that collaborate synergistically to drive economic growth, improve customer experiences, and foster social inclusion. These elements include start-ups, technology firms, government bodies, customers, and traditional financial institutions such as banks [7].

Some other authors categorize FinTech as a disruptive innovation and delve into the primary business models in which FinTech operates. They extensively discuss the roles played by blockchain, crowdfunding, payments, insurance, wealth and asset management, big data analysis, and application programming interface [18].

FinTech ecosystems exhibit distinct features such as heterogeneity, non-linearity, dynamism, and complexity due to their intricate network of agents. These agents interact with each other to offer a diverse range of financial products and services to end customers. As complementary technologies continue to emerge, the complexity of FinTech ecosystems grows exponentially, with new players entering the scene and new connections being established [19]. Despite the considerable attention that FinTech ecosystems have garnered from both academia and industry, our understanding of the emergence of such ecosystems remains limited.

At the same time, crowdfunding offers a fresh approach for founders to secure funding for a diverse range of projects. This innovative concept finds its foundation in the broader concept of crowdsourcing, which involves tapping into the collective wisdom of the crowd to acquire ideas, feedback, and solutions to advance corporate endeavors [20,21]. In this regard, if there is a need to apply interest on the amount involved in rewards-based crowdfunding, the borrowers have the autonomy to determine the interest rate that suits them best.

Additionally, they can provide assurance of repayment within the specified timeframe [22]. Entrepreneurs can utilize crowdfunding as a means to secure funding by making an open call on the internet. However, for crowdfunding to become a feasible alternative to the traditional investor- or creditor-based funding methods like banks, business angels, or venture capital, it is crucial to establish a community that derives additional private benefits from participating in the crowdfunding process [23]. At the same time, investors participating in crowdfunding campaigns are offered assets in exchange for their funds, which can take the form of either regular interest payments or an ownership stake in the funded organization [24].

On the other hand, it has been suggested that although FinTech firms may capture a portion of the market share from banks, it is not anticipated that they would completely replace banks. Nevertheless, banks are urged to expedite their adoption of innovative technologies in order to remain competitive with FinTech firms. Additionally, it is proposed that strategic partnerships and collaborations between banks and FinTech companies could be established in a mutually beneficial manner, offering advantages to both sides [25].

Undoubtedly, financial technology (FinTech) stands out as one of the most prominent recent innovations within the financial sector. Its remarkable ability to potentially revolutionize the financial landscape by offering convenience and enhanced security in financial transactions has garnered significant recognition. The advent of this groundbreaking FinTech technology is reshaping the world, creating a distinctive biosphere characterized by streamlined transactions and heightened security [26].

A cutting-edge FinTech solution is accessible anytime and anywhere for various transactional needs, such as hailing a ride, shopping at a local store, or engaging in online transactions. This innovation is significantly transforming the financial sector by reducing costs, enhancing the quality of financial services, and enabling organizations to manage efficiently their finances while ensuring robust security against cyber-attacks [27].

The convergence of the digital and physical realms has given rise to new approaches to customer interaction [28]. Over the past decade, there has been a notable surge in the frequency of customer engagement through various interaction channels. To adapt to this trend, financial service providers have introduced hybrid client interactions, which have contributed to the widespread adoption of FinTech.

In addition, the advent of recent technological innovations has brought about significant changes in financial information flows, resulting in the emergence of novel competitive and cooperative mechanisms that facilitate the creation and distribution of value [29].

The FinTech industry continues to demonstrate its resilience and growth potential, despite experiencing a decrease in financing during Q2 2022 [30]. With a 39% decline compared to Q4 2021, it reached its lowest level in the previous five quarters. However, this setback did not deter the global FinTech sector, as it managed to raise an impressive $21.5 billion during the same period, making it the sector with the highest number of investment rounds worldwide.

The widespread adoption of FinTech services is evident, with approximately 90% of people in the USA currently utilizing these digital financial solutions [30]. This high level of adoption reflects the shift towards customer-focused digital processes, which have been further accentuated by global quarantines and lockdowns. Looking ahead, the FinTech market is projected to experience substantial growth, with estimates suggesting a value surge from $110.57 billion in 2020 to a staggering $698.48 billion by 2030 [30].

In terms of specific trends, open banking is predicted to witness significant growth, with an estimated 63.8 million users anticipated by 2024, representing a nearly fivefold increase compared to 2020 [30]. Additionally, the number of individuals holding at least one neobank account is expected to reach 39.1 million by 2025, up from 20 million in 2021 [30]. The reliance on artificial intelligence (AI) and machine learning within the FinTech industry is also noteworthy, as the global market for AI in FinTech is projected to reach $26.67 billion by 2026. Moreover, Chime, one of the leading neobanks in the US, has amassed over 13 million users who access their personal banking services through the Chime mobile banking app.

The digitization of financial services has the potential to redirect the flow of financial information away from established incumbents and traditional infrastructures, leading to potential instability in established ecosystems. One example of this is the rise of peer-to-peer payments, which enables individuals to transfer funds directly between themselves, bypassing the payment infrastructures that have been collectively developed and funded by traditional banks. As a result, the introduction of such innovations is affecting the existing competitive and cooperative dynamics among industry participants [31].

The present study aims to address the existing gaps and provide a novel contribution to the field of FinTech research. Although there is a growing volume of FinTech research, there is a lack of standardized best practices and methodological norms for researchers to rely on [32]. This study recognizes the early stages of development in the field of FinTech research, suggesting that it is still in its infancy [13].

To overcome these challenges and provide valuable insights, the study proposes the use of bibliometric analysis. This quantitative method utilizes data from scientific publications to examine various aspects of the FinTech research field. By analyzing publication records, citation patterns, collaboration networks, and other bibliographic indicators, researchers can gain a comprehensive understanding of the intellectual structure and impact of FinTech research.

Through this bibliometric analysis, the study aims to uncover trends, patterns, and influential factors driving advancements in FinTech research. This includes identifying key topics, leading researchers, influential institutions, and emerging trends within the multidisciplinary field of FinTech. By doing so, the study will provide a novel perspective and contribute to the growing body of knowledge in the FinTech research domain.

The objective of this article is to present a comprehensive bibliometric analysis of research on financial technology, exploring the evolution of FinTech literature, identifying influential contributors, and uncovering the most prominent research themes. By examining a vast array of scholarly publications, including academic articles, conference papers, and patents, this analysis aims to provide researchers, industry professionals, and policymakers with valuable insights into the current state and future directions of FinTech research.

This article will proceed by outlining the methodology employed for the bibliometric analysis, including data collection, bibliographic databases, and selection criteria. It will then present an overview of the global research output in FinTech, including publication trends, geographic distribution, and collaboration patterns among researchers and institutions.

Furthermore, the article will delve into the analysis of highly cited papers, top authors, and leading academic journals, elucidating the knowledge hubs and influential figures driving FinTech research. In addition to analyzing the overall landscape, this article will highlight the emerging research themes within FinTech, such as blockchain technology, digital payments, robo-advisors, peer-to-peer lending, and regulatory frameworks. By exploring these thematic clusters and their interconnectedness, we can gain a deeper understanding of the critical areas where research efforts are concentrated, and identify potential avenues for future research and innovation.

Overall, this bibliometric analysis aims to provide a comprehensive overview of the research landscape in financial technology, enabling stakeholders to navigate the vast body of knowledge, identify research gaps, and foster collaborations. Understanding the dynamics of FinTech research is essential for driving advancements in this rapidly evolving field and harnessing the transformative power of technology to shape the future of finance.

This article is structured into several sections to explore bibliometric analysis related to financial technology. The subsequent section focuses on the data and methodology, outlining the sources used and the research approach employed. Following this, the third section presents the data analysis, utilizing statistical tools and algorithms to examine trends and correlations within the collected data. A thematic analysis is then conducted in the fourth section to identify and explore key themes emerging from the findings. The fifth section incorporates a comprehensive document analysis, examining relevant literature and regulations. Finally, the last section provides a concise summary of the study's main findings, their significance, and recommendations for future research and industry practices, while reflecting on the theoretical implications of the study.

2. Data and Methodology

The methodology employed in this study involved a bibliometric analysis to explore the field of financial technology (FinTech) research. This section provides a detailed overview of the fundamental search key strings, identification criteria, selection criteria, synthesis technique, and quality assessment of the bibliometric data utilized.

Data Collection: The study used "FINTECH" or "Financial Technology" as the primary search keywords to identify relevant articles for analysis. The initial search yielded a total of 1972 articles that met this criterion. Subsequently, a selection process was implemented to refine the dataset.

Sample Selection: To ensure consistency and focus on a specific linguistic context, only English-language articles were selected for further analysis. This language restriction reduced the dataset to 1945 articles. The final database comprised 1373 publications, covering various disciplines such as business, management and accounting, economics, finance, and social sciences. These disciplines were chosen to align with the research area of FinTech.

Data Analysis: The study employed a variety of bibliometric analytic approaches to analyze the collected data. Frequency tables were utilized to examine the publications based on different parameters, including year of publication, nation of origin, and authorship. This analysis provided insights into temporal trends, geographic distribution, and prominent authors within the field of FinTech research.

To identify the most influential articles, citation analysis was conducted to determine the citation count and impact of each publication. These influential articles played a crucial role in shaping the field of FinTech research.

Keyword analysis and thematic mapping techniques were applied to identify prevailing topics and themes within the field. This analysis provided a deeper understanding of the research focus areas and emerging trends in FinTech.

To conduct the synthesis analysis, the study utilized biblioshiny software [33]. This software facilitated the organization and analysis of the bibliometric data, allowing for a comprehensive synthesis of the findings. Additionally, Lotka's Law and Bradford's Law were applied to measure the reliability and distribution patterns of the publications within the dataset, enhancing the quality assessment of the bibliometric analysis. Table 1 summarized the methodological steps.

Table 1. Methodological steps.

Methodological Steps	Actions
search key strings	"FINTECH" or "Financial Technology"
identification criteria	Articles in the SCOPUS Database
selection criteria	English Language articles
synthesis technique	Analysis using Biblioshiny software
quality assessment of bibliometric data	Lotka Law, Bradford Law

The methodology employed in this study provided a rigorous framework for conducting the bibliometric analysis of FinTech research. By specifying the search key strings, identification criteria, selection criteria, synthesis technique, and quality assessment of the bibliometric data, this article ensures transparency and validity in the research process (Table 2). The utilization of various bibliometric analytic approaches and software tools strengthens the reliability of the findings and contributes to the growing body of knowledge in the field of FinTech research.

Table 2. Main information about the database.

Timespan	1986–2023
Sources (journals, books, etc.)	637
Documents	1373
Annual growth rate (%)	15.74
Document average age	2.33
Average citation per doc	12.01
References	69,744

3. Results and Discussion

Figure 1 depicts the publication trend in the research on "financial technology" for the Scopus database, from 1986 to 2023. In the year 2023 (till May) the number of publications was 190. From 1986 to 2014, the annual average number of publications is about 1 for a few years, but zero publications for most years. Since 2014 there is a steady growth in publications. The maximum number of publications in the year 2022 was 386. This illustrates the significant growth of publications in this sector, due to the innovations in this area in the entire world.

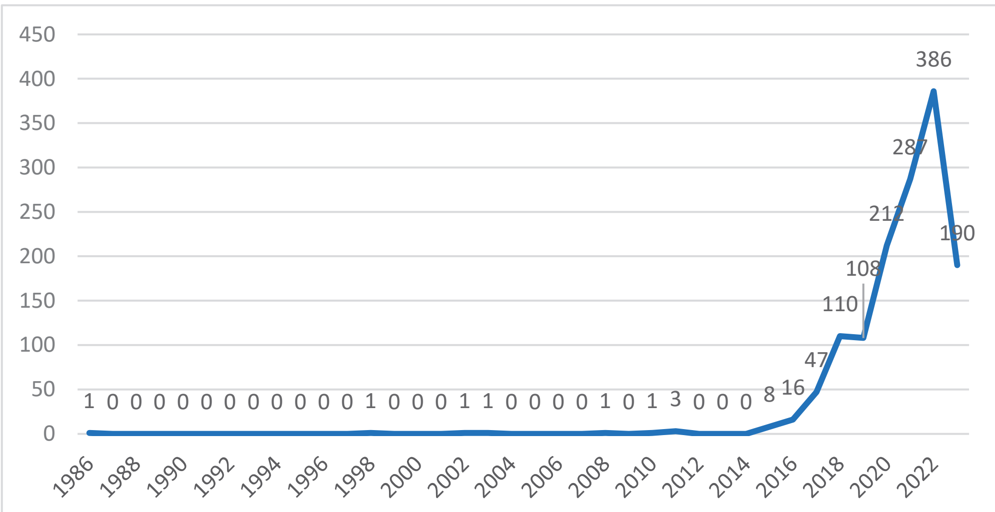

Figure 1. Publication trend in the research on "financial technology" for the Scopus database (1986–2023).

This section analyzes the most productive and impactful countries, publishing articles on 'financial technology". Eighty-eight countries have made significant contributions in the last two decades. Table 3 reveals that China, the USA, and the United Kingdom are the top three countries with citations greater than 1000. As the most productive country in this area of research, 521 articles were published in China and received the highest number of citations. However, the second highest number of publications owned by Indonesia only received 209 citations, which was 9th in the list. This country analysis exhibits that there is an empirical gap to conduct research in developing economies.

Table 3. Country-wise publications.

Country	TP	TC	Average Article Citations
China	521	2080	13.3
USA	275	1735	26.3
United Kingdom	218	1075	20.3
South Korea	70	998	29.4
Germany	77	939	58.7
France	33	414	29.6
Australia	107	403	14.4
Spain	48	302	25.2
Indonesia	307	299	4.9
Hong Kong	31	234	18

TP—Total publications; TC—Total citations.

The collaborative country map provided displays the frequency of collaborations between different countries in the context of FinTech research (Figure 2). The map highlights significant collaborations between various countries in the field of FinTech research. Some notable collaborations include the United States (USA) collaborating with Bahrain 16 times and with the United Kingdom 15 times. China and the United Kingdom also have a strong collaboration with 13 instances, followed by China and the USA with 12 instances. Other noteworthy collaborations include India and Bahrain (10), Indonesia and Malaysia (10), and Malaysia and the United Arab Emirates (8). Table 4 highlights the main collaboration links with countries which frequency is greater than 5.

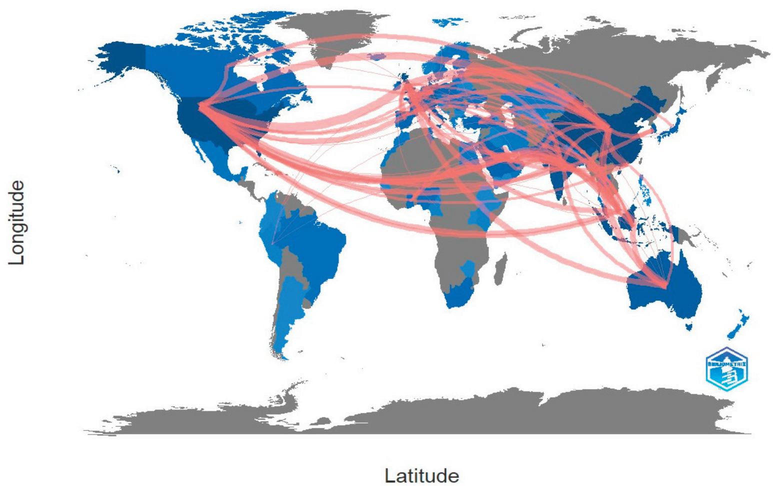

Figure 2. The collaborative country map.

Table 4. Country collaboration frequency.

From	To	Frequency
USA	Bahrain	16
USA	United Kingdom	15
China	United Kingdom	13
China	USA	12
China	Australia	11
India	Bahrain	10
Indonesia	Malaysia	10
Malaysia	United Arab Emirates	8
United Kingdom	Australia	8
China	Hong kong	7
Indonesia	Australia	6
Malaysia	Pakistan	6
Malaysia	Saudi Arabia	6
United Kingdom	Germany	6
United Kingdom	Malaysia	6
USA	France	6
USA	India	6
China	Canada	5
China	Korea	5
China	Pakistan	5
China	Turkey	5
Malaysia	Bahrain	5
United Kingdom	Bahrain	5
USA	Malaysia	5

These collaborative efforts indicate the global nature of FinTech research, with countries across different regions actively engaging in partnerships and knowledge exchange. Such collaborations contribute to the advancement and growth of FinTech innovation, benefiting the participating countries and the global FinTech ecosystem as a whole.

The database contains 1373 documents that were published in 632 sources. Table 5 highlights the top 10 journals with the highest citations for "Financial Technology." Out of the total publications, 17 percent of the publications identified are published in these journals. Journal of Management Information Systems, published by Taylor and Francis online, has the most cited publications, with 602 citations for four documents, followed by Technological Forecasting and Social Change published by ScienceDirect (544 citations). Next, Financial Innovation which was published by Springer Open also received 544 citations. Three journals are ranked as Q1 journals by the SCIMAGO ranking. It indicates the research works on Financial Technology are published in top-ranked journals worldwide; hence, these articles have influenced the subsequent literature.

Table 5. Journal-wise publications.

Element	h Index	g Index	m Index	TC	NP	PY Start
Journal of Management Information Systems	3	4	0.5	602	4	2018
Technological Forecasting and Social Change	11	18	2.75	544	18	2020
Financial Innovation	10	23	1.25	541	24	2016
Industrial Management and Data Systems	5	7	0.83	498	7	2018
Business Horizons	1	1	0.17	473	1	2018
Sustainability (Switzerland)	11	20	2.2	437	38	2019
Journal of Business Economics	1	1	0.14	418	1	2017
Electronic Commerce Research and Applications	3	3	0.19	401	3	2008
Journal of Financial Economics	3	3	0.5	367	3	2018
Journal of Economics and Business	4	8	0.67	358	8	2018

The database contains 2817 authors from which only 307 authors are considered to be single authors and other authors published joint publications. According to Lotka Law, 86% of authors publish only one publication and more than 10 publications are written by only 11%. The top 10 authors publishing their research on 'financial technology" are listed in Table 6. The findings reveal that Gomber P, Kauffman Rj, Parker C Weber Bw, Shin Yj, and Lee I are the six authors who have received citations greater than 450. According to the number of publications, the highest number of articles published by Hassan MK with 17 publications received 107 citations.

Table 6. Author-wise publications.

Authors	h Index	g Index	m Index	TC	NP	PY Start
Gomber P	3	3	0.43	917	3	2017
Kauffman Rj	4	4	0.25	812	4	2008
Parker C	2	2	0.33	499	2	2018
Weber Bw	2	2	0.33	499	2	2018
Shin Yj	2	2	0.33	498	2	2018
Lee I	1	1	0.17	473	1	2018
Koch J-A	1	1	0.14	418	1	2017
Siering M	1	1	0.14	418	1	2017
Hornuf L	4	5	0.57	371	5	2017
Buchak G	1	1	0.17	320	1	2018

Table 7 and Figure 3 present the keyword analysis using a frequency table and word cloud. Keyword analysis brings to light the antecedents of financial technology. Financial technology, blockchain, and financial inclusion are highlighted keywords in the word cloud. China is also highlighted because of the highest number of articles published and which are used as keywords. In addition, COVID-19, innovation, crowdfunding, cryptocurrency, and artificial intelligence are also highlighted.

Table 7. Keyword analysis.

Words	Occurrences
FinTech	657
financial technology	137
financial inclusion	83
blockchain	55
innovation	49
banking	42
China	39
COVID-19	38
artificial intelligence	34
crowdfunding	34

Figure 3. Word cloud.

4. Thematic Analysis

Figure 4 represents a thematic map related to the field of financial technology (FinTech). The purpose of this map is to visually present the prominent and trending themes within FinTech research. The map is divided into different sections, each highlighting specific categories of themes.

In the bottom-right part of the map, the basic themes are depicted. These themes, including financial technology, security, investment, innovation, banking, financial inclusion, perceived risk, Islamic banks, and mobile money, represent well-established research issues in the field of FinTech. These themes are foundational and have received significant attention and study in the past.

Moving to the top-right part of the map, it showcases the themes that have gained importance in the recent past. The two main research issues highlighted in this section are "g21" and "g20". g20 indicates high-level principles for digital financial inclusion while g21 means banks, depository institutions, micro finance institutions, mortgages. These themes signify emerging areas of interest and research focus within FinTech.

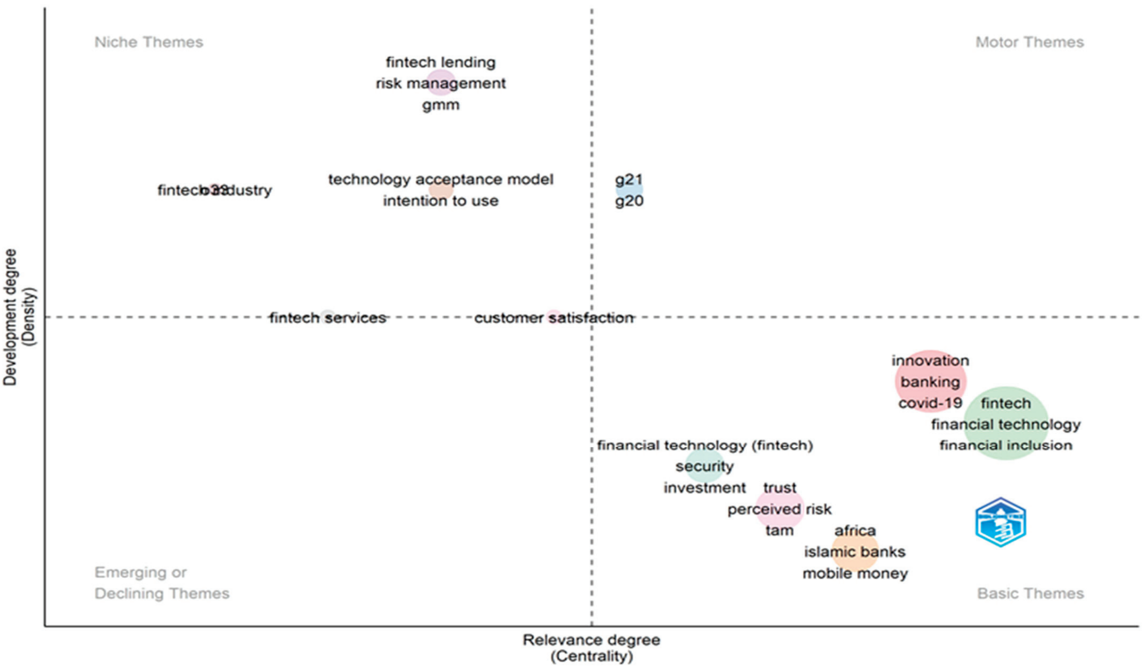

Figure 4. Thematic map.

The top-left part of the map represents the niche themes. These themes, such as FinTech lending, risk management, and technology acceptance model, indicate areas that require further exploration and investigation in future research. These themes have the potential to contribute to the advancement of knowledge and understanding in FinTech.

Lastly, the transition themes, categorized as emerging or declining themes, are depicted. FinTech services and customer satisfaction fall under this category. These themes are considered transitional because they have been extensively studied, and further research is needed to investigate them using different approaches or perspectives rather than repeating the same keywords or concepts.

Overall, Figure 4 provides a comprehensive overview of the thematic landscape in the field of financial technology. It highlights the foundational themes, emerging research areas, niche topics for further exploration, and transitional themes that require fresh perspectives. This map serves as a visual representation to guide researchers in identifying the trending and underexplored themes within FinTech research.

5. Documents Analysis

This section summarises the literature related to the highly cited articles related to "Financial Technology".

Gomber et al. (2018) conducted a study "On the Fintech Revolution: Interpreting the Forces of Innovation, Disruption, and Transformation in Financial Services" and provides a comprehensive examination of the impact of financial technology (FinTech) on the financial services industry [34]. Through a detailed analysis of innovation, disruption, and transformation, the paper explores the dynamic forces driving the FinTech revolution. It delves into the key aspects of FinTech, including technological advancements, changing consumer behavior, regulatory challenges, and the emergence of new business models. By interpreting these forces, the paper offers valuable insights into the transformative power of FinTech and its implications for the future of financial services.

Additionally, a paper titled "Fintech: Ecosystem, Business Models, Investment Decisions, and Challenges" provides a comprehensive overview of the FinTech landscape, including its ecosystem, various business models, factors influencing investment decisions, and the challenges faced by FinTech companies [7]. The paper explores the interconnectedness of technology, finance, and entrepreneurship, highlighting the disruptive potential of FinTech in revolutionizing traditional financial services. It examines different business models adopted by FinTech firms, ranging from payment solutions and lending platforms to robo-advisory services and blockchain applications. Additionally, the paper addresses the factors that influence investment decisions in the FinTech sector, such as market trends, regulatory frameworks, and technological advancements. It also identifies and analyzes the challenges faced by FinTech companies, including cybersecurity risks, regulatory compliance, customer trust, and scalability issues. Overall, the paper offers a comprehensive understanding of the FinTech industry, its business models, investment dynamics, and the hurdles it must overcome to thrive in the financial services landscape.

Moreover, Gomber et al. (2017) published "Digital Finance and FinTech: Current Research and Future Research Directions" and provided an overview of the current state of research in digital finance and FinTech while highlighting potential areas for future exploration [35]. The paper discusses the transformative impact of digital technologies on financial services and the emergence of FinTech as a catalyst for innovation in the industry. It explores various research topics within digital finance and FinTech, including blockchain technology, digital payments, crowdfunding, online lending, and regulatory frameworks. The paper also addresses the importance of interdisciplinary research and collaboration between academia, industry, and policymakers to further advance knowledge in this rapidly evolving field. By identifying research gaps and suggesting future directions, the paper serves as a roadmap for researchers seeking to contribute to the growing body of knowledge in digital finance and FinTech.

Another important paper, entitled "Fintech, Regulatory Arbitrage, and the Rise of Shadow Banks", examines the relationship between financial technology (FinTech), regulatory arbitrage, and the emergence of shadow banks [36].

The paper highlights how FinTech companies, by leveraging technological innovations and operating outside traditional regulatory frameworks, have disrupted the financial industry and created new avenues for regulatory arbitrage. It explores the risks and challenges associated with the rise of shadow banks, including potential systemic risks, regulatory loopholes, and consumer protection concerns. The paper sheds light on the evolving regulatory landscape and the need for effective oversight to ensure financial stability and consumer welfare in the context of FinTech and shadow banking activities.

Lastly, the paper "The Economics of Mobile Payments: Understanding Stakeholder Issues for an Emerging Financial Technology Application" delves into the economic aspects of mobile payments and provides insights into the various concerns faced by stakeholders in this emerging field [37]. The paper explores the economic implications of mobile payment systems, including their impact on transaction costs, efficiency, and consumer behavior. It examines the perspectives of different stakeholders, such as merchants, consumers, financial institutions, and technology providers, shedding light on their concerns regarding security, privacy, interoperability, adoption, and revenue models. By understanding these stakeholder issues, the paper aims to provide a comprehensive understanding of the economics surrounding mobile payments and offers valuable insights for policymakers, industry players, and researchers seeking to navigate this evolving financial technology application.

Together, the above papers provide valuable insights into the transformative power, challenges, and regulatory considerations surrounding FinTech, guiding industry practitioners, policymakers, and researchers in navigating this dynamic field. As a result of the review is presented a table summarizing the main contributions in the field (Table 8).

Table 8. Main scientific contributions in the FinTech field, by authors, titles, and main findings.

Authors	Title	Main Findings
Lee (2018) [7]	FinTech: Ecosystem, Business Models, Investment Decisions, and Challenges	Provides insights into the FinTech ecosystem, various business models, investment decisions, and challenges.
Gomber (2018) [34]	On the FinTech Revolution: Interpreting the Forces of Innovation, Disruption, and Transformation in Financial Services	Examines the forces of innovation, disruption, and transformation brought by the FinTech revolution.
Buchak (2018) [36]	FinTech, Regulatory Arbitrage, and the Rise of Shadow Banks	Explores the relationship between FinTech, regulatory arbitrage, and the emergence of shadow banks.
Gomber (2017) [35]	Digital Finance and FinTech: Current Research and Future Research Directions	Presents an overview of current research and future research directions in digital finance and FinTech.
Thakor (2020) [3]	FinTech and Banking: What do we Know?	Provides an overview of the existing knowledge on the relationship between FinTech and banking.
Haddad (2019) [38]	The Emergence of the Global FinTech Market: Economic and Technological Determinants	Examines the economic and technological determinants of the emergence of the global FinTech market.
Schueffel (2017) [10]	Taming the Beast: A Scientific Definition of FinTech	Proposes a scientific definition of FinTech to clarify its scope and boundaries.
Anagnostopoulos (2018) [39]	FinTech and regtech: Impact on regulators and banks	Explores the impact of FinTech and RegTech on regulators and banks.
Chen MA (2019) [40]	How Valuable is FinTech Innovation?	Investigates the value of FinTech innovation.
Jagtiani (2018) [41]	Do Fintech Lenders Penetrate Areas that are Underserved By Traditional Banks?	Examines the extent to which FinTech lenders serve underserved areas compared to traditional banks.

6. Conclusions

In conclusion, this article has presented a comprehensive bibliometric analysis of research on financial technology (FinTech), offering valuable insights into the research landscape, trends, and influential factors within this dynamic field.

The findings of this analysis highlight the growing importance of FinTech as a research area, with a substantial increase in the number of publications over the years. The geographic distribution of research output demonstrates a global interest in FinTech, with contributions from various countries and regions. Furthermore, collaboration networks reveal the interconnectedness of researchers and institutions, emphasizing the collaborative nature of FinTech research.

The identification of highly cited papers, top authors, and leading academic journals provides valuable insights into the knowledge hubs and influential figures driving FinTech research. These key contributors serve as a valuable resource for researchers and industry professionals seeking expertise and guidance in the field. Moreover, the analysis of emerging research themes within FinTech has shed light on critical areas of focus, such as blockchain technology, digital payments, robo-advisors, peer-to-peer lending, and regulatory frameworks. These thematic clusters represent areas of active research and innovation, where further exploration and advancements are expected.

Financial advisors can leverage the insights from this analysis to enhance their practices. By staying updated on the latest trends and developments in FinTech, advisors can identify areas of opportunity for integrating FinTech solutions into their advisory services. Understanding the current state and future directions of AI in FinTech can guide advisors in utilizing AI-powered tools to enhance their decision-making processes and provide more accurate and personalized recommendations to clients.

Insights into digital payment solutions can help financial advisors explore and adopt innovative payment technologies, streamlining transactions and enhancing convenience and security for their clients. Furthermore, understanding emerging regulatory frameworks related to FinTech enables advisors to navigate compliance requirements and stay informed about the legal implications of utilizing specific FinTech solutions in their practice.

The analysis also reveals collaboration patterns among researchers and institutions within the FinTech domain. Financial advisors can leverage this information to identify potential collaboration opportunities with academic institutions, FinTech startups, or other industry players. Collaborations can facilitate knowledge exchange, access to cutting-edge technologies, and the development of innovative solutions tailored to the needs of financial advisory clients.

By incorporating these practical implications into their practice, financial advisors can harness the findings of the bibliometric analysis to enhance their service offerings, improve client experiences, and stay competitive in an increasingly technology-driven financial landscape.

In conclusion, the comprehensive understanding gained through this bibliometric analysis serves as a valuable resource for financial advisors, empowering them to leverage FinTech innovations and technologies effectively in their advisory practice and ultimately deliver enhanced value to their clients. As FinTech continues to evolve, further bibliometric analyses will be essential to track and understand emerging trends, technological advancements, and regulatory developments within the field. By leveraging the insights gained from bibliometric analysis, stakeholders can make informed decisions, promote collaboration, and contribute to the advancement of FinTech research and its real-world applications.

Author Contributions: Conceptualization, A.I., C.P. and H.D.; Data curation, A.I. and H.D.; Formal analysis, A.I., C.P. and H.D.; Investigation, A.I., C.P. and H.D.; Methodology, A.I. and H.D.; Supervision, A.I., C.P. and H.D.; Validation, A.I., C.P. and H.D.; Visualization, A.I., C.P. and H.D.; Writing—Original draft, A.I., C.P. and H.D.; Writing—Review and editing, A.I., C.P. and H.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare that they have no conflict of interest.

References

1. Kawai, Y.; Sasaki, K.; Aoki, S.; Nagase, T. Fintech. International Association of Insurance Supervisors (IAIS) Newsletter, 2016. Available online: https://www.amt-law.com/asset/res/news_2021_pdf/publication_0022808_ja_001.pdf (accessed on 2 June 2023).
2. The Economist. The FinTech Revolution: A Wave of Startups is Changing Finance-for the Better. 2015. Available online: https://www.economist.com/leaders/2015/05/09/the-fintech-revolution (accessed on 9 May 2015).
3. Thakor, A. Fintech and banking: What do we know? *J. Financ. Intermediation* **2020**, *41*, 100833. [CrossRef]
4. Gabor, D.; Brooks, S. The digital revolution in financial inclusion: International development in the fintech era. *New Political Econ.* **2017**, *22*, 423–436. [CrossRef]
5. Leong, C.T.; Tan, B.; Xiao, X.; Tan, F.T.C.; Sun, Y. Nurturing a FinTech ecosystem: The case of a youth microloan startup in China. *Int. J. Inf. Manag.* **2017**, *37*, 92–97. [CrossRef]
6. Flohr Nielsen, J. Internet technology and customer linking in Nordic banking. *Int. J. Serv. Ind. Manag.* **2002**, *13*, 475–495. [CrossRef]
7. Lee, I.; Shin, Y.J. Fintech: Ecosystem, business models, investment decisions, and challenges. *Bus. Horiz.* **2018**, *61*, 35–46. [CrossRef]
8. Ashta, A.; Biot-Paquerot, G. FinTech evolution: Strategic value management issues in a fast changing industry. *Strateg. Chang.* **2018**, *27*, 301–311. [CrossRef]

9. Suryono, R.R.; Budi, I.; Purwandari, B. Challenges and Trends of Financial Technology (Fintech): A Systematic Literature Review. *Information* **2020**, *11*, 590. [CrossRef]
10. Schueffel, P. Taming the beast: A scientific definition of fintech. *J. Innov. Manag.* **2017**, *4*, 32–54. [CrossRef]
11. Arner, D.W.; Barberis, J.N.; Buckley, R.P. The Evolution of Fintech: A New Post-Crisis Paradigm? *Geo. J. Int'l L.* **2015**, *47*, 1271. [CrossRef]
12. Puschmann, T. Fintech. *Bus. Inf. Syst. Eng.* **2017**, *59*, 69–76. [CrossRef]
13. Cui, M.; Qian, J. Business transformation from B2C to B2C & B2B: A fintech company case study. *Technol. Anal. Strateg. Manag.* **2022**, 1–12. [CrossRef]
14. He, J.; Zhang, S. How Digitalized Interactive Platforms Create new Value for Customers by Integrating B2B and B2C Models? An Empirical Study in China. *J. Bus. Res.* **2022**, *142*, 694–706. [CrossRef]
15. Keränen, J.; Jalkala, A. Towards a framework of customer value assessment in B2B markets: An exploratory study. *Ind. Mark. Manag.* **2013**, *42*, 1307–1317. [CrossRef]
16. Liu, Y.; Foscht, T.; Eisingerich, A.B.; Tsai, H.T. Strategic management of product and brand extensions: Extending corporate brands in B2B vs. B2C markets. *Ind. Mark. Manag.* **2018**, *71*, 147–159. [CrossRef]
17. Gozman, D.; Liebenau, J.; Mangan, J. The Innovation Mechanisms of Fintech Start-Ups: Insights from Swift's Innotribe Competition. *J. Manag. Inf. Syst.* **2018**, *35*, 145–179. [CrossRef]
18. Siddiqui, Z.; Rivera, C.A. FinTech and FinTech ecosystem: A review of literature. *Risk Gov. Control. Financ. Mark. Inst.* **2022**, *12*, 63–73. [CrossRef]
19. Muthukannan, P.; Tan, B.; Gozman, D.; Johnson, L. The emergence of a Fintech Ecosystem: A case study of the Vizag Fintech Valley in India. *Inf. Manag.* **2020**, *57*, 103385. [CrossRef]
20. Bayus, B.L. Crowdsourcing New Product Ideas over Time: An Analysis of the Dell IdeaStorm Community. *Manag. Sci.* **2012**, *59*, 226–244. [CrossRef]
21. Kleemann, F.; Voß, G.G.; Rieder, K. Un (der) paid innovators: The commercial utilization of consumer work through crowdsourcing. *Sci. Technol. Innov. Stud.* **2008**, *4*, 5–26. [CrossRef]
22. Mollick, E. The dynamics of crowdfunding: An exploratory study. *J. Bus. Ventur.* **2014**, *29*, 1–16. [CrossRef]
23. Belleflamme, P.; Lambert, T.; Schwienbacher, A. Crowdfunding: Tapping the right crowd. *J. Bus. Ventur.* **2014**, *29*, 585–609. [CrossRef]
24. Fleming, L.; Sorenson, O. Financing by and for the masses. *Calif. Mgmt. Rev.* **2016**, *58*, 5–19. [CrossRef]
25. Elsaid, H.M. A review of literature directions regarding the impact of fintech firms on the banking industry. *Qual. Res. Financ. Mark.* **2021**. *ahead-of-print*. [CrossRef]
26. Bajwa, I.A.; Ur Rehman, S.; Iqbal, A.; Anwer, Z.; Ashiq, M.; Khan, M.A. Past, Present and Future of FinTech Research: A Bibliometric Analysis. *SAGE Open* **2022**, *12*, 21582440221131242. [CrossRef]
27. Subbarao, D.J.I.J.O. Disruptive innovation in the financial sector. *J. Bank. Financ. Technol.* **2017**, *1*, 85–88.
28. Brenner, W.; Karagiannis, D.; Kolbe, L.; Krüger, J.; Leifer, L.; Lamberti, H.-J.; Leimeister, J.M.; Österle, H.; Petrie, C.; Plattner, H.; et al. User, use & utility research. *Bus. Inf. Syst. Eng.* **2014**, *6*, 55–61. [CrossRef]
29. Dunbar, R.L.M.; Starbuck, W.H. Learning to Design Organizations and Learning from Designing Them. *Organ. Sci.* **2006**, *17*, 171–178. Available online: http://www.jstor.org/stable/25146022 (accessed on 15 March 2023). [CrossRef]
30. Blog | TechMagic. Top FinTech Trends to Watch in 2023—TechMagic. 2023. Available online: https://www.techmagic.co/blog/fintech-trends/ (accessed on 2 June 2023).
31. Hedman, J.; Henningsson, S. Competition and Collaboration Shaping the Digital Payment Infrastructure. In Proceedings of the ICEC '12 14th Annual International Conference on Electronic Commerce, Singapore, 7–8 August 2012; Srivastava, R., Miller, S., Ee-Peng, L., Eds.; Association for Computing Machinery: New York, NY, USA, 2012; pp. 178–185. [CrossRef]
32. Jourdan, Z.; Corley, J.K.; Valentine, R.; Tran, A.M. Fintech: A content analysis of the finance and information systems literature. *Electron. Mark.* **2023**, *33*, 2. [CrossRef]
33. Aria, M.; Cuccurullo, C. bibliometrix: An R-tool for comprehensive science mapping analysis. *J. Informetr.* **2017**, *11*, 959–975. [CrossRef]
34. Gomber, P.; Kauffman, R.J.; Parker, C.; Weber, B.W. On the Fintech Revolution: Interpreting the Forces of Innovation, Disruption, and Transformation in Financial Services. *J. Manag. Inf. Syst.* **2018**, *35*, 220–265. [CrossRef]
35. Gomber, P.; Koch, J.-A.; Siering, M. Digital Finance and FinTech: Current research and future research directions. *J. Bus. Econ.* **2017**, *87*, 537–580. [CrossRef]
36. Buchak, G.; Matvos, G.; Piskorski, T.; Seru, A. Fintech, regulatory arbitrage, and the rise of shadow banks. *J. Financ. Econ.* **2018**, *130*, 453–483. [CrossRef]
37. Au, Y.A.; Kauffman, R.J. The economics of mobile payments: Understanding stakeholder issues for an emerging financial technology application. *Electron. Commer. Res. Appl.* **2008**, *7*, 141–164. [CrossRef]
38. Haddad, C.; Hornuf, L. The emergence of the global fintech market: Economic and technological determinants. *Small Bus. Econ.* **2019**, *53*, 81–105. [CrossRef]
39. Anagnostopoulos, I. Fintech and regtech: Impact on regulators and banks. *J. Econ. Bus.* **2018**, *100*, 7–25. [CrossRef]

40. Chen, M.A.; Wu, Q.; Yang, B. How Valuable Is FinTech Innovation? *Rev. Financ. Stud.* **2019**, *32*, 2062–2106. [CrossRef]
41. Jagtiani, J.; Lemieux, C. Do fintech lenders penetrate areas that are underserved by traditional banks? *J. Econ. Bus.* **2018**, *100*, 43–54. [CrossRef]

FinTech
Article

The Study of the Relationship among GCI, GII, Disruptive Technology, and Social Innovations in MNCs: How Do We Evaluate Financial Innovations Made by Firms? A Preliminary Inquiry

Aurel Burciu [1,*], Rozalia Kicsi [1], Simona Buta [1], Mihaela State [1], Iulia Burlac [1,2], Denisa Alexandra Chifan [1,3] and Beatrice Ipsalat [1]

1 Department of Management, Business Administration and Tourism, Faculty of Economics and Business Administration, "Ștefan cel Mare" University of Suceava, 720229 Suceava, Romania; rozaliak@usm.ro (R.K.); simonab@usm.ro (S.B.); mihaela.state@usm.ro (M.S.); iulia.burlac@usm.ro (I.B.); chifan.denisa@yahoo.com (D.A.C.); ipsalationelabeatrice@yahoo.com (B.I.)
2 Department of Organisation of Companies and Commercialisation, Faculty of Economics and Business Administration, University of Santiago de Compostela, 15705 Santiago de Compostela, Spain
3 Department of Management and Economics, Faculty of Social Sciences, University of Beira Interior, 6201-001 Covilha, Portugal
* Correspondence: aurel.burciu@usm.ro

Citation: Burciu, A.; Kicsi, R.; Buta, S.; State, M.; Burlac, I.; Chifan, D.A.; Ipsalat, B. The Study of the Relationship among GCI, GII, Disruptive Technology, and Social Innovations in MNCs: How Do We Evaluate Financial Innovations Made by Firms? A Preliminary Inquiry. *FinTech* **2023**, *2*, 572–613. https://doi.org/10.3390/fintech2030033

Academic Editors: David Roubaud, Riza Demirer, Otilia Manta, Mohammed K. A. Kaabar, Eglantina Hysa, Ovidiu Folcuţ and Anuradha Iddagoda

Received: 8 June 2023
Revised: 12 August 2023
Accepted: 18 August 2023
Published: 28 August 2023

Abstract: This study aims to assess and identify the role of disruptive/digital technologies in financial innovation strategies as part of social innovations at both the firm and country level. The analysis proposed by the present study brings useful theoretical/pragmatic insights on the application of financial technologies in the context of the "fintech" revolution, as a disruptive innovation. There are few studies of this type that "cross-examine" technical/social innovative capacity at the firm level vs. the same innovative capacity at the level of the world's major countries. Our proposed study brings some novel elements to the literature on this topic. First, the study synthesizes the factors/variables explaining technical/social innovative capacity as ranked by the GCI (Global Competitiveness Index) and GII (Global Innovation Index) at the country level and then correlates informal/empirical variables with the factors explaining innovative capacity for the 50 companies in the BCG (Boston Consulting Group) ranking. Second, the study identifies three "driving forces" (digital technologies, managers, and the market) as the main variables determining financial innovativeness (fintech revolution) at the firm level. Third, based on the "over-cross assessment" (non- statistical) of the information/data provided by the BCG study vs. the GII and GCI studies, the study suggests some ways to delineate and quantify financial innovation as part of social innovation (e.g., it is argued that up to 80% of the social innovation achieved annually by a firm relates to the financial relationships engaged by the firm with various categories of stakeholders). Finally, the study is also important from a pragmatic point of view as it suggests/proposes a number of principles that can be considered by managers for building a KM (knowledge management) and continuous financial innovation strategy. From a theoretical perspective, the study provides a starting point for further research aimed at explaining firm-level financial innovation (fintech as a disruptor) through the massive use of disruptive technologies.

Keywords: disruptive technology; financial innovation; social innovation; fintech revolution; MNCs

1. Introduction

From the 1990s to the present, the entire business environment in the global economy has entered in a phase of instability and/or successive and increasing change, due to political, technological, social, ecological, cultural, and other factors. Since 1970, Drucker [1] partially anticipated the new realities that were to emerge in the world economy, in that major transformations in technology, industrial structures, education, and public policy would generate a chaotic environment for all firms that operate transnationally. This idea has been confirmed by its existence since 1990, and the Great Global Recession of 2008–2010 came as further confirmation [2] of the unprecedented instability of the business environment. More recently, other major events at the global level (the trade war between the US and China, the social crisis caused by COVID-19, the war triggered by Russia in Ukraine, etc.) show us more and more clearly that we live in a risk society [3,4]. Major turbulences of the type mentioned above over the last three decades have generated chaotic changes in the business environment and especially in the financial markets [2]; only in the case of the social crisis generated by COVID-19 has there been relative stability in the financial markets. The stability of stock markets and financial markets at the international level, visible from 2020 until today, can be explained by the fact that systemic trust has remained relatively stable in the main countries of the world as well as at the global level, between firms/institutions and different international organizations [5]. In 2021, the Global Risks Report ranked epidemics among the top global risks with potentially significant impact, whereas after 2010, the main risk was considered financial failure [6]. According to Chen et al. (2019), there is no standard definition for what "fintech" means and what specific technologies have led to its manifestation as a "revolution" and/or disruptive innovation. The present study aims to provide some clarification on the use of digital/disruptive technologies as a tool to support firms in the realization of fintech innovations.

In the context described, given the unstable nature of the capitalist system, innovation can become a creative response to trends and transformations taking place in the economic and social environment [7–10]. Added to this is the technological opportunity created by progressive research in areas such as advanced manufacturing, robotics, and digital technologies and their implementation in different socio-economic areas. In contrast, the turbulence that spread throughout the economy during the economic crisis of 2008 [2] affected the innovative behavior of firms [11,12], especially as a result of delaying access to financial resources, all the more so as the nature of innovation projects makes their financing different from the financing of ordinary assets [13].

This study proposes an analysis of the relationship between financial innovative capacity at the country level (according to GII and GCI) and financial innovative capacity at the firm/company level (according to BCG and Forbes), taking into account that any entity can make extensive use of various disruptive technologies. In relation to the above-mentioned purpose, it is easy to deduce that there are several subsidiary objectives that are considered by the authors:

- A first objective is to conduct an in-depth analysis at the level of major countries (based on the rankings given by GCI and GII) to understand which are the main factors/pillars that highlight the use of disruptive financial technologies (associated with fintech) to explain technical, social, and financial innovative capacity.
- Another objective is to conduct a descriptive analysis at the level of MNCs considered to be innovative and high-performing (BCG and Forbes studies) to understand which are the main factors explaining the technical, social, financial, and other innovative capacities of these corporations. Associated with this objective, the study considers some generalizations from MNCs to the SME sector in the context of the fintech revolution over the past decade [14] and to outline/describe potential directions in which various disruptive financial technologies will be used in the future.

Finally, another objective related to the purpose of the present research is to analyze on the basis of "crossover assessment", from countries to firms and vice versa, what has been and is the role of disruptive financial technologies in the context brought by fintech. With regard to this objective of the study, it should be stressed that it does not aim to provide a single/unitary answer to the question in the title "How do you evaluate financial innovation made by firms", given the existence of millions of firms in the global economy. Also, in connection with this third objective of the study, it should be mentioned that the "crossover assessment" envisaged by the authors is to be made only on the basis of an informal and economic analysis (not on the basis of descriptive statistics). This is because, as Krugman argues [15], countries are "closed socio-economic systems" and firms are "open socio-economic systems"; any crossover assessment of macrosocial vs. organizational perspectives must be approached with great caution, whatever the subject of analysis of the research.

In a turbulent and/or chaotic business environment, the use of digital technologies as part of disruptive technologies can assist firms to improve their technical and social innovative capacity, and thus better respond to the challenges of going through a downswing in the cyclical evolution of business. More specifically, this study aims to identify the clearest and most substantiated principles that would support firms to implement financial innovation (as a major part of social innovation) through the extensive use of disruptive technologies.

A more in-depth analysis of what we call social innovations, and in particular disruptive social innovations, is needed, taking into account existing conceptualizations of disruptive innovation in general. By definition, continuous innovative activity at the firm level assumes the acquisition and processing of new knowledge by skilled employees who are motivated to learn persistently. A paper published in 1995 by Nonaka and Takeuchi argues how tacit and explicit knowledge held by employees in firms is transformed into innovations and patents, respectively, but it is particularly concerned with technical innovations [16]. By explicit knowledge we mean knowledge that exists in books and manuals and can be easily transferred to others. By tacit knowledge we mean knowledge of an intuitive nature, based on experience and which is more difficult to transfer to others.

The structure of our proposed research includes a literature review section, followed by a research design section. In this third section of the study, we formulate some hypotheses of the study and a logic flowchart. In Section 4 of the study, we carry out an in-depth analysis of the factors/variables explaining the competitive position and/or innovative capacity according to the GCI and GII rankings for the main countries of the world. Subsequently, in Section 5 of the study, we present the company approached as a "system" and the financial relationships it engages in with various stakeholders, relationships that can be managed efficiently based on digital technologies. In the final part of the study (Section 6), we present some "driving forces" for financial innovation using disruptive technologies at the firm level and analyze the main variables/factors that explain financial/social innovative capacity for the 50 companies included in the BCG ranking. Also, in the sixth part of the research, we recurred to our own analysis in which we "cross-reference" (mix) the main data provided by the international literature, the GCI study, and the GII study, including the BCG study, in an attempt to suggest our own way of assessing financial innovations as part of the social innovations that are carried out by firms. In this stage, we have outlined a number of "*n*" principles that can be considered for strategic thinking on social innovation at the firm level in different countries of the world. The same principles for financial/social innovation are also of interest from a theoretical perspective as they provide a "common denominator" for future studies that aim to argue the relationship between disruptive technologies and innovative capacity at the firm/country level.

2. Literature Review

One of the main ideas of Schumpeter's thought explains economic cyclicality as the result of innovation, which in turn is shaped by economic dynamics [17]. In Schumpeter's view [18], entrepreneurs successively bring technical, organizational, or other novelties to the market and society, which means technical and social innovations. The competition between entrepreneurs and continuous innovation generates, under certain conditions, the emergence of a new industry, which means "creative destruction" [18,19].

In the 1980s, Drucker and other authors argued quite well that social innovations are at least as important as technical innovations [20,21]. Thus, from the 1980s to the present day, we discuss technical innovations (mainly concerning products and technologies) and social innovations (mainly concerning market relations and organization). In 1997, Christensen [22] proposed the concept of "disruptive innovation" as equivalent to "creative destruction"; subsequently, dozens of volumes and articles have been written on disruptive innovations/technologies and their role for the economic progress of countries/firms [22–28]. There is no single or unified approach to defining the concepts of "technical innovation" and "social innovation" and the elements that give content to each concept. In the same vein, we would point out that the international literature does not provide a clear and uniform method for quantifying "technical innovation" vs. "social innovation", especially when it comes to evaluating/measuring the results of such innovation on social progress.

In organizational studies, Grimm et al. (2013) [29] argue social innovation can refer to social capital, organizational learning and employee training, knowledge sharing, and other aspects that strengthen the capacity of firms/organizations to become more resilient to the changes that a completely chaotic business environment generates [2]. Social innovation, argue Pot and Vass [30], has become one of the major challenges facing Europe today; this type of innovation refers to vision and management structures, organizational flexibility, the development of skills and competences, networking with other organizations, and any other aspect whereby technological innovations are embedded in social structures and contribute to social progress. Most studies on social and/or technical innovation converge towards the conclusion that the widest possible use of digital technologies directly supports companies in achieving core competences [30–32]. At the same time, the use of digital technologies can be located at three levels of analysis, i.e., the macro-level, meso-level, and micro-level [29]; these technologies directly enhance the achievement of technical and social innovations alike. However, it is extremely difficult to quantify precisely the effect/benefits brought about by technical and social innovations at any of the three levels of localization. Even with reference to technical innovations, for which we have the number of patents a firm has annually (by aggregation at the national/regional level), which we also refer to through the sample of 50 innovative companies in the BCG study (Table S2), it is difficult to estimate the commercial effects and impact of a higher number of patents on a company's performance. As shown in Table S2, companies such as IBM obtain up to 9000 patents annually, which gives a fairly clear picture of the R&D investment and creative capacity of the organization (but only a quarter to a third of the annual patent portfolio has commercial application). Even more so, when looking at social innovations at the micro-, meso-, or macro-level, it is almost impossible to quantify precisely the benefits that such innovations bring (both for the world's leading countries and for MNCs entering rankings such as Forbes 2000.

According to the Pareto principle, regarding the random distribution of the results that a process or an economic variable generates, one can accept as a starting point the 80–20% rule in trying to estimate the importance of social innovations vs. technical innovations as an influence on social/economic progress. The same Pareto principle can be used, also as a starting point, when aiming to make a clear distinction between financial innovation and other types of social innovation (which we refer to in more detail from Section 4 of the study to the conclusions part). According to the arguments made by Pot and Vass [30], social innovations account for about 75% of the cumulative effect of innovations on social progress. In Figure 1, we present this delimitation between social innovations and technical innovations as a preliminary argument to the question in the title of the study: "how do we evaluate financial innovations made by firms?"

In relation to the Pareto principle we have invoked, it should be underlined that it is not true in all cases in the global economy and that it is not necessary to confirm it in the activity of thousands or dozens of firms (depending on the field in which a firm is located, there will be situations of the distribution of results such as 60–40%, 50–50%, etc.). Even if the pragmatic usefulness of the Pareto principle is limited, its acceptance can support the extension of fintech theories and the construction of effective KM and continuous innovation strategies at the firm level.

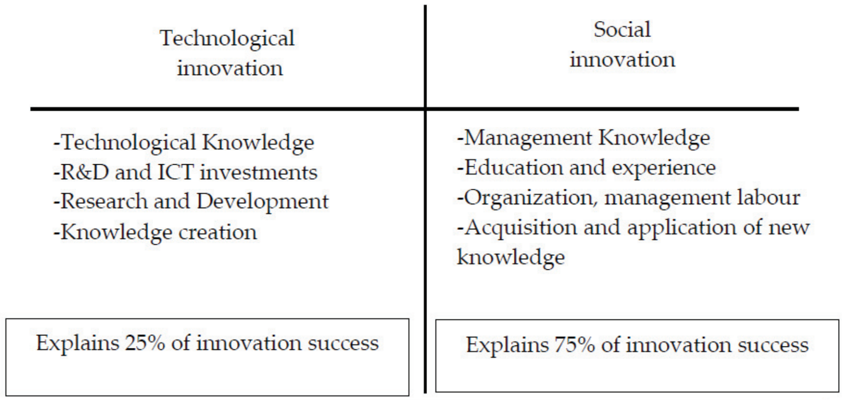

Figure 1. Impact of technological and social innovation on social progress. Source: [30].

In direct connection with the distinction between social innovations and technical innovations, it is appropriate to further recall/define concepts such as “disruptive innovation”, “creativity”, “fintech”, “open innovation”, “financial innovation”, etc. By disruptive innovation we refer to a technical and/or social innovation carried out by a company/organization that brings an element of novelty to the product/service, organization, or market, which then generates major changes in the relationship with consumers and, as a consequence, challenges established companies in the field [22]. Whatever the type of innovation carried out by a company, other organizations, or an individual, at the core of the process of bringing an element of novelty is tacit knowledge and individual and/or group creativity. In a general sense, creativity is the ability to think in new ways in relation to already known problems and to formulate new questions through ‘thinking outside the box’ processes. The concept of ‘fintech’ has emerged relatively recently (last decade) in the strategies/practices applied by some firms using digital technologies and bringing major innovations to segments of the financial markets in the global economy. Some authors [14] estimate that, as of 2017, we must discuss a real revolution in relation to the implications of the fintech concept and/or major transformations in financial services. This is because fintech has become a disruptive innovation with major effects on the functioning of traditional financial markets; the fintech concept is challenging banks, insurance companies, investment funds, management consulting firms, etc. The disruptive effects of fintech, according to Gomber et al. [14], take the form of new business models, new markets, new ITC networks, cross-border innovations, new forms of lending, cross-border payments, open banking operations, etc. In summary, it can be said that fintech greatly extends the application of financial technology to individuals, start-ups, thousands of SMEs, etc. [27,31]; fintech is therefore a kind of disruptive social innovation involving major benefits/transformations that may prove to be more socially important than technical innovations on products [29]. In direct connection with disruptive innovation, the concept of open innovation has developed more recently [32,33], which essentially refers to the orientation of a firm towards various stakeholders to build alliances, partnerships, and other business networks through the use of digital technologies, leading to a cumulative effect on the sources for continuous innovation. In regards to the concept of “financial innovation”, it refers to any innovation that an organization or country manages to bring about with regard to processes, operations, or activities involving financial flows either of the traditional type (through banks, insurance companies, investment funds, etc.) or of the digital type, among which fintech operations and/or markets already have a well-defined position. The expansion of fintech firms has relied, in particular, on “unbanked costumers”, various start-up firms in high-tech industries, and millions of investors from various countries; a new business model applied by fintech firms through the digitization of financial services has given rise to new market segments. From the perspective of studies on fintech, as assessed by Aysan and Nanaeva [34], fintech has become a financial disruptor; most studies on this topic, a total of 363 papers, have only been published since 2017. It will be very difficult for large corporations, argue Gomber et al. [14], to build strategies in KM and with respect to the acquisition of new knowledge and Human Resources (HR) to be competitive in fintech markets where small start-ups that rely exclusively on disruptive financial technologies are already operating.

In some situations, Christensen argues [22], large companies remain somehow captive "by their customers", they react slowly and the new markets that emerge are quickly filled by successful start-ups that build their strategy on the use of digital technologies. According to a study by Deloitte [35], traditional financial institutions are increasing their investments in fintech operations/activities year after year, particularly in the acquisition of new disruptive technologies, in order to compete with fintech start-ups based on cloud computing, mobile telecommunications, and similar technologies. The same Deloitte study anticipates that there are several important trends in the fintech markets (trend 1: traditional financial firms are increasingly involved in fintech operations; trend 2: blockchain technology eliminates the need for intermediaries in various asset transactions; trend 3: in various countries, governments and other regulators are increasingly interested in regulating fintech markets; and trend 4: financial company executives are increasingly interested in the challenges that disruptive technologies bring). According to some assessments made by fintech industry experts for the year 2023 [36], especially following the bankruptcy of the American company FTX, new regulations will be adopted in the fintech markets, but fintech technologies will continue to remain popular in the future (such predictions are also found in some units/services of large corporations such as IBM, according to financial services digital transformation). Regional and/or country differences in fintech adoption exist and will remain, but all assessments indicate that the fintech industry will continue to expand rapidly in the coming years [37].

The disruptive or non-disruptive nature of a technical, social, or financial innovation cannot be anticipated by innovators, firms, or organizations; it will be determined by the confrontation between the outcome of the innovation and the market and/or society. When discussing the practice of innovation, says Drucker, one can only speak of intentional innovation as the result of a systematic analysis/effort made by individuals and organizations [21]. In some cases, companies may imitate other competitors with respect to technical/social innovations that are made and already have acquired market effects [20]. the orientation of Chinese firms towards "market-driven R&D" and/or "knowledge-driven R&D" has allowed some MNCs in China to develop "open innovation" networks and become formidable competitors in some international markets. Chinese companies such as Alibaba or Yuwell, say Yip & McKern, have realized their own social innovations and started to develop separate divisions for fintech operations/markets [20]. The orientation of firms towards both technical and social "open innovation" networks, the formation of various alliances/partnerships, and the extensive use of disruptive financial technologies directly support KM application strategies for continuous innovation [38,39].

Some studies highlight the role of digital technologies in enhancing sustainable development in various countries/regions of the world, in balancing gender ratios, in managing various organizations, in holding social positions, etc. [40–43]. Other studies explore, as appropriate, the role of digital/disruptive technologies for GDP growth at the country level, for process optimization at the company level, as well as on the changes these technologies bring to society; times of crisis in society/economy seem to be better managed through ICT-enabled advances [8,13,44–48]. In short, it can be concluded that episodes of crisis transform the environment and the innovative behavior of firms. Thus, while the pre-crisis model of creative accumulation better explains the results, in the post-crisis period, the model of creative destruction seems to dominate. Moreover, the manufacturing sector, the main generator of technological innovations, tends to matter less in value creation and employment, while the services sector is more likely to compete through non-technological innovations.

3. Research Design

3.1. Hypotheses and Stages

In our study, we aimed to identify/argue the relationship between disruptive technology and financial innovations (related to fintech) simultaneously at the level of major countries of the world and performing MNCs in international competition. At the same time, we intend to suggest some principles for the realization of financial innovation by firms; such principles would also be of theoretical interest in that they would become a starting point for other similar studies. Most studies [43,49] on financial innovation through the use of disruptive technologies refer either to firms in high-tech sectors of the manufacturing industry (pharmaceuticals, ITC, etc.) or to firms in more knowledge-intensive service sectors—KIS (especially in the banking sector, insurance sector, and other fintech start-ups; [36]). There are few studies that propose financial innovation evaluation by technologies from both a country and a firm perspective and that, in addition, propose a synthetic analysis of the factors/principles that explain the innovative capacity of an entity (whether it is a firm in the manufacturing industry or KIS). Another important aspect to achieve the aim of our research is the identification of a unified classification of innovation types/categories. In the sense invoked, according to the Oslo Manual under the auspices of the OECD [50] and the European Commission, there are four types/categories of innovations: product innovations, process innovations, marketing innovations, and organizational innovations (ref. [50]). As we will show later (point 6.2 in Section 6 of the study), financial innovation at the level of any firm refers, in particular, to marketing innovations and organizational innovations (even if it is not possible to clearly delimit/dissociate between the four types of innovations mentioned, the way in which protection can be obtained for an element of novelty in a firm, and the industry sector in which the firm is located). In direct connection with the intended purpose of the study, it aims to conduct an assessment/analysis from the SME sector to established MNCs in the context of the revolution brought by fintech firms and/or markets (ref. [14]) in order to identify strategies/practices that large corporations (non-financial and financial), according to UNCTAD classification [51], are resorting to in order to adapt to the new realities generated by financial technologies. Also, in the sense mentioned above, we aim to understand the conceptualizations that have recently emerged in the literature on fintech and the directions that can be envisaged regarding the quantification of financial innovations based on disruptive technologies.

In order to achieve the proposed objectives, we have proceeded through several steps/stages specific to such research:

- ✓ In stage 1 (abbreviated S1), we selected and reviewed the international literature on the concept of fintech and on financial innovation, the use of digital technologies in society, etc., both from a macro-social/societal perspective and from the perspective of firms.
- ✓ In stage 2 (abbreviated S2), at the basis of our study, we state the following four research hypotheses:

H1: There is no direct correlation (causality, association, etc.) between annual technical innovation, in terms of the number of patents, and annual social innovation (trademarks, industrial designs, etc.; social innovations related to strategy and organizational structure and which cannot be protected with registration) at the level of MNCs or SMEs. The sector in which a firm is located (high-tech, medium-tech, low-tech, etc.) provides opportunities/conditions for firms to innovate towards technical innovations, social innovations, or both. However, it remains essential for the top-management vision of any organization, MNCs, or SMEs, regarding the achievement of technical vs. social innovations through the acquisition and processing of new knowledge.

H2: In the overall social innovation carried out annually by a firm, MNCs, or SMEs, financial innovation may account for up to 80% of the novelty elements brought by the organization in relation to its organizational structures, market, or society. This hypothesis is taken into account in the study, since most of the current relationships (daily, monthly, etc.) that a firm engages in with various stakeholders (shareholders, suppliers, customers, banks, etc.) also involve financial relationships. It is neither possible nor necessary to quantify precisely the share of financial innovations as part of annual social innovations, as there are millions of firms in the global economy. The widespread application of digital technologies in most countries of the world and the almost exponential growth of interest in the concept of fintech is a relatively current reality, respectively, from 2018 to the present, with particular reference to financial industries. It is useful and beneficial to clearly differentiate between financial innovation and other social innovations based on the Pareto principle for the random distribution of outcomes of economic variables.

H3: Countries that are internationally competitive/innovative have a number of MNCs and/or SMEs that are each at least average in innovation and annual performance (both technical and social). This is even if only a small number of MNCs from various countries end up being included in international rankings pre-like BCG, Forbes, etc. The "over-cross assessment" of the influence relationship between firms and countries with respect to annual technical/social innovation cannot be performed on the basis of descriptive statistics. This assessment can and should only be made on an empirical basis, taking into account studies on fintech and financial innovation [14,29,31,37,52], together with a logical and cross-sectional analysis of the information provided by some firm rankings (BCG, Forbes, etc.) vs. some country rankings (GCI, GII, etc.).

H4: The widest possible use of disruptive technologies (especially digital ones) greatly enhances the innovative capacity of any entity (country, company, and other organizations), both for technical and financial/social innovations. All the international rankings on which the present study is based (GCI, GII, BCG, etc.) include in their calculation methodology at least two or three sub-pillars that take into account the use of ITC by firms or individuals at various levels of a reference/analysis. This is particularly because digital technologies have become essential today for education, access to knowledge, increasing labor productivity, continuous innovation, open innovation networking, etc.

- ✓ In stage 3 (abbreviated S3), we selected the GCI (Global Competitiveness Index) ranking [53,54] for the period 2009–2019 in an attempt to obtain a first picture of the competitiveness/innovative capacity of the world's major countries. This first picture based on the GCI gives us, at the same time, elements of interest for our study on the innovative capacity existing in the firms of these countries (since some sub-pillars such as social capital, cooperation in labor employer relation, university industry collaboration in R&D, and the extent of staff training give us important information for innovation in firms). In the case of this GCI ranking, we selected only 28 main countries of the world for which we present in Table S1 the preliminary statistical data on which we subsequently applied specific assessments such as a factor analysis, regression analysis, etc. According to the summary in Table S1, it appears that we selected at the same time only seven sub-pillars considered as main and which provide relevant information for the cross analysis of innovative capacity, simultaneously at the level of firms and countries. In the case of the GCI ranking, we selected 2019 vs. 2009, and then in the case of the GII ranking, we selected the ranking for 2020 vs. 2010 since, for the purpose of the proposed research, an evaluation based on descriptive statistics between the two different rankings is not envisaged. The assessment is intended to be performed only empirically and economically between the information provided by the GCI and the GII for the factors that support/explain innovative capacity in firms (part 2 of the proposed study).
- ✓ In stage 4 (abbreviated S4), we selected the GII (Global Innovation Index) ranking [55,56] for the period 2010–2020 to see which of the world's major countries have an innovative capacity above the average of the entire group of countries analyzed by this annual ranking. Even the choice of this ranking was determined by the fact that some of the sub-indexes (e.g., gross expenditure on R&D and global R&D companies; ICT access, ICT use, GERD performed by business enterprise, etc.) also provide valuable

information on the innovative capacity of firms in these countries. The inclusion in our study of GCI and GII at slightly postponed times has been foreseen for informal comparisons that can be formulated already at this stage of the study (year 2010 vs. 2009, respectively, year 2020 vs. 2019), in order to connect these comparisons later with the microeconomic perspective on innovative, technical, and/or other capacities in the main countries/firms of the world.

✓ In stage 5 (abbreviated S5), we chose a study provided by BCG (Boston Consulting Group) [44], which highlights 50 of the most innovative companies in the world (27 firms—USA; 15 firms—Asia; and 8 firms—Europe) and for which, based on the Annual Report of each organization, we highlighted, in Table S2, technical and social innovative capacity together with some information on size, financial performance, etc. The ranking provided by BCG (summarized in Section 6 of the study and excerpted in Table S2) is for the years 2022 and 2023, but has been calculated annually by the Boston consulting firm since 2004. The data on the 50 MNCs in the BCG study were then statistically ordered with a clustering analysis of the firms in the sample, drawing dendograms for the selected firms, etc., trying to identify association relationships between companies, sectors in which they are located, net income, and countries of affiliation. In addition to the information provided by the BCG study, we analyzed in depth the annual ranking published by Forbes, namely Forbes 2000 [45], to see, selectively, the association between some of the less-known companies, their inclusion in the fintech category, and their countries of origin.

The evaluations in the S5 stage started with the S3 stage of the study and ran continuously, simultaneously, and in parallel with other stages of the study such as S4, S6, S7, S8, and S9, as we present graphically, in the next section of the study, under a flowchart underlying our research.

✓ In stage 6 (abbreviated S6), we conducted, in parallel with S3, an analysis based on descriptive statistics on all the information provided by the seven sub-pillars of the GCI ranking; this information was then empirically and not statistically correlated with similar information provided by the GII and that based on descriptive statistics in the BCG ranking.

✓ In stage 7 (abbreviated S7), similarly to the previous step, but in parallel with S4, we carried out an analysis also based on descriptive statistics on all the information provided by the GII ranking; this information on innovative capacity at the level of the main countries was then correlated empirically and not statistically with similar information provided by the GCI and that based on descriptive statistics in the BCG ranking.

✓ In stage 8 (abbreviated S8), we conducted an in-depth analysis based on descriptive statistics for only the 50 companies considered by BCG to be the most innovative globally in 2022. Including for this ranking, we empirically and informally analyzed the innovation situation at the time of 2023 vs. 2022, but the static tests of correlation, clustering, etc., and the data in Table S2 are only for the 2022 ranking. It is not possible to make a statistical analysis of the relationship between the innovative capacity at the firm level (the 50 firms in the BCG ranking) and the innovative capacity at the country level; this relationship can only be described and interpreted empirically and informally.

✓ In stage 9 (abbreviated S9), we include, as a separate step, a sequential "crossover assessment" between factors/variables, showing financial innovation as part of social innovation on the relationship between countries and firms and vice versa. Including in this S9 stage, no statistical tests were considered and applied to analyze the relationship between the information provided by the BCG survey and the information provided by the two country rankings.

3.2. Logical Framework of the Study

The international literature on fintech firms/organizations [14,31,37] shows us that particularly in the case of SMEs, there has been a strong interest in applying digital technologies to develop/expand mainstream and/or disruptive financial innovations from 2016 to the present. This topic related to fintechevolution was continuously considered by the authors in the development/study of all nine stages of the study. The flow chart of the study is presented in Figure 2.

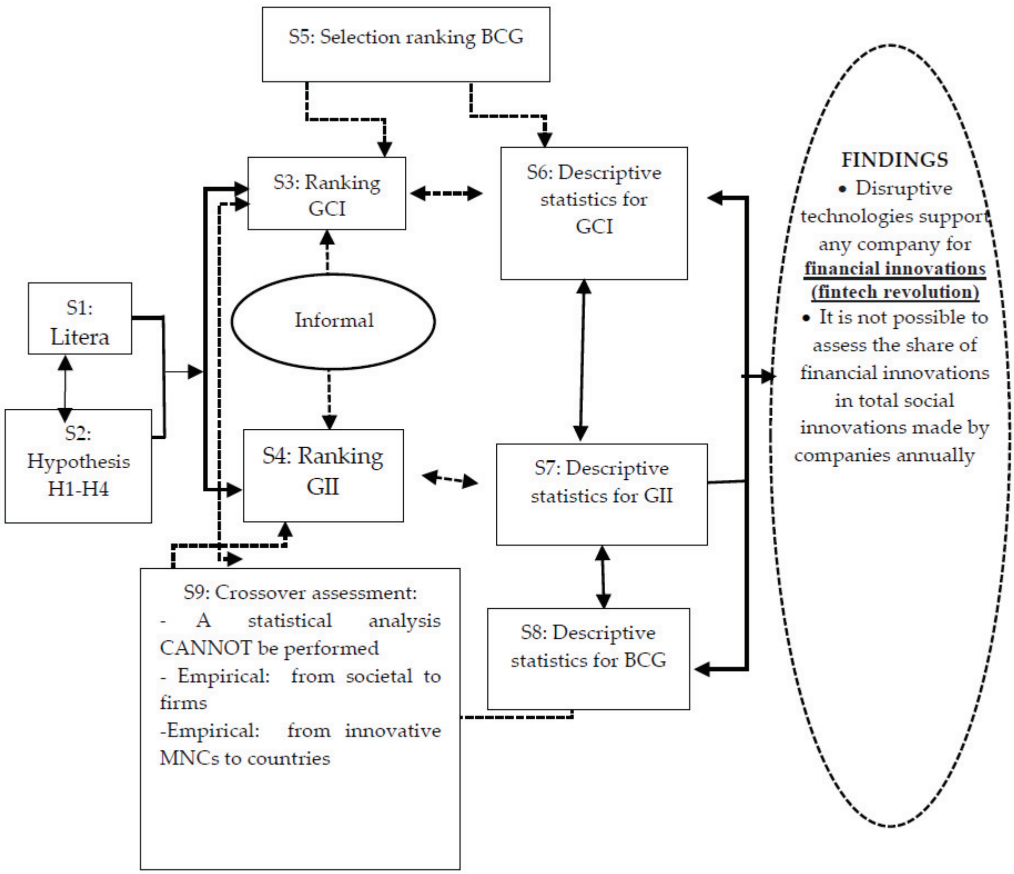

Figure 2. The logic flowchart of the study. Source: elaborated by the authors.

In direct relation to this section of the study (Section 3), we formulate two mentions related to the research methodology:

a. First, the analysis based on "descriptive statistics" is applied only for the processing/interpretation of data "inside" each in-country ranking, i.e., GCI, GII, and distinctly BCG, not for the "crossover assessment" on the identification of factors explaining the financial/social innovation capacity simultaneously at the firm and country level. The hypothesis of applying a crossover assessment based on descriptive statistics from the BCG study to the two country rankings was considered by the authors, but it leads to non-rational conclusions that contradict the realities of the global economy (it would be inferred that only US firms, which categorically dominate such rankings in the proportion of about 2/3 of the total ranked firms, are the most financially/socially innovative and that only the culture of these firms supports the application of KM strategies).

b. We used a double-cross analysis of the information provided by the GCI and GII rankings reflecting the technical/social innovation capacity of the world's major countries. Thus, in the case of the GCI ranking, we first selected 7 sub-pillars (out of 12 pillars), based on two criteria, considered to be more important for the purpose of the study, together with 28 countries, and then we evaluated this information only economically vs. GII vs. BCG (not statistically). Secondly, in the case of the GII ranking, we performed a descriptive statistics analysis based on the "inside" ranking data and following a clustering analysis, we retained which sub-pillars are more important (along with average/above-average countries) that could explain the financial/social innovation capacity at the firm level. It is neither appropriate nor necessary to perform a crossover assessment analysis based on descriptive statistics between the GII and GCI data, given the intended purpose of the study. It is neither appropriate nor necessary to perform a similar "crossover assessment" based on descriptive statistics between the information provided by BCG for 50 innovative companies and the information provided by GCI and GII (the study argues that a firm is an open socio-economic system and any country is a closed socio-economic system, so they are different realities and should be evaluated with great caution whatever the topic of the research).

4. Analysis from Societal Perspective

4.1. Implications of GCI for Financial Innovation

By "implications of the GCI for financial innovation" we mean that this ranking provides some useful, although partial, information for understanding and subsequently assessing (Section 5 of the study, Main Findings) innovative capacity at the firm level. Our assessment focuses on MNCs, as the realities of the last three decades in the global economy lead to the conclusion that these categorized organizations in particular have become the main vectors for technical and social innovation. As argued in [57], medium and large firms have become essential for R&D and innovation, job creation, exports, revenues, productivity, and other critical indicators for competition in different markets. At the same time, our assessment, reasoning, and conclusions may also include, where appropriate, firms in the SME category (in high-tech sectors such as IT, telecommunications, etc., firms with a significant number of employees can quickly become highly innovative).

Based on this ranking (GCI), we conducted a comparative analysis at the time of 2009 and, respectively, 2019, trying to identify what are the main correlations and significant associations between the different sub-pillars of the ranking, as well as the extent to which these sub-pillars support the understanding of technical and social innovative activity at the firm level (from a microeconomic analysis perspective). As is well known, the GCI ranking is based on 12 main pillars (institution, infrastructure, ICT adoption, macro-economic stability, product market, business dynamism, innovation capability, etc.); countries are grouped by main ranking and by sub-pillars, based on a "score" expressed on a scale of 0–100 (the relative position of countries). In our analysis, we selected the number of seven variables that should show us, cumulatively, the innovative capacity at the country level (abbreviations used: social capital—SC; health and primary education—HPE; health–life expectancy—HLE; higher education and training—HET; mean years of schooling—MYS; extent of staff training—EST; cooperation in labor–employer relations—CLER; state of cluster development—SCD; university–industry collaboration in R&D—UIC-R&D; and multistakeholder collaboration—MC). In relation to the seven variables selected by the authors for the statistical evaluation of possible correlations in 2019 vs. 2009 (data resulting in tables starting from Tables 1–9), we mention:

Table 1. Correlation Matrix [a] for the year 2009.

Variables		SC	HPE	HLE	EST	CLER	SCD	UIC-R&D
Correlation	SC	1.000	**0.500**	**0.496**	**0.402**	0.305	0.035	0.289
	HPE	0.500	1.000	**0.748**	0.297	**0.425**	0.123	**0.429**
	HET	0.496	0.748	1.000	**0.694**	**0.555**	0.179	**0.791**
	EST	0.402	0.297	0.694	1.000	**0.705**	0.087	**0.800**
	CLER	0.305	0.425	0.555	0.705	1.000	**−0.296**	**0.689**
	SCD	0.035	0.123	0.179	0.087	−0.296	1.000	0.101
	UIC-R&D	0.289	0.429	0.791	0.800	0.689	0.101	1.000
Mr (1-tailed)	SC		0.003	0.004	0.017	***0.058***	***0.431***	***0.068***
	HPE	0.003		0.000	***0.063***	0.012	***0.267***	0.011
	HET	0.004	0.000		0.000	0.001	***0.181***	0.000
	EST	0.017	0.063	0.000		0.000	***0.330***	0.000
	CLER	0.058	0.012	0.001	0.000		0.063	0.000
	SCD	0.431	0.267	0.181	0.330	0.063		***0.304***
	UIC-R&D	0.068	0.011	0.000	0.000	0.000	0.304	

[a] Determinant = 0.007.

Table 2. Correlation Matrix [a] for 2019.

Variables		SC	HLE	MYS	EST	CLER	SCD	MC
Correlation	SC	1.000	**0.703**	**0.539**	**0.398**	**0.514**	**0.572**	**0.348**
	HLE	0.703	1.000	0.466	0.164	0.296	**0.450**	0.124
	MYS	0.539	0.466	1.000	**0.563**	**0.439**	**0.510**	**0.526**
	EST	0.398	0.164	0.563	1.000	**0.799**	**0.666**	**0.932**
	CLER	0.514	0.296	0.439	0.799	1.000	**0.563**	**0.738**
	SCD	0.572	0.450	0.510	0.666	0.563	1.000	**0.735**
	MC	0.348	0.124	0.526	0.932	0.738	0.735	1.000
Mr (1-tailed)	SC		0.000	0.002	0.018	0.003	0.001	0.035
	HLE	0.000		0.006	***0.203***	***0.063***	0.008	***0.265***
	MYS	0.002	0.006		0.001	0.010	0.003	0.002
	EST	0.018	0.203	0.001		0.000	0.000	0.000
	CLER	0.003	0.063	0.010	0.000		0.001	0.000
	SCD	0.001	0.008	0.003	0.000	0.001		0.000
	MC	0.035	0.265	0.002	0.000	0.000	0.000	

[a] Determinant = 0.002.

Table 3. KMO and Bartlett's Test for 2009.

KMO and Bartlett's Test		
Kaiser–Meyer–Olkin Measure of Sampling Adequacy.		0.627
Bartlett's Test of Sphericity	Approx. Chi-Square	119.937
	df	21
	Mr	0.000

Table 4. KMO and Bartlett's Test for 2019.

KMO and Bartlett's Test		
Kaiser–Meyer–Olkin Measure of Sampling Adequacy.		0.780
Bartlett's Test of Sphericity	Approx. Chi-Square	143.035
	df	21
	Mr	0.000

Table 5. Total Variance Explained for 2009.

Component	Initial Eigenvalues	Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings			
	Total	% of Variance	Cumulative %	Total	% of Variance	Total
1	3.770	53.860	53.860	3.770	53.860	3.763
2	1.234	17.623	71.484	1.234	17.623	1.238
3	0.938	13.395	84.879			
4	0.586	8.378	93.257			
5	0.258	3.684	96.941			
6	0.147	2.095	99.037			
7	0.067	0.963	100.000			

Extraction Method: Principal Component Analysis. (When components are correlated, sums of squared loadings cannot be added to obtain a total variance).

Table 6. Total Variance Explained pentru 2019.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.216	60.222	60.222	4.216	60.222	60.222	3.848
2	1.369	19.562	79.784	1.369	19.562	79.784	2.741
3	0.534	7.625	87.408				
4	0.435	6.212	93.620				
5	0.255	3.642	97.262				
6	0.140	1.997	99.259				
7	0.052	0.741	100.000				

Extraction Method: Principal Component Analysis.

Table 7. Matrix of components rotated at the time of 2009.

Pattern Matrix [a]		
Variables	Component	
	1	2
SC	0.599	
HPE	0.714	
HET	0.924	
EST	0.837	
CLER	0.759	−0.541
SCD		0.881
UIC-R&D	0.868	

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization [a].

[a] Rotation converged in 4 iterations.

Table 8. Matrix of rotated components at the time of 2019.

Pattern Matrix [a]		
Variables	**Component**	
	1	**2**
SC	0.721	0.544
HLE	0.535	0.766
MYS	0.736	
EST	0.871	
CLER	0.824	
SCD	0.839	
MC	0.852	−0.464
Extraction Method: Principal Component Analysis [a].		

[a] Two components extracted.

Table 9. Rotated Component Matrix at the time of 2019.

Rotated Component Matrix [a]		
	Component	
	1	**2**
SC		0.833
HLE		0.985
MYS		0.485
EST	1.001	
CLER	0.816	
SCD	0.649	
MC	1.015	
Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization [a].		

[a] Rotation converged in 6 iterations.

In the following, we summarize in Tables 1 and 2 the “correlation matrix” for previously reported issues at the time of 2009 and 2019, respectively.

We present below the correlation matrix in SPSS for 2009 (Table 1) and for 2019 (Table 2). In the first half of the tables are the pairwise correlations between the seven variables included in the analysis for the 2 years (sub-pillars). In the second half of the table are the significance coefficients calculated for the correlation coefficients obtained (having different values in 2019 vs. 2009).

The methodology for calculating the GCI in 2019 has changed significantly compared to the one applied in 2009, which is why some sub-pillars in 2019 have different names from their 2009 counterpart, as they have taken in their content other elements/factors of the same nature (pillar HPE and HLE have different names, but both refer to human capital; similar to HET and MES; similar to innovative capacity, i.e., UIC-R&D and MC).

The selection of the seven sub-pillars was made based on the relevance/significance criteria they cumulatively provide on the factors determining technical and social innovative capacity at the firm level; the same relevance of the selection criterion was taken into account by empirically relating the information provided by GCI vs. GII (the latter is presented by us in the next subsection of the study). A second selection condition was given by the need to “cover” most of the 12 main pillars with the seven variables and which refer, at the same time, directly or indirectly, to R&D and innovation activity in firms. A total of 28 main countries of the world were selected (countries that are in the top positions in the ranking both at the time of 2009 and at the time of 2019; Switzerland, USA, Japan, Singapore, South Korea, Germany, Denmark, France, the Netherlands, UK, etc.; countries that are important in the global economy but have a more prudent/modest position in the ranking; countries such as Argentina, Brazil, China, India, Mexico, South Africa, etc.).

In both tables, we used some unitary underlining, respectively:

In each table, we marked in bold the significant correlations between the seven variables (this means statistically significant correlations; some sub-pillars help us to further understand the factors explaining the innovative capacity of the companies in the BCG ranking).

We marked in bold and italics in each table the sig. coefficients of significance greater than 0.05 between the seven variables, which indicate that there are no statistically significant correlations.

Taking into account the previous mentions, some conclusions of interest for our study can be drawn (which will then be correlated with the information shown by the GII ranking and the situation of the 50 companies in the BCG ranking):

The situation of insignificant correlations between the seven variables has changed significantly during the decade under analysis, i.e., in 2009, there were five correlations of this type, and in 2019, there were only two correlations of this type:

At the time of 2009, the realities of the following variables were insignificant:

- SC variable and CLER, SCD variable and UIC-R&D;
- HPE variable and EST, SCD;
- HET variable and SCD;
- EST variable and SCD;
- SCD variable and UIC-R&D.

At the time of 2009, a smaller number of the following variables were insignificant:

- HLE variable and EST;
- CLER variable and MC.

In addition, it is easy to notice that the association between variables recording insignificant correlations is completely different at the two moments of analysis (this means that different pillars of the GCI component advanced/evolved differently from one country to another and led to changes in position at both the pillar and ranking level in 2019 vs. 2009).

The situation of significant correlations between the seven variables has changed significantly over the decade analyzed, i.e., in 2009, there were three such correlations and in 2019, there were four such correlations:

✓ At the time of 2009, there were significant differences between the following variables:
  - HPE and HET (0.748);
  - EST and CLER (0.791);
  - EST and UIC-R&D (0.800).

✓ At the time of 2019, there were significant realities between the following variables:
  - EST and CLER (0.799);
  - EST and MC (0.932);
  - CLER and MC (0.738);
  - SCD and MC (0.735).

From the data presented in Tables 1 and 2, it is easy to see that the association between variables with significant correlations has changed significantly during the decade under analysis, 2019 vs. 2009. At the time of 2019, there were four statistically significant correlations between the seven variables compared to only three such correlations at the beginning of the period. These statistical correlation changes between the different variables/factors about which the GCI provides information derive from changes in the overall ranking and/or ranking of the pillars in the competitive position component. Such changes in terms of the ranking provided by the GCI for the world's leading countries will then be analyzed, "cross-referenced", with the main conclusions provided by the GII ranking (including performing an informal analysis, using main influencing factors, of some deductible aspects for the year 2020 vs. 2019 and 2010 vs. 2009, respectively) and the main conclusions provided by the BCG ranking for the 50 MNCs considered to be the most innovative in the world.

Next, based on the information provided by the same GCI ranking, we calculate and present synthetically the KMO and the Bartlett sphericity test (Tables 3 and 4), as well as the Initial Eigenvalues associated with each factor before extraction, after extraction, and after rotation (Tables 5 and 6).

Tables 3 and 4 present two indicators relevant to our study, namely the KMO (Kaiser–Meyer–Olkin) and the Bartlett sphericity test. The KMO varies between 0 and 1. A value close to 0 indicates that the sum of partial correlations is relatively high compared to the sum of correlations and a factor analysis is not indicated while a value close to 1 indicates that a factor analysis should produce distinct and reliable factors. A value above 0.5 is considered acceptable (http://cda.psych.uiuc.edu/psychometrika_highly_cited_articles/kaiser_1974.pdf; accessed on 11 August 2023). In this case, the value is 0.627, so it is an acceptable value.

Bartlett's test of sphericity is highly significant, the sig. value is less than 0.01, which means that the correlation matrix R is not an identical matrix. There are links between variables that could be included in our analysis based on the GCI ranking.

In the following table, applying the same tests based on data provided by the GCI at the time of 2019 leads to slightly higher values than at the time of 2009.

Tables 5 and 6 centralize the Initial Eigenvalues associated with each factor before extraction, after extraction, and after rotation. Before extraction, seven factors were identified corresponding to the seven variables included in the analysis. The initial values associated with each factor also show the weight of the explained variants. For example, at the time of 2009, the first factor explains 53.86% of the total variance and the second factor explains 17.623%. It can be seen that the first two factors together explain 71.48% of the total variance. After extraction, at the same time of 2009, only two factors remained as can be seen in Table 5 (SPSS extracts—only factors that have values above 1). It can be seen that for the extracted factors, the values are identical to those before extraction. In the last part of the table are the Eigenvalues after rotation, before and after rotation; the first factor and the second factors keep their values.

A more synthetic version of the analysis on the seven variables at the time of 2019 vs. 2009 can be obtained by plotting a Scree plot for the year 2009 (Figure 3) and 2019 (Figure 4).

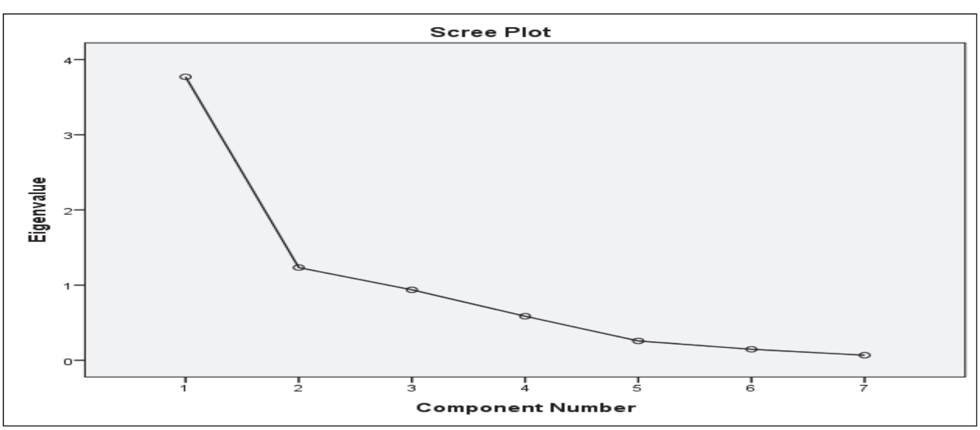

Figure 3. Presentation of the 2009 Scree plot.

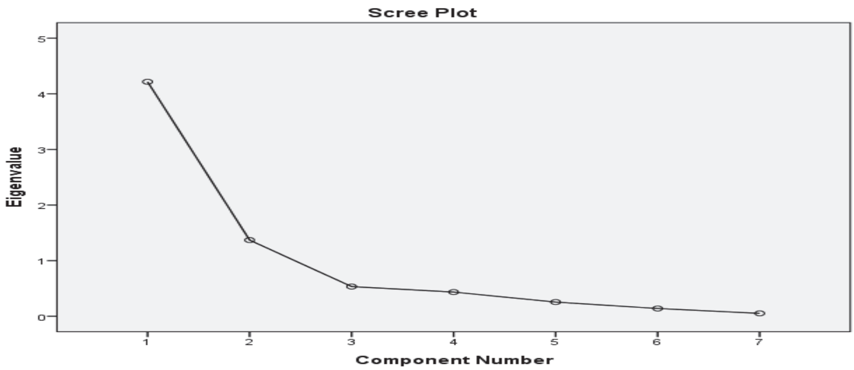

Figure 4. Presentation of the 2019 Scree plot.

From Figures 3 and 4, it can be deduced that the main points of inference occur in variables 2 and 3, which means that education, employee training, and R&D investment are the main factors explaining innovative capacity at the country level. This preliminary conclusion has significance for the objective of our research, and we will analyze whether or not various elements related to education, training, and R&D are reflected in the methodology applied by BCG to establish the ranking of the 50 globally innovative companies.

The next step the authors used was to analyze the variables that were assigned in the first factor to see if there is some common theme. It can be seen that between the variable *SCD*, which has the highest loadings distributed in component 2, and the variable *CLER*, there is a certain relationship. Therefore, the variables allocated to the first component at the time of 2009 seem to fall under the same theme, namely education. All of them are related to the same aspect as follows: *HET*, *UIC-R&D*, *EST*, *CLER*, *HPE*, and *SC*.

Table 7 shows the matrix of rotated components, for the year 2009, then in Table 8, the same data for the year 2019.

Factor loadings less than 0.5 were removed from the Table 7. We can see that there are two components and most of the variables are distributed in the first component, except for two variables: *CLER* and *SCD*, which have been distributed in the second component. The variables are presented in the table in the order in which they were entered. A descending sort by load size places the variable *HET* first, followed by *UIC-RD*.

Factor loadings less than 0.4 were removed from the Table 8. We can see that two components and four variables (EST, CLER, SCD, and MC) are distributed in the first and three variables (SC, HLE, and MYS/MC) are distributed in the second component.

The Multistakeholder_collaboration2019 variable is ranked first by the upload size. Therefore, it can be inferred that, although there have been some changes on the variables/factors explaining the innovative capacity of countries in 2019 vs. 2009, education, staff training, and collaboration with various categories of stakeholders remain essential for innovative capacity at the country level. Finally, the last stage of the authors' analysis of the importance of the variables/factors on which the GCI ranking is based is presented at the time of 2019, as shown in Table 9.

It can be seen that there have been some changes in 2019 in the distribution of variables by components compared to 2009; however, the conclusion remains that social capital, education, staff training, R&D activity, and collaboration with various categories of stakeholders remain the main factors conditioning the innovative capacity of countries. As we will see later (evaluation based on the top 50 BCG rankings [58]), employee education, investment in R&D, firms' orientation towards open networks for innovation, staff training, organizational culture and/or social capital, collaboration between management and employees/trade unions, etc., are the main factors determining innovative capacity at the firm level. It is, however, extremely difficult to argue which would be the "common factors" that simultaneously explain innovative capacity at the firm and country level.

Next, we conduct an analysis based on the Global Innovation Index (GII) to further assess innovative capacity at the country level and the theoretical/hypothetical relationship between such rankings and innovative capacity at the firm level. Later (Section 5 of the study, Main Findings), when we perform an in-depth analysis based on the BCG survey of the 50 most innovative companies internationally, we will try to "disentangle/separate" social/financial innovation from overall firm-level innovative capacity. Also, in the above sense, based on the information provided by the GCI and GII, we will then try to "cross-check" the results we arrive at on financial innovativeness as part of social innovation, both at the firm and country level.

4.2. Implications of GII for Financial Innovation

In order to understand and assess financial innovative capacity at the firm level (BCG Innovation Study), we further provide an assessment of innovative capacity (technical and social) at the level of major countries of the world. For this purpose, we will use the data provided by the GII ranking.

We use a data set of the Global Innovation Index (GII), sub-indexes, and components for 2010 and 2020; in the following table, we summarize the main variables selected for the analysis. In our study, we chose to assess the relationship between GII and firm-level innovative capacity at 2020 vs. 2010 in order to have a broader picture (4 years if information offered by GII and GCI is cumulated, respectively, 2010 vs. 2009 and 2020 vs. 2019) of the factors/variables determining technical, social, and other types of innovation at the country/firm level. In the Table 10 we presented data description for this ranking (the name of each index is in bold).

Table 10. Data description.

	Index/Component	Description
[1]	***Global Innovation Index***	Composite index calculated as the average between the average of the input and output sub-indices (7 pillars, 80 components)
[2]	***Innovation Input Sub-index***	Five input pillars capture elements of the national economy that enable innovative activities
[3]	***Innovation Output Sub-index***	The result of innovative activities within the economy (two pillars, with the same weight in the overall GII scores as the input sub-index)
[4]	***Gross expenditure on R&D (GERD)***	Total domestic intramural expenditure on R&D during a given period as a percentage of GDP
[5]	***Global R&D companies, average expenditure (top 4)***	Average expenditure on R&D of the top global companies
[6]	***ICT access***	A composite index that weighs five ICT indicators (20% each): fixed telephone subscriptions per 100 inhabitants; mobile cellular telephone subscriptions per 100 inhabitants; international Internet bandwidth (bit/s) per Internet user; percentage of households with a computer; and percentage of households with Internet access
[7]	***ICT use***	A composite index that weighs three ICT indicators (33% each): percentage of individuals using the Internet; fixed (wired)-broadband Internet subscriptions per 100 inhabitants; and active mobile broadband subscriptions per 100 inhabitants
[8]	***GERD performed by business enterprise***	Gross expenditure on R&D performed by business enterprise as a percentage of GDP
[9]	***GERD financed by business enterprise***	Gross expenditure on R&D financed by business enterprise as a percentage of total gross expenditure on R&D
[10]	***GERD financed abroad***	Percentage of gross expenditure on R&D financed abroad (billions, national currency)
[11]	***Joint venture/strategic alliance deals***	Joint ventures/strategic alliances: Number of deals and fractional counting (per billion PPP$ GDP)
[12]	***High-tech and medium high-tech output***	High-tech and medium-high-tech manufacturing (% of total manufacturing output)
[13]	***High-tech exports***	High-tech net exports (% of total trade)
[14]	***Computer and comm. service exports***	Computer, communication, and other service exports (% of commercial service exports)
[15]	***ICT service exports***	Telecommunication, computer, and information service exports (% of total trade)
[16]	***ICTs and business model creation***	Average answer to the question: in your country, to what extent do ICTs enable new business models?
[17]	***ICTs and organizational model creation***	Average answer to the question: in your country, to what extent do ICTs enable new organizational models (e.g., virtual teams, remote working, and telecommuting) within companies?
[18]	***Mobile app creation***	Global downloads of mobile apps, by origin of the headquarters of the developer/firm, scaled by PPP$ GDP (billions).

In order to determine the paternity of evolution, i.e., the central tendency and the variability of the components, we used a quantitative analysis using descriptive statistics. In the first step, we identified global patterns of evolution for all countries included in the index calculation. In the second step, we selected countries that scored above the world average on the GII and determined the central tendency and variability for these groups of countries. For the group of countries that scored above the world average, we performed a correlation analysis.

Table 11 summarizes descriptive statistics for the GII and selected components in 2010, both for all countries included in the index calculation and for the group of countries scoring above the world average.

Table 11. Descriptive analysis of selected GII components (2010 scores).

Index/ Component	Total Savings						Above Mean Economies					
	Mean	**Median**	**SD**	**Min**	**Max**	**Count**	**Mean**	**Median**	**SD**	**Min**	**Max**	**Count**
[1]	37	34	11	20	64	125	47	48	8	37	64	51
[2]	43	40	12	23	74	125	54	53	9	38	74	51
[3]	30	28	11	8	59	125	40	41	9	21	59	51
[4]	18	11	21	0	100	99	32	29	22	3	100	46
[6]	45	39	23	12	88	124	66	71	16	32	88	51
[7]	20	12	19	0	71	124	38	41	17	9	71	51
[8]	48	49	28	0	100	80	64	64	22	17	100	46
[9]	45	49	26	0	100	74	60	58	20	19	100	44
[10]	30	24	27	0	100	78	27	24	18	0	81	44
[11]	16	5	24	0	100	125	28	17	28	0	100	51
[13]	17	6	22	0	100	108	31	25	25	0	100	50
[14]	40	36	24	0	100	120	51	49	20	15	100	48
[16]	59	59	12	30	89	122	68	70	10	43	89	51
[17]	54	51	12	26	84	122	62	64	11	38	84	51

Overall, the trend in innovation performance (GII) in 2010 remains somewhat constant, with a relatively normal distribution of values. The best performers are countries such as Switzerland, Sweden, Singapore, Hong Kong (SAR), China, Finland, Denmark, the United States of America, Canada, Netherlands, the United Kingdom, Iceland, Germany, Ireland, Israel, New Zealand, Korea, Rep, Luxembourg, Norway, Austria, Japan, Australia, France, Estonia, Belgium, Hungary, Qatar, etc., while the lowest performers are associated with countries such as Senegal, Swaziland, Venezuela, Cameroon, Tanzania, Pakistan, Uganda, Mali, Malawi, Rwanda, Nicaragua, Cambodia, Bolivia, Madagascar, Zambia, Syrian Arab Republic, Tajikistan, Cote d'Ivoire, Benin, Zimbabwe, Burkina Faso, Ethiopia, Niger, Yemen, Sudan, Algeria, etc. As we will see later (Section 6, BCG ranking starting-point study), there are several European countries such as Sweden, Estonia, Belgium, Hungary, France, Finland, Denmark, etc., that are in good positions in the GII vs. GCI ranking, but do not have large/representative MNCs to include companies from these countries in the BCG ranking. How can this situation be explained? Also, in the sense mentioned, there are countries such as Qatar, Canada, New Zealand, etc., that do not have representative companies in the top tier of the innovation category that is summarized by the BCG study.

Among the selected components, the best scores were obtained in the infrastructure pillar on components such as ICT access and creative outputs (ICTs and business model creation, ICTs, and organizational model creation). In regards to business sophistication, notable performances were obtained regarding GERD performed by business enterprises (GERD financed by a business enterprise), but the importance of inter-firm cooperation through strategic alliances or joint ventures in innovation was rather low. The central trend towards the human capital and research pillar is also rather moderate, with a dispersed distribution of values across the board. The central tendency towards high-tech exports as a means of knowledge diffusion is also low, with a dispersed distribution of values.

In the group of countries performing above the world average in innovation, the central trend is relatively constant, but with a more dispersed distribution of variables. In this group, there is a noticeable trend towards a much stronger focus on infrastructure (through components such as ICT access and ICT use), business sophistication (GERD performed by a business and GERD financed by a business enterprise), and creative outputs (ICTs and business model creation; ICTs and organizational model creation). Also noteworthy is the increasing trend of knowledge diffusion, through high-tech exports and ICT service exports. However, the trend towards attracting external sources for research and development (GERD financed abroad) is less pronounced than the worldwide trend.

Table 12 illustrates the correlation matrix for the group of countries scoring above the world average in the GII, highlighting a number of significant influences that various components/variables have on innovation.

Table 12. Correlation matrix (above mean economies) 2010.

	[1]	[2]	[3]	[4]	[6]	[7]	[8]	[9]	[10]	[11]	[13]	[14]	[16]	[17]
[1]	1.00													
[2]	0.92	1.00												
[3]	0.91	0.70	1.00											
[4]	0.73	0.66	0.71	1.00										
[6]	0.76	0.85	0.58	0.60	1.00									
[7]	0.79	0.87	0.61	0.69	0.90	1.00								
[8]	0.66	0.64	0.58	0.74	0.47	0.61	1.00							
[9]	0.52	0.46	0.48	0.66	0.19	0.42	0.93	1.00						
[10]	−0.10	−0.04	−0.10	−0.24	0.20	−0.04	−0.39	−0.67	1.00					
[11]	0.53	0.67	0.31	0.30	0.42	0.45	0.41	0.41	−0.31	1.00				
[13]	0.40	0.30	0.39	0.24	0.02	0.14	0.48	0.50	−0.28	0.08	1.00			
[14]	0.48	0.36	0.55	0.59	0.21	0.26	0.47	0.44	−0.06	0.03	0.35	1.00		
[16]	0.69	0.69	0.58	0.61	0.58	0.58	0.58	0.46	−0.14	0.46	0.34	0.32	1.00	
[17]	0.71	0.70	0.60	0.61	0.55	0.53	0.56	0.47	−0.15	0.55	0.30	0.35	0.95	1.00

In 2010, in the group of countries scoring above the world average, innovation performance is positively and significantly associated with gross expenditure on R&D, infrastructure (ICT access and ICT use), and business sophistication. Also, a significant influence has been had by the creation of business and organizational models through the use of ICT, which are positively associated with R&D financed and carried out by firms and with access to ICT (which predominantly means common social innovations of which some may later prove to be disruptive in society). An insignificant influence was exerted by R&D financed abroad. In regards to joint ventures and strategic alliances, there is a positive association with the use of ICT and R&D activity carried out within firms, positively influencing overall innovation performance. Thus, based on the 2010 GII data, it is quite clear that some factors/variables related to the innovative capacity of an entity (gross expenditure on R&D, with infrastructure (ICT access and ICT use) and with business sophistication, a business model, alliances and open innovation in R&D activity, etc.) are simultaneously found at the level of countries and/or firms that are considered to be innovative. However, it is extremely difficult to quantify and argue to what extent the existing technical or social innovative capacity in firms conditions/determines the same innovative capacity in countries A, B, C, etc. This is because, according to the Forbes rankings for both 2010 and more recently in 2022 [59], at the time of 2022, there were at least 2000 important/significant companies globally, yet the vast majority of them are far from making the BCG ranking, even if they also have quite good achievements on technical and social innovations. We analyzed 2010–2020 span time and there have been major changes in the number of companies and countries of origin that are included in the various international rankings (Forbes 2022; Fortune 2022; etc.). However, the dominance of US innovative capacity at the country and firm level remains; more recently, China and companies originating from this country have improved their international competitive capacity. In a few cases, we find companies that have a turnover of USD 2–10 billion or more (Gold Fields—South Africa; Grifols—Spain; Cencosud—Chile; Dexus—Australia; Ayala Corporation—Philippines; Fertiglobe—United Arab Emirates; etc.) have a good position in Forbes 2022 and come from countries that do not have an above-average position in the GCI and GII. Simply put, the world's leading developed countries with relatively high GDP per capita dominate R&D activity (funding by firms as well as by the government) and perform better annually in terms of the number of patents, social innovations, financial innovations, etc.

Table 13 summarizes descriptive statistics for the GII and selected components in 2020, both for all countries included in the index calculation and for the group of countries scoring above the world average.

Table 13. Comparative descriptive analysis of selected components of the GII (2020 scores).

Index/			Total						Above Mean			
Component	**Mean**	**Median**	**SD**	**Min**	**Max**	**Count**	**Mean**	**Median**	**SD**	**Min**	**Max**	**Count**
[1]	34	31	12	14	66	131	47	46	9	34	66	53
[2]	43	41	12	20	70	131	55	55	9	40	70	53
[3]	24	21	13	7	63	131	38	36	9	23	63	53
[4]	17	10	20	0	100	131	33	27	22	3	100	53
[5]	20	0	32	0	100	131	45	49	35	0	100	53
[6]	61	66	20	21	93	131	77	80	11	38	93	53
[7]	54	54	24	3	90	131	73	77	13	25	90	53
[8]	10	2	18	0	100	131	24	18	21	0	100	53
[9]	32	23	30	0	100	131	60	61	22	0	100	53
[10]	13	3	20	0	100	131	26	23	24	0	100	53
[11]	17	7	23	0	100	131	31	18	29	2	100	53
[12]	25	17	24	0	100	131	43	43	22	3	100	53
[13]	29	20	27	0	100	131	51	51	25	3	100	53
[15]	21	16	21	0	100	131	30	23	26	1	100	53
[17]	53	53	17	0	84	131	66	65	11	44	84	53
[18]	13	2	23	0	100	131	27	16	28	0	100	53

Source: Processed from GII2020.

The trend for the Global Innovation Index in 2020 remains somewhat constant, close to the trend recorded in 2010 in terms of value distribution. The best performers are Switzerland, Sweden, the United States of America, the United Kingdom, the Netherlands, Denmark, Finland, Singapore, Germany, the Republic of Korea, Hong Kong, China, France, Israel, China, Ireland, Japan, Canada, Luxembourg, Austria, Norway, Iceland, Belgium, Australia, Estonia, the Czech Republic, New Zealand, Malta, Cyprus, Italy, Spain, and Portugal, while the lowest performances are associated with countries such as Bolivia, Guatemala, Ghana, Pakistan, Tajikistan, Cambodia, Malawi, Côte d'Ivoire, Lao People's Democratic Republic, Uganda, Bangladesh, Madagascar, Nigeria, Burkina Faso, Cameroon, Zimbabwe, Algeria, Zambia, Mali, Mozambique, Togo, Benin, Ethiopia, Niger, Myanmar, Guinea, Yemen, etc. Of the selected components, the best scores were obtained in the *infrastructure* pillar (on components such as ICT access and ICT use), *business sophistication* (GERD financed by a business enterprise), and *creative outputs* (ICTs and business model creation; ICTs and organizational model creation), while the central trend towards the *human capital and research* pillar is still rather moderate, with a dispersed distribution of values across all situations. Also notable is the central trend of increasing high-tech exports, as a means of knowledge diffusion, but still with a dispersed distribution of values; this time, among the leaders are Malaysia, Vietnam, the Philippines, the Republic of Korea, China, and Singapore, together with the Czech Republic, France, Germany, etc. Together with other conclusions that can be drawn, it follows that the GCI and GII rankings are still largely dominated by the developed countries of the world by 2020. In a few cases, we will find, in 2020, companies that are globally significant [41,42] but come from countries that are well below the average GII ranking. Therefore, we see that there is a certain conditionality/correlation between existing technical and social capacity at the firm/company level and innovative capacity and/or competitive position at the country level. In the next part of the study (Section 5), we address the same topic, but from the microeconomic perspective of analyzing financial innovations as part of social innovations at the firm/country level.

In the group of countries performing above the world average in GII (Table 14), the central trend is relatively constant, but with a more dispersed distribution of variables. In this group, there is a perceptible trend towards a much stronger focus on infrastructure (through components such as ICT access and ICT use), *business sophistication* (GERD financed by a business enterprise), and *creative outputs* (ICTs and business model creation; ICTs and organizational model creation); at the same time, the central trend towards the *human capital and research* pillar, although still moderate and rather spread, is more consistent than the global trend. The orientation towards attracting external sources for research and development (GERD financed abroad) should also be highlighted, with Israel, the Czech Republic, Austria, Iceland, Belgium, Sweden, Finland, etc., leading the way. Japan, Malaysia, China, Thailand, India, etc., have shown less interest in this direction. Last but not least, mobile app creation is showing a more consistent, albeit still dispersed, upward trend than the global trend.

Table 14. Correlation matrix 2020 (economies with above-mean scores).

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[15]	[17]	[18]
[1]	1															
[2]	0.95	1.00														
[3]	0.95	0.81	1.00													
[4]	0.75	0.74	0.68	1.00												
[5]	0.69	0.68	0.64	0.70	1.00											
[6]	0.60	0.68	0.47	0.41	0.31	1.00										
[7]	0.74	0.79	0.62	0.54	0.37	0.85	1.00									
[8]	0.70	0.67	0.66	0.98	0.66	0.35	0.47	1.00								
[9]	0.43	0.37	0.45	0.44	0.46	0.15	0.30	0.48	1.00							
[10]	0.43	0.38	0.43	0.55	0.18	0.28	0.35	0.54	−0.02	1.00						
[11]	0.60	0.63	0.52	0.30	0.24	0.48	0.56	0.27	0.02	0.23	1.00					
[12]	0.47	0.39	0.50	0.50	0.47	−0.01	0.11	0.53	0.51	0.24	−0.04	1.00				
[13]	0.24	0.11	0.34	0.34	0.17	−0.23	−0.04	0.39	0.46	0.18	−0.18	0.74	1.00			
[15]	0.07	−0.03	0.15	0.04	0.04	−0.20	−0.18	0.08	−0.24	0.33	0.22	0.05	−0.04	1.00		
[17]	0.81	0.81	0.73	0.60	0.53	0.45	0.61	0.53	0.28	0.42	0.58	0.34	0.24	0.06	1.00	
[18]	0.37	0.35	0.35	0.25	−0.01	0.21	0.29	0.25	0.03	0.27	0.49	0.02	−0.02	0.39	0.29	1.00

In 2020, the innovation performance of the 53 countries scoring above the world average was positively and significantly associated mainly with resources invested in R&D activity, infrastructure, R&D activity carried out by firms, and especially the creation of new organizational models under the impact of ICT (the United States of America, Sweden, Finland, the Netherlands, Estonia, the United Kingdom, Denmark, Germany, Switzerland, Norway, Israel, Canada, Iceland, Singapore, Luxembourg, and Belgium). The creation of these new organizational models is positively and significantly associated with ICT use, cooperation through joint ventures and strategic alliances, and R&D activities carried out by firms. The conclusions that can be drawn from the GCI and GII rankings over the last 10 years largely confirm Porter's concept of "the five forces" shaping competition at the level of industrial sectors and/or countries [60].

In contrast to 2010, the role of strategic alliances, but especially R&D financed abroad, has increased. High-tech and medium-tech production is mainly supported by in-house R&D, and high-tech exports are positively associated with R&D financed by firms. Moreover, in 2020, the role, albeit still modest, of mobile technologies is being felt, which is positively associated with cooperation through JVs and strategic alliances.

Up to this point, our assessments have predominantly focused on the macro-economic perspective of country/firm-level innovation processes through the use of disruptive technologies. In the following sections of the study, we aim to focus the analysis on the same topic from a microeconomic perspective, i.e., with reference to the realities in different categories of firms (especially MNCs). In the innovative sense, we then aim to "intersect" the two perspectives of analysis in order to reach some clearer conclusions on the role/importance of disruptive/digital technologies in the case of financial innovations made by firms.

5. Financial Innovations with Disruptive Technology

As we argue in our study, there is no clear/unambiguous distinction between "financial innovation" and other types of "social innovation" in the entire international literature. Previously, we listed some of the world's leading countries that are significantly above the GII average at both 2010 (Table 11) and 2020 (Table 13). Comparing the information provided by the GCI and the GII (for about a decade of the analysis of the two rankings), it can be deduced that the world's leading countries with higher annual nominal GDP per capita will also have a better position with regard to innovative capacity in general. Innovative capacity in such leading countries of the world is, however, determined with a complex of factors (values, institutions, government policies, government- and/or firm-funded R&D investments, university education, competition between firms, scientific competition, etc.), even for smaller countries (Sweden, Denmark, Finland, Spain, Portugal, Italy, etc.) that do not have MNCs to be included in the BCG ranking of the most innovative companies. Some important questions arise that are related to the basic idea of our study: "In all or most of these countries, do we find MNCs and SMEs that are technically, socially, and financially innovative? Do such firms excel or not on all three innovation dimensions? Do such firms excel or not on all four types of innovation, i.e., product, process, marketing, and organization?". It is difficult to formulate clear and reasoned answers to such questions because, globally, there are about 2000 companies (Fortune 2000–2022) that are in various rankings and have a significant innovative capacity, even if very differently from one organization to another. In our study, we included in the analysis only 50 companies considered to be the most innovative from 2004–2022, according to the BCG (Boston Consulting Group) study, and they are analyzed together in Table S2. Also in the sense mentioned, we admit that there are relatively clear/consistent statistical data for the innovative capacity of the main countries of the world (studies such as GII, Global Competitiveness Report, WIPO [61], etc.), but there are only a few studies on the same subject on MNCs coming from different countries as the location of headquarters.

Over the past three decades, disruptive technologies have emerged as a common element/vector for knowledge acquisition, exploitation, and transformation into patents and various types of social innovation [62,63] both at the level of firms, other organizations, and countries. Any firm and/or other type of organization, regardless of size or country of origin, has the opportunity to use digital and other disruptive technologies (robots, satellites, biotechnologies, etc.) to improve its organizational, production, and market processes.

Any firm can be approached as a socio-economic system, i.e., a hub that is in permanent connection with certain stakeholders (investors, shareholders, managers, suppliers, employees, customers, banks, insurers, state institutions, universities, other firms, etc.). Current relations with the vast majority of stakeholders involve financial relations (i.e., with investors, shareholders, managers, suppliers, employees, customers, banks, etc.). Any firm, regardless of size, needs to manage capital and cash flows extremely preventively, in order not to end up making "book profit" and at the same time being in a financial crisis [64]. These ongoing relationships with various other entities require the widest possible use of digital and other types of technology, and at the same time require financial innovations as part of social innovations [24]. In Figure 5, we present a firm approached as a social–economic system in its relations with various stakeholders.

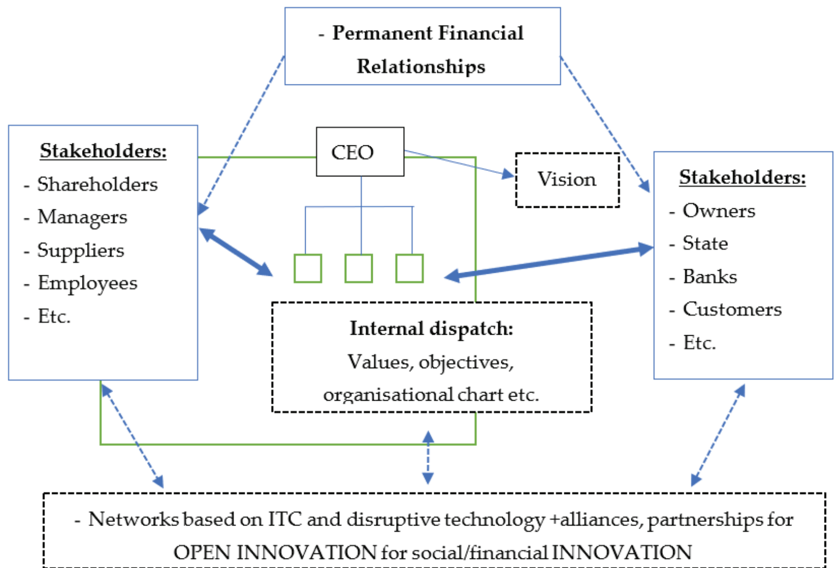

Figure 5. A company approached as a "system" and financial relationships with some stakeholders. Sources: author's design.

The main idea that we want to highlight through the graphic sketch in the following figure is that any firm/company, from the moment of its establishment, inevitably develops multiple financial relationships, along with commercial/human relationships with different stakeholders. According to the UNCTAD classification [51], companies are classified into non-financial companies (those in various industries and some KIS sectors) and financial companies, i.e., banks, insurance companies, investment funds, etc. This does not mean, however, that companies in the non-financial category would not engage in various financial relationships with numerous stakeholders. In fact, the revolution brought by fintech has primarily manifested itself in various financial markets and all assessments show that the fintech industry has become of utmost interest to non-financial companies as well (refs. [14,31,35]; etc.). The study we include in Table S2 on the BCG ranking only includes non-financial companies in the analysis, but the Forbes study also includes companies such as large banks and insurance companies. Therefore, the reality encountered in the global economy at both the MNCs and SMEs level is extremely diverse and a summary on fintech industries/markets [52] is useful in the context of the rapid advancement of disruptive technologies in different segments of international financial markets. As we show later, also in this section of the study, disruptive strategies or alliances recently implemented by large MNCs can be considered as disruptive innovations and will have major financial effects in the coming years even in traditional industries such as in the global automotive industry. Also, in the sense invoked, how a traditional MNC or fintech start-up prudently manages its own cashflow has become a key issue for imposing financial innovations as part of social innovations. There are therefore several direct/indirect arguments to clearly highlight the position of the socio-economic system that any business organization has and the fact that this system is essentially different from a national economy, as argued by Krugman [15].

In so far as we approach a firm as an open socio-economic system, depending on the field in which it is located (manufacturing industry, knowledge intensive services, and other fields), it follows that a large part of the relationships it engages in with other entities also involve and/or require financial flows. Since a large part of the relationships that any firm (MNCs and SMEs), in any country, engages in materialize as financial relationships, it can be considered empirically, according to Pareto's principle, that 80% of the social innovations that a firm/organization is able to achieve annually are in fact financial innovations (we have previously shown that applying the Pareto principle only allows us to suggest the direction in which the answer to the question of how to evaluate financial innovations should be identified and that in many cases, this principle will have corresponding weights of 50–50%, 60–40%, etc.). Therefore, any technological input that a firm uses to improve its innovative capacity, both technical and social, is highly beneficial and is reflected in the financial innovations achieved annually by firms. This is even though we do not have studies measuring/quantifying a firm's financial innovative capacity as part of its social innovative capacity. In turbulent/chaotic times, argues the author of [65], the CEO of any company should consider that "financial strength" is far more important than revenue and profit; this was true in the 1980s and has become much more evident after 2008 and up to the present.

As can be seen from Table S2 and the tables showing the companies in the BCG study (Section 6 of the study), Toyota was ranked 21st in the 2022 ranking, but is no longer in the 2023 ranking (we return to this sample of companies in the last part of the study). Toyota's cash-flow management strategy in relation to the thousands of stakeholders with whom it works on a regular basis has been extremely conservative over the past six decades; the conservative nature of this strategy has enabled the company to more easily overcome the crisis of 2008–2010 [66]. More recently, starting in 2015, Toyota adopted a disruptive strategy of exploiting EV (electric vehicle) patents in the sense that it offers around 23,000 patents without paying annual royalties to any other competitor [67,68]. A few years later, Tesla adopted a disruptive strategy similar to Toyota for EVs manufactured by it; the EV car industry has clearly become a disruptive industry and one that relies heavily on the use of digital technologies. Also relatively recently, in 2023, Ford, Tesla, GM, and Rivian formed an alliance to jointly operate and improve EV battery charging equipment; the alliance invoked is clearly also disruptive in nature and will generate major financial implications for the four members, but also with reference to the use of financial technologies to support social innovations. Questions arise that are tangential to the basic idea of the present study: "What are the financial and open innovation implications of the EV strategies already applied by Toyota and Tesla?"; "What are the financial implications in relation to the thousands of stakeholders of the alliance formed by the four US companies?"; "How will such realities in the world of large non-financial MNCs reflect on the evolution of the fintech concept?". We are not in a position to answer and it is not the purpose of this study to formulate answers to questions of the type mentioned. However, it is easy to deduce that even large MNCs in various industries are able to exploit digital technologies intensively as part of various disruptive technologies to achieve new financial innovations, some of which will prove to be disruptive over time. As we will show later (point 6.3 in Section 6 of the study), a large part of the companies considered innovative by BCG have been applying innovative strategies and practices on cash flow management and other financial aspects in their relationship with most of their stakeholders, since 2–3 decades ago (as shown in Figure 5). Also, in the sense invoked, digital and other types of disruptive technologies have supported established companies (financial and non-financial) to form financial alliances, strategies, and practices of various types to realize "open innovation" networks [38] since two decades ago already, i.e., before the individualization of fintech markets.

We mentioned earlier (Section 4.1) about the four types of innovation according to the existing OECD [50] classification (product, process, marketing, and organizational). The use of digital/disruptive technologies supports a firm's effort to bring elements of novelty in any of the four directions/types of innovation. However, some differentiations can be made by categories of firms, depending on the domain in which they are located (but not on the countries they belong to), respectively:

- Firms in high-tech and medium-high-tech sectors are more likely to achieve technical, product, and process/technological innovations/inventions; the field does not limit innovation in these entities on marketing and organizational issues;

- Firms in medium-low-tech and low-tech sectors are more likely to achieve social innovation, i.e., on marketing and organizational issues; the area in which they are located partially limits the achievement of product and process innovation (but there may be many exceptions to this rule);
- Firms in various service sectors are more likely to achieve social innovations, i.e., on marketing and organizational issues; also, the area in which they are located partially limits the achievement of product and process innovations (but there may be many exceptions to this rule).

6. Main Findings

6.1. Driving Forces for Financial Innovation

From a historical perspective, social innovations such as the newspaper, the insurance system, hire–purchase, labor relations, or the pension system have fundamentally changed the Western economy/society, as Drucker points out [21]. It is obvious, however, that social innovations of any kind cannot be protected with patents, as is the case with a technical innovation (only some social and/or technical innovations can be protected). In Table S1, we summarized together the technical innovative capacity given with the number of patents of the 50 companies in the BCG study [58], and the social innovative capacity for the same companies (reflected by the number of trademarks, industrial designs, etc., registered with various state agencies, as appropriate). Some of the social innovations, i.e., trademarks, trade names, industrial designs, logos, symbols, etc., can be protected by firms through registrations with the agencies under which patents are usually granted (national agencies such as USPTO in the case of the US, EPO in the case of Europe, etc.). Even in such cases where the law offers some protection for any element of novelty brought by a firm, some social innovations will become sources of orientation for competitors and will gradually be taken over by other firms. Only in the case of social innovations made by a firm on the basis of employees 'tacit knowledge, which is dependent on the values they believe in and is more difficult to transform into explicit knowledge (i.e., know-how, ways of solving a problem, mental models, etc.), the organization can hope for a longer protection of such elements of novelty.

There are, as we argue below, at least three driving forces that directly support any firm to achieve social innovations in general (only some of which will also prove to be disruptive social innovations). As the case may be, it is likely that the result of the cumulative action of the three driving forces will be a mix/combination of technical innovation and social innovation. In other words, only each firm can correctly assess on which direction of action it should focus its resources in order to overcome the specific crisis of the period 2021–2022 through social innovation. As we have shown above, most of the social innovations made by firms will be found in the market and/or in society as financial innovations.

The three types of driving forces for financial/social innovation are the following:

✓ Firstly, the technologies already existing in society, especially digital technologies (but not the only ones), are a real catalyst for companies to maintain their position in the market, improve performance, etc. This means massive recourse to digital technologies, which requires skilled employees, investments, own intranet systems, permanent connections with customers/suppliers and other stakeholders, etc. This trend of an increasing use of digital technologies started in the 1990s, became more pronounced in the context of the Great Recession of 2008, and has become essential for the survival of firms from 2020 onwards. Computer networks, communication networks, and satellites have made e-commerce possible, which in turn has fundamentally changed social and business relations in modern society. In the age of e-commerce, Drucker argues, even small, locally operating firms must be managed transnationally if they are to survive [62]. The new IT&C systems that firms are developing are leading to changes in processes within a firm and in its relationship with the outside world, changes that significantly alter the organizational culture. Almost every employee in firms and other organizations in modern society can gradually make small improvements in the performance of job tasks when using elements of digital technology. In other words, digital/disruptive technology supports employees at all levels of an organization chart to contribute directly to the realization of social innovations by firms. For some of the social/financial innovations achieved to be disruptive, there needs to be a 'mindset' across the culture of an organization that aims to systematically take advantage of the benefits given with digital technologies [23]. There is no known 'recipe' or mechanism with which firms should proceed to achieve disruptive social/financial innovation. Each firm needs to define and identify its own direction in which it should focus, to act systematically to understand the constraints and opportunities given with the market on the product/service offered. Only then, after understanding what has real value for its customers [64], can a firm choose a favorable combination of existing technologies that will support its continuous innovation effort.

✓ Another driver forcing companies to resort to technical and social innovations is the competition in the market itself. Simply put, the market, with all its imperfections, offers constraints as well as opportunities for any business organization. Particularly in the context of a global recession such as the current one, it is essential for companies to understand in depth what is of value to the customers to whom the product/service offered is addressed. More importantly, the very values to which customers (end consumers) relate are changing rapidly in a global and increasingly interdependent society. The values, preferences, consumption habits, time-sharing of each individual, and social conditioning imposed by governments are all changing in a social climate defined by uncertainties. What directions for action can firms see in this new social climate?

So, for the whole period after 2008 and up to the present, the market and what the customer considers to be of value as a product/service has become the key element for companies to relate to. The general allocation of funds to R&D and obtaining patents and various trademarks, designs, etc., must be "doubled" by a systematic CEO effort to make disruptive innovations and especially disruptive financial innovations. The ownership of a large portfolio of patents by leading companies in high-tech and medium-tech sectors seems to be no longer sufficient to overcome the current global recession. The question arises as to whether some of the patents held by such companies will be transformed into low-end disruptive products/services. For companies in low-tech and service industries, the use of digital technologies and investment in their own IT&C systems seems to be the best way to adapt the product/service to the new requirements of low-end disruptive markets.

✓ Thirdly, managers and particularly the CEO and their team have become, perhaps more than a decade ago, the essential vector or "driving force" for firms (in any economic sector) that have a distinct strategy for achieving disruptive technical and social innovation. This CEO strategy/vision also requires skilled employees who are willing to continuously learn and to accumulate new explicit and tacit knowledge. In fact, the role of professional managers became essential with the emergence of large corporations, first in the US from 1880 to the present. The emergence of managerial capitalism was an economic phenomenon of American origin that then spread to Europe and Japan [69]. During the post-war period, the importance and role of professional managers has increased in all major countries of the world (including China in the last four decades). Since the 1980s, as digital technologies have become ubiquitous in society, the tasks to be performed by CEOs and the skills required have increased greatly in complexity.

In Figure 6 below, we present the three "driving forces" that together support the systematic effort of firms to achieve social innovation, of which the vast majority (about up to 80%) will be financial.

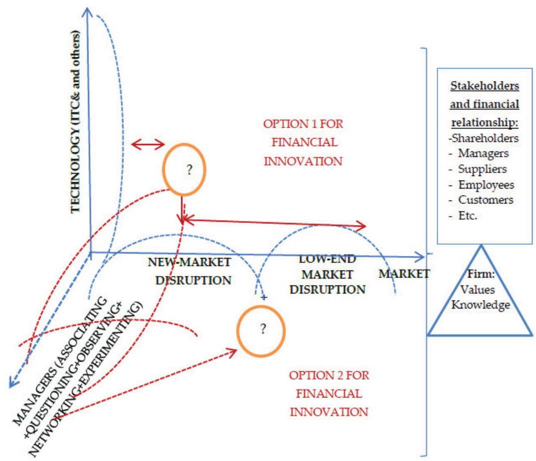

Figure 6. The driving forces for financial/social innovation. Sources: Author's design.

In relation to the three "driving forces" suggested by us in Figure 6, two or more variants (marked by us with a question mark in the figure) emerge, quite obviously, as a solution of connection/intersection between the support given by technologies and what the market considers to be of value to consumers. As can be easily deduced from the figure, the first variant of "intersection" or connection, usually accessible, can be more easily intuited by managers in established companies in a given market. As it can be seen, "option 1 for financial innovation" is given with the combination of the benefits brought with technologies and new market disruption, as an immediate direction of action for the managers of firms; only in the second place, the mix of the two elements can also be carried out in relation to "low-end market disruption". The financial relationships that a firm engages in with various categories of stakeholders (argued in Section 4 of the study; Figure 3), together with the values, knowledge, and training of the firm's human resources, will determine over time the financial/social innovation capacity of the organization. Through the policies applied, investments in R&D, the quality of education, and the quality of the infrastructure built, governments can support this direction of action in innovative firms (even if no distinction is made between technical and social innovation through such policies). On the other hand, when the support given with ICT would intersect with the value given with the market in any other location in the three-dimensional plane (of analysis), it becomes much more difficult for any manager to intuit at what point the "intersection" between the two might take place. As noted from the figure, along this line of action and/or intuitive assessment of social innovation opportunities, managers should first build their KM/innovation strategy on the basis of going through steps such as associating, questioning, observing, networking, and experimenting [32]. Therefore, a different vision, thinking differently, is needed for managers to be able to intuit what would be "option 2 for financial innovation" action to achieve social innovations of which most of them will turn out to be financial innovations. In this case, depending on the vision and intuition of managers, any kind of intersection between technologies and the two types of markets becomes possible, which then confirms or disproves the disruptive nature of any innovation (be it social, financial, or other). It is not the size of a firm that limits an organization's innovative capacity, Drucker argues, but the kind of developed culture and entrepreneurship that can be learned over time through practice [64].

6.2. Financial Innovation of MNCs and SMEs

Our assessments of financial innovation globally to this point in the study lead us to conclude that any type of organization, i.e., MNCs, SMEs, universities, public institutions, etc., can achieve significant, modest, or more significant social innovations through the extensive use of digital/disruptive technologies. This means that any of the tens of millions of firms globally can have an effective KM, HR, and continuous innovation strategy. There are no studies that highlight/synthesize the technical and social innovative capacity for millions of firms in Europe, America, Asia, and other regions of the world. Specifically in the case of our study, we restrict ourselves to a more in-depth analysis of innovative capacity at the level of 50 major companies that have been monitored by BCG over the last two decades (approximately).

The BCG study is based on a questionnaire methodology that is applied annually to top executives of leading companies in both industries and services globally (the questionnaire is structured on four dimensions: Global Mindshare; Industry Peer View; Industry Disruption; and Value Creation). The very structure of the BCG questionnaire, used to determine each year which are the most innovative companies in the world, takes into account the strategies and/or disruptive innovations achieved by the companies, as well as the practices and platforms used by innovative companies. The BCG methodology lists three pillars for practices (portfolio management, funnel management, and project management) and eight pillars for platforms (idea to impact process, talent and culture, organization setup and ecosystems, performance management and metrics, innovation governance, innovation domains, and innovation ambition). Some of the 50 companies (depending on the score obtained on each pillar) will be considered as more committed innovators and others as less committed to innovation (as an explicit top management strategy). In the same sense, we find that the content of the 11 pillars of the BGC methodology is only partially matched by the content of the various pillars of the GCI and GII rankings (the application of KM and systematic innovation is to a large extent dependent on a CEO's vision, the company culture, the cyclical evolution of the business, and other similar factors; only to a certain extent can the innovative capacity of the country of origin influence/determine the innovation orientation of the companies). In Table 15, we present the BCG ranking for 2022, and in Table 16, we present the BCG ranking for 2023; in our substantive analysis, we will only deepen the ranking for 2022 for which we have the extended assessment in Table S2 of the study.

Table 15. The Most Innovative Companies of 2022.

		Ranking		
1–10	**11–20**	**21–30**	**31–40**	**41–50**
1 Apple	11 Meta [1]	21 Toyota	31 Xiaomi	41 Tencent
2 Microsoft	12 Nike	22 Alibaba	32 eBay	42 General Motors
3 Amazon	13 Walmart	23 HP	33 Hyundai	43 Ford ○
4 Alphabet	14 Dell	24 Lenovo	34 Procter	44 Intel ○
5 Tesla	15 Nvidia ●	25 Zalando ●	35 Adidas	45 ByteDance ●
6 Samsung	16 LG	26 Bosch	36 Coca-Cola	46 Panasonic ●
7 Modern	17 Target	27 Johnson & Johnson	37 3 M ○	47 Philips
8 Huawei	18 Pfizer	28 Cisco	38 PepsiCo	48 Mitsubishi
9 Sony	19 Oracle	29 General Electric	39 Hitachi ○	49 Nestlé ○
10 IBM	20 Siemens	30 Jingdong ○	40 SAP	50 Unilever ○
		New entrant ● Returned ○		

Source: BCG Most Innovative Companies (MIC) Report 2022; the full version of the ranking and our assessment can be found in Table S1. Note: Industry classification is based on Capital IQ; some companies play across industries. [1] Facebook became Meta in 2021; in previous BCG Most Innovative Companies reports, it appeared under the name Facebook.

Table 16. The Most Innovative Companies of 2023.

Ranking				
1–10	**11–20**	**21–30**	**31–40**	**41–50**
1 Apple	11 Pfizer (+7)	21 Rock	31 Sony	**41 Saudi Aramco**
2 Tesla (+3)	12 Johnson & Johnson (+15)	22 Oracle (−3)	32 Sinopec	42 Coca-Cola (−6)
3 Amazon	13 SpaceX	23 BioNTech	33 Hitachi (+6)	43 Mercedes-Benz Group [1]
4 Alphabet	14 Nvidia (+1)	24 Shel	34 McDonald's	44 Alibaba (−22)
5 Microsoft (−3)	15 ExxonMobil	25 Schneider Electric	35 Merck	45 Walmart (−32)
6 Modern (+1)	16 Goal (−5)	26 P&G (+8)	36 ByteDance	46 PetroChina
7 Samsung (−1)	17 Nike (−5)	27 Nestlé (+22)	37 Bosch (−11)	47 NTT
8 Huawei	18 IBM (−8)	28 General Electric (+1)	38 Dell (−24)	**48 Lenovo (−24)**
9 BYD Company	19 3 M (+18)	**29 Xiaomi (+2)**	39 Glencore	**49 BMW**
10 Siemens (+10)	20 Tata Group	**30 Honeywell**	**40 Stripe**	**50 Unilever**
xxx—Returned xxx—New entrant				

Sources: BCG [70] Global Innovation Survey 2023; BCG analysis. Note: +/− indicates change from 2022 MIC ranking. [1] Mercedes-Benz Group was previously identified as Daimler; in bold are new entry.

The same BCG study of the most innovative companies globally for 2023 is shown in Table 16:

The comparative analysis of Tables 15 and 16 shows that there is a very robust competition between internationally known MNCs and that there are annual changes in positions (companies dropping out of the ranking and coming in; changes in the actual position of those remaining; etc.). In 2023, companies such as Saudi Aramco or PetroChina have recently entered (so companies from countries with a more modest position in the GII can enter this ranking; in the same sense, although it is a developing country by GDP per capita, it has improved its competitive position in the last decade, and an increasing number of companies are starting to find themselves in various international rankings).

In the manufacturing industry, there is a separation of industries into four broad sectors: high technology, medium-high technology, medium-low technology, and low technology [71,72]. In regards to the services sector, depending on the intensity of technology use, the knowledge-intensive services (KIS) sector has a special place; in this sector, we include high-tech knowledge-intensive services (HTKIS); knowledge-intensive market services (KIMS); knowledge-intensive financial services (KIFS); and other knowledge-intensive services (OKIS) [72]. In the category of other services, which are less knowledge-intensive, we will classify areas/sectors such as tourism, road transport, retail, etc.; they are classified under the Eurostat less-knowledge-intensive services (LKIS) [72].

Based on the data in Tables 15 and 16 and Table S2, we present below a more in-depth analysis of the situation of the 50 companies in the BCG 2022 ranking. This analysis highlights the following issues:

It is possible to perform a pairwise comparison between variables to identify the type of link that might exist between the 50 companies (based on geographical location, the number of employees, net income, registered trademarks, and patents obtained by each entity, as summarized in Table S2). In Figure 7, we present the summary of the statistical evaluation of this comparison between the 50 companies.

In Figure 7, we retained only four variables for pairwise comparisons, since the variable continents are clarified in Table S2 and maintained in the first part of the study (the structure by continents is the following: 27 firms—USA; 15 firms—Asia; and 8 firms—Europe). The retreat of the figure only by including the other four variables leads us to the conclusion that the 50 firms have a fairly wide distribution on the basis of the characteristics taken into account (the synthetic evaluation shows aspects such as the following: most firms have up to 500,000 employees, obtain up to 2500 patents per year, have up to 1500 social innovations in their portfolios, achieve up to a 40 billion net income per year, etc.). The same preliminary conclusions can be drawn from the empirical evaluation of the data in Table S2. The data in Table S2 show a rather large dispersion of the variables taken into account (examples: from about 400 employees at Moderna to about 420 thousand employees at Bosch; from a symbolic profit of 0.1 billion at Zalando to a profit of almost 100 billion USD at Apple; from 40 social innovations at Zalando to over 1500 social innovations at other companies; and from 10 patents per year at Moderna to over 6000 patents per year at Samsung), which is reflected in the distribution of companies in the previous figure.

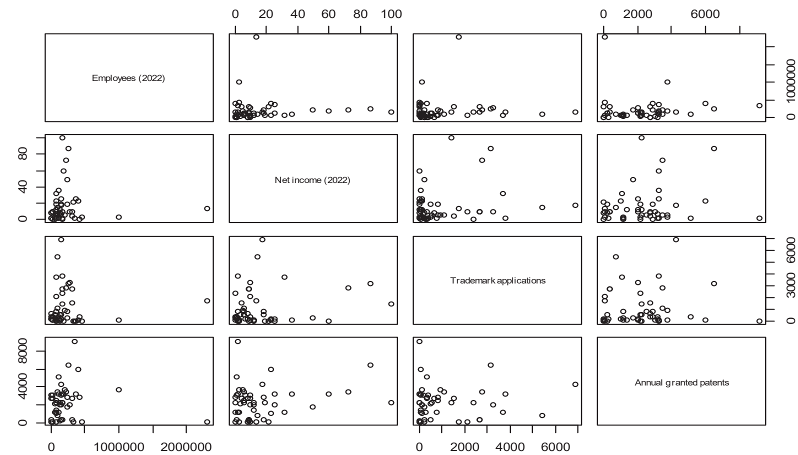

Figure 7. Pairwise comparisons between variables to identify the link type.

If we select only the number of patents (as equivalent for technical innovations) vs. the number of trademarks, trade names, logos, etc. (as equivalent for social innovations), the distribution of the 50 firms is shown in Figure 8.

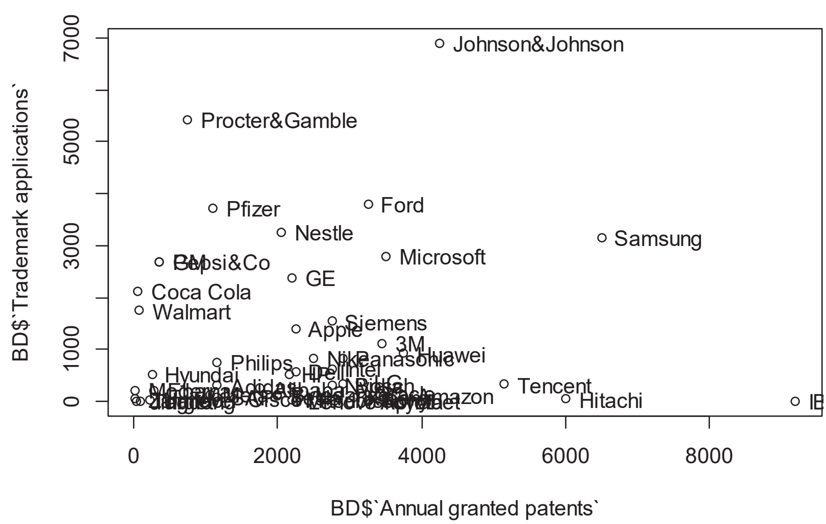

Figure 8. Analysis of the relationship between the variables: number of patents (technical innovations) and number of registered trademarks (social innovations).

From what has been presented up to this point regarding the distribution of the 50 companies in the BCG ranking, only a few preliminary conclusions can be formulated with respect to the objective of our research. We recall the basic idea of the present study, i.e., to further analyze the relationship between GCI, GII, and disruptive technology simultaneously at the level of core countries and MNCs considered to be innovative and successful. The question included in the title of the study "How do we evaluate financial innovation made by firms?" is predominantly rhetorical and aimed only at suggesting some directions/clarifications regarding the concept of fintech and innovations made by firms using digital technologies. The synthesis presented by us previously (Section 6.1 of the study) allows us to mention that disruptive technologies have now become a kind of "driving force" for financial/social innovation by firms. The rather in-depth assessment of the realities and prospects that lie ahead for the 50 companies in the BCG study (the present section of the study) gives us an indirect confirmation of the role that disruptive financial technologies are playing in various segments of international financial markets (particularly those where fintech start-ups are already operating). On the basis of the BCG ranking for 2022, also taking into account the analysis based on the GCI (Section 4.1) and the GII (Section 4.2), we find that there are some common "driving forces" to explain the innovative capacity both at the firm and country level. This is because some of the pillars of the BCG methodology (e.g., Global Mindshare, Value Creation, etc.), as well as most of the eight elements that form the basis of the strategies applied by innovative firms (practices and platforms), have as their country-level equivalent education, training, stakeholder relations, government policies, and other variables that explain innovative capacity from a macro-economic perspective. A partial and indirect confirmation, also in the sense mentioned above, is provided with the synthetic evaluation of the ranking provided by Forbes 2000 [59] (there is a significant number of companies performing well and registering a somewhat more modest level of annual innovative capacity, even if they do not enter the BCG ranking, namely companies such as Hon-Hai in Taiwan, Caisa bank in Spain, Horton in Mexico, etc.).

Next, in order to identify the extent to which there are certain sub-clusters (small clusters that have similar characteristics based on 2–3 variables considered) within the entire sample of 50 companies, we will proceed to plot a dendogram (Figure 9) and a scree plot to determine the number of clusters (Figure 10). Theoretically, there are two extreme situations (all 50 firms are differentiated and no sub-clusters can be established; all 50 firms are similar and form a single cluster).

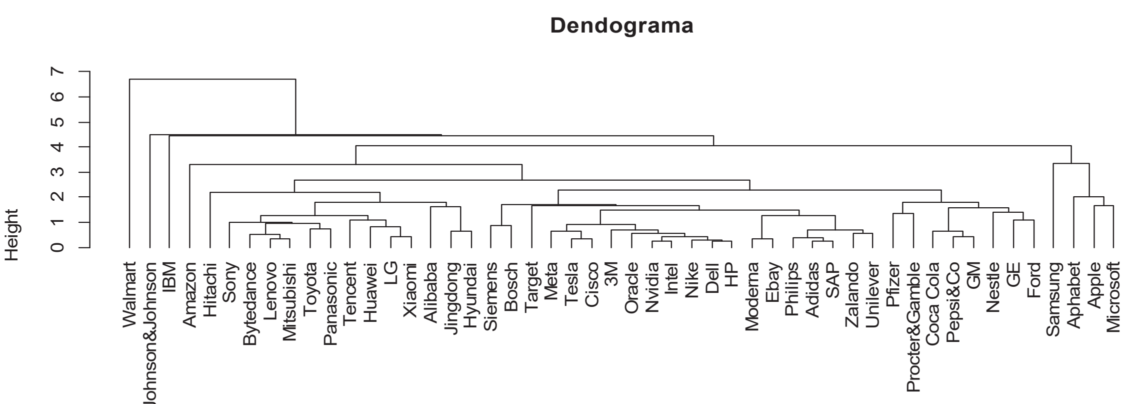

Figure 9. Dendogram (classification tree).

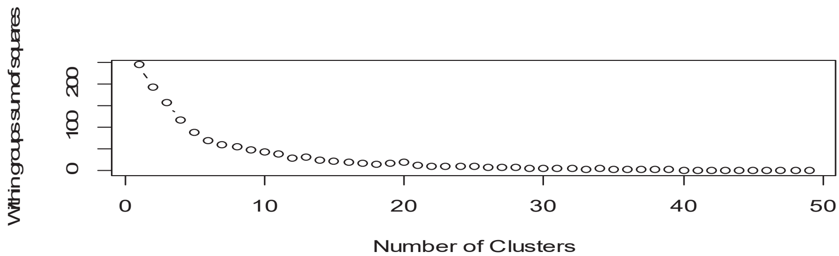

Figure 10. Scree plot for determining the optimal number of clusters.

Based on the data in Figures 9 and 10, it follows, depending on the variables considered, that the optimal number of clusters would be between three and five different sub-cluster firms.

In order to highlight more clearly the number of subgroups (distinct clusters that can be constituted for the entire BCG sample), we resorted to the presentation of cluster mapping (Figure 11) and a cluster plot (Figure 12).

From Figures 11 and 12, it is easy to deduce that 3–4 sub-clusters can be formed, depending on the variables by which the firms are compared to each other; each sub-cluster/cluster would, however, have a different number of firms that it is made up of (from about 5 firms to 20 firms per cluster).

The data presented by us previously (Sections 3–6 of the study), together with those shown at this point of the study, lead us to some preliminary conclusions.

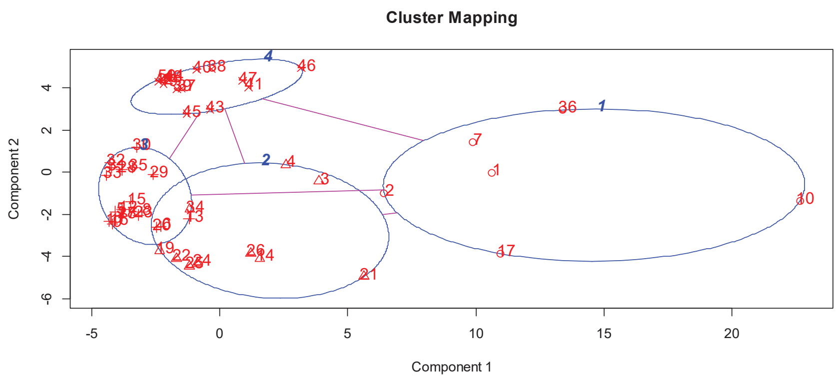

Figure 11. Cluster mapping presentation.

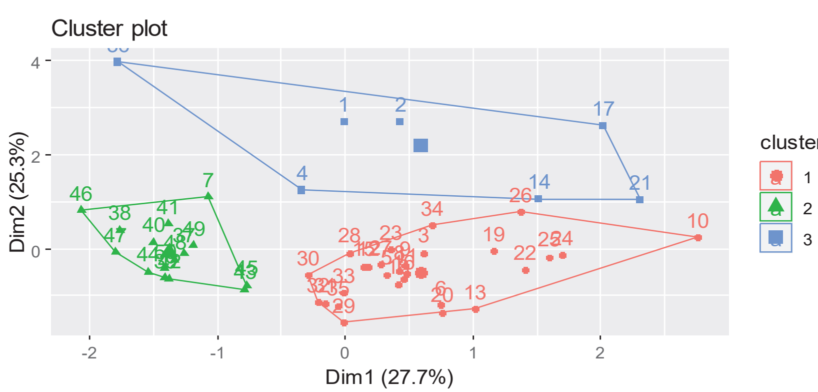

Figure 12. Cluster plot presentation.

Following the cross-assessment of financial/social innovation capacity from firms to countries (only as an economic assessment and not as a statistical one), most of the hypotheses, H1–H4, formulated at the beginning of the study are at least partially confirmed:

- ✓ Hypotheses H1 and H2 formulated by us at the beginning of the study (Section 3.1) are fully confirmed, in the sense that there is no direct association/conditioning/influence relationship between the financial/social innovative capacity and the technical innovative capacity of a firm. As a confirmation of H2, it follows that, whether or not disruptive technologies are used extensively, the financial innovations obtained annually can be empirically evaluated as representing up to about 80% of the social innovations that are achieved by such entities. On the other hand, with regard to hypothesis H3 formulated by us, it appears that this is only partially confirmed, based on "cross-checking" between the BCG studies and the GII and GCI reports, as there are hundreds of thousands of other innovative firms that are not included in any international innovation ranking. However, at the same time, hypothesis H3 is partially confirmed because the world's leading countries that dominate the GCI and GII rankings have firms in the BCG survey, the Forbes survey, and other international rankings at the same time. The H4 hypothesis is also fully confirmed in the sense that disruptive technologies, especially those with financial implications in the range of digital technologies, have become essential not only for fintech firms but for any other company and/or country.
- ✓ The existing innovative capacity of the world's leading countries (both financial and technical innovation) is reflected in the existence of a number of firms that are large enough to enter various international innovation rankings. Even when looking at the 2000 firms in the Forbes ranking [59], it appears that this ranking is far dominated by American MNCs, then Asian MNCs, and then European MNCs. Simply put, the number of European firms that are sufficiently competitive and innovative has decreased significantly in terms of representation in the BCG survey and/or representation in other international rankings.
- ✓ There is a fairly strong conditioning from countries to firms on the innovative capacity achieved annually, as countries and various international entities (EU and OECD) directly influence R&D activity through regulations and funds allocated to firms. This means that, theoretically, we will find medium and large firms coming from countries at the middle of the GCI and GII rankings that are not included in the BCG study, but have significant annual financial or technical innovation achievements.
- ✓ Conversely, the existence of technical and social innovation capacity at the firm level does not automatically/implicitly reflect on innovation capacity at the country level.
- ✓ Leading US-based companies in various international rankings [59] have a real monopoly on international technical and social innovation. Companies that make it into the BCG rankings and come from European countries are finding it increasingly difficult to maintain their innovative position internationally (Europe is far behind the US and even Japan and China more recently).
- ✓ With the use of digital/disruptive technologies, any company in industries, commerce, or tourism can be considered innovative at the international level even if it does not obtain its own annual patents (such as Walmart, Zalando, Jingdong, most of fintech, firms, etc.); it can still be extremely innovative in its relationship with the market, its customers, its organizational structures, etc. It is not by chance that tourism companies such as Marriott and Hilton have been found in various BCG rankings as being among the most innovative in terms of funds allocated to digital technologies and networking with various stakeholders (Marriott was also, in 2019, in a similar ranking by Forbes).
- ✓ The majority of marketing and organizational innovations made annually by firms (whether or not they belong to countries considered to be innovative) will take the form of social innovations of which about up to 80% will be found as financial innovations.
- ✓ Internationally, there has been a trend in recent decades to set up "international/global-born companies", which means that investors from one or more countries raise capital

and set up successful start-ups, fintech or not, to operate from scratch in various foreign markets [73,74]. In the same vein, we recall "fintech" investments/firms [75], whereby the owners aim to create from scratch a successful start-up in high-tech sectors of the global economy. Such internationally newly created firms, through the strategies applied and the results obtained, seem to deviate from the criteria for gaining competitive advantage that were outlined by Porter [60].

Therefore, it is necessary to conclude that digital technologies are currently generating new paradoxes in the theory of competitive advantage and classical organizational theory. From the perspective of our study, this means that it is not possible to assess globally and/or with large sectors of the economy the number and importance of financial innovations made by firms with disruptive technologies. It is only possible for such an assessment to be made by managers in firms that have KM and social innovation strategies.

6.3. Principles for Financial Innovation

Following the issues/arguments we have raised in the first sections of the research (Sections 2–5), as well as the clear and argued distinction between financial innovation and social innovation, a number of theoretical principles can be formulated that could be considered by firms (MNCs and SMEs) to base their strategies on innovation, KM, HR, the use of financial technologies, etc.

First of all, we stress that to improve financial innovation in companies with the help of digital technologies, there must be 2–3 key values at the core of the organizational culture and a single vision at the top management level (in relation to product, technologies, market, and organization). It should be concluded in advance that the realization of technical innovations by firms that are protected with patenting (as shown in Table S2) is not directly conditioned by the realization of financial innovations as part of social innovations (which may or may not be protected using registration with a state agency). At the same time, it appears that the competitive position of a company operating in the manufacturing industry is mainly determined with the stock of the tacit knowledge of employees, such as know-how (technical innovations that can be protected). The financial innovations that can be protected by companies (according to Table S2) are empirically estimated, according to the Pareto principle, to represent about up to 80% of the total social innovations made annually by organizations. Therefore, the largest share of social innovations achieved annually by a firm, i.e., 80% of the total, will be found as financial innovations (what can or cannot be protected using registration within a state agency).

To a large extent (but not totally), both categories of financial innovations refer to innovations related to the market and the organization of a firm. The whole "pyramid construction" that explains financial innovation at the firm level is based on existing values, culture, and education at the country/firm level, as shown in Figure 13. The basic idea in the following figure is that the essential foundation for any kind of innovation (technical vs. social; financial vs. other social innovations; and disruptive vs. business-as-usual innovations) is based on a clear and coherent vision at the top management level of an organization and on the tacit–explicit knowledge stock held by the employees at the bottom of the pyramid and employees who are willing to continuously learn and use creativity to bring about novelties that will then be confirmed by the market. This means a proper KM and HR strategy to motivate, reward, train, and qualify all employees. There are obviously some influences from the macro-social to the organizational level on the development of innovative capabilities (social and technical) at the firm level. However, it is not possible to formulate a clear and reasoned answer from the title of the study: "How do you evaluate financial innovation?". The realities of the acceptance of the fintech concept over the last decade show that, particularly in Asian countries, fintech companies and fintech-based operations have expanded the most rapidly [37]. The vast majority of MNCs in the BCG 2023 study, as well as large banks or insurance companies in the UNCTAD classification [51], are rapidly expanding their financial technology base to adapt to the fintech revolution [14]. One of the preliminary conclusions of our study is that only managers within a company can assess and/or intuit the more accurate share of financial innovations based on disruptive technologies in the overall social innovation set. This idea is explicitly illustrated by us in the following figure. Within the same graphical scheme in Figure 13, we explicitly highlight the share that fintech-industry-specific financial innovations could reach in the total annual social innovations made by a company.

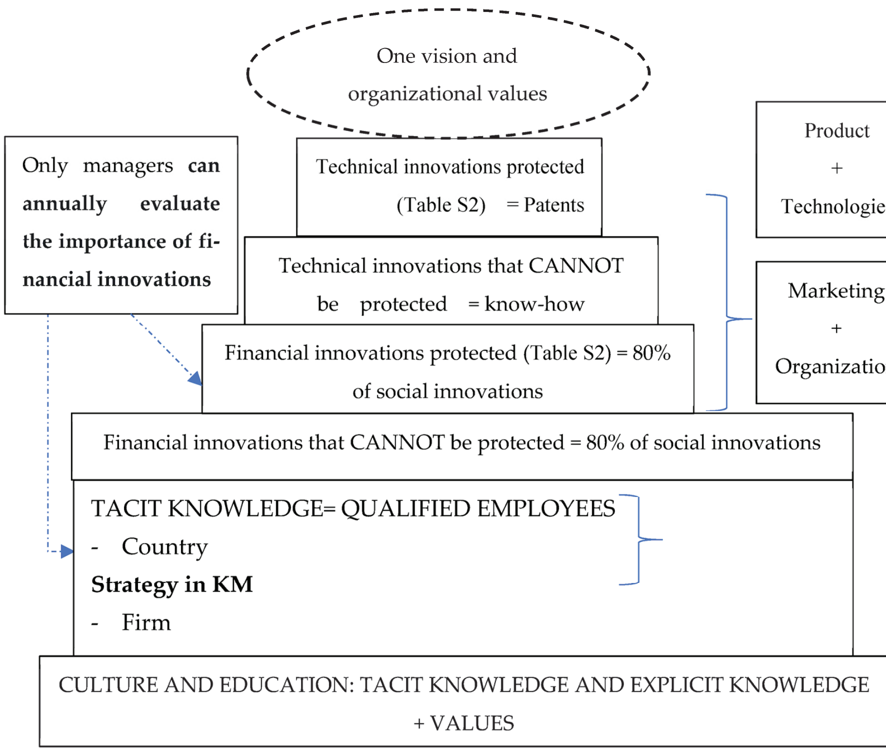

Figure 13. Financial innovation as part of social innovation within firms. Source: Authors' design.

In the first part of the study (Section 2. Literature Review), we argued that it is useful to apply the Pareto principle on the random distribution of outcomes generated with an economic variable to the success and/or commercial application of social innovations vs. technical innovations. The same Pareto principle is useful to make a clear distinction between financial and other types of social innovations (up to 80% of social innovations achieved annually by a firm can be included in the category of financial innovations). It is only by measuring the commercial exploitation of a financial innovation based on disruptive technologies that one can more accurately assess/quantify the success of such an innovation. The statement in Figure 13 "Only managers can annually evaluate the importance of financial innovations" is directly related to the basic idea of our study. Simply put, it is not possible to formulate a precise and reasoned answer to the question "How do we evaluate the financial innovations made by firms?", since we are talking about millions of firms in the real economy.

As mentioned earlier, the vast majority of MNCs in the BCG study for 2023 and 2022 are making successful use of various disruptive technologies (digital ones as appropriate, but also some technologies such as non-digital EV batteries and the aforementioned alliance between Tesla, Rivian, Ford, and GM) [76,77]. The disruptive strategy applied by Toyota and then Tesla with respect to exploiting patents to improve EVs clearly has major financial implications, both for companies that are essentially changing practices previously applied to patents over more than two centuries, and for the thousands of firms that have already taken over various patents from the two companies. Out of the total of around 23,000 EV patents, Toyota has already assigned more than 8000 patents to thousands of companies, including fintech start-ups, to date. Since 2000 or even earlier, companies such as Toyota, IBM, Samsung, Apple, etc., have resorted to organizational innovations with major financial implications for their results/performance over the last two decades. A well-known example is Samsung, which has resorted to major changes in the organizational structure and marketing strategy to overcome the effects of the 1997 Asian crisis [78].

As a result of Samsung's organizational and marketing strategy innovations, it doubled its brand value within 5 years of initiating the reforms [78]. A more precise evaluation of organizational, marketing, and similar innovations, including for the adaptation of large MNCs to the fintech revolution [14,35], can only be performed by the top management of these companies and on medium time intervals (not necessarily annually). The assessment carried out for the 50 companies in the BCG study based on AR 2019–2021 (Table S2 in Supplementary) leads us to the conclusion that the vast majority of these firms have applied and are applying digital technologies massively to improve their financial/social innovation capability. The very concept of social innovation [29] has become a real challenge for large non-financial MNCs such as those in the BCG study. The same is true for financial companies that are included in the UNCTAD rankings, including banks, insurance companies, investment funds, etc. [51]. According to [29], large banks such as Deutsch Bank or City Group have set up units to manage "micro-funds" to support small start-ups and/or people with more modest incomes. The examples cited show that even large financial companies that are not included in the BCG study (analyzed by us) have applied strategies/practices specific to fintech markets since 2000.

The major problem currently faced by large MNCs is to adapt quickly to the new trends imposed by fintech firms and markets [31]. The Forbes 2000 study [45] includes banks, insurance companies, and investment funds; the ranking remains dominated by American firms, but also includes banks/firms from other countries and regions of the world (Canara Bank—Sweden; Axis Bank—India; DNB Bank—Norway; E-L Financial—Canada, etc.). Such banking and credit institutions have started to make massive use of financial technologies in order to adapt to the social innovation imposed by modern society and to resist the competition with fintech firms [30]. The concept of social innovation is, argues [29]. "under-theorized" even though there are hundreds of papers/studies on it; it has become a real challenge for Europe over the last decade as the fintech revolution manifests itself. Our proposed study sheds some light on the relationship between financial and other social innovations amidst the use of disruptive technologies, as well as on the relationship between the organizational and societal perspective of social/financial innovation. In addition to what has been shown in this section of the study, we list below 10 principles that are "de facto" at the core of financial innovation with disruptive technologies over the last two decades at the global level.

✓ Principle 1 (P1): Using disruptive technologies

The first principle is that any business (MNCs and SMEs), as well as other types of organizations, can and should make extensive use of disruptive/digital technologies to improve their financial innovation capacity as part of their social innovations. One of the directions of innovation strategy is towards open innovation by setting up various business networks for innovation.

✓ Principle 2 (P2): Applying strategies in KM

Every company should have a clear and distinct strategy for KM and continuous innovation. The focus of this strategy should be on technical and/or social innovation, depending on the field/sector in which a company operates. The best theoretical approaches can be taken towards social innovation in relation to different stakeholders.

✓ Principle 3 (P3): Stakeholder orientation

Any company has, by the very nature of its daily activity, a certain volume of financial relations with a group of stakeholders (suppliers, customers, employees, shareholders, public institutions, etc.). These day-to-day financial relationships are nowadays carried out through various solutions offered by ITC and other disruptive technologies. The strengthening of financial stakeholder relationships needs to be continuously monitored and improved as new tools and disruptive technologies emerge, especially from the artificial intelligence (AI) category.

✓ Principle 4 (P4): Multiplying financial innovations

When a company/organization has a KM strategy and systematically uses various digital/disruptive technologies, it can exploit the multiplier effect of an innovation. This means that a financial innovation based on digital technologies achieved in one direction of action (e.g., in relation to suppliers) can then be extended/duplicated very quickly in another direction of action/interest of a firm (e.g., in relation to customers/consumers). According to Drucker's arguments, customers and the market should be the most important source of inspiration for a firm in its attempt to achieve financial innovation by acquiring new knowledge and managing this knowledge through the use of various technologies [64].

✓ Principle 5 (P5): Customer/market orientation

The most important element/factor that should be at the heart of a continuous innovation strategy in the financial sector using various technologies remains the customer and the market, including other competitors. In other words, the customer and the market have become, over the last three decades, the "core" element of any strategy applied by firms in KM and continuous innovation. The continuous innovation of the "financial innovation" type remains the most important part of the social innovation undertaken/achieved by firms; the former cannot be "broken/dissociated" from the broader framework of social innovation [21]. Whatever the size of a firm and whatever the area of location, the starting/foundation point of KM strategy and continuous innovation is given with the values that customers/consumers believe in. Only by starting from this point and building ICT-based networks for open innovation can firms strengthen their competitive position and innovative capacity in a given market. It is only the satisfied customer that determines the outcome and/or existence of a firm [64].

✓ Principle 6 (P6): Financial innovation is partially associated with the business area

Most financial innovation will be related to process, marketing, and organizational innovation. However, the chances of achieving such innovations are conditioned by the location of firms in large sectors (from high-tech to low-tech).

✓ Principle 7 (P7): Disruptive technologies diminish the importance of size

The widespread use of digital and other technologies tends to eliminate/diminish the importance of the size of a firm in all cases where the KM strategy focuses on financial innovation as part of social innovation. Only a fraction of financial/social innovations will prove, over time, to be disruptive in the market and society.

✓ Principle 8 (P8): Financial innovation is decoupled from technical innovation

The existing vision at the company level must clearly differentiate between financial/social innovation and technical innovation; there are companies that have a large number of patents obtained annually, but have an insignificant position on social innovation that can be protected (as shown in Figure 11).

✓ Principle 9 (P9): Innovation in firms should be systematic

Firms aiming to become innovative need to build their continuous/systematic innovation strategies (according to the existing EU and countries rules, as well as the most innovative firms' practices) with regard to KM, MRU, and proposed targets as a result of innovation.

✓ Principle 10 (P10): Some financial innovations will be disruptive

Provided that a firm has a systematic innovation strategy, it follows that we can talk about sustaining and disruptive innovations [28]; not all the novel elements brought by a firm in its financial relationships with various stakeholders will turn out to be immediately disruptive. This implicitly means orienting the firm towards open innovation networks for which management optimization requires various ITC solutions [24].

7. Conclusions

The comparative analysis based on Global Innovation Index and Global Competitiveness Index data vs. the BCG ranking shows significant changes in the strategies applied by countries/firms regarding technical and social innovations/inventions carried out by different entities (researchers, firms, universities, etc.). However, it is difficult to assess the situation of social/financial innovations made by the same countries and firms in the two contexts of a global crisis or recession. This is even if, as we highlighted above, the GII and GCI components also include indicators such as business models developed by firms, the relationship with the market, etc. Our assessments based on BCG 2022–2023 lead us to conclude that there are certain common elements between the financial innovative capacity in firms and the same innovative capacity at the country level, and that at both levels of analysis, disruptive technologies have become the essential supporting/enhancing factors.

The question formulated in the title of the study "How do we evaluate financial innovations?" is predominantly rhetorical, as the realities encountered in various financial markets, whether associated with fintech markets or not, are extremely diverse. In the same sense, the existing conceptualizations in the literature on the use of financial technologies at the firm and/or country level are made from significantly different perspectives (banks, traditional industries, SMEs, sociology, digital technologies, etc.). The major changes brought about by fintech firms and markets over the last decade at the global level will, we believe, generate significant reconceptualization that will occur in organizational theory, start-up financing, innovation strategies, etc. One of the conclusions of our study is that digital and other disruptive technologies offer major opportunities for researchers, as well as MNCs' and SMEs' firms and managers, to build effective KM and social innovation strategies. Another conclusion of the study is that the fintech revolution in the use of digital technologies to create new markets is starting to decisively influence the innovation strategies of established MNCs in almost all sectors of the global economy (industry, distribution, telecommunications, banking, insurance, etc.). It is difficult to predict precisely in which directives and how future trends will manifest themselves in the strategies applied by thousands of fintech firms and/or traditional firms involved in fintech operations. The present study, however, makes some clear arguments that the fintech revolution is only at its beginning, that it requires new regulations/rules adopted by governments/international institutions, and that it will generate social benefits for millions of people. In order to overcome the specific economic challenges of the 2020–2021 period, social innovations have become more necessary than ever for any type of business organization. Among other conclusions our study leads to, we mention the 10 principles that companies can consider to build their KM and continuous social innovation strategies.

The post-2000 literature on the concept of "disruptive innovation", "open innovation", "financial innovation", "social innovation", etc., undoubtedly creates some confusion when companies propose strategies for strengthening/orienting their culture towards continuous innovation. It is necessary and useful for firms, we believe, to distinguish as clearly as possible, both conceptually/theoretically and pragmatically, between technical innovations and social innovations. Of course, technical innovations (also called sustaining and/or disruptive innovations) will remain a major, essential objective for companies in various industrial sectors. On the other hand, firms operating in various service sectors (banking, insurance, retailing, transport, consultancy, health, etc.) can, at best, make more intensive use of existing technologies to strengthen their market position, which requires precisely that social/financial innovations be made through the use of equipment/technology. As we have shown, there are theoretically three 'driving forces' (technologies, managers, and competition) that can jointly support the improvement in innovative capabilities at the firm/country level. The present study is only a preliminary one on the complex relationship between financial/social innovation capacity within firms and the same innovation capacity at the country level. It is theoretically useful as it provides a starting point for other similar studies that aim to present a clear/consistent picture of the role of disruptive technologies in improving innovative capacity in firms and countries alike. The study is also useful from a pragmatic perspective, as it proposes/suggests small points of support for managers in any type of firm and any country in their attempt to build effective strategies on financial/social innovation. In future studies, the authors aim to expand the sample of firms that are internationally significant (considering 200–300 firms that are nominated in various rankings) and on the basis of a thorough assessment of technical and social innovative capacity to draw further conclusions that explain innovative capacity at the country level and would support policy makers in formulating macro-economic strategies on education, R&D, research infrastructure, etc.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fintech2030033/s1. Table S1. Preliminary Statistical Data for GCI, Selective for Seven Sub-pillars (Total GCI Score and Seven Existing Sub-pillars in 2019); Table S2. Summary of BCG Companies According to Social/Financial and Technical Innovation, Period of 2004–2022 (Assessment at the Time of 2022 Based on Annual Report).

Author Contributions: Each author made contributions to the conception and design of the work, and the acquisition, analysis, and interpretation of data. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data can be shared with other researchers; data used can be found in international rankings and the final list of references.

Acknowledgments: We thank the editor and reviewers for their support in improving the quality of this study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Drucker, P.F. *The Age of Discontinuity. Guidelines to Our Changing Society*; Heinemann: London, UK, 1969.
2. Kotler, P.; Caslione, J.A. *Chaotics: The Business of Managing and Marketing in the Age of Turbulence*; AMACOM: New York, NY, USA, 2009.
3. Adam, B.; Van Loon, J.; Beck, U. *The Risk Society and Beyond: Critical Issues for Social Theory*; SAGE Publications Ltd.: London, UK, 2000. [CrossRef]
4. Beck, U. *World at Risk*; Polity Press: Cambridge, UK, 2009.
5. Burciu, A.; Kicsi, R.; Bostan, I. Social Trust and Dynamics of Capitalist Economies in the Context of Clashing Managerial Factors with Risks and Severe Turbulence: A Conceptual Inquiry. *Sustainability* **2020**, *12*, 8794. [CrossRef]
6. World Economic Forum. *The Global Risks Report 2021*, 16th ed.; World Economic Forum: Cologny, Switzerland, 2021.
7. Archibugi, D.; Filippetti, A.; Frenz, M. Economic crisis and innovation: Is destruction prevailing over accumulation? *Res. Policy* **2013**, *42*, 303–314. [CrossRef]
8. Brem, A.; Nylund, P.; Viardot, E. The impact of the 2008 financial crisis on innovation: A dominant design perspective. *J. Bus. Res.* **2020**, *110*, 360–369. [CrossRef]
9. Taalbi, J. What drives innovation? Evidence from economic history. *Res. Policy* **2017**, *46*, 1437–1453. [CrossRef]
10. Matyushok, V.; Krasavina, V.; Berezin, A.; García, J.S. The global economy in technological transformation conditions: A review of modern trends. *Econ. Res.-Ekon. Istraživanja* **2021**, *34*, 1471–1497. [CrossRef]
11. Kanerva, M.; Hollanders, H. *The Impact of the Economic Crisis on Innovation*; OECD Science, Technology and Industry Outlook: Paris, France, 2009.
12. Filippetti, A.; Archibugi, D. *Innovation in Times of Crisis: The Uneven Effects of the Economic Downturn across Europe*; MPRA Paper 22084; University Library of Munich: Munich, Germany, 2010.

13. Giebel, M.; Kraft, K. Bank credit supply and firm innovation behavior in the financial crisis. *J. Bank. Financ.* **2020**, *121*, 105961. [CrossRef]
14. Gomber, P.; Kauffman, R.J.; Parker, C.; Weber, B.W. On the Fintech Revolution: Interpreting the Forces of Innovation, Disruption, and Transformation in Financial Services. *J. Manag. Inf. Syst.* **2018**, *35*, 220–265. [CrossRef]
15. Krugman, P. *A Country Is Not a Company*; Harvard Business Review: Brighton, MA, USA, 1996.
16. Nonaka, I.; Takeuchi, H. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*; Oxford University Press: Oxford, UK, 1995.
17. Schumpeter, J. *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process*; McGraw Hill Book Company: New York, NY, USA, 1939.
18. Schumpeter, J.A. The Creative Response in Economic History. *J. Econ. Hist.* **1947**, *VII*, 149–159. [CrossRef]
19. Schumpeter, J.A. *Capitalism, Socialism and Democracy*; Routledge: London, UK, 1994.
20. *NEW REFS: George S Yep and Bruce McKern--China' Next Strategic Advantage*; The MIT Press: Cambridge, MA, USA, 2015.
21. Drucker, P.F. *Innovation and Entrepreneurship: Practice and Principles*; Harper & Row: New York, NY, USA, 1986.
22. Christensen, C.M. *The Innovator's Dilemama*; Harvard Business School Press: Brighton, MA, USA, 1997.
23. McQuivey, J. *Digital Disruption: Unleashing the Next Wave of Innovation*; Forrester Research, Incorporated; Amazon Publishing: Seattle, WA, USA, 2013.
24. Prahalad, C.K.; Krishnan, M.S. *The New Age of Innovation: Driving Cocreated Value through Global Networks*; McGraw-Hill: New York, NY, USA, 2008.
25. Christensen, C.M. The Ongoing Process of Building a Theory of Disruption. *J. Prod. Innov. Manag.* **2006**, *23*, 39–55. [CrossRef]
26. Martone, N.J. *Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns*; Christensen, C.M., Johnson, C.W., Horn, M.B., Eds.; McGraw-Hill: New York, NY, USA, 2008.
27. Christensen, C.M.; McDonald, R.; Altman, E.J.; Palmer, J.E. Disruptive Innovation: An Intellectual History and Directions for Future Research. *J. Manag. Stud.* **2018**, *55*, 1043–1078. [CrossRef]
28. What Is Disruptive Innovation?—Article—Faculty & Research—Harvard Business School. Available online: https://www.hbs.edu/faculty/Pages/item.aspx?num=50233 (accessed on 2 July 2023).
29. Grimm, R.; Fox, C.; Baines, S.; Albertson, K. Social innovation, an answer to contemporary societal challenges? Locating the concept in theory and practice. *Innov. Eur. J. Soc. Sci. Res.* **2013**, *26*, 436–455. [CrossRef]
30. Pot, F.; Vaas, F. Social innovation, the new challenge for Europe. *Int. J. Prod. Perform. Manag.* **2008**, *57*, 468–473. [CrossRef]
31. Putri, R.T.; Isyanto, P.; Sumarni, N. The Role of Financial Technology (Fintech) in MSMEs. *Int. J. Econ. Dev. Res.* **2023**, *3*, 276–289.
32. Lindegaard, S. The Open Innovation Revolution by Stefan Lindegaa eBook | Perlego. Available online: https://www.perlego.com/book/1007547/the-open-innovation-revolution-essentials-roadblocks-and-leadership-skills-pdf (accessed on 3 July 2023).
33. Chesbrough, H.W. The Era of Open Innovation. *Manag. Innov. Chang.* **2006**, *127*, 34–41.
34. Aysan, A.; Naneva, Z. Fintech /as a Financial Disruptor: The Bibliometric Analysis. *FinTech* **2022**, *1*, 412–433. [CrossRef]
35. Deloitte Report—FintechOn the Brink of Further Disruption. Deloitte Financial Advisory Netherlands Valuation & Modelling, Corporate Finance. 2020. Available online: https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/financial-services/deloitte-nl-fsi-fintech-report-1.pdf (accessed on 11 August 2023).
36. Johansson, E. 50 Fintech Experts Share Industry Predictions for 2023. 2022. Available online: www.verdict.co.uk/deals (accessed on 5 July 2023).
37. Buchholz, K. The Regional Differences of Fintech Adoption. 2022. Available online: https://www.statista.com/ (accessed on 5 July 2023).
38. Chesbrough, H.; Vanhaverbeke, W.; West, J. *Open Innovation: Researching a New Paradigm*; Oxford University Press: Brighton, MA, USA, 2008.
39. Hippel, V. *The Sources of Innovation*; Oxford University Press: Brighton, MA, USA, 1988.
40. Zhu, T.; Sun, X. Enterprise Financialization and Technological Innovation: An Empirical Study Based on A-Share Listed Companies Quoted on Shanghai and Shenzhen Stock Exchange. *FinTech* **2023**, *2*, 16. [CrossRef]
41. Anakpo, G.; Xhate, Z.; Mishi, S. The Policies, Practices, and Challenges of Digital Financial Inclusion for Sustainable Development: The Case of the Developing Economy. *FinTech* **2023**, *2*, 19. [CrossRef]
42. Wang, H.; Zhang, Z. The Influence of Corporate Networks on the Competitive Advantage of High Technology Enterprises in China: The Mediating Effects of Dynamic Capacities and Ambidextrous Combination. *Int. J. Financ. Stud.* **2021**, *9*, 42. [CrossRef]
43. Wang, L.; Zhang, M.; Verousis, T. The road to economic recovery: Pandemics and innovation. *Int. Rev. Financ. Anal.* **2021**, *75*, 101729. [CrossRef]
44. Antonelli, C. *The Economic Complexity of Innovation as a Creative Response*; Collegio Carlo Alberto: Turin, Italy, 2013.
45. Paunov, C. The global crisis and firms' investments in innovation. *Res. Policy* **2012**, *41*, 24–35. [CrossRef]
46. Giebel, M.; Kraft, K. The Impact of the Financial Crisis on Investments in Innovative Firms. SSRN J. No 15-069, Discussion Papers from ZEW—Leibniz Centre for European Economic Research. 2015. Available online: https://ftp.zew.de/pub/zew-docs/dp/dp15069.pdf (accessed on 11 August 2023).
47. Giebel, M.; Kraft, K. External Financing Constraints and Firm's Innovative Activities during the Financial Crisis. Centre for European Economic Research Discussion Paper No. 17-064. 2017. Available online: https://www.econstor.eu/bitstream/10419/172324/1/1009187635.pdf (accessed on 11 August 2023).

48. Galanakis, C.M.; Rizou, M.; Aldawoud, T.M.S.; Ucak, I.; Rowan, N.J. Innovations and technology disruptions in the food sector within the COVID-19 pandemic and post-lockdown era. *Trends Food Sci. Technol.* **2021**, *110*, 193–200. [CrossRef] [PubMed]
49. Rotaba, Z.; Beaudry, C. How do high, medium, and low tech firms innovate? A system of innovation (Si) approach. *Int. J. Innov. Technol. Manag.* **2012**, *9*, 1250034. [CrossRef]
50. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition | The Measurement of Scientific and Technological Activities | OECD 2005, iLibrary. Available online: https://www.oecd-ilibrary.org/science-and-technology/oslo-manual_9789264013100-en (accessed on 11 August 2023).
51. UNCTAD. 2022. Available online: https://unctad.org/system/files/ (accessed on 11 August 2023).
52. Chen, M.A.; Wu, Q.; Yang, B. How Valuable Is FinTech Innovation? *Rev. Financ. Stud.* **2019**, *32*, 2062–2106. [CrossRef]
53. Schwab, K. *The Global Competitiveness Report 2009–2010*; World Economic Forum: Cologny, Switzerland, 2009.
54. Schwab, K. *The Global Competitiveness Report 2019*; World Economic Forum: Cologny, Switzerland, 2019.
55. Release of the Global Innovation Index 2020: Who Will Finance Innovation? Available online: https://www.wipo.int/global_innovation_index/en/2020/index.html (accessed on 11 August 2023).
56. World Intellectual Property Organization. *Global Innovation Index 2022: What Is the Future of Innovation-Driven Growth?* 15th ed.; WIPO: Geneva, Switzerland, 2022; Available online: https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2022-en-main-report-global-innovation-index-2022-15th-edition.pdf (accessed on 11 August 2023).
57. Atkinson, R.D. *Emerging Technologies and Preparing for the Future Labor Market*; Information Technology and Innovation Foundation (ITIF): Washington, DC, USA, 2018.
58. Available online: https://web-assets.bcg.com/63/15/963298f5460f8b768403b24ac242/bcg-most-innovative-companies-2022-sep-2022-1.pdf (accessed on 6 April 2023).
59. The Global 2000. 2022. Available online: https://www.forbes.com/lists/global2000/?sh=1d7635225ac0 (accessed on 6 April 2023).
60. Porter, M. On Competition—Book—Faculty & Research—Harvard Business School. Available online: https://www.hbs.edu/faculty/Pages/item.aspx?num=34977 (accessed on 11 August 2023).
61. WIPO—World Intellectual Property Organization. Available online: https://www.wipo.int/ (accessed on 11 August 2023).
62. Drucker, P.F. *Managing in the Next Society*; St. Martin's Publishing Group: New York, NY, USA, 2003.
63. Furr, N.; Dyer, J. *The Innovator's Method: Bringing the Lean Start-Up into Your Organization*; Harvard Business Review Press: Brighton, MA, USA, 2014.
64. Drucker, P. *The Essential Drucker*; Elsevier: Amsterdam, The Netherlands, 2001.
65. Drucker, P.F. *Managing in Turbulent Times*; Harper & Row: New York, NY, USA, 1980. [CrossRef]
66. Liker, J.; Ogden, T.N. *Toyota under Fire; How Toyota Faced the Challenges of the Recall and the Recession to Come out Stronger*; McGraw-Hill: Singapore, 2011.
67. Toyota Industries Corporation. Toyota AR—Annual Financial Report 2020, for the Year Ended March 31. 2020. Available online: https://www.toyota-industries.com/investors/items/2020_annual_financial_report (accessed on 11 August 2023).
68. Ellis, J. Has Toyota Turned Tesla with Its Latest 'Open' Patent Pledge? 2021. Available online: https://jacknwellis.medium.com/has-toyota-turned-tesla-with-its-latest-open-patent-pledge-not-quite-1dee8d70d9bd (accessed on 11 August 2023).
69. Chandler, A.D. *The Visible Hand: The Managerial Revolution in American Business*; Belknap Press: Cambridge, MA, USA, 1977.
70. Available online: https://web-assets.bcg.com/45/1a/7c66e24b48c08619e61cf0d6afea/bcg-most-innovative-companies-2023-reaching-new-heights-in-uncertain-times-may-2023.pdf (accessed on 20 April 2023).
71. Glossary: High-Tech Classification of Manufacturing Industries. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:High-tech_classification_of_manufacturing_industries (accessed on 20 April 2023).
72. Aggregations of Manufacturing Based on NACE Rev 2, Eurostat. 2023. Available online: https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF (accessed on 11 August 2023).
73. Cavusgil, S.T.; Knight, G. *Born Global Firms: A New International Enterprise*; Business Expert Press: New York, NY, USA, 2009.
74. Gabrielsson, M.; Kirpalani, V.H. *Handbook of Research on Born Globals*; Edward Elgar Publishing: Cheltenham, UK, 2012.
75. Koroleva, E. FinTech Entrepreneurial Ecosystems: Exploring the Interplay between Input and Output. *Int. J. Financ. Stud.* **2022**, *10*, 92. [CrossRef]
76. Valdes-Dapena, P. Rivian joins Ford and GM in Turning to Tesla Chargers. CNN Business. 2023. Available online: https://edition.cnn.com/2023/06/20/business/rivian-tesla-chargers/index.html (accessed on 20 June 2023).
77. Bierenkoven, C. *Rivian Will Adopt Tesla's NACS Charger, Following Ford, GM*; Edmunds: Santa Monica, CA, USA, 2023.
78. Michell, T. *Samsung Electronics and the Struggle for Leadership of the Electronics Industry (Tony Michell, 2010)*; Wiley: Singapore, 2010.

FinTech

Article

The Role of Financial Sanctions and Financial Development Factors on Central Bank Digital Currency Implementation

Medina Ayta Mohammed [1,*], Carmen De-Pablos-Heredero [1] and José Luis Montes Botella [2]

1 Department of Business Economics (Administration, Management, and Organization), Applied Economics II and Fundamentals of Economic Analysis, Universidad Rey Juan Carlos, Paseo de los Artilleros s/n, 28032 Madrid, Spain; carmen.depablos@urjc.es
2 Department of Applied Economy I, Universidad Rey Juan Carlos, Paseo de los Artilleros s/n, 28032 Madrid, Spain; joseluis.montes@urjc.es
* Correspondence: medina.mohammed@urjc.es

Abstract: This study investigates the influence of a country's financial access and stability and the adoption of retail central bank digital currencies (CBDCs) across 71 countries. Using an ordinal logit model, we examine how individual financial access, the ownership of credit cards, financing accessibility by firms, offshore loans, financial sanctions, and the ownership structure of financial institutions influence the probability of CBDC adoption in nations. These findings reveal that nations facing financial sanctions and those with substantial offshore bank loans are more inclined to adopt CBDCs. Furthermore, a significant relationship is observed in countries where many people have restricted financial access, indicating heightened interest in CBDC adoption. Interestingly, no statistically significant relationship was found between the adoption of CBDCs and the percentage of foreign-owned banks in each country. The results show that countries with low financial stability and financial access adopt CBDCs faster. This study expands our knowledge of how a nation's financial situation influences its adoption of CBDCs. The results provide important and relevant insights into the current discussion of the direction of global finance.

Keywords: central bank digital currencies; financial development; financial access; financial stability; CBDC

JEL Classification: E42; E58

Citation: Mohammed, M.A.; De-Pablos-Heredero, C.; Montes Botella, J.L. The Role of Financial Sanctions and Financial Development Factors on Central Bank Digital Currency Implementation. *FinTech* **2024**, *3*, 135–150. https://doi.org/10.3390/fintech3010009

Academic Editors: David Roubaud, Ovidiu Folcuţ, Mohammed K. A. Kaabar, Anuradha Iddagoda, Eglantina Hysa and Otilia Manta

Received: 21 December 2023
Revised: 31 January 2024
Accepted: 13 February 2024
Published: 15 February 2024

1. Introduction

The global financial landscape is undergoing a dynamic shift, driven primarily by emerging technologies. This transformation introduces opportunities and challenges to the monetary system. As the world becomes increasingly interconnected and reliant on digital financial systems, the idea of monetary hegemony is facing new challenges [1]. This digital transformation not only reshapes the way we perceive and utilize money but also raises critical questions about the dynamics of power and control. Monetary hegemony traditionally rests on the dominance of a few global reserve currencies, such as the Dollar and the Euro [2]. The emergence of central bank digital currencies (CBDCs) is projected to challenge this established order by offering a new paradigm for financial transactions and cross-border trade. The report prepared by the U.S Congressional Research Service [3] addresses this concern as follows: "some observers have speculated whether changes in the global economy and geopolitical shifts could cause a shift from the dollar to other currencies. Focus in particular is centered on China's economic rise, U.S. sanctions, and digital currencies" (p. 1).

The U.S. government has progressively imposed restrictions on access to U.S. dollars and the U.S. financial system to influence foreign governments' behaviour [4]. A report by the U.S. Department of Treasury [5] reveals that sanction designations by the Office of

Foreign Assets Control (OFAC) have increased over the past 20 years by +933%. At the core of this evolving landscape, the question of financial access also lies, which is the ability of individuals, businesses, and nations to participate in the global economy on equitable terms. These measures affect these countries' financial access and stability, potentially prompting them to explore alternative routes and seek to reduce their dependency [6]. More recently, the United States and its closest allies have subjected Russia to severe sanctions. The top ten Russian-owned banks and over 80% of the financial industry's assets are among the penalties [7]. The imposition of such sanctions harms citizens and enterprises operating in designated nations, thus impeding their capacity to conduct cross-border transactions [8].

Various studies have projected that CBDCs have immense potential to revolutionize the financial landscape. CBDCs have the potential to significantly enhance universal financial inclusion [9], stimulate green financing initiatives, and advance sustainable development [10] by improving payment efficiency and expanding financial access. Simultaneously, they have the potential to introduce a novel dimension of monetary independence because the control and distribution of these digital currencies can significantly impact a nation's economic sovereignty and global influence. The U.S. Department of Treasury [5] explains the projected potential of CBDCs as "These technologies offer malign actors opportunities to hold and transfer funds outside the traditional dollar-based financial system. They also empower our adversaries seeking to build new financial and payment systems intended to diminish the dollar's global role" (p. 2).

Many nations are presently investigating the potential applications of CBDCs and analyzing the associated risks and their effects on economies, monetary systems, and stability. Current research on the determinants of CBDC adoption reveals a complex landscape shaped by economic, financial, and cultural factors (see Table 1). Financial factors remain relatively understudied despite some examination of variables by Dong et al. [11], such as the influence of financial inclusion, net foreign assets, and remittances on CBDC adoption. However, there is scope to address further financial variables.

Building on prior research, this study illuminates the complex relationship between financial access, stability, and adoption of retail CBDCs across nations, with a particular focus on the role of monetary independence in this dynamic equation. This study examines the impact of financial sanctions, financial institution ownership structures, offshore loans, accessibility to financial institutions, availability of financing infrastructure, and credit to businesses on a country's adoption of CBDCs. We adopted the financial development framework built by Cihak et al. [12]. In doing so, we hope to contribute to a deeper understanding of the transformative forces that reshape the global financial landscape and the implications of these changes for nations. Such a study can assist countries in crafting appropriate policies and initiatives to encourage the adoption of central bank digital currency. The remainder of this paper is organized as follows. Section 2 provides a literature review and theoretical background. Section 3 presents the materials and methods used in this study. Sections 4 and 5 present the results and discussion and directions for future research, respectively.

Table 1. Literature findings on the determinants of nations' CBDC adoption.

Themes	Significant Drivers	References
Economic developmental factors	High level of democracy, public confidence in governance, regulatory quality, income inequality, FDI inflow, young populations, urban societies	[13,14]
Financial factors	Higher levels of financial inclusion, net foreign assets, remittances, income	[11]
Cultural factors	High power distance, masculinity, and long-term orientation	[15]
A mix of one or more of the above factors	Government performance, inflation rate, economic inequality, technological literacy, anti-money laundering, and terrorist financing	[16,17]
CBDC Implications	Enhance the effectiveness of current monetary policy instruments, financial inclusion, financial stability, Inclusive welfare	[18–21]

2. Conceptual Background and Hypothesis Development

Contemporary investigations of the determinants of CBDC adoption have revealed a multifaceted landscape shaped by a confluence of economic, financial, and cultural factors (Table 1). In-depth analyses of these determinants provide insights into the dynamics that influence the decision-making processes in countries' CBDC adoption.

Previous studies reveal various facets that can influence a country's inclination to adopt CBDCs. Potential macroeconomic factors considered include nations' population demography, foreign direct investment inflow, and legal factors. Notably, the findings from these studies reveal that democratic governance and high regulatory quality correlate with countries' CBDC adoption [13,14]. Luu et al. [15] also addressed cultural dimensions such as the role of power distance, masculinity, and long-term orientation in shaping nations' CBDC adoption. Moreover, Le et al. [17] and Ngo et al. [16] outlined factors such as government performance and technological literacy to understand how these variables shape the adoption landscape. It is noteworthy that financial factors have not been extensively addressed. Nonetheless, Dong et al. [11] examined the relationship between a country's likelihood of adopting CBDCs and its level of revenue, remittances, and net foreign assets.

These studies have made substantial contributions to our knowledge of the factors influencing CBDC adoption across different countries. Building on earlier studies, our study primarily focuses on the elements of financial stability and accessibility that influence a country's decision to implement CBDCs. The literature extensively highlights the significance of CBDCs in enhancing financial stability [18,19] and broadening access to financial services [20,21]. Given this context, we believe that it is essential to understand the precise roles of financial stability and access in shaping a nation's inclination to adopt CBDCs.

2.1. Financial Stability

2.1.1. Financial Sanction

Numerous studies have found that sanctions can hinder the targeted nation's access to global financial markets. Peksen and Woo's [22] comprehensive study covering emerging market economies observed that countries facing economic sanctions, particularly those imposed by the United States and international institutions, are less likely to secure funds from the International Monetary Fund (IMF). This study also suggests that nations implementing sanctions may utilize their political influence within the IMF to withhold funds from the economies they target. Sanctions not only restrict a nation's ability to access financial resources but also obstruct its engagement in global trade. As highlighted in Caruso's [23] study, this stresses the substantial negative impact of sanctions on bilateral trade. This constrained participation in global trade can adversely affect foreign exchange reserves and the overall economic stability. Some countries may develop and adopt alternative financial systems or technologies to counteract sanctions. As Selden [6] underlines, sanctions tend to stimulate the growth of domestic industries in the targeted country over time, reducing external dependencies and diminishing the ability of sanctioning entities to influence the target via economic pressure [24]. Thus, we propose the following hypothesis:

Hypothesis 1 (H1). *Countries under sanction are highly likely to adopt CBDCs more rapidly.*

2.1.2. Ownership Structure

The presence of foreign-owned banks in a country shapes the economy's financial landscape in several ways. As highlighted by Beck, Thorsten Demirgüç-Kunt, Asli, and Martinez Peria [25], the ownership structure of banking systems significantly influences the level of barriers encountered by customers. When a nation places a high priority on government control, consumers encounter various challenges, including access to finance. Beck, Thorsten Demirgüç-Kunt, Asli, and Martinez Peria [25] further highlight despite higher fees charged by foreign banks, financial systems dominated by foreign institutions often exhibit lower fees and increased accessibility for services such as opening bank accounts and applying for loans. However, nations with many financial institutions controlled by the government may benefit from quick monetary policy decisions that consider the needs of the public. As Spendzharova [26] emphasizes, in instances where a smaller proportion of banks are foreign-owned, reliance on external financial institutions is lower, which grants domestic regulators a more direct influence on monetary policies. Due to these dynamics, countries with a higher proportion of locally owned banks may show a propensity to embrace innovative financial technologies, such as CBDCs. Luu et al. [27] suggested that CBDC adoption is associated with expanded lending, increased asset quality, and reduced loan loss reserves. Moreover, substantial ownership by local banks and the government might foster the consideration of local interests, extending beyond private concerns. This control over monetary policies allows them to tailor their financial strategies to specific needs without excessive external influence. Thus, we propose the following hypothesis:

Hypothesis 2 (H2). *Countries with a low proportion of foreign-owned banks are more likely to adopt CBDCs quickly.*

2.1.3. Offshore Loan

An offshore loan indicates a country's indebtedness to a foreign bank (usually located in low-tax jurisdictions or tax havens) that provides financial and legal advantages [12]. This ratio is an indicator of a country's ability to meet financial obligations, with default on debt posing risks to both the domestic and international markets. According to Grennes et al. [28], in emerging economies, a debt-to-GDP ratio surpassing 64 percent can lead to a notable loss in annual real growth. Furthermore, countries heavily reliant on offshore bank loans face various risks, such as currency risks (due to exchange rate fluctuations), which potentially affect debt repayments [29]. Moreover, these offshore transactions often entail additional costs, such as fees for currency conversions and cross-border transfers [30]. A report from the Bank of England [31] suggests that CBDCs can promote nations' financial stability by accelerating or modifying policy rate transmission and adjusting the quantity and cost of credit. As wholesale CBDCs are also being established by various regional governments and new emerging partnerships in developing economies, they may offer diverse opportunities for new financial collaboration. Furthermore, because CBDCs are digital and decentralized, they can facilitate cost-effective transactions. The adoption of CBDCs by countries may reduce them from incurring excessive costs and heavy reliance on offshore financial services. Nations with high offshore bank loans may adopt CBDCs for both technical use and as a strategic move to foster economic growth. Therefore, we propose the following hypothesis:

Hypothesis 3 (H3). *Nations with outstanding offshore bank loans are likely to adopt CBDCs.*

2.2. *Access to Finance*

2.2.1. Accessibility of Financial Institutions

As articulated in a policy research paper by the World Bank, the availability of physical infrastructure is one of the most robust predictors of barriers to deposit, loan, and payment services in developing countries [25]. The study further highlights that in more competitive, open, and transparent economies and those with superior contractual and informational frameworks, banks tend to impose lower barriers [25]. According to the International Monetary Fund [32], 152 developing nations currently have a population of approximately 6.75 billion, representing a significant proportion (approximately 85%) of the global population. Some studies posit that central bank digital currencies could offer an effective solution to financial access challenges in these nations [33]. The attributes of CBDCs, such as tokenization [34], decentralization, digital nature, and smart contract functionality [35], may enable financial institutions to establish a robust presence in underserved areas. This contrasts with traditional banking hours and physical branch limitations that provide more flexible and convenient options for individuals with restricted access to conventional banking services. In nations in which a significant proportion of the population encounters obstacles in traditional banking, the adoption of CBDCs may be actively endorsed as a strategic component to enhance financial inclusion [11]. Hence, we propose the following hypothesis:

Hypothesis 4 (H4). *Countries with a high number of individuals with limited access to financial institutions are more interested in adopting CBDCs.*

2.2.2. Accessibility of Financing

Access to finance refers to a person's or business's capacity to obtain various financial services such as loans, deposits, and risk control. However, this study refers only to two variables. The first is the possibility of enterprises obtaining credit in each country, followed by individual ownership of credit cards. The motivation behind CBDC's introduction in emerging markets, as Singh et al. [36] highlighted, revolves around enhancing financial inclusion and payment efficiency. CBDCs may offer financially feasible possibilities for enterprises in these circumstances owing to their distinctive qualities, which include decentralization and their digital nature. Wronka [37] emphasizes that CBDCs have the potential to provide cost-effective digital payment solutions for businesses that are unbanked, fostering economic growth. Businesses operating in places where traditional banking is limited may face obstacles to accessing finance. Therefore, governments in countries with low bank dependence may consider adopting CBDCs to boost financial inclusion and economic expansion. Consequently, we propose the following hypothesis:

Hypothesis 5 (H5). *Countries with fewer firms that access banks to finance asset purchases exhibit faster adoption rates of CBDCs.*

However, nations with widespread credit card accessibility may exhibit a greater propensity to adopt CBDCs than those that lack access. The literature attributes the prevalence of credit card ownership in nations to a range of factors, including the technological ecosystem [38], culture [39], digital payment familiarity [40], and trust in digital transactions. In regions where credit cards are highly available, the economic prosperity stemming from credit card usage may foster an environment conducive to CBDC adoption. Moreover, the convenience and efficiency associated with digital transactions via credit card usage may contribute to a seamless transition to CBDCs in these areas. Thus, we propose the following hypothesis:

Hypothesis 6 (H6). *Countries with citizens who have high access to credit cards exhibit a faster adoption rate of CBDCs.*

Drawing from the existing literature, we formulated a conceptual model (depicted in Figure 1) that organizes the crucial financial factors influencing a nation's adoption of CBDC, along with the impact of the independent variables.

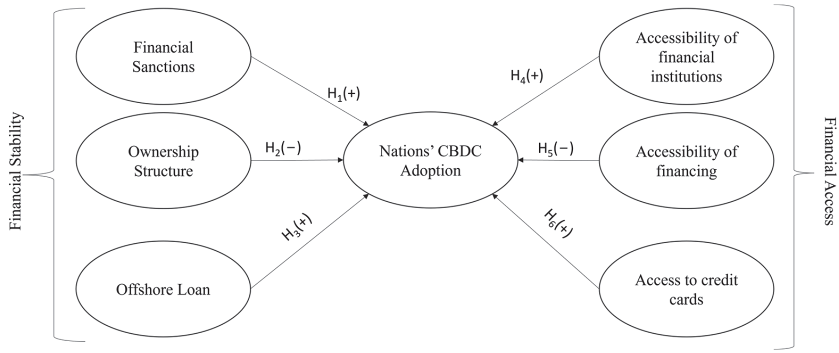

Figure 1. The conceptual model and hypotheses.

3. Data and Methods

To investigate how the level of financial development in different nations affects the adoption of retail central bank digital currencies, we use the financial development framework originally formulated by Cihak et al. [12]. They introduced the "Global Financial Development Database", an extensive global database that combines and updates several financial datasets. The database generates several metrics for four key attributes of financial institutions and markets: first, the extent to which individuals utilize financial institutions and markets (access); second, the size of financial institutions and markets (financial depth); third, the effectiveness of financial institutions and markets in delivering financial services (efficiency); and fourth, the resilience of financial institutions and markets (stability) [12]. In this study, we concentrated specifically on the components of "Access" and "Stability" within the framework, utilizing a subset of the indicators for assessing their role in nations' CBDC adoption. This emphasis aligns with prior research predictions, indicating that the adoption of CBDCs has the potential to enhance both access to [11] and stability of financial services [19]. We used the most recent data available for each variable in our study. Specifically, the data for FINA, TRUS, FIRMCR, and DEBT are based on data from the year 2021. However, it is important to note that for the OWN variable, the latest available data pertain to the year 2013. This approach was adopted to ensure the incorporation of the latest data for the variables.

Additionally, we incorporated a binary variable to account for countries subject to financial sanctions, specifically those imposed by the United States Office of Foreign Assets Control (OFAC), the United Kingdom, the European Union, and those mandated by the United Nations Security Council. The selection of these sanctions is further substantiated by the existing literature, which suggests that nations subject to economic sanctions, particularly those imposed by the United States and international institutions, face various challenges, including securing funds from the International Monetary Fund (IMF) [22].

Our assessment of access to finance encompasses the following indicators:

- Accessibility of financial institutions: this was measured as the percentage of respondents who neither deposited nor withdrew funds from their accounts in the past year, including those engaging in any form of digital payment.
- Availability of financing for firms: this is gauged by the percentage of firms that use banks to finance the acquisition of fixed assets.
- Access to credit cards: this variable was determined by the percentage of respondents who reported having credit cards.

In evaluating financial stability, we use the following variables:

- Offshore Loan: this is represented by the outstanding amount of debt securities held by offshore investors as a percentage of the GDP.
- Foreign investment: this variable is expressed as the percentage of foreign banks out of the total number of banks.
- Financial sanction: this variable captures the presence of global sanctions impacting financial stability.

In this study, the dependent variable is ordinal, with values of 1, 2, and 3 representing distinct stages in the adoption of retail central bank digital currencies by country. Specifically, a value of one corresponds to countries in the research stage, two to those in the proof-of-concept stage, and three to those that have advanced to the pilot and launch stages of the CBDCs. The data for this study were obtained from the CBDC Tracker (2023), encompassing 71 countries across a spectrum of economic statuses ranging from developed to developing nations. The methodology employed in this study is ordinal logistic regression, chosen for its suitability in modelling the relationship between an ordinal response variable (representing the CBDC adoption stages) and six explanatory variables (see Table 2 and Appendix A for details). Given the nature of the outcome variable "CBDC" being ordinal, the study judiciously utilizes the ordinal logistic regression model to capture the nuances and ordinal nature of the CBDC adoption process in different countries. This methodological choice ensured a rigorous exploration of the factors influencing the progression of countries via various stages of CBDC implementation.

Table 2. List of variables.

Variables Description	Label	Value and Description	Variable Type	References
Country retail CBDC adoption	CBDC	Dependent variable	Ordinal	
Financial sanctions on nations	SANC	Positive	Dummy	[6,22–24]
Accessibility of financial institutions	ACC	Positive	Numeric	[25,32,33]
Availability of credit financing to firms	FIRMCR	Negative	Numeric	[36,37]
Offshore bank loans	DEBT	Positive	Numeric	[28–30]
Foreign-owned banks	OWN	Negative	Numeric	[25–27]
Credit card ownership	FINA	Positive	Numeric	[36]

4. Results

The outcomes from the ordered logistic regression analysis, investigating the association between diverse independent variables and the adoption status of CBDCs across nations, reveal noteworthy patterns. The literature explores the potential influence of financial access and stability on countries' CBDC adoption of CBDC. In this section, we scrutinize the identified factors and evaluate their impact on adoption status. The model outputs are presented in Table 3.

4.1. Analysis of Model Fit

The results in Table 3 reveal a statistically significant overall model, as evidenced by a prob > chi^2 value of 0.0001. This value represents the likelihood of observing the likelihood ratio chi-square statistic of 28.03 if there is no collective impact of the independent variables on the dependent variable [41].Additionally, the pseudo-R^2 of 0.3834 suggests that the model explains a substantial proportion of the variation in the dependent variable, CBDC. The cutoff points indicate the increments in log odds, which illustrates a progression in the likelihood of CBDC adoption across different categorical stages [41]. Progressing from the absence of CBDC adoption to the first category (cut1) entails a log-odds increase of 1.641014, indicating a notable shift in the likelihood of favouring CBDC adoption at the initial level. Subsequently, advancing from the first category to the second category (cut2) leads to an additional log-odds increase of 3.959928. This highlights a substantially further enhancement in the odds of CBDC adoption when transitioning from the initial to the subsequent level. The following section presents the estimated coefficients of each variable.

Table 3. Ordered logistic regression on nations' financial development and CBDCs adoption status.

					Number of Obs	**40**
					Log−likelihood	−22.540485
					LR $chi^2(6)$	28.03
					Pseudo R^2	0.3834
					Prob > chi^2	0.0001
CBDC	**Coefficient**	**Std. err.**	**z**	***p* > z**	**[95% Conf. Interval]**	
SANC	3.47084	1.791629	1.94	0.053	−0.0406887	6.982369
ACC	0.3207459	0.1265858	2.53	0.011	0726422	0.5688495
FIRMCR	−0.1253228	0.0428092	−2.93	0.003	−0.2092273	−0.0414184
DEBT	0.1106195	0.051294	2.16	0.031	0.010085	0.211154
OWN	−0.0001059	0.0249527	−0.00	0.997	−0.0490122	0.0488005
FINA	0.0881731	0.0329024	2.68	0.007	0.0236855	0.1526607
/cut1	1.641014				−1.512674	4.794701
/cut2	3.959928				0.4491786	7.470678

4.2. Statistical Significance

Looking at the coefficient estimates, the parameter estimate for the variable SANC is 3.47084, signifying that a one-unit increase in SANC, transitioning from a state of no sanctions to being sanctioned, is linked to a 3.47084 increase in the dependent variable CBDC. This relationship remains consistent when all other independent variables are held constant [41]. Practically, this implies that when countries face sanctions, the logit of favouring CBDC adoption is anticipated to increase by 3.4. Larger logits indicate higher probabilities, suggesting that nations subjected to substantial sanctions are inclined to embrace CBDC adoption [41].However, the *p*-value of 0.053 was slightly above the conventional significance level of 0.05, indicating a marginally significant relationship. The confidence interval, encompassing zero, introduces some uncertainty regarding statistical significance.

Similarly, a one-unit increase in ACC, DEBT, and FINA corresponded to increases of 0.3207459, 0.1106195, and 0.0881731, respectively, for the dependent variable CBDC. The positive coefficient of ACC implies that higher levels of individuals lacking access to financial institutions are associated with an increased probability of favouring CBDC adoption. A *p*-value of 0.011 signifies statistical significance at the level of 0.05, and a confidence interval entirely above zero reinforces the significance of the relationship. The positive coefficient of DEBT indicates that higher levels of offshore loans are linked to an increased probability of favouring CBDC adoption. A *p*-value of 0.031, which is below 0.05, indicates statistical significance, and a confidence interval entirely above zero supports the significance of this relationship [41].The positive coefficient of FINA suggests that high credit card ownership is associated with an increased probability of favouring CBDC adoption. A *p*-value of 0.007 was below 0.05, indicating statistical significance, and a confidence interval entirely above zero supported the significance of the relationship.

Conversely, the coefficients for the variables OWN and FIRMCR are negative, with values of −0.0001059 and −0.1253228, respectively. The negative coefficient of FIRMCR implies that firms' greater access to credit is associated with a decrease in the probability of favouring CBDC adoption. A *p*-value of 0.003 indicated a highly significant relationship, and a confidence interval entirely below zero reinforced this significance. The coefficient of OWN is very close to zero, and a high *p*-value of 0.997 indicates insufficient evidence to conclude a significant relationship between ownership structure and CBDC adoption. The confidence interval, including zero, supported the lack of statistical significance.

In a one-tailed test with a predetermined significance level of 0.05, we determined null hypotheses for various variables. Specifically, as shown in Table 4, we reject the null hypothesis for the variables SANC, ACC, FIRMCR, DEBT, and FINA because each of these variables exhibits a *p*-value of less than 0.05, indicating statistical significance. This implies that there is evidence of a significant relationship or effect between these variables. Conversely, when assessing OWN, the null hypothesis was not rejected at a significance level of 0.05. The *p*-value associated with this variable surpassed 0.05, leading us to accept the null hypothesis for OWN. In practical terms, this suggests that there is insufficient statistical evidence to conclude a significant relationship or effect of OWN in the analysis.

Table 4. Testing the hypotheses.

		Coeff. $p > z$	**Result**
H1	Financial sanction (SANC) → Adoption of retail CBDCs	($\beta = 3.47$, $p = 0.05$)	Pass
H2	Access to banks (ACC) → Adoption of retail CBDCs	($\beta = 0.32$, $p = 0.01$)	Pass
H3	Availability of credit financing to firms (FIRMCR) → Adoption of retail CBDCs	($\beta = -0.12$, $p = 0.003$)	Pass
H4	Offshore bank loans (DEBT) → Adoption of retail CBDCs	($\beta = 0.11$, $p = 0.03$)	Pass
H5	Foreign-owned banks (OWN) → Adoption of retail CBDCs	($\beta = -0.0001$, $p = 0.99$)	Reject
H6	Ownership of credit card (FINA) → Adoption of retail CBDCs	($\beta = 0.08$, $p = 0.007$)	Pass

5. Discussion and Directions for Future Research

5.1. Discussion

The global financial landscape is changing due to the advent of new technologies and increased interest in innovative financial technologies, such as CBDCs. As CBDCs gain prominence worldwide, understanding the factors that influence their adoption is crucial. This study investigates the role of bank ownership structures, offshore loans, financial sanctions, and financial institution accessibility in shaping countries' CBDC adoption. These findings offer valuable insights for scholars, financial institutions, and policymakers, shedding light on the complex processes that shape the evolution of international monetary systems. The first three hypotheses focus on a country's financial stability, whereas the last three address financial access.

5.1.1. Central Bank Digital Currencies and Nations' Financial Stability

To test the first hypothesis, we explore the impact of financial sanctions and countries' inclinations to adopt CBDCs. As the literature suggests, sanctions can harm bilateral trade [23] and a nation's access to global financial markets [22], potentially prompting countries to explore and adopt innovative financial technologies such as CBDCs. In line with this, Selden [6] also underlines that countries under sanctions may navigate these economic pressures by reducing external dependencies and diminishing the influence of sanctioning entities via regional collaborations. The findings of this study indicate a positive association between a nation's CBDC adoption status and the presence of financial sanctions, with a *p*-value of 0.053, approaching marginal significance. While these results lend some support to our hypothesis, the marginal significance and confidence interval, including zero, indicates the importance of cautious interpretation. The observed association aligns with our expectations, suggesting that financial sanctions may act as a catalyst, compelling nations to explore alternative financial systems such as CBDCs.

International organizations have imposed financial sanctions on numerous countries, targeting individuals, entities, and sectors within their economies. The CBDC developments in China and Russia may serve as compelling evidence, illustrating the role that CBDCs play in shaping countries' responses to financial sanctions and influencing their broader economic strategies. Current data from the CBDC tracker [42] and Atlantic Council CBDC tracker [43] indicate that both China and Russia are actively engaged in piloting central bank digital currencies. This places both countries among the top 18% of countries exploring CBDC implementation [43]. China, which announced its exploration of CBDCs in 2014 [44], took a significant step in April 2020 by becoming among the world's first major economies to pilot a digital currency known as E-CNY [21]. On the other hand, Russia, despite announcing its exploration of CBDCs in 2019 [42], is also in an advanced stage of CBDC development [34]. Russia has faced financial sanctions by various countries and entities, including the EU and the U.K., due to geopolitical tensions and alleged interference in other countries' affairs [45].

For instance, after Russia's military operation in Ukraine in February 2022, the EU adopted restrictive measures on 28 February 2022, including a ban on transactions with the Central Bank of Russia, restrictions on overflight of EU airspace, and exclusion of key Russian banks from the SWIFT system (1 March 2022) [46]. Similarly, China has encountered financial sanctions, particularly from the United States [47], driven by concerns related to human rights, trade practices, and geopolitical tensions. The possible implications of these sanctions include restricted access to international financial markets and currency depreciation [48]. In response to financial sanctions, Russia may explore CBDCs to reduce reliance on traditional global banking networks. China, with its strategic focus on internationalizing the yuan [49], may see the use of CBDCs to facilitate cross-border transactions and increase its influence in the global financial system [50]. These instances substantiate the affirmative association between the implementation of central bank digital currencies by countries and the imposition of financial sanctions.

The second hypothesis posits that countries with a lower proportion of foreign-owned banks would adopt CBDCs at a faster pace. The literature suggests that countries with few foreign-owned banks often have a lower reliance on external financial institutions that grant domestic regulators a more direct influence on monetary policies [26]. These dynamics may allow nations to embrace innovative financial solutions, such as CBDCs. Despite the expectation that countries with fewer foreign-owned banks will be more receptive to CBDC adoption, the lack of statistical significance in this study suggests that the proportion of foreign-owned banks may not be a determining factor in the rate of CBDC adoption. Contrary to the literature emphasizing the impact of bank ownership structure on the adoption of innovative financial solutions, this hypothesis is not supported by the empirical results. Nevertheless, the data highlight a temporal constraint linked to the OWN variable, given that data are available only up to the year 2013. Researchers should be cognizant of this temporal gap when interpreting and extending the findings concerning the OWN variable within the framework of our study.

These results also confirm the third hypothesis, indicating that countries with substantial offshore bank loans are more likely to embrace CBDCs at an accelerated rate. The variable in this study (DEBT), which symbolizes offshore loans, has a positive and statistically significant coefficient ($p = 0.031$). This observation corresponds to the International Monetary Fund's [29] assertion that nations heavily dependent on offshore bank loans face financial and currency risks that can potentially lead to economic instability. The adoption of CBDCs by these nations may be due to the government's strategic response to address challenges stemming from exchange rate fluctuations, additional costs, and heavy reliance on offshore financial services. These findings are also in agreement with the Bank of England [31], which underscores that CBDCs can promote nations' financial stability by accelerating or modifying policy rate transmission and adjusting the quantity and cost of credit. The adoption of CBDCs by countries with offshore loans may focus on cultivating a positive economic environment, attracting investments, and fostering sustainable growth.

As highlighted in the literature, also per the findings of Grennes et al. [28], it is emphasized that emerging economies witnessing a debt-to-GDP ratio surpassing 64 percent may endure a substantial loss in annual real growth. This insight serves as a critical benchmark for evaluating the financial health and growth prospects of nations. A closer examination of the financial landscapes of both the Bahamas and Jamaica indicates the significance of debt-to-GDP ratios in shaping their economic trajectories. Notably, from the data of the Global Financial Development Database [12], as of 2021, the Bahamas exhibited a debt-to-GDP ratio of 99.14%, showcasing a relative decrease from the previous year's 105.28%. Despite this reduction, the ratio still signals a considerable dependence on offshore bank loans, emphasizing the potential economic vulnerability of the nation. Similarly, Jamaica, while experiencing a commendable reduction from 78.49% in 2020 to 68.49% in 2021, maintains a relatively high debt-to-GDP ratio. This reduction reflects a concerted effort by Jamaica to enhance its economic stability, signaling a proactive approach to fiscal management. The implementation of central bank digital currencies in both nations, with the Bahamas launching the Sand Dollar in 2020 [12,51] and Jamaica's introduction of JAM-DEX [52], aligns with the findings of the study. These initiatives further pinpoint the commitment of these countries to embrace technological advancements and digital financial solutions as integral components of their evolving financial landscapes.

As indicated above, the first three hypotheses validate two of these. These findings provide insights into why nations with lower financial stability may expedite the implementation of CBDCs. One possible rationale for this phenomenon could be the adverse impact of economic instability on individuals and businesses in these countries. The attraction to CBDCs in these high-instability nations may stem from CBDC's digital characteristics, distinctive technological attributes, and the collective efforts of various countries in establishing regional wholesale CBDCs.

5.1.2. Central Bank Digital Currencies and Nations' Access to Finance

The findings from the following three hypotheses focus on how a country's ability to access finance affects its likelihood of adopting CBDCs. The findings from testing the fourth hypothesis reveal a positive association between the prevalence of individuals lacking access to financial institutions and nations' inclinations to adopt CBDCs. This implies that nations with higher levels of this demographic—that is, individuals lacking access to financial institutions—are linked to an increased likelihood of favouring CBDC adoption.

Furthermore, in this study, the average ACC (inaccessibility of financial institutions) across the sample countries is 3.57%. However, when we delve into the data of individual countries, interesting variations emerge. In 2021, Jamaica demonstrated an ACC of 11.81%, reflecting the proportion of respondents not depositing or withdrawing funds [12]. Comparatively, in 2017, this figure was slightly higher at 13.17%, suggesting a subtle shift over time. Similarly, India's ACC in 2021 was 27.44%, a decline from the 30.62% reported in 2017 [12]. Notably, India entered the pilot phase of implementing the Digital Rupee on 1 December 2022, marking a significant milestone in its digital currency journey [53]. Concurrently, Jamaica has already made strides by launching JAM-DEX, further emphasizing its commitment to digital financial innovations. These distinctive developments in India and Jamaica serve as compelling supportive evidence, potentially substantiating the positive associations between access to financial institutions and the accelerated implementation of central bank digital currencies. This observation also aligns with insights from the literature that emphasize the potential role of CBDCs in minimizing the challenges individuals face in accessing traditional banking services. Studies have proposed that the features of CBDCs, including tokenization, decentralization, digital nature, and smart contract functionality, empower financial institutions to overcome their financial accessibility limitations [34,35]. The attributes of CBDCs facilitate the establishment of a robust presence in underserved areas, providing a flexible and convenient option for individuals with limited access to conventional banking services [34,35]. According to policy studies conducted by the World Bank, in most developing nations, insufficient physical infrastructure is the main factor preventing consumers from accessing financial institutions [25]. Considering that among 152 developing nations, representing approximately 85% of the global population [32], a significant proportion of individuals may face financial access challenges, CBDCs may emerge as a potential solution for these nations. Policymakers may actively endorse the adoption of CBDCs in regions where a significant proportion of the population encounters barriers to accessing traditional banking.

Hypotheses 5 and 6 are also accepted at a significant level. Hypothesis 5 posits that countries with a lower percentage of firms that rely on banks to finance fixed asset purchases exhibit a faster adoption rate of CBDCs. The highly significant relationship, supported by the low p-value of 0.003, emphasizes the robustness of this finding. As highlighted, the studies by Singh et al. [36] and Wronka [37] support this observation by emphasizing that CBDCs, with their decentralized and digital nature, present viable alternatives that are useful to enterprises, especially in regions where businesses have minimal access to traditional banking. Furthermore, looking into the most recent data from the countries under investigation reveals that, on average, the proportion of firms accessing banks to finance fixed asset purchases in each country is 26.81%. It is particularly interesting to observe that Nigeria deviates from this trend, displaying a relatively lower percentage at 6.9%. This distinctive pattern coincides with a significant event as Nigeria officially launched eNaira on 25 October 2021 [54,55]. This development supports our findings, pointing to a potential relationship between the accessibility of financing for firms and the inclination toward implementing central bank digital currencies on a national scale. The lower percentage in Nigeria, coupled with the recent introduction of eNaira, suggests that advancements in digital currency initiatives may be influenced by the dynamics of financial accessibility for businesses. Hypothesis 6 suggests that countries with high access to credit cards have higher CBDC adoption rates. The positive coefficient for FINA, indicating increased log odds of favouring CBDC adoption with high credit card ownership, supports this hypothesis. The literature suggests that widespread credit card access in a country stems from an advanced technological ecosystem, a culture of digital payment familiarity, and established trust in digital transactions [38–40]. Awareness of extensive credit card usage coupled with government support for financial education and innovation may create an environment conducive to the adoption of CBDCs.

The results of the last three hypotheses indicate that the percentage of individuals and enterprises with access to finance affects a nation's adoption of CBDC. The findings show that the inaccessibility of financing and the absence of banking infrastructure are both important determinants. From this, we can infer that governments in nations with large populations of people and enterprises with limited financial access might actively support CBDCs to improve financial inclusion and therefore spur economic growth. The findings of this study underscore the complex relationships among factors influencing the adoption of CBDCs across nations. While some variables exhibit statistically significant relationships, others show marginal significance or a lack thereof. This nuanced perspective highlights the complexity of the adoption landscape and emphasizes the multifaceted dynamics at play.

5.2. Practical Implications and Direction for Future Research

The findings of this study have significant practical implications for understanding the adoption dynamics of CBDCs across different nations. Our study found that nations with high instability and low access to financial institutions and services tend to adopt CBDCs faster. The positive association between CBDC adoption and the presence of elevated offshore bank loans and financial sanctions indicates that countries in such a situation are more inclined to explore alternative financial systems such as CBDCs.

We propose that policymakers, countries, and institutions imposing sanctions on nations explore alternative negotiation approaches that do not violate certain global agreements. It is crucial to find methods that address these concerns without jeopardizing the welfare of small businesses and individuals in the affected nations. As Selden [6] has highlighted, conventional sanctions may not consistently achieve their intended goals but rather prompt nations to seek alternative avenues. Moreover, there is a pressing need for technological advancements in the development of CBDCs to safeguard against misuse of technology for malicious purposes. Sanchez-Roger and Puyol-Antón [56] pointed out that the design of a CBDC significantly determines its implementation success rate and impact on the banking sector. In essence, our suggestion advocates a balanced strategy that involves diplomatic alternatives and technological safeguards, navigating the complexities of sanctions while fostering responsible technological evolution.

The identified positive associations, notably the relationship between constrained financial access and hastened adoption of CBDCs, imply that countries might strategically embrace CBDCs to foster financial inclusion and access. To expedite CBDC adoption, we recommend that governments and policymakers implement various strategies. These initiatives include the formulation of supportive regulatory frameworks, fostering collaboration with financial institutions, investing in technological infrastructure, and consistently dedicating R&D resources. These proactive measures may cultivate a conducive environment, instill public trust, and streamline the integration of CBDCs into the existing financial systems.

One limitation of this study is its dependence on fixed-year data without considering changes in variables over time. A potential avenue for improvement in future research would involve addressing this limitation by integrating temporal variations in the variables. Future research within the CBDCs domain may also focus on various crucial aspects. Future research may include longitudinal studies to track CBDC adoption over time (by considering the variables considered previously), which may offer a deeper understanding of the evolving patterns and influential factors. Furthermore, a qualitative comparative analysis across countries with diverse adoption rates may shed light on best practices and provide valuable insights. Subsequent studies may also delve into the effects of CBDCs on a nation's financial autonomy, with a particular focus on identifying the factors that contribute to achieving monetary independence. Another interesting study might investigate the impact of regulatory frameworks, technological advancements, and regional collaborations on wholesale CBDC implementation for a more profound comprehension of these pivotal elements. Further research directions may also encompass assessing the tangible effects of CBDCs on financial inclusion, investigating cybersecurity and privacy concerns, and integrating principles from behavioural sciences.

Author Contributions: Conceptualization, M.A.M.; methodology and software, J.L.M.B.; validation, M.A.M., C.D.-P.-H. and J.L.M.B.; writing—original draft preparation, M.A.M.; writing—review and editing, C.D.-P.-H.; supervision, C.D.-P.-H. and J.L.M.B. All authors have read and agreed to the published version of the manuscript.

Funding: The study was supported by the Universidad Rey Juan Carlos (Ref: PREDOC22-001).

Data Availability Statement: Links and information about the data source can be found in Appendix A.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Origin of the database, clarification of indicators, corresponding code, and associated description.

	Indicator Code in Our Study	Indicator Name	Definition	Source	Code at Source
Access	FINA	Owns a credit card (% age 15+)	The percentage of respondents who report having a credit card.	Global Financial Inclusion (Global Findex) Database, World Bank	Global Findex fin7_t_d
Access	TRUS	Has an inactive account (% age 15+)	The percentage of respondents who report neither a deposit into nor a withdrawal from their account in the past year. This also includes making or receiving any digital payment.	Global Financial Inclusion (Global Findex) Database, World Bank	Global Findex fin9N_10N_t_d

Table A1. *Cont.*

	Indicator Code in Our Study	Indicator Name	Definition	Source	Code at Source
Access	FIRMCR	Firms using banks to finance investments (%)	Percentage of firms using banks to finance purchases of fixed assets.	Enterprise Surveys, World Bank	GFDD.AI.28
Stability	DEBT	Debt securities by offshore investors (amounts outstanding) to GDP (%)	The ratio of outstanding offshore bank loans to GDP. An offshore bank is a bank located outside the country of residence of the depositor, typically in a low-tax jurisdiction (or tax haven) that provides financial and legal advantages.	Debt Securities Statistics (DSS), Bank for International Settlements (BIS). International debt securities—all issuers.	GFDD.OI.09
Stability	OWN	Foreign banks among total banks (%)	Percentage of the number of foreign-owned banks to the number of the total banks in an Economy. A foreign bank is a bank where foreigners own 50 percent or more of its shares.	CLAESSENS, S. and VAN HOREN, N. (2014), "Foreign Banks: Trends and Impact", Journal of Money, Credit and Banking, 46: 295–326. [57] CLAESSENS, S. and VAN HOREN, N. (2015), "The Impact of the Global Financial Crisis on Banking Globalization", DNB WP No. 459 [58]	GFDD.OI.15
Stability	SANC	Global Sanction dummy (1 = sanction exists on the country, 0 = none)	We considered the imposition of sanctions by various countries and on other nations, including: **U.S. OFAC Sanctions**: These sanctions can be either broad-based or targeted, involving measures such as asset freezes and trade restrictions to achieve foreign policy and national security objectives. Financial sanctions enforced by the **United Kingdom.** Sanctions imposed by the **United Nations Security Council.** Sanctions imposed by the **European Union (EU).**	https://ofac.treasury.gov/sanctions-programs-and-country-information (accessed on 12 February 2024) https://www.sanctionsmap.eu/#/main?checked=40 (accessed on 12 February 2024) https://www.gov.uk/government/collections/financial-sanctions-regime-specific-consolidated-lists-and-releases (accessed on 12 February 2024)	SELF CREATED
	CBDC		CBDC refers to the status of countries' adoption of CBDC. We assigned a value of 1 for countries in the research stage, 2 for countries that have published proof of concept, and 3 for countries that have advanced to the pilot and launch stages of CBDC.	https://cbdctracker.org/ (accessed on 12 February 2024)	SELF CREATED

Note: The indicator name and definitions for the variables "FINA" and "TRUS" are adapted from Global Findex (World Bank) (https://www.worldbank.org/en/publication/globalfindex (accessed on 12 February 2024)). The definitions, and indicator name for for the variables FIRMCR, DEBT, and OWN is adapted from the Global Financial Development Database (https://www.worldbank.org/en/publication/gfdr/data/global-financial-development-database (accessed on 12 February 2024)).

References

1. Vermeiren, M. The Crisis of US Monetary Hegemony and Global Economic Adjustment. *Globalizations* **2013**, *10*, 245–259. [CrossRef]
2. Salvatore, D. The Euro, the Dollar, and the International Monetary System. *J. Policy Model.* **2000**, *22*, 407–415. [CrossRef]
3. Congressional Research Service. The U.S. Dollar as the World's Dominant Reserve Currency. 2022. Available online: https://crsreports.congress.gov/ (accessed on 1 January 2024).
4. Weiss, C. Geopolitics and the U.S. Dollar's Future as a Reserve Currency. *Int. Financ. Discuss. Pap.* **2022**, *2022*, 1–37. [CrossRef]
5. U.S. Department of Treasury. The Treasury Sanctions Review. 2021. Available online: https://home.treasury.gov/ (accessed on 1 January 2024).
6. Selden, Z. *Economic Sanctions as Instruments of American Foreign Policy*, 1st ed.; Bloomsbury Publishing: London, UK, 1999.
7. U.S. Department of Justice. Office Of Public Affairs. Available online: https://www.justice.gov/opa/speech/deputy-assistant-attorney-general-eun-young-choi-delivers-keynote-remarks-gir-live (accessed on 1 January 2024).
8. Sedrakyan, G.S. Ukraine War-Induced Sanctions against Russia: Consequences on Transition Economies. *J. Policy Model.* **2022**, *44*, 863–885. [CrossRef]
9. Náñez Alonso, S.L.; Jorge-Vazquez, J.; Reier Forradellas, R.F. Detection of Financial Inclusion Vulnerable Rural Areas through an Access to Cash Index: Solutions Based on the Pharmacy Network and a CBDC. Evidence Based on Ávila (Spain). *Sustainability* **2020**, *12*, 7480. [CrossRef]
10. Yang, Q.; Zheng, M.; Wang, Y. The Role of CBDC in Green Finance and Sustainable Development. *Emerg. Mark. Financ. Trade* **2023**, *59*, 4158–4173. [CrossRef]
11. Dong, Z.; Umar, M.; Yousaf, U.B.; Muhammad, S. Determinants of Central Bank Digital Currency Adoption—A Study of 85 Countries. *J. Econ. Policy Reform* **2023**, 1–15. [CrossRef]
12. Cihak, M.; Demirguc-Kunt, A.; Feyen, E.H.B.; Levine, R.E. *Benchmarking Financial Systems Around the World (English)*; World Bank Group: Washington, DC, USA, 2012; Available online: http://documents.worldbank.org/curated/en/868131468326381955/Benchmarking-financial-systems-around-the-world (accessed on 1 January 2024).
13. Mohammed, M.A.; De-Pablos-Heredero, C.; Montes Botella, J.L. Exploring the Factors Affecting Countries' Adoption of Blockchain-Enabled Central Bank Digital Currencies. *Future Internet* **2023**, *15*, 321. [CrossRef]
14. Alfar, A.J.K.; Kumpamool, C.; Nguyen, D.T.K.; Ahmed, R. The Determinants of Issuing Central Bank Digital Currencies. *Res. Int. Bus. Financ.* **2023**, *64*, 101884. [CrossRef]
15. Luu, H.N.; Do, D.D.; Pham, T.; Ho, V.X.; Dinh, Q.-A. Cultural Values and the Adoption of Central Bank Digital Currency. *Appl. Econ. Lett.* **2023**, *30*, 2024–2029. [CrossRef]
16. Ngo, V.M.; Van Nguyen, P.; Nguyen, H.H.; Thi Tram, H.X.; Hoang, L.C. Governance and Monetary Policy Impacts on Public Acceptance of CBDC Adoption. *Res. Int. Bus. Financ.* **2023**, *64*, 101865. [CrossRef]
17. Le, T.D.Q.; Tran, S.H.; Nguyen, D.T.; Ngo, T. The Degrees of Central Bank Digital Currency Adoption across Countries: A Preliminary Analysis. *Econ. Bus. Lett.* **2023**, *12*, 97–104. [CrossRef]
18. Chen, H.; Siklos, P.L. Central Bank Digital Currency: A Review and Some Macro-Financial Implications. *J. Financ. Stab.* **2022**, *60*, 100985. [CrossRef]
19. Tercero-Lucas, D. Central Bank Digital Currencies and Financial Stability in a Modern Monetary System. *J. Financ. Stab.* **2023**, *69*, 101188. [CrossRef]
20. Maryaningsih, N.; Nazara, S.; Kacaribu, F.N.; Juhro, S.M. Central Bank Digital Currency: What Factors Determine Its Adoption? *Bull. Monet. Econ. Bank.* **2022**, *25*, 1–24. [CrossRef]
21. Allen, F.; Gu, X.; Jagtiani, J. Fintech, Cryptocurrencies, and CBDC: Financial Structural Transformation in China. *J. Int. Money Financ.* **2022**, *124*, 102625. [CrossRef]
22. Peksen, D.; Woo, B. Economic Sanctions and the Politics of IMF Lending. *Int. Interact.* **2018**, *44*, 681–708. [CrossRef]
23. Caruso, R. The Impact of International Economic Sanctions on Trade: An Empirical Analysis. *Peace Econ. Peace Sci. Public Policy* **2003**, *9*. [CrossRef]
24. Kaempfer, W.H.; Lowenberg, A.D. *Chapter 27 The Political Economy of Economic Sanctions*; Elsevier: Amsterdam, Netherland, 2007; pp. 867–911. [CrossRef]
25. Beck, T.; Demirgüç-Kunt, A.; Martinez Peria, M.S. Banking Services for Everyone? Barriers to Bank Access and Use around the World. *World Bank Econ. Rev.* **2008**, *22*, 397–430. [CrossRef]
26. Spendzharova, A.B. Banking Union under Construction: The Impact of Foreign Ownership and Domestic Bank Internationalization on European Union Member-States' Regulatory Preferences in Banking Supervision. *Rev. Int. Polit. Econ.* **2014**, *21*, 949–979. [CrossRef]
27. Luu, H.N.; Nguyen, C.P.; Nasir, M.A. Implications of Central Bank Digital Currency for Financial Stability: Evidence from the Global Banking Sector. *J. Int. Financ. Mark. Inst. Money* **2023**, *89*, 101864. [CrossRef]
28. Grennes, T.; Caner, M.; Koehler-Geib, F. *Finding the Tipping Point—When Sovereign Debt Turns Bad*; Policy Research Working Papers; The World Bank: Washington, DC, USA, 2010. [CrossRef]
29. International Monetary Fund. *Building Strong Banks Through Surveillance and Resolution*; International Monetary Fund: Washington, DC, USA, 2002. [CrossRef]

30. Ahmed, J.; Mughal, M.; Martínez-Zarzoso, I. Sending Money Home: Transaction Cost and Remittances to Developing Countries. *World Econ.* **2021**, *44*, 2433–2459. [CrossRef]
31. Bank of England. Central Bank Digital Currency Opportunities, Challenges and Design. 2020. Available online: https://www.bankofengland.co.uk/-/media/boe/files/paper/2020 (accessed on 1 January 2024).
32. International Monetary Fund. Available online: https://www.imf.org/external/datamapper/LP@WEO/OEMDC/ADVEC/WEOWORLD/ARG (accessed on 12 February 2024).
33. Didenko, A.N.; Buckley, R.P. Central Bank Digital Currencies as a Potential Response to Some Particularly Pacific Problems. *Asia Pacific Law Rev.* **2022**, *30*, 44–69. [CrossRef]
34. Kochergin, D.A. Central Banks Digital Currencies: World Experience. *Mirovaia Ekon. I Mezhdunarodnye Otnos.* **2021**, *65*, 68–77. [CrossRef]
35. Jabbar, A.; Geebren, A.; Hussain, Z.; Dani, S.; Ul-Durar, S. Investigating Individual Privacy within CBDC: A Privacy Calculus Perspective. *Res. Int. Bus. Financ.* **2023**, *64*, 101826. [CrossRef]
36. Singh, S.; Gupta, S.; Kaur, S.; Sapra, S.; Kumar, V.; Sharma, M. The Quest for CBDC: Indentifying and Prioritising the Motivations for Launching Central Bank Digital Currencies in Emerging Countries. *Qual. Quant.* **2023**, *57*, 4493–4508. [CrossRef]
37. Wronka, C. Central Bank Digital Currencies (CBDCs) and Their Potential Impact on Traditional Banking and Monetary Policy: An Initial Analysis. *Digit. Financ.* **2023**, *5*, 613–641. [CrossRef]
38. Gawer, A.; Cusumano, M.A. Industry Platforms and Ecosystem Innovation. *J. Prod. Innov. Manag.* **2014**, *31*, 417–433. [CrossRef]
39. Abdul-Muhmin, A.G.; Umar, Y.A. Credit Card Ownership and Usage Behaviour in Saudi Arabia: The Impact of Demographics and Attitudes toward Debt. *J. Financ. Serv. Mark.* **2007**, *12*, 219–234. [CrossRef]
40. Gan, L.L.; Maysami, R.C.; Chye Koh, H. Singapore Credit Cardholders: Ownership, Usage Patterns, and Perceptions. *J. Serv. Mark.* **2008**, *22*, 267–279. [CrossRef]
41. Harrell, F.E. *Regression Modeling Strategies*; Springer Series in Statistics; Springer International Publishing: Cham, Switzerland, 2015. [CrossRef]
42. CBDC Tracker. Available online: https://cbdctracker.org/timeline (accessed on 15 June 2023).
43. Atlantic Council. Available online: https://www.atlanticcouncil.org/cbdctracker/ (accessed on 17 January 2024).
44. Xu, J. Developments and Implications of Central Bank Digital Currency: The Case of China E-CNY. *Asian Econ. Policy Rev.* **2022**, *17*, 235–250. [CrossRef]
45. Crozet, M.; Hinz, J. Friendly Fire: The Trade Impact of the Russia Sanctions and Counter-Sanctions. *Econ. Policy* **2020**, *35*, 97–146. [CrossRef]
46. EU Sanctions Map. Available online: https://www.sanctionsmap.eu/ (accessed on 17 January 2024).
47. Gloria, E.V. Justifying Economic Coercion: The Discourse of Victimhood in China's Unilateral Sanctions Policy. *Pac. Rev.* **2023**, *36*, 521–551. [CrossRef]
48. Guo, L.; Wang, S.; Xu, N.Z. US Economic and Trade Sanctions against China: A Loss-Loss Confrontation. *Econ. Polit. Stud.* **2023**, *11*, 17–44. [CrossRef]
49. Cohen, B.J. The Yuan Tomorrow? Evaluating China's Currency Internationalisation Strategy. *New Polit. Econ.* **2012**, *17*, 361–371. [CrossRef]
50. Wang, H. How to Understand China's Approach to Central Bank Digital Currency? *Comput. Law Secur. Rev.* **2023**, *50*, 105788. [CrossRef]
51. Wenker, K. Retail Central Bank Digital Currencies (CBDC), Disintermediation and Financial Privacy: The Case of the Bahamian Sand Dollar. *FinTech* **2022**, *1*, 345–361. [CrossRef]
52. Alonso, S.L.N. Can Central Bank Digital Currencies Be Green and Sustainable? *Green Financ.* **2023**, *5*, 603–623. [CrossRef]
53. Banerjee, S.; Sinha, M. Promoting Financial Inclusion through Central Bank Digital Currency: An Evaluation of Payment System Viability in India. *Australas. Account. Bus. Financ. J.* **2023**, *17*, 176–204. [CrossRef]
54. Esoimeme, E. A Critical Analysis of the Effects of the Central Bank of Nigeria's Digital Currency Named ENaira on Financial Inclusion and AML/CFT Measures. *SSRN Electron. J.* **2021**. [CrossRef]
55. Ahiabenu, K. A Comparative Study of the Design Frameworks of the Ghanaian and Nigerian Central Banks' Digital Currencies (CBDC). *FinTech* **2022**, *1*, 235–249. [CrossRef]
56. Sanchez-Roger, M.; Puyol-Antón, E. Digital Bank Runs: A Deep Neural Network Approach. *Sustainability* **2021**, *13*, 1513. [CrossRef]
57. Claessens, S.; Van Horen, N. Foreign banks: Trends and impact. *J. Money Credit. Bank.* **2014**, *46*, 295–326. [CrossRef]
58. Claessens, S.; Van Horen, N. The impact of the global financial crisis on banking globalization. *IMF Econ. Rev.* **2015**, *63*, 868–918. [CrossRef]

FinTech

Review

Transforming Financial Systems: The Role of Time Banking in Promoting Community Collaboration and Equitable Wealth Distribution

Otilia Manta [1,2,*] and Maria Palazzo [3]

1 Centre for Financial and Monetary Research "Victor Slăvescu", Romanian Academy, 050711 Bucharest, Romania
2 Research Department, Romanian American University, 012101 Bucharest, Romania
3 Department of Law and Economics, Universitas Mercatorum, 00186 Rome, Italy; maria.palazzo@unimercatorum.it
* Correspondence: otilia.manta@rgic.ro

Abstract: The existing global multi-crises have generated significant transformations in the architecture of financial systems, impacting local communities. Furthermore, the digital era has created a conducive environment for the development of financial innovations that can generate financial instruments supporting financial inclusion. Our research aims to identify and develop innovative financial instruments that foster closer collaboration within communities and promote a more equitable distribution of wealth and resources, directly impacting financial inclusion and well-being. The methodology used in our study is based on existing empirical research in the specialized scientific literature, as well as on identifying variables within existing models. Additionally, the use of bibliometric analyses and research tools based on artificial intelligence allows us to structure the innovative financial instruments found in the scientific databases. Building on the existence of innovative financial instruments, our paper specifically explores the concept of time banking as an innovative financial instrument, offering a new approach to economic exchange and the construction of financial mechanisms at the local community level. By using technology, especially in digital and ecological eras, time banks can be efficiently managed through online platforms where individuals can register their contributed hours and access the services they need. This study's conclusions emphasize that time banks have the potential to serve as innovative financial instruments. Furthermore, through the analysis conducted in this study and the identified models, this study contributes to redefining the concept of time banking as an innovative financial instrument. Time banks focus on the productivity and efficiency of local community activities, with direct implications for reducing dependence on traditional currency and promoting an equitable distribution of labor. This innovative approach is promising, especially in an increasingly digitized financial landscape. Our paper seeks to capture this transformative potential and highlight our personal contributions to redefining the time bank as an innovative financial instrument.

Keywords: time banks; financial instruments; collaborative economy; sustainability; community

JEL Classification: G29; G23; P49; Q56; J29

Citation: Manta, O.; Palazzo, M. Transforming Financial Systems: The Role of Time Banking in Promoting Community Collaboration and Equitable Wealth Distribution. *FinTech* **2024**, *3*, 407–423. https://doi.org/10.3390/fintech3030022

Academic Editor: David Roubaud

Received: 27 June 2024
Revised: 6 August 2024
Accepted: 19 August 2024
Published: 22 August 2024

1. Introduction

Time banks (TBs) represent a dynamic concept in the realm of financial systems, shaped by diverse socio-economic phenomena and challenges that continually redefine their scope and significance. Unlike conventional financial systems, TBs are characterized by fundamental principles of equity, equality, and reciprocity among their members, reflecting a multidisciplinary approach to addressing societal needs. Exploration of the scientific literature underscores the complementary nature of TBs alongside traditional financial systems, emerging as responsive mechanisms to societal demands and challenges impacting financial structures. This study aims to elucidate various global models of TBs, offering detailed insights into their defining characteristics and their profound significance in meeting societal needs. Viewed as supportive and complementary financial instruments, TBs embody values such as accessibility, tolerance, and transparency, making them adaptable to local contexts. Moreover, this research endeavors to define the financial instrument of "Time Bank", contributing to the ongoing innovation dynamics within the financial system, particularly geared towards fulfilling the diverse needs of local communities. Leveraging technology as metasystems based on knowledge and Systems Theory, time banks are poised to enhance financial processes, facilitating efficient management through online platforms for logging hours worked and accessing services, thereby fostering collaboration and knowledge sharing within communities. Despite the inherent challenges such as valuing services and ensuring fair participation, time banks represent a creative approach to economic exchange and community building. As innovative financial instruments, they allow for the exchange of value outside traditional monetary systems. To elucidate their potential, this paper proposes identifying and exploring several scientific considerations within the specialized literature regarding time banks and their impact and potential, as well as participation in time banks, offering individuals the opportunity to meet needs without monetary dependency or debt, thus adding a social dimension to the economic landscape. Time banks have a rich conceptual history, originating in the United States and expanding globally. While their exact count remains elusive due to their adaptable nature, TBs are considered complementary currencies, operating parallel to mainstream monetary economies. They facilitate exchanges based on time units, offering a platform for individuals to exchange skills and services.

The concept of TBs is multidisciplinary, with educational and social responsibility aspects intertwined. The incentivization of community engagement and problem solving within TBs reflects principles articulated by renowned economists such as Mill J.S. and underpins the coproduction principle outlined by Edgar S. Cahn.

TBs are characterized by their adaptability to various cultural environments and regional realities, reflecting their chameleonic nature. Despite challenges in identification and quantification, TBs play a crucial role in fostering community collaboration and social capital development.

The bookkeeping aspect of TBs extends beyond recording exchanges to include contributions to community building and problem solving, simplifying monitoring and evaluation processes. This multidimensional approach underscores the complex yet impactful nature of TBs in reshaping economic and social paradigms.

As we delve deeper into this study, we find that the accounting aspect of time banks (TBs) goes beyond simply keeping transactional records. It includes vital contributions to community growth and problem solving, streamlining monitoring and evaluation procedures. Through our personal contribution to this research, we aim to enrich the scientific literature by shedding light on the multifaceted and interdisciplinary nature of TBs. By highlighting the complex yet powerful impact of TBs on economic and social paradigms, we hope to provide valuable insights derived from the bibliometric analysis identified and presented in this study.

Literature Review

Time banks have a rich conceptual history, characterized by their ability to leverage individuals' skills and professional qualities, which operate outside the regulatory frameworks of the traditional job market. Originating in the United States, this concept has expanded globally, with some sources [1] suggesting the world's first time banks (TBs) began in Japan in the 1970s, initiated by Teruko Mizushima. Nevertheless, their global recognition only ensued nearly a decade later, coinciding with the introduction of a Time Dollar in the United States [2]. TBs, at their core, use time units as currency [3]. Functioning as a service-oriented initiative, time banks establish foundational principles applicable to various economic activities, facilitating interaction with other endeavors in related sectors [4].

The prevalence of the social or trade aspect in a TB system is determined by its adaptation to the current needs of a community in a particular environment. TBs face challenges and adapt to various cultural environments, often reflecting regional realities to tackle local and regional issues [5,6].

The global count of TBs is in constant flux, making it challenging to determine their exact number [7,8]. TBs are considered "chameleonic" and challenging to identify, not only in terms of their quantity but also the number of participants [9,10]. Considered a complementary economic system, TBs are described as existing parallel to a mainstream monetary economy and are identified as complementary currency due to their use of time. Participants typically join for non-financial reasons [10]. One study [11] defines the time bank as a complex system that measures the effort expended by people to carry out their activities, in which effort is repaid through informal support when they need support, with time thus being a kind of "money" reward. At the same time, another author [12] defines the time bank concept as a "community model", and, based on it, exchanges are generated at the community level, as happened in the USA in the 1980s and in Great Britain during the end of the 1990s.

Returning to the idea of currency as an information system [13], TB bookkeeping goes beyond recording exchanges, detailing contributions to community building, social capital, and problem solving [14]. This feature adds value by simplifying the monitoring and evaluation of all exchanges [15]. Identification of a TB previously relied on core values and adherence to the coproduction principle outlined by Edgar S. Cahn in the 1980s [16]. Co-production involves individuals taking responsibility for solving problems, a principle found in various fields, including knowledge management and open-source software development [17,18]. In the context of time banks (TBs), a crucial aspect lies in the incentive provided to community members for engagement and participation, a concept articulated by the renowned economist Mill J.S. in his works [19]. Its implication in global institutions, such as The International Labor Organization (ILO) (2022), presents mechanisms and support solutions for the development of small businesses, including the diversification of financing tools and risk reduction, where such a mechanism could be a time bank. The association between business performance, the use of bank loans [20] and the orientation of the business environment towards new innovative financing instruments based on technology represents a new challenge in the reconfiguration of financial instruments. Moreover, this orientation of financial innovations towards technology (fintech) improves offerings for small entrepreneurs [21]. However, it also poses challenges from the regulatory perspective for authorities and regulators, aspects that are also pertinent for time banks. Along with the scientific literature related to time banks, it is important to emphasize the multidisciplinary character of this concept, in which education has an essential role, both upstream and downstream [22]. Global social responsibility means a reorientation of business activities [23], inclusive at the level of specific time bank activities.

In the scientific literature, there are numerous valuable works [24], which highlight that in recent years we have witnessed simultaneous processes of monetary innovation—the digitalization of money and the proliferation of social currencies. These trends have combined to give rise to digital social currencies [24], which are appreciated as potentially relevant to the time bank model. Furthermore, ref. [24] evaluates both the advantages and disadvantages of the complete digitalization of social currencies. Although new technologies and digitalization offer significant benefits, such as increased reach and efficiency of social currencies [25], they are accompanied by important challenges, including the exclusion of users with limited digital skills. The study [24] utilized multilevel logistic models and data from the Global Findex survey to identify segments of the population less likely to use digital payment methods, aiming to improve financial and digital inclusion globally.

A relevant example of a time bank is the Barakaldo Time Bank [26], as an alternative for organizing and functioning within the community, while the time bank model [27] is that of an online time bank. In [28], the author explores the concept of the "time bank" as a strategy for mutual aid within communities. Additionally, ref. [28] analyzes how time banks facilitate the exchange of services and resources among members without involving traditional financial transactions and indicates how these initiatives contribute to strengthening community ties and mutual support, highlighting the advantages and challenges faced in implementing and operating these systems and promoting a solidarity-based economy and stronger social cohesion [29].

2. Materials and Methods

In the framework of the research methodology, classic tools specific to empirical studies were used, based primarily on the scientific literature on time banks (TBs). Furthermore, in our study, structuring working hypotheses helps us to use appropriate research tools such as bibliometric analyzes that allow us to quickly identify time bank patterns that respond to our structured hypotheses. Moreover, a primary methodological tool for understanding soft systems was defined by Checkland P., known as a "Soft System" [30]. To understand why, from a methodological point of view, a system is considered soft rather than hard, the distinguishing characteristics of each type of system have been highlighted. It is observed that hard systems are easier to instrument, and authors such as Skyttner [31] argue that these hard systems are easier to manage compared to soft systems and are characterized by a more general definition from a human perspective, proving more difficult to analyze and interpret, according to Checkland [32]. These distinctive elements suggest the current situation where certain economies are defined as "soft power" economies.

In our research methodology, we adopted classic tools commonly used in empirical studies, primarily drawing from the scientific literature on time banks (TBs). Structuring working hypotheses guided our selection of appropriate research tools, such as bibliometric analysis, to swiftly identify patterns within time banks that align with our structured hypotheses.

A key methodological tool we employed to understand soft systems was Checkland P.'s "Soft System" methodology. This approach helped us grasp why certain systems are categorized as soft rather than hard, highlighting the distinguishing characteristics of each. Unlike hard systems, which are perceived as easier to instrument and manage, soft systems pose greater challenges due to their broader definition and the complexity introduced by human factors.

For the methodological analysis of time banks, we examined the variables defining the causal relationships between various factors and TBs, as identified in the specialized scientific literature. Among the most prevalent methodological tools encountered in our study were Causal Loop Diagrams (CLDs), popularized by Sterman [33]. CLDs proved effective in capturing the polarity of reactions within time banks, shaping community behavior within the integrated system.

The Soft System Methodology (SSM) emerged as the most suitable approach for analysing TBs, given their classification as "soft systems" by Checkland. Details on diagram notation, essential for understanding CLDs, were gleaned from works such as Sterman's. Moreover, CLDs could be further developed into quantitative modeling tools, facilitating the transformation of qualitative models into quantitative ones.

By applying intuitive elements derived from our working hypotheses and adhering to established methodologies, we discerned that the innovative characteristics of a time bank are contingent upon the community's abilities and characteristics. This nuanced perspective, reflected in our study's results, serves as a response to our working hypotheses and underscores the unique soft qualities inherent in time banks.

3. Results

3.1. Analysis/Result Interpretation

The key outcome of the time bank (TB) analysis is a set of systemic features believed to be inherent to any TB to some extent. In the reference study [17] of our work, characteristics of time banks are highlighted that work together as an element of justification for the established hypotheses and are inter-connected, as illustrated in the Causal Loop Diagram in Figure 1, demonstrating the influence of systemic characteristics on each other [17]. For example, characteristics such as adaptability and equality in the case of time banks are excluded from Table 1.

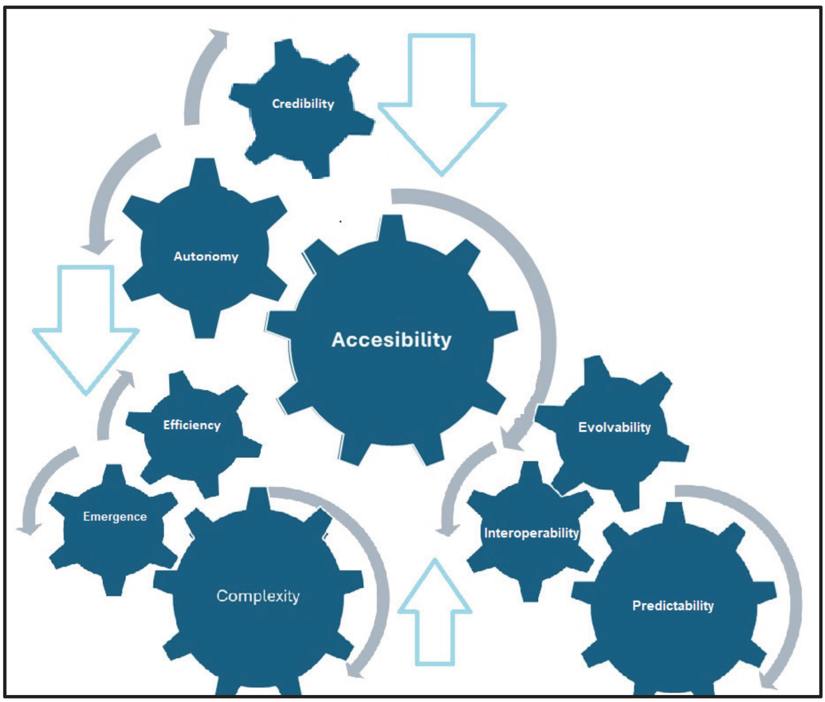

Figure 1. Presentation of time bank features integrated and based on variables adapted to challenges.

Accessibility: TBs are open to anyone, fostering inclusivity by welcoming diverse individuals with various offers, backgrounds, and limitations. This diversity is crucial to maintaining a dynamic and vibrant TB system.

Adaptability: TBs consider legal, cultural, language, and social factors [5].

Affordability: While some TBs may require a symbolic fee, most are free, ensuring affordability. This fee, if present, is not a significant barrier to participation.

Autonomy: Although TBs operate under a "Base Organization", the co-production imperative ensures that TB objectives align with societal problem solving [17].

Credibility: The existence of any TB relies on mutual trust, with credibility determining the success and longevity of the system. Failure in certain contexts can make restarting time banking challenging [34].

Customizability: This technical term, akin to adaptability, encompasses digital solutions for platforms.

Complexity: While inherently complex due to human connections, TBs can be analyzed by identifying separate system entities, facilitating specific interactions.

Efficiency: Within TBs, the optimization of time and resources in work processes is guaranteed [17].

Emergence: TBs bring like-minded individuals together to create initiatives that might not occur outside of the TB framework.

Equality: Fundamental to TBs, exchanges occur on a 1:1 basis, ensuring equality in all offers and requests. This principle is inherent to the TB concept.

Table 1. Features and their mutual links.

Equality	Efficiency (+): The more efficient the TB is, the easier it is to adopt it and the less it costs.
Accessibility	Autonomy (+): The more autonomous a TB becomes, the fewer external resources it needs; thus, it becomes more affordable.
Autonomy	Equality (+): Equality is one of main features of a TB, and because of it, the exchanges within TB are always 1:1. This simple rule ensures autonomous operation.
Credibility	Transparency (+): Credibility in this model is influenced only by transparency. The TB must continuously demonstrate that it is fair and that exchanges are safe and beneficial for everyone. Total transparency is a must to keep the credibility of any TB.
Complexity	Modularity (+): The more parts a TB is composed of (more modules), the more complex it becomes. Universality (+): The fact that the TB concept is universal gives it potential for high complexity. Autonomy (−): The more autonomous a TB becomes, the less complex it becomes.
Efficiency	Universality (+): By being universal, a TB can cover many topics and fields, which makes it more efficient in solving societal problems. Complexity (+): By being more complex, a TB loses its flexibility in solving the same problems and is thus less efficient.
Emergence	Efficiency (+): The more autonomous a TB becomes, the fewer resources it needs. This makes it more efficient in the input-to-output ratio. When a TB is efficient, it easily transforms inputs to outputs and covers the necessary tools to solve actual societal problems; this allows members to produce not only further "products" outside of the TB framework but also new "modules" within. Sustainability (+): Only if a TB is apparently sustainable (has a successful history and has an apparent future) is it able to produce other "spin-off products".
Evolvability	Tailorability (+): A TB can evolve based on being tailored to specific conditions. New approaches to TBs are evolving from needs specific to the TB system. Interoperability Universality (+): By being universal, the TB concept allows for interconnection and the mutual operation of individual TBs.
Modularity	Emergence (+): By taking an active role in societal problem solving, members develop new parts or modules of an individual TB. So, with increasing emergence, more modules are created internally (now abstracting from emergence outside of the TB system).
Predictability	Equality (+): A clear concept of equality increases the predictability of the TB system. Complexity (−): The more complex a TB becomes, the less predictable it will be. More people in a soft system means higher entropy. Accessibility (−): Similar to the point above, accessibility allows more people in. With more people involved, predictability is lowered.
Sustainability	Evolvability (+): The higher the ability of a TB to evolve and follow particular needs of stakeholders, the more sustainable it is. Credibility (+): Without credibility, there is no future for a TB. So, higher credibility gives a TB more chances to sustainably exist. Affordability (+): The higher the affordability, the more members will become involved, and for a sustainable TB, it is key to have a variable and active member base.
Tailorability	Customizability (+): The more a TB can be customized, the more it can be tailored to specific conditions. Adaptability (+): The more a TB adapts to certain conditions, the more it can be tailored to them as well.
Transparency	Equality (+): The main concept of equality makes the TB transparent. Predictability (+): The fact that it is predictable makes a TB transparent. The more predictable it is, the more it will be perceived as transparent.
Universality	Tailorability (+): The fact that the TB can be tailored to many conditions makes it universal.

Source: personal processing according to Table 1. Features and their mutual links [17].

Evolvability: From its origins and by advocating and endorsing policies from one individual to another, the development of time banks has taken diverse forms, shaped by the specific characteristics of its members. This has resulted in the emergence of the most innovative models that are individual-oriented yet possess organizational significance [17].

Interoperability: TBs share the same internal makeup, enabling them to be interconnected into networks.

Modularity: Certain parts of a TB can be added as needed, allowing for flexibility in the system's structure. For example, a coordinator, although recommended, is not mandatory for a TB's existence.

Predictability: Operating on a TB system can introduce fluidity, albeit influenced by human behavior.

Sustainability: Meeting basic requirements, including funding and external inputs, ensures a TB's sustainability as a system [17].

Tailorability: TBs meet the requirements of established organizations while also catering to the individual needs of the TB's community members, ensuring the optimal stimulation of all activities conducted by citizens.

Transparency: TBs establish explicit and transparent guidelines for all participants in a TB; clear regulations and the presence of a coordinator enhance the transparency of the TB system.

Universality: TBs can be universally applied as a result of their adaptability, customizability, and tailorability features.

Simulation components, following the mentioned methodology, specifically the Causal Loop Diagram (CLD), enables the modeling of time banks based on qualitative organization variables, as well as their quantitative modeling and orientation towards an innovative definition of the type of time bank. This process is illustrated in Figure 2 below.

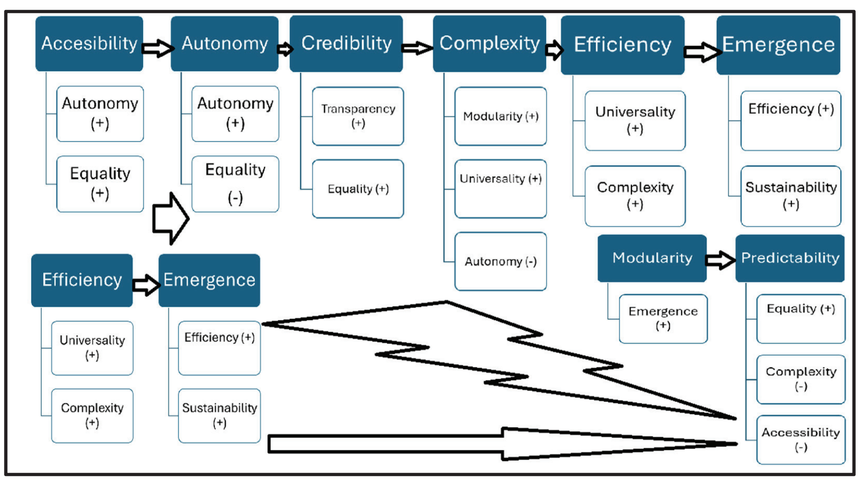

Figure 2. Presentation of the TB operating system diagram based on the identified factors. Source: own processing.

The examination of members' behavior within the metasystem is meticulously scrutinized and presented through the specialized methodology of TBs [17]. The inference drawn from employing this model is that, at the level of time banks, an increase in the number of active members leads to a more intricate system due to the distinct needs of everyone, making accessibility more challenging and rendering the credibility of the TB system vulnerable or diminishing. By following this diagram, both the positive aspects of TBs and their vulnerabilities or negative elements can be emphasized. In the modeling process (Figure 2), factors related to accessibility and innovation, which may be inversely proportional to control elements and transparency, are distinctly highlighted.

As previously mentioned, the intricacy of the system within time banks (TBs) is a noteworthy attribute, particularly considering how the TB metasystem is tailored to individual needs. This often constrains the development of TB due to the resulting complexity, which introduces certain risks and vulnerabilities. However, as evident in the structure of a TB's specific characteristics, complexity is intrinsic, playing a role in enabling the TB to fulfill its intended purpose (Figure 3).

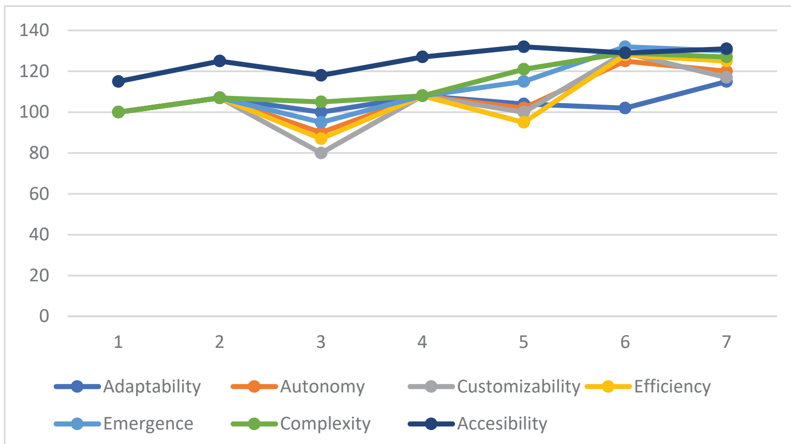

Figure 3. Evolution of the main factors of the TB model. Source: own processing.

The identified outcomes shed light on multiple aspects, emphasizing that the more intricate a TB becomes, the greater the challenges in terms of predictability and transparency (Figure 4). In a balanced scenario, the metasystems of TBs are highlighted as having network-type connections, fostering a balanced development aligned with the specific needs of communities of individuals who are direct beneficiaries of TBs.

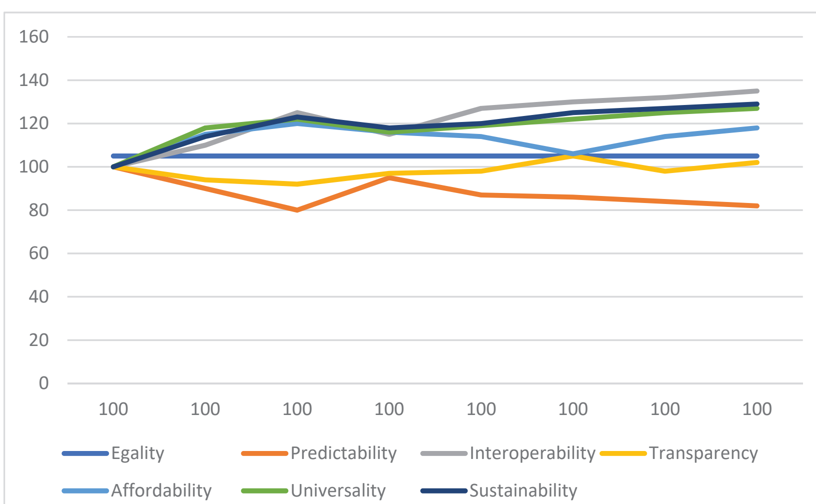

Figure 4. Representation of the TB model related to sustainability. Source: own processing.

3.2. Setting Focused on Sustainability

Sustainability is a fundamental attribute within the time bank (TB) system. However, in the context of the specific TB model, sustainability does not exhibit significant oscillations or fluctuations; instead, it remains consistently stable. This stability is influenced by the fact that sustainability at the TB system level is an intrinsic characteristic that cannot be directly influenced. Rather, it results from multiple interactions among various characteristics. The sustainability of a TB metasystem is achieved through a continual and balanced equilibrium among the other specific characteristics inherent to a TB. Maintaining the sustainability of a TB requires a delicate balance among the various other features.

Based on the variables identified within the Valek, L. and Bures, V model that were highlighted above, we can say that the first hypothesis is confirmed; that is, it is based on variables such as accessibility, adaptability, personalization, and efficiency, which enables time bank participants to diversify the way they invest their time and skills, replacing or supplementing traditional money transactions.

Hypothesis no. 2 is supported by variables such as accessibility (a symbolic fee), through which time banks allow for access to resources without using money, and evolvability, the appearance of the most innovative models that are oriented towards the individual but have organizational significance. Moreover, through the variable universality, we appreciate that the hypothesis is confirmed; used in communities where access to money is limited, the time bank can be applied universally, deriving from its characteristics of adaptability, customization, and adaptability.

Regarding hypothesis 3 being established, this is supported by the variables credibility (the existence of any TB is based on mutual trust, credibility, determining the success and longevity of the system regarding the encouragement of community collaboration through time banks, such as the promotion of community collaboration and solidarity), equality (fundamental for a TB, exchanges take place on a 1:1 basis, ensuring equality in all offers and requests), and, last but not least, accessibility (TB is open to anyone, promoting inclusion by welcoming diverse people with different offers, backgrounds, and limitations. This diversity is crucial to maintaining a dynamic and vibrant TB system). All these variables support the hypothesis of the fundamental role of time banks through which people can come together to help each other and create an economic system based on more personal and trusting relationships.

Hypothesis 4 brings together variables such as adaptability (TBs taking into account legal, cultural, linguistic, and social factors), customization (digital solutions for platforms), efficiency (the optimization of time and resources in work processes within TBs), and, ultimately in turn, the variable transparency (establishing explicit and transparent guidelines for all TB participants, clear regulations, and the presence of a coordinator, thus increasing the transparency of the TB system) and the variable universality (TBs can be applied universally, deriving from its characteristics of adaptability, customization, and adaptability). All of these variables that are specific to hypothesis 4 contribute to the definition of this innovative financial instrument, which can evaluate time as a form of value; time banks thus emphasize the importance of contributing to the community. Moreover, through these financial instruments, a special contribution can be made to the process of different evaluations of work and services and in the elimination of different discrepancies between remunerations for the same activities performed.

Reducing money dependence is a specific component of hypothesis 5, and among variables that are related and support this working hypothesis, we mention the following: complexity (the identification of separate entities of the system, facilitating specific interactions), efficiency (the optimization of time and resources in the work processes within TBs), adaptability (meeting the requirements of established organizations while also responding to the individual needs of TB community members, ensuring the optimal stimulation of all citizen activities), transparency (establishing explicit and transparent guidelines for all TB participants, clear regulations, and the presence of a coordinator, which increase the transparency of the TB system), and universality (TB can be applied universally). These variables support the working hypothesis that time banks give people the opportunity to obtain what they need without needing money or falling into debt.

Moreover, to have a clear picture of the existing time banks (at the beginning of the road, from the point of view of financial innovation), in addition to the key variables that define them, it is important to highlight how these time banks are structured depending on the main exchanges made at the level of a time bank. In what follows, we will try to capture some of these defining elements.

3.3. What's Happening to TimeBanks.org?

In the pursuit of societal well-being, the time bank model has been deemed a potential contributor to the welfare of individuals within specific communities, sectors of activity, and various social or professional groups to which individuals belong. The primary advantage of time banks lies in their optimization of resources, encompassing financial, human, material, and informational resources. While this conceptualization of time banks has been a prevailing constraint, recent developments indicate notable outcomes, especially in the context of multiple crises and contemporary challenges. The results achieved in the recent period merit thorough analysis by the authorities responsible for managing community assets.

Time banking transcends mere group participation, evolving into a distinctive method of community building founded on trust, where members rely on mutual support. Functioning as a mechanism for giving and receiving, time banking fosters the establishment of robust support networks, where one hour of assistance earns an individual one credit.

This approach encourages a return to values surpassing monetary considerations, prioritizing aspects like family, social justice, and the preservation of democratic processes. As participants in a time bank, individuals, groups, or organizations accumulate time credits by fulfilling requests for assistance from others, which can later be redeemed for the support they require.

Whether the exchange involves yard work, medical care, transportation, minor home repairs, computer support, grocery pickup, or meal preparation, all contributions are regarded as equally valuable, measured solely by the time invested in providing them. Offering an hour of service equates to receiving a single credit—a one-to-one exchange where no monetary transactions occur; only time is exchanged.

Time bank members have the autonomy to choose the services they wish to offer or request, ensuring a straightforward and egalitarian process. These exchanges maintain equality, with their value determined solely by the time invested in the activity.

3.4. There Are Four Primary Types of Time Bank Exchanges

One-to-One Exchange: Involves a trade between two individuals. For instance, Artika reads a story, earning time credits, which she subsequently redeems for Daiki's guitar lessons.

One-to-Many Exchange: Occurs when one person helps multiple individuals. For example, Jose earns credit by planting a small garden, benefiting several members of the community.

Many-to-One Exchange: Involves multiple community members collaborating to assist one individual, such as collectively cleaning a community member's home for the holiday season.

Many-to-Many Exchange: Encompasses a scenario where numerous individuals collaborate to assist various others, such as a community group planning, organizing, and executing an annual carnival for the enjoyment of all.

All time banks comprise members who agree to exchange services. Individuals, groups, organizations, agencies, churches, and businesses can all be members of a time bank. Members must apply to join the time bank. Local time bank access gives members the opportunity to exchange their time credits on its global platform.

Edgar's Five Values for Successful Time Banking.

Asset: Recognizes the inherent value everyone possesses to share with others.

Redefining Work: Recognizes types of labor that may not be easily remunerated with currency—significant contributions.

Reciprocity: Shifts the focus from "How can I help you?" to "Will you help some-one, too?" Encourages a culture of paying it forward, fostering collective efforts to build a shared world.

Community/Social Networking: Highlights the importance of building communities through mutual support, strength, and trust. Emphasizes community development by establishing roots, building trust, and creating networks through collaborative efforts.

Respect: Identifies respect as the heart and soul of democracy. Advocates for acknowledging and appreciating individuals for their current state, not just hopeful future aspirations. Contrasting the global market's tendencies, Edgar champions an economy rewarding decency, care, civic participation, and continuous learning.

Edgar's concept is straightforward: one hour equals one credit, valuing every hour, human being, and contribution equally. This forms Edgar's legacy, and TimeBanks.org is dedicated to honoring and building upon it.

Time banks vary in size, with some supporting only a few members and others spanning thousands. Smaller time banks may face challenges with funding and re-sources, and TimeBanks.Org provides support through educational programs, connections with like-minded time bankers, and software to assist in community building.

Time banks can range from local groups to large organizations, managed by single or multiple coordinators. The structure and focus of a time bank are shaped by the choices of its founders, emphasizing the vital role played by the individuals who drive them forward.

In the words of Margaret Mead, "Timebanks vary from place to place and mission to mission". Starting a time bank is akin to embarking on a great journey, requiring planning, preparation, and commitment. Leadership and funding are essential ingredients for most time banks, and considerations for preferred leadership approaches and support plans are crucial.

Leadership structures in time banks vary, with some led by a single coordinator, others sharing this role, and some relying on members to actively manage exchanges. Funding models differ, with coordinators earning time credits for their invested hours or, if funds are available, receiving part-time payment. Funding may come from member donations, fundraisers, sponsorships, or partnerships with organizations that share a common mission.

For those contemplating starting a new time bank, "Gathering with a Purpose" offers an action-based workshop to explore time banking before making a commitment. Guides and materials are provided for free download, facilitating an understanding of time banking principles through hands-on experience.

3.5. Time Banking Worldwide

Time Banking in Great Britain

In 1998, time banking was established in England, specifically in Stroud. Subsequently, in 2002, Simon M. founded a time bank identified by the acronym TBUK, drawing inspiration from the flourishing time banking movement in the United States. Functioning as a charitable organization and membership entity, TBUK offers guidance, resources, software, and training for those interested in initiating a community time bank, enhancing existing ones, or deepening their understanding of time banking principles.

TBUK not only serves as a support system for time banks but also actively advocates for time banking at governmental and policy levels in the UK. The organization encourages the adoption of an asset-based approach by supporting entities in incorporating this philosophy into their practices. As of March 2021, TBUK members had collectively exchanged nearly six million hours.

In 2013, Time Republik introduced the Global Time Bank, marking a significant advancement by removing the geographical restrictions that were prevalent in earlier time banks.

Since 2015, Time Republik has played a pivotal role in advocating for time banking within companies, local administrations, municipalities, universities, and major corporations.

As emphasized throughout this study, time banks contribute to social well-being through their conceptual definition. Among the numerous works in the specialized scientific literature, we underscore the contributions of authors who provide valuable insights and knowledge [35].

We appreciate the innovative time bank financial instrument as being able to combine, on the one hand, the specific elements of the traditional time bank concept combined with the specific instruments of platform-type digital financial technologies, as can be seen in the figure below (Figure 5).

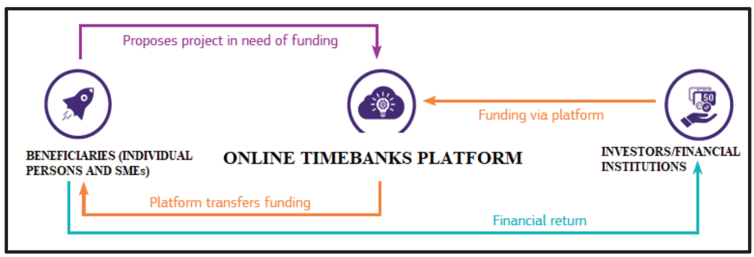

Figure 5. Time bank—innovative financial instrument. Source: own processing based on "Creating a more competitive and innovative financial market", #FinTechEU.

A time bank is an innovative financing opportunity for citizens and small businesses, including start-ups. Especially in the context of the digital era, this innovative financing tool allows individuals and small companies to identify financial resources for their projects with societal impact that need financing by connecting them with investors/financial institutions through an online platform. Investors/financial institutions, in return, receive profits/interest for their investment/placement.

The time bank model, as an innovative financial instrument, can be defined as an efficient tool for the graphical representation of resources, activities, and time within a project, organization, or at the local community level. Moreover, through this model, available resources, activities, and time can be managed, facilitating efficient planning and allocation, thereby contributing to local well-being.

A graphical representation of the time bank model can be seen in Figure 6 below:

Figure 6. Graphical representation of the time bank model. Source: own processing.

The graphical representation (Figure 6) of the time bank model was based on three beneficiaries of the time bank model directly involved in carrying out three activities performed within allocated time intervals of 1 h, 2 h, and 3 h (See Table 2 for details).

Table 2. Building the time bank model matrix.

			Hours	
Person A	Activity 1	1	2	3
Person B	Activity 1	2	3	1
Person C	Activity 1	3	2	1
Person A	Activity 2	1	2	3
Person B	Activity 2	2	3	1
Person C	Activity 2	3	2	1
Person A	Activity 3	1	2	3
Person B	Activity 3	2	3	1
Person C	Activity 3	3	2	1

Source: own processing.

The time bank model proves to be an innovative and efficient financial tool for the graphical representation of resources, activities, and time, whether within a project, organization, or at the local community level. The use of this model allows for optimal management of available resources and time, thereby facilitating more efficient planning and allocation. These benefits directly contribute to the enhancement of local well-being. Figure 6 illustrates the graphical representation of the time bank model, based on the activities of three individuals involved in carrying out three distinct activities, each conducted within time intervals of 1, 2, and 3 h. This visual representation clearly highlights how resources and time can be managed to maximize efficiency and outcomes.

3.6. Discussion on Banking Industry

Innovative financial instruments are often sources of financial risks, which makes their specific regulation necessary, like that applicable to banking institutions. A relevant example is the study conducted by [36], which examines the impact and effectiveness of liquidity risk support in financial institutions in the Middle East and North Africa (MENA) region. The authors analyze an extensive set of financial and economic data and evaluate the measures implemented by banks in this region to manage and mitigate liquidity risks. They also explore the role of financial regulations and liquidity management strategies, highlighting both their successes and limitations within the specific economic context of the MENA region. The results suggest that, although significant measures have been implemented, major challenges remain in ensuring adequate support for liquidity risks, with important implications for financial stability and future economic policies. This research leads us to assert that, in the context of innovative financial instruments such as time banking, regulation is essential. Additionally, we believe that the indicators identified in the specialized scientific literature can serve as a useful starting point for both our study and future research in the field. Time banks are appreciated as innovative financial instruments for local communities; however, how these specific instruments will be financially supported is very relevant. A relevant study that analyzes the impact of capital empowerment on the lending competence of financial institutions, using a segmental analysis to provide detailed insights, is the one by [37]. This study evaluates how variations in capital levels influence the financing capabilities and performance of these institutions across different market segments. The analysis employs advanced econometric techniques to assess the relationship between capital endowment and financing practices, considering various contextual factors that may affect this dynamic; these techniques could be relevant for defining the specific model of time banks. Furthermore, the study by [37] highlights the importance of capital adequacy in enhancing the ability of financial institutions to extend credit effectively, with implications for regulatory policies and financing strategies aimed at supporting financial stability and economic growth. However, it is important to emphasize the unique aspect of this innovative financial instrument, time banks, given that "time" represents the evaluated financial resource that contributes to the sustainable development of local communities, as highlighted throughout our study.

4. Conclusions

This paper possesses practical application potential by providing a structured overview that can assist both theorists and practitioners in understanding the dynamics propelling the various forces within time banks (TBs). A collaborative economy and time banks share commonalities, offering avenues for effective collaboration to sustainably exchange resources, services, and knowledge within communities [38]. Key areas of complementarity include the following.

By correlating the variables identified with those specific to the model that are identified as most relevant, which define and are related to time banks, key areas of complementarity and specificity in the time bank model and in the collaborative economy model can be noted, listed as follows:

Resource sharing: both the collaborative economy and time banks center around the concept of sharing resources and services. While the sharing economy utilizes online platforms for exchanges, strategic planning of management, and innovations [39], time banks introduce a temporal dimension by facilitating services based on time.

Building community: emphasizing the importance of community, both the sharing economy and time banks foster social relations and mutual trust through shared resources and time.

Resource utilization efficiency: both concepts advocate for resource utilization efficiency, with the sharing economy focusing on physical resource sharing and time banks prioritizing time as the primary resource.

Sustainable approach: the collaborative economy and time banks contribute to a more sustainable approach by reducing the need for excessive production and consumption through resource and service exchanges.

Use of technology: technology plays a crucial role in facilitating and managing exchanges in both concepts. Online platforms connect individuals for resource and service transactions [40], yet challenges such as equitable valuation must be addressed for a well-functioning system. When managed appropriately, the collaborative economy and time banks can enhance community connectivity and equity.

The future of research in time banks (TBs) holds promising avenues for further exploration and development. As TBs have evolved over more than 30 years and have garnered attention across various disciplines, there remain several critical areas that warrant in-depth investigation.

Complex Systems Analysis: Future research can delve deeper into the complexities of TBs as a system. Adopting advanced analytical techniques such as network analysis or system dynamics modeling could provide a more nuanced understanding of the intricate relationships within the TB framework.

Integration of Emerging Technologies: With the rapid advancement of technology, exploring how emerging technologies such as blockchain or artificial intelligence can be seamlessly integrated into TB platforms is a promising area. This could enhance the efficiency, transparency, and security of TB transactions.

Global Comparative Studies: Conducting comparative studies across diverse global contexts can offer valuable insights into the adaptability and effectiveness of TB models. Understanding how TBs function in various cultural, economic, and social settings will contribute to a more comprehensive understanding of their impact.

Longitudinal Studies: Tracking the long-term impact of TB participation on individuals, communities, and societal structures is essential. Longitudinal studies can provide valuable data on the sustained benefits, challenges, and evolving dynamics within the TB ecosystem.

Policy Implications: Investigating the policy implications of TBs on local and national levels is crucial. Research focusing on how TBs align with or challenge existing economic and social policies can inform policymakers and contribute to the development of supportive frameworks.

Interdisciplinary Approaches: Future research in TBs can benefit from interdisciplinary collaboration, involving experts from fields such as economics, sociology, psychology, public health, and technology. This collaborative approach can provide a holistic understanding of TB dynamics.

Inclusivity and Diversity: Exploring the inclusivity and diversity aspects of TBs is essential. Research can investigate how TBs can better engage marginalized or under-served communities, ensuring that the benefits of time-based exchange systems are accessible to a broader population.

Educational Initiatives: Developing educational initiatives and resources to raise awareness about TBs and promote participation is an area that merits attention. Research can focus on effective strategies for community outreach and education to enhance TB adoption.

Impact on Well-being: Research can delve into the impact of TB participation on individual well-being, mental health, and community cohesion. Understanding the psychosocial dimensions of time-based exchanges can contribute to fostering resilient and connected communities.

In essence, the future of TB research lies in a multifaceted exploration that combines advanced analytical methodologies, technological innovations, global perspectives, and a commitment to addressing societal challenges. The evolving landscape of time-based exchange systems presents a rich terrain for researchers to uncover new insights and contribute to the sustainable development of these innovative socio-economic models.

In this investigation, we delved into the intricate interplay of systemic features within time banks (TBs) and observed how their influence has evolved over time. Despite the inherent complexities associated with analyzing TBs, this study has provided valuable insights into their dynamics and implications for reshaping socio-economic paradigms. However, like any research endeavor, this study is not without its limitations.

The primary limitation stems from the inherent complexity of TBs as metasystems, with numerous integrated subsystems operating within their operational processes. While our initial analysis has provided a structured overview and has optimized the understanding of TB dynamics, further research is warranted to identify additional characteristics and establish more intricate connections within the system. Nevertheless, our findings hold practical application potential, offering both theorists and practitioners a comprehensive understanding of the dynamics propelling TBs. We have identified key areas of complementarity between TBs and the collaborative economy, emphasizing resource sharing, community building, resource utilization efficiency, sustainable approaches, and the role of technology in facilitating exchanges. Moreover, this study incorporates computer-aided simulations and agent-based modeling, marking a departure from traditional approaches in examining TBs. This methodological innovation expands the scope of analysis and provides a more nuanced understanding of TB dynamics.

Looking ahead, the future of TB research holds promising avenues for further exploration and development. Complex systems analysis, the integration of emerging technologies, global comparative studies, longitudinal studies, policy implications, inter-disciplinary approaches, inclusivity and diversity, educational initiatives, and the impact on well-being are all critical areas warranting attention.

Our involvement in the future of TB research may take various forms, including research collaboration, data collection and sharing, community engagement, advocacy for funding, the dissemination of knowledge, educational initiatives, technological integration, policy advocacy, longitudinal studies, and global perspectives. By actively participating in these endeavors, we aim to contribute to the sustainable development of innovative socio-economic models within the TB ecosystem.

In conclusion, while challenges and limitations persist, the evolving landscape of TBs presents a rich terrain for researchers to uncover new insights and shape the future of time-based exchange systems. Through continued dedication and collaboration, we can collectively advance our understanding and foster the sustainable development of TBs in diverse global contexts.

Author Contributions: The authors O.M. and M.P. contributed to conceptualization, formal analysis, investigation, methodology, and writing and editing of the original draft. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: Many special thanks to the editorial team of FinTech Journal, as well as the review team for the helpful suggestions that contributed to the quality of this study.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Miller, J. Teruko Mizushima: Pioneer Trader in Time as a Currency. Intersections: Gender and Sexuality in Asia and the Pacific. 2008. Available online: http://intersections.anu.edu.au/issue17/miller.htm (accessed on 8 June 2024).
2. Cahn, E.S.; Rowe, J. *Time Dollars: The New Currency That Enables Americans to Turn Their Hidden Resource–Time–into Personal Security & Community Renewal*; Family Resource Coalition of America: Chicago, IL, USA, 1998.
3. Clement, N.; Holbrook, A.; Forster, D.; Macneil, J.; Smith, M.; Lyons, K.; Donald, E.M. Time banking, co-production, and normative principles: Putting normative principles into practice. *Int. J. Community Curr. Res.* **2017**, *21*, 37–52. [CrossRef]
4. Glynos, J.; Speed, E. Varieties of co-production in public services: Timebanks in a UK health policy context. *Crit. Policy Stud.* **2013**, *6*, 402–433. [CrossRef]
5. Valek, L. Risk factors and issues which might arise while implementing and running a time bank: Learning from success and failure. In Proceedings of the 22nd International-Business-Information-Management-Association Conference on Creating Global Competitive Economies: 2020 Vision Planning and Implementation, Rome, Italy, 13–14 November 2013.
6. Valek, L.; Bures, V. *Time Bank as a Complementary Economic System: Emerging Research and Opportunities*; IGI Global: Hershey, PA, USA, 2018; ISBN 13: 9781522569749. [CrossRef]
7. Blanc, J. Classifying "CCs": Community, complementary and local currency's types, and generations. *J. Community Curr. Res.* **2011**, *15*, 4–10.
8. Schroeder, R.; Miyazaki, Y.; Fare, M. Community currency research: Analysis of literature. *Int. J. Community Curr. Res.* **2011**, *15*, 31–41. Available online: https://ijccr.net/2012/05/29/community-currency-research-an-analysis-of-the-literature/ (accessed on 29 May 2024).
9. Collom, E.; Lasker, J.N.; Kyriacou, C. *Equal Time, Equal Value: Community Currencies and Time Banking in the US*; Ashgate Publishing Limited: Farnham, UK, 2012.
10. Valor, C.; Papaoikonomou, E. Time banking in Spain. Exploring their structure, management, and users' profile. *Rev. Int. Sociol.* **2016**, *74*, e14. [CrossRef]
11. Boyle, D. The Potential of Time Banks to Support Social Inclusion and Employability. Seville, Spain: European Commission, Joint Research Centre, Institute for Prospective Technological Studies. 2014. Available online: https://www.shareable.net/wp-content/uploads/2014/07/ftp.jrc_.es_EURdoc_JRC85642.pdf (accessed on 24 May 2024).
12. Gregory, L. Time and punishment: A comparison of UK and US time bank use in criminal justice systems. *J. Comp. Soc. Welf.* **2012**, *28*, 195–208. [CrossRef]
13. Lietaer, B. *The Future of Money*; Random House Group Limited: London, UK, 2001.
14. Available online: https://www.researchgate.net/profile/Ed_Collom/publication/277709163_Equal_Time_Equal_Value_Community_Currencies_and_Time_Banking_in_the_US/links/58cc0b8b4585157b6dabfee5/Equal-Time-Equal-Value-Community-Currencies-and-Time-Banking-in-the-US.pdf (accessed on 10 June 2024).
15. Valek, L. Three new directions for time banking research: Information management, knowledge management, and the open-source model. In *Multidisciplinary Perspectives on Human Capital and Information Technology Professionals*; Ahuja, V., Rathore, S., Eds.; IGI Global: Hershey, PA, USA, 2018; pp. 324–340.
16. Cahn, E.S. *No More Thrown-Away People: Co-Production Imperative*; Essential: Washington, DC, USA, 2000.
17. Valek, L.; Bures, V. Time Bank and Dynamics of its Metamodel. *Postmod. Open.* **2018**, *9*, 157–183. [CrossRef]
18. Manville, B.; Foote, N. Harvest your workers' knowledge. *Datamation* **1996**, *42*, 78–83.
19. Mill, J.S. *Utilitariarismus [Utilitarism]*; Nakladatelstvi Vysehrad, spol. s r.o.: Prague, Czech Republic, 2011.
20. Gonçalves, M.P.; Reis, P.M.N.; Pinto, A.P. Bank Market Power, Firm Performance, Financing Costs and Capital Structure. *Int. J. Financ. Stud.* **2024**, *12*, 7. [CrossRef]

21. Zheng, C.; Rahman, M.A.; Hossain, S.; Moudud-Ul-Huq, S. Does Fintech-Driven Inclusive Finance Induce Bank Profitability? Empirical Evidence from Developing Countries. *J. Risk Financ. Manag.* **2023**, *16*, 457. [CrossRef]
22. Rotaru, I.G. Valences of Education. In Proceedings of the 24th International RAIS Conference on Social Sciences and Humanities, Princeton, NJ, USA, 15–16 August 2021; pp. 190–196.
23. Khan, S.A.R.; Yu, Z.; Panait, M.; Janjua, L.R.; Shah, A. (Eds.) *Global Corporate Social Responsibility Initiatives for Reluctant Businesses*; IGI Global: Hershey, PA, USA, 2021.
24. Albert, J.F.; Fernández, N.G.; Alonso, S.L.N. Social currencies in the digital era: Challenges and opportunities. *CIRIEC-Spain J. Public Soc. Coop. Econ.* **2024**, *110*, 163.
25. Tucnik, P.; Valek, L.; Blecha, P.; Bures, V. Use of time banking as a nonmonetary component in agent-based computational economics models. *WSEAS Trans. Bus. Econ.* **2016**, *13*, 229–237. Available online: http://www.wseas.org/multimedia/journals/economics/2016/a425807-496.pdf (accessed on 4 June 2024).
26. Vidal, J.P.; García, A.; de Fuentes, S.; Iñarra, J. The Barakaldo time bank. In *The Community as an Alternative*; Hezkuntza Aldizkaria: Arbela, Colombia, 2014; Volume 46, pp. 43–46.
27. Valero Restrepo, J.J. On-Line Time Bank. 2022. Available online: https://repositorio.utp.edu.co/items/5de66387-f743-4d75-9dc5-16218ba538c1 (accessed on 4 June 2024).
28. Raposo, M. Mutual Aid Strategies: The Time Bank Report. 2015. Available online: https://uvadoc.uva.es/handle/10324/14944 (accessed on 29 May 2024).
29. International Labour Organization [ILO]. Child Labor and the Impact of Financial Services in Malawi Smallholder Tea Households on. 2022. Available online: https://www.ilo.org/wcmsp5/groups/public/---africa/---ro-abidjan/documents/publication/wcms_872193.pdf (accessed on 8 June 2024).
30. Checkland, P. Soft systems methodology: A thirty-year retrospective. *Syst. Res. Behav. Sci.* **1999**, *17* (Suppl. S1), S11–S58. [CrossRef]
31. Skyttner, L. *General Systems Theory: Problems, Perspectives, Practice*, 2nd ed.; World Scientific: Hackensack, NJ, USA, 2005.
32. Checkland, P. *Systems Thinking, Systems Practice*; John Wiley & Sons Ltd.: Chichester, UK, 1993.
33. Sterman, J. Does System Dynamics Training Improve Understanding of Accumulation? *Syst. Dyn. Rev.* **2009**, *26*, 316–334. [CrossRef]
34. Valek, L. Simulations and modelling of non-mainstream economic realities: Final study. In Proceedings of the 26th International Business Information Management Association Conference: Innovation and Sustainable Economic Competitive Advantage: From Regional Development to Global Growth, Madrid, Spain, 11–12 November 2015.
35. Chivu, L.; Georgescu, G. The foundation of real-world economics: What every student needs to know. *Econ. Thought J.* **2023**, *68*, 343–350. [CrossRef]
36. Abu Khalaf, B.; Awad, A.B. Exploring the bearing of liquidity risk in the Middle East and North Africa (MENA) banks. *Cogent Econ. Financ.* **2024**, *12*, 2330840. [CrossRef]
37. Tran, P.Q.; Phan, A.; Tran, D.V.; Shahrour, M.H. The Effect of Capital Empowerment on the Lending Competence of Banks: Evidence from Segmental Analysis. *Econ. Bull.* **2024**, *44*, 731–746.
38. Madawala, K.; Foroudi, P.; Palazzo, M. Exploring the role played by entrepreneurial self-efficacy among women entrepreneurs in tourism sector. *J. Retail. Consum. Serv.* **2023**, *74*, 103395. [CrossRef]
39. Alfaro, E.; Yu, F.; Rehman, N.U.; Hysa, E.; Kabeya, P.K. Strategic management of innovation. In *The Routledge Companion to Innovation Management*; Routledge: London, UK, 2019; pp. 107–168.
40. Wang, T.; Manta, O.; Zhang, Y. The Relationship between Learning Motivation and Online Learning Performance: The Mediating Role of Academic Self-Efficacy and Flow Experience. *Int. J. Emerg. Technol. Learn. (Ijet)* **2023**, *18*, 27–38. [CrossRef]

MDPI AG
Grosspeteranlage 5
4052 Basel
Switzerland
Tel.: +41 61 683 77 34

FinTech Editorial Office
E-mail: fintech@mdpi.com
www.mdpi.com/journal/fintech

MDPI

Academic Open
Access Publishing

mdpi.com

ISBN 978-3-7258-2122-8