

Article

ESG Performance, Economic Policy Uncertainty, and Forward-Looking Bank Credit Risk: Evidence from U.S. Banks

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Abstract

This study examines the relationship between environmental, social, and governance (ESG) performance and bank credit risk among publicly listed U.S. banks over the period 2016–2025. It distinguishes between forward-looking and realized credit risk by using the loan loss provision ratio (LLPR) as the primary measure of expected credit risk and the non-performing loan ratio (NPLR) as a robustness measure. Using fixed-effects and dynamic System Generalized Method of Moments (System GMM) estimations, the results show that stronger ESG performance is associated with lower forward-looking expected credit risk. The ESG pillar analysis indicates that the social dimension exerts the strongest risk-reducing effect, followed by governance and environmental performance. In addition, economic policy uncertainty weakens the beneficial effect of ESG on bank credit risk. By contrast, ESG performance is not significantly associated with realized credit deterioration measured using NPLR, suggesting that ESG primarily influences banks' expectations of future credit losses rather than realized loan performance. Overall, the findings demonstrate that the impact of ESG on bank credit risk depends on both the measurement of credit risk and the surrounding macroeconomic environment.

Keywords: ESG performance; credit risk; loan loss provisions; economic policy uncertainty; banks; sustainable finance



Academic Editors: Maria-Eleni K. Agoraki, Konstantina K. Agoraki, Nicholas Belesis and Christos Kampouris

Received: 1 July 2026

Revised: 1 August 2026

Accepted: 3 August 2026

Published: 4 August 2026

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1. Introduction

Environmental, social, and governance (ESG) considerations have become increasingly important in the banking sector as regulators, investors, and financial institutions place greater emphasis on sustainability, resilience, and responsible risk management. Following major disruptions such as the global financial crisis, the COVID-19 pandemic, and rising macroeconomic uncertainty, banks have faced growing pressure to integrate ESG principles into governance structures, lending practices, and strategic decision-making. Given banks' central role in financial intermediation and credit allocation, understanding whether ESG performance improves loan quality, reduces credit risk, and enhances financial resilience has become an important issue in both academic research and policy discussions.

Despite the growing integration of ESG considerations into banking practices, the empirical evidence on whether ESG performance consistently reduces bank credit risk remains inconclusive. While several studies document a risk-mitigating effect of ESG through enhanced governance, stakeholder engagement, and risk management practices,

others report weak, insignificant, or context-dependent relationships. These mixed findings suggest that the effectiveness of ESG may depend not only on banks' internal sustainability practices but also on the external economic environment and the way credit risk is measured. Consequently, understanding when and under what circumstances ESG contributes to lower bank credit risk remains an important empirical and policy question.

Credit risk remains one of the primary sources of banking vulnerability because deteriorating loan quality weakens profitability, liquidity, capitalization, and overall financial stability. Traditional banking literature identifies non-performing loans (NPLs) as a key indicator of banking fragility and emphasizes that credit risk is shaped by both bank-specific characteristics and macroeconomic conditions. [Berger and DeYoung \(1997\)](#) argue that inefficient management weakens borrower monitoring and screening, leading to higher levels of non-performing loans. Similarly, [Kwan and Eisenbeis \(1997\)](#) highlight the importance of operating efficiency and capitalization in explaining banking risk, while [Salas and Saurina \(2002\)](#) and [Louzis et al. \(2012\)](#) show that both bank-specific and macroeconomic factors significantly influence credit deterioration. More recent studies continue to confirm that profitability, operational efficiency, and capitalization remain key determinants of loan quality and banking stability ([Koju et al., 2018](#); [Naili & Lahrichi, 2022](#)).

Within this context, ESG performance has increasingly been viewed as a mechanism for strengthening bank resilience and improving risk management. Stakeholder theory, developed by [Freeman \(1984\)](#), suggests that firms that effectively address stakeholder interests can enhance reputational capital, reduce operational risk, and achieve more sustainable long-term performance. In the banking sector, stronger ESG engagement may improve governance quality, transparency, stakeholder confidence, and monitoring mechanisms, thereby encouraging more prudent lending practices and stronger risk oversight. Consistent with this view, [Forcadell and Aracil \(2017\)](#) argue that socially responsible banking strengthens reputational capital and customer trust. By contrast, the shareholder perspective proposed by [Friedman \(1970\)](#) maintains that firms should primarily maximize shareholder value. From this perspective, ESG-related investments are justified only when they enhance firm value and financial performance; otherwise, they may impose additional costs and managerial complexity without generating sufficient economic benefits. Consequently, whether ESG engagement strengthens bank credit risk management remains an empirical question rather than a theoretical certainty.

Although the ESG-banking literature has expanded rapidly, empirical findings regarding the relationship between ESG performance and bank credit risk remain mixed across countries and institutional settings. More importantly, existing studies primarily focus on realized measures of credit risk, such as non-performing loans, while comparatively limited attention has been given to forward-looking measures of expected credit deterioration. This distinction is important because non-performing loans reflect realized credit outcomes, whereas loan loss provisions capture banks' forward-looking assessment of expected credit losses. Prior banking and accounting research emphasizes that timely loan loss provisioning improves the recognition of expected credit losses and strengthens bank risk management ([Laeven & Majnoni, 2003](#); [Beatty & Liao, 2011](#); [Bushman & Williams, 2012](#)). The introduction of expected credit loss accounting frameworks, including IFRS 9 and the Current Expected Credit Loss (CECL) model, has further reinforced the forward-looking nature of loan loss provisioning ([Cohen & Edwards, 2017](#)). Although loan loss provisions may involve managerial discretion, they remain widely used as forward-looking proxies for expected credit risk ([Fonseca & Gonzalez, 2008](#); [Beatty & Liao, 2014](#)). Consequently, ESG engagement is expected to influence banks' forward-looking assessment of credit risk more strongly than realized credit deterioration.

Although forward-looking loan loss provisions provide a more timely measure of expected credit deterioration than realized non-performing loans, the extent to which ESG influences banks' provisioning decisions may depend on the broader macroeconomic environment. During periods of heightened economic policy uncertainty, banks face greater challenges in assessing borrower creditworthiness, forecasting future economic conditions, and estimating expected credit losses. As uncertainty increases, the risk-management benefits associated with ESG may therefore become either more valuable by enhancing organizational resilience or less effective if macroeconomic shocks dominate bank-specific sustainability practices. This possibility suggests that the relationship between ESG performance and forward-looking credit risk is likely to be conditional rather than uniform across different economic environments.

Economic policy uncertainty (EPU) represents an important determinant of banking risk. Baker et al. (2016) define EPU as uncertainty arising from unpredictable fiscal, monetary, and regulatory policy conditions. Elevated uncertainty may weaken investment activity, impair borrower repayment capacity, and reduce banks' ability to assess future economic conditions. Consistent with this view, prior studies show that policy uncertainty undermines financial stability, weakens bank lending, and worsens loan quality (Pastor & Veronesi, 2012; Caglayan & Xu, 2019; Danisman et al., 2020; Karadima & Louri, 2021; Ozili, 2022; Tran, 2020). These findings suggest that economic policy uncertainty constitutes an important external source of bank credit risk and may influence the effectiveness of banks' risk-management strategies.

Recent studies further suggest that economic policy uncertainty and ESG performance are closely interconnected. Firms increasingly adopt ESG practices to strengthen governance quality and organizational resilience during periods of heightened policy uncertainty (Vural-Yavas, 2021; Wu et al., 2024; Li et al., 2025). Likewise, Fan et al. (2025) show that stronger ESG performance can mitigate the adverse effects of economic policy uncertainty on firm risk, suggesting that ESG may serve as a resilience mechanism under uncertain policy environments. However, whether ESG can maintain this risk-mitigating role within the banking sector remains largely unresolved. Heightened policy uncertainty may weaken the effectiveness of ESG-related governance and risk-management mechanisms by increasing macroeconomic uncertainty and reducing the predictability of future credit conditions. This issue motivates the examination of the moderating role of economic policy uncertainty in the relationship between ESG performance and bank credit risk.

Despite the rapid expansion of the ESG–banking literature, several important research gaps remain. First, most existing studies rely on realized measures of credit risk, providing limited evidence on whether ESG influences banks' forward-looking credit risk expectations. Second, relatively little is known about whether the effectiveness of ESG depends on macroeconomic policy uncertainty rather than remaining constant across different economic conditions. Third, although ESG is inherently multidimensional, comparatively limited evidence exists regarding the distinct effects of its environmental, social, and governance pillars on bank credit risk. Addressing these gaps constitutes the primary motivation for the present study.

Against this background, the present study examines the relationship between ESG performance and bank credit risk among publicly listed U.S. banks over the period 2016–2025. Specifically, the study distinguishes between realized credit deterioration, measured by the non-performing loan ratio (NPLR), and forward-looking expected credit risk, measured by the loan loss provision ratio (LLPR). The analysis further examines the environmental, social, and governance pillars separately and investigates whether economic policy uncertainty moderates the ESG–credit risk relationship.

To address these research gaps, this study contributes to the literature in four important respects. First, it builds on previous research by focusing on forward-looking loan loss provisions (LLPR) as the primary measure of credit risk while complementing the analysis with non-performing loan ratios (NPLR) as a robustness measure, thereby providing a more comprehensive assessment of both expected and realized credit risk. Second, the study examines whether economic policy uncertainty (EPU) conditions the effectiveness of ESG performance in mitigating bank credit risk, offering new evidence on how macroeconomic uncertainty shapes the risk implications of corporate sustainability. Third, by separately analyzing the environmental, social, and governance pillars, the study provides additional insights into the heterogeneous channels through which ESG influences banks' credit risk. Finally, using a panel of publicly listed U.S. commercial banks over the 2016–2025 period allows the analysis to capture recent developments in banking regulation, expected credit-loss provisioning, and changing macroeconomic conditions, thereby extending the existing empirical evidence on ESG and bank risk.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature and develops the study hypotheses. Section 3 describes the data, variables, and empirical methodology. Section 4 presents the empirical findings and robustness analyses. Section 5 discusses the results. Section 6 concludes the study and outlines the main implications.

2. Literature Review and Hypotheses Development

2.1. Theoretical Framework

Credit risk remains one of the primary sources of vulnerability in banking systems because deteriorating loan quality directly affects profitability, liquidity, capitalization, and overall financial stability. Traditional banking literature emphasizes that bank credit risk is shaped by both bank-specific characteristics and macroeconomic conditions. Berger and DeYoung (1997) argue that poor management quality weakens monitoring and screening mechanisms, leading to higher levels of problem loans and deteriorating asset quality. Similarly, Kwan and Eisenbeis (1997) emphasize the importance of capitalization and operating efficiency in explaining banking risk and financial fragility, while Salas and Saurina (2002) and Louzis et al. (2012) show that macroeconomic conditions significantly influence non-performing loans. More recent studies continue to confirm that profitability, operational efficiency, and capitalization remain important determinants of bank credit risk (Koju et al., 2018; Naili & Lahrichi, 2022).

Against this background, ESG performance has increasingly been viewed as a potential mechanism for improving bank resilience and strengthening risk-management practices. Stakeholder theory, developed by Freeman (1984), suggests that firms that effectively address stakeholder interests may achieve stronger reputational capital, lower operational risk, and more sustainable long-term performance. Within the banking sector, stronger ESG engagement may improve governance quality, transparency, stakeholder confidence, and monitoring effectiveness, thereby encouraging more prudent lending practices and reducing excessive risk-taking.

The growing body of research on ESG, including comprehensive literature reviews, generally suggests that stronger ESG performance enhances bank stability and reduces financial risk, although the magnitude and consistency of these effects vary across institutional settings (Tsang et al., 2023). Existing studies indicate that ESG engagement strengthens reputational capital, stakeholder trust, governance quality, and risk-management practices, thereby improving banks' resilience to financial shocks (Forcadell & Aracil, 2017; Gangi et al., 2018; Scholtens & van't Klooster, 2019; Di Tommaso & Thornton, 2020; Chiaramonte et al., 2022). Recent evidence also suggests that stronger governance-related ESG

practices reduce banks' contribution to systemic risk (Aevoae et al., 2023), while higher overall ESG performance lowers the probability of bank failure (Bouattour et al., 2024). Nevertheless, these findings are not entirely uniform. The effectiveness of ESG appears to depend on institutional characteristics, the specific ESG dimensions examined, and the measures used to capture bank risk, suggesting that the relationship between ESG performance and credit risk may be context-dependent rather than universal.

Despite this generally positive evidence, the relationship between ESG performance and bank credit risk remains both theoretically and empirically ambiguous. From the shareholder perspective proposed by Friedman (1970), the primary responsibility of firms is to maximize shareholder value. Under this view, investments in ESG-related activities are justified only if they ultimately enhance firm value and financial performance. Accordingly, ESG initiatives may be viewed as increasing operating costs, managerial complexity, and resource allocation pressures unless they generate measurable economic benefits. Nevertheless, empirical findings remain inconclusive. Liu et al. (2023) report that higher ESG ratings are associated with lower non-performing loan ratios among U.S. commercial banks, whereas Bruno et al. (2024) provide mixed evidence for European banks, particularly with respect to governance-related ESG components and ESG controversies. These contrasting findings suggest that the relationship between ESG performance and bank credit risk may vary across institutional settings, macroeconomic environments, and credit risk measures.

Information asymmetry theory further complements stakeholder and shareholder perspectives by explaining how ESG disclosure improves the information environment surrounding banks. Recent evidence indicates that higher-quality environmental and social disclosures reduce information asymmetry between banks and market participants (Acheampong & Elshandidy, 2024). In addition, recent research emphasizes that improved ESG disclosure enhances transparency, strengthens information quality, and contributes to a more transparent information environment by reducing information frictions (Awwad et al., 2026). Enhanced transparency improves the credibility of non-financial information, facilitates more accurate risk assessment, strengthens monitoring, and supports more informed lending decisions, which may ultimately reduce expected credit risk. From this perspective, ESG contributes to credit risk management not only through stronger stakeholder relationships but also by improving information quality and reducing uncertainty surrounding banks' risk exposures.

Furthermore, the aggregate ESG score may conceal important differences across its environmental, social, and governance dimensions. The environmental pillar may influence banks indirectly through climate-related exposures and sustainable lending activities because banks operate primarily as financial intermediaries rather than direct polluters. By contrast, the social and governance pillars are expected to be more closely associated with credit-risk management because they reflect stakeholder engagement, customer responsibility, reputational capital, board oversight, internal controls, and risk-management structures. Consistent with this view, Aevoae et al. (2023) show that governance-related ESG practices reduce banks' contribution to systemic risk, while Di Tommaso and Thornton (2020) highlight the importance of governance structures in shaping bank risk-taking. Consequently, ESG performance is expected to influence bank credit risk primarily through its social and governance dimensions rather than environmental practices, providing the theoretical basis for expecting heterogeneous effects across the three ESG pillars.

2.2. Forward-Looking Credit Risk and LLPR

A particularly important issue in the ESG-banking literature concerns the distinction between realized credit deterioration and forward-looking expected credit risk. Non-performing loan ratios (NPLRs) capture loan defaults and credit deterioration that have

already materialized. Although NPLRs remain widely used indicators of realized credit deterioration and banking fragility, they may respond relatively slowly to improvements in governance quality, borrower screening, and monitoring effectiveness. By contrast, loan loss provisions (LLPs) reflect banks' forward-looking assessment of expected deterioration in loan portfolios and anticipated credit losses, allowing banks to recognize expected credit losses before they are realized (Laeven & Majnoni, 2003; Beatty & Liao, 2011; Bushman & Williams, 2012). Because provisioning decisions incorporate managers' expectations regarding future credit quality, loan loss provision ratios (LLPRs) provide a forward-looking proxy for expected credit risk, although they may also reflect managerial discretion (Beatty & Liao, 2014). Consequently, improvements in governance quality, transparency, monitoring systems, and stakeholder relationships are expected to influence banks' forward-looking assessment of credit risk before such effects become fully observable in realized non-performing loans.

Prior research on loan loss provisioning strongly supports this distinction. Laeven and Majnoni (2003) show that banks often delay provisioning for bad loans until economic downturns become severe, while Beatty and Liao (2011) argue that delayed recognition of expected loan losses affects banks' lending behavior, particularly during recessions. Bushman and Williams (2012) distinguish between forward-looking provisioning that reflects timely recognition of expected future losses and discretionary provisioning associated with income smoothing. Similarly, Bhat et al. (2019) show that banks' credit-risk modeling practices are associated with timelier loan loss provisions and improved prediction of future loan charge-offs. More recently, the adoption of expected credit loss accounting frameworks under IFRS 9 and the Current Expected Credit Loss (CECL) model has reinforced the forward-looking nature of loan loss provisioning by requiring banks to recognize expected credit losses before they are incurred (Cohen & Edwards, 2017).

Despite these limitations, loan loss provisions should not be interpreted as pure measures of future losses because provisioning decisions may also reflect managerial discretion, regulatory incentives, capital-management motives, and income-smoothing behavior (Fonseca & Gonzalez, 2008; Beatty & Liao, 2014). Nevertheless, loan loss provision ratios remain useful forward-looking proxies for expected credit risk because they capture banks' anticipatory recognition of potential loan portfolio deterioration. This distinction is particularly important for ESG research because improvements in governance quality, transparency, monitoring systems, and borrower screening are expected to influence banks' expectations of future credit quality before such improvements become reflected in realized non-performing loans. Consequently, the loan loss provision ratio provides a more appropriate measure than realized non-performing loan ratios for evaluating whether ESG performance improves banks' forward-looking credit-risk management.

2.3. The Moderating Role of Economic Policy Uncertainty

Economic policy uncertainty represents another important determinant of banking risk and can significantly alter the effectiveness of ESG-related risk-management mechanisms. Baker et al. (2016) define economic policy uncertainty as uncertainty arising from unpredictable fiscal, monetary, and regulatory policy conditions. Elevated uncertainty may weaken investment activity, increase information asymmetry, impair borrower repayment capacity, reduce lending efficiency, and make future economic conditions more difficult to forecast. A growing body of evidence suggests that economic policy uncertainty adversely affects financial stability, bank lending, and loan quality. Pastor and Veronesi (2012) argue that uncertainty regarding government policy influences financial markets and risk pricing, while Caglayan and Xu (2019) show that economic policy uncertainty weakens credit activity and financial stability. Danisman et al. (2020) further report that policy uncertainty

reduces bank credit growth, whereas Karadima and Louri (2021) and Ozili (2022) document a significant relationship between policy uncertainty and non-performing loans. Tran (2020) also finds that U.S. banks reduce lending activity during periods of elevated policy uncertainty. Collectively, these studies suggest that economic policy uncertainty constitutes an important external source of bank credit risk and may weaken the effectiveness of banks' risk-management strategies.

Building on this evidence, recent studies increasingly suggest that ESG engagement may partially mitigate the adverse effects of economic policy uncertainty by strengthening governance quality, transparency, and organizational resilience. Fan et al. (2025) show that stronger ESG performance weakens the positive relationship between economic policy uncertainty and firm risk, suggesting that ESG can serve as a resilience mechanism under uncertain policy environments. Similarly, Nasraoui et al. (2026) argue that ESG practices enhance organizational resilience by reducing information asymmetry and easing financial constraints during periods of heightened policy uncertainty. Li et al. (2025) further show that firms strengthen ESG engagement as a strategic response to rising economic policy uncertainty, highlighting the close interaction between policy uncertainty and corporate sustainability practices.

Nevertheless, heightened economic policy uncertainty may simultaneously weaken the effectiveness of ESG-related monitoring and risk-management mechanisms within the banking sector. As uncertainty increases, information asymmetry intensifies, borrower conditions become more difficult to assess, and future macroeconomic conditions become less predictable. Consequently, even banks with stronger ESG practices may find it more difficult to translate improvements in governance quality and organizational resilience into lower credit risk, particularly when provisioning decisions rely heavily on expectations regarding future economic conditions and borrower repayment capacity. Collectively, the theoretical arguments and emerging empirical evidence suggest that economic policy uncertainty may weaken the risk-reducing effect of ESG performance, providing the theoretical foundation for the proposed moderating relationship.

Despite the growing literature on ESG, bank credit risk, and economic policy uncertainty, several important research gaps remain. First, prior studies primarily focus on broad measures of banking stability rather than explicitly distinguishing between realized credit deterioration and forward-looking expected credit risk. Second, although non-performing loan ratios are widely used indicators of banking fragility, comparatively limited attention has been given to loan loss provision ratios as forward-looking proxies for expected credit risk in ESG-related banking research. Third, empirical findings regarding the relationship between ESG performance and bank credit risk remain inconclusive across institutional settings, suggesting that this relationship may depend on both credit risk measures and macroeconomic conditions. Fourth, relatively limited evidence examines whether economic policy uncertainty moderates the effectiveness of ESG-related risk-management mechanisms within the banking sector. Finally, the heterogeneous effects of the environmental, social, and governance pillars remain underexplored, particularly with respect to forward-looking expected credit risk.

To address these gaps, this study examines the relationship between ESG performance and bank credit risk among publicly listed U.S. banks over the period 2016–2025. The analysis primarily focuses on forward-looking expected credit risk, measured by the loan loss provision ratio (LLPR), and subsequently examines the robustness of the findings using the non-performing loan ratio (NPLR) as a measure of realized credit risk. The study further investigates the heterogeneous effects of the environmental, social, and governance pillars and examines whether economic policy uncertainty moderates the relationship between ESG performance and bank credit risk.

The study's conceptual framework is therefore grounded in the integration of stakeholder theory, information asymmetry theory, and the emerging empirical evidence on ESG, forward-looking credit risk, and economic policy uncertainty. Building on this foundation, the following hypotheses are developed.

Taken together, the theoretical arguments and empirical evidence suggest that stronger ESG engagement can improve banks' credit risk management by enhancing governance quality, transparency, stakeholder relationships, and monitoring effectiveness. Because these mechanisms are expected to influence banks' assessment of future credit quality before realized loan defaults emerge, the effect of ESG should be more pronounced for forward-looking measures of credit risk.

Accordingly, the study proposes the following hypotheses:

H1. *Higher ESG performance is associated with lower forward-looking expected credit risk, measured by loan loss provision ratios (LLPR).*

However, the effectiveness of ESG-related risk management is unlikely to remain constant across different macroeconomic environments. As discussed above, heightened economic policy uncertainty may weaken the ability of banks to translate stronger governance and sustainability practices into lower credit risk. Therefore, the following moderating hypothesis is proposed:

H2. *Economic policy uncertainty weakens the negative relationship between ESG performance and bank credit risk.*

Furthermore, the multidimensional nature of ESG suggests that its environmental, social, and governance components are unlikely to contribute equally to bank credit risk management. Given the central role of governance structures and stakeholder relationships in banking activities, the social and governance dimensions are expected to exert stronger effects than the environmental dimension. Accordingly, the following hypothesis is proposed:

H3. *The social and governance pillars exhibit stronger risk-reducing effects than the environmental pillar.*

Although this study primarily focuses on forward-looking expected credit risk, examining realized credit deterioration provides an additional robustness assessment. If ESG improves banks' overall credit risk management, its effects should also be reflected in realized credit outcomes, albeit potentially with a weaker magnitude because non-performing loans capture past rather than expected credit deterioration. Accordingly, the following hypothesis is proposed:

H4. *Higher ESG performance is associated with lower realized bank credit risk, measured by non-performing loan ratios (NPLR).*

3. Research Methodology

3.1. Sample Selection and Data Sources

This study examines the relationship between environmental, social, and governance (ESG) performance and bank credit risk among publicly listed U.S. commercial banks over the period 2016–2025. The banking sector provides an appropriate setting because banks play a central role in financial intermediation, credit allocation, and risk transmission while

operating under extensive regulatory oversight and heightened exposure to macroeconomic and policy uncertainty.

Financial and accounting data were obtained from Refinitiv Eikon, which provides standardized bank-level information on financial statements, ESG performance, and market indicators. ESG-related variables include the aggregate ESG score and its three individual pillars: environmental (ENV), social (SOC), and governance (GOV). Data on economic policy uncertainty (EPU) were obtained from the Federal Reserve Economic Data (FRED) database maintained by the Federal Reserve Bank of St. Louis and correspond to the U.S. Economic Policy Uncertainty Index developed by Baker et al. (2016). Because the empirical analysis is conducted at the annual frequency, the monthly EPU index was aggregated into annual averages before being merged with the bank-level panel dataset.

The initial U.S. banking sample comprised 554 publicly listed commercial banks covered by Refinitiv Eikon during the study period. After applying the data-availability requirements, particularly the availability of ESG scores and the financial variables required for the empirical analysis, the final sample consisted of 1429 bank-year observations representing 226 banks. The resulting dataset is structured as an unbalanced panel, reflecting differences in ESG disclosure and financial-data availability across banks and years. The number of observations varies across empirical specifications because of the inclusion of lagged explanatory variables and differences in variable availability.

Consistent with prior banking and finance research, observations with missing values for the variables required in each empirical specification were excluded, and all continuous variables were winsorized at the 1st and 99th percentiles to reduce the influence of extreme observations.

The empirical analysis combines bank-specific financial variables with macroeconomic information. Forward-looking expected credit risk is measured using the loan loss provision ratio (LLPR), while the non-performing loan ratio (NPLR) is employed as a robustness measure of realized credit risk. The analysis also separately examines the environmental, social, and governance pillars and evaluates whether economic policy uncertainty moderates the relationship between ESG performance and bank credit risk.

3.2. Variable Definitions

Table 1 presents the definitions, measurements, and expected signs of all variables used in the analysis. Consistent with the study's conceptual framework, the analysis distinguishes between forward-looking expected credit risk and realized credit deterioration.

Table 1. Definitions, Measurements, and Expected Signs of the Study Variables.

Variable	Measurement	Data Source	Expected Sign
Dependent Variables			
LLPR	Loan loss provisions/Total loans (forward-looking credit risk proxy)	Refinitiv Eikon	—
NPLR	Non-performing loans/Total loans (realized credit risk)	Refinitiv Eikon	—
Independent Variables			
ESG	Refinitiv ESG Score	Refinitiv Eikon	—
ENV	Refinitiv Environmental Score	Refinitiv Eikon	—
SOC	Refinitiv Social Score	Refinitiv Eikon	—
GOV	Refinitiv Governance Score	Refinitiv Eikon	—

Table 1. Cont.

Variable	Measurement	Data Source	Expected Sign
Moderating Variable			
EPU	U.S. Economic Policy Uncertainty Index	FRED (Baker et al., 2016)	+
Interaction Variables			
ESG × EPU	Interaction between ESG and EPU	Authors' calculations based on Refinitiv Eikon and FRED	—
ENV × EPU	Interaction between Environmental Score and EPU	Authors' calculations based on Refinitiv Eikon and FRED	—
SOC × EPU	Interaction between Social Score and EPU	Authors' calculations based on Refinitiv Eikon and FRED	—
GOV × EPU	Interaction between Governance EPU	Authors' calculations based on Refinitiv Eikon and FRED	—
Control Variables			
SIZE	Natural logarithm of total bank assets	Refinitiv Eikon	±
CAP	Total equity/Total assets	Refinitiv Eikon	—
LDR	Total loans/Customer deposits	Refinitiv Eikon	±
OER	Operating expenses/Total assets	Refinitiv Eikon	+

The primary dependent variable is the loan loss provision ratio (LLPR), calculated as loan loss provisions divided by total loans. Because loan loss provisions reflect banks' expectations of future loan portfolio deterioration, LLPR is employed as a forward-looking proxy for expected credit risk, although provisioning decisions may also reflect managerial discretion and regulatory considerations ([Laeven & Majnoni, 2003](#); [Beatty & Liao, 2011](#); [Bushman & Williams, 2012](#)).

As an alternative measure, the study employs the non-performing loan ratio (NPLR), calculated as non-performing loans divided by total gross loans. NPLR is widely used as an indicator of realized credit risk because it reflects loan defaults that have already materialized. Employing both LLPR and NPLR allows the analysis to distinguish between forward-looking expected credit risk and realized credit deterioration.

The primary independent variable is the ESG score obtained from Refinitiv Eikon. The aggregate ESG score reflects a bank's overall environmental, social, and governance performance and ranges from 0 to 100, with higher values indicating stronger sustainability performance. To provide additional insights, the analysis separately examines the three ESG pillars: environmental (ENV), social (SOC), and governance (GOV). The environmental pillar captures environmental management and sustainability initiatives, the social pillar reflects employee relations, customer responsibility, and stakeholder engagement, while the governance pillar measures board structure, shareholder rights, internal controls, and governance quality. To mitigate potential simultaneity concerns and allow sustainability practices sufficient time to influence banks' risk profile, all ESG variables are lagged by one year.

Economic policy uncertainty (EPU) serves as the moderating variable. The EPU index developed by [Baker et al. \(2016\)](#) measures uncertainty related to fiscal, monetary, and regulatory policy in the United States. Higher values of the index indicate greater uncertainty surrounding U.S. economic policy. To examine whether policy uncertainty alters the relationship between ESG performance and bank credit risk, interaction terms between ESG variables and EPU are included in the empirical models.

The empirical models additionally include several bank-specific control variables commonly employed in banking and financial stability studies. Bank size (SIZE), measured as the natural logarithm of total assets, captures scale and diversification effects. Capital adequacy (CAP), measured as equity divided by total assets, reflects banks' financial resilience and loss-absorption capacity. The loan-to-deposit ratio (LDR) captures lending intensity and liquidity management, while the operational efficiency ratio (OER) reflects banks' operating efficiency and cost management.

3.3. Empirical Model Specification

To examine the relationship between ESG performance and bank credit risk, the study employs panel-data regression models with bank fixed effects and year fixed effects. Consistent with the study's conceptual framework, the baseline specification focuses on forward-looking expected credit risk, proxied by the loan loss provision ratio (LLPR). The baseline empirical specification is expressed as follows:

$$LLPR_{it} = \alpha + \beta_1 ESG_{(it-1)} + \beta_2 (ESG_{(it-1)} \times EPU_t) + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where:

LLPR_{it} represents the loan loss provision ratio of bank *i* in year *t*, employed as a forward-looking proxy for expected credit risk.

ESG_(it-1) denotes the lagged ESG score.

EPU_t represents the economic policy uncertainty index.

ESG_(it-1) × EPU_t captures the moderating effect of economic policy uncertainty on the ESG–credit risk relationship.

Controls_{it} includes bank-specific control variables.

μ_i represents unobserved bank-specific fixed effects.

λ_t captures year-fixed effects.

ε_{it} is the error term.

To examine whether the relationship between ESG performance and bank credit risk differs across sustainability dimensions, the aggregate ESG score is decomposed into its environmental (ENV), social (SOC), and governance (GOV) pillars. Separate fixed-effects models are estimated for each ESG dimension:

Environmental Pillar Model

$$LLPR_{it} = \alpha + \beta_1 ENV_{(it-1)} + \beta_2 (ENV_{(it-1)} \times EPU_t) + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Social Pillar Model

$$LLPR_{it} = \alpha + \beta_1 SOC_{(it-1)} + \beta_2 (SOC_{(it-1)} \times EPU_t) + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

Governance Pillar Model

$$LLPR_{it} = \alpha + \beta_1 GOV_{(it-1)} + \beta_2 (GOV_{(it-1)} \times EPU_t) + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

Although the fixed-effects estimator controls for unobserved time-invariant heterogeneity, the estimated relationship may still be affected by endogeneity arising from reverse causality, omitted variables, and the persistence of bank credit risk. Accordingly, the study additionally estimates a dynamic specification using the two-step System Generalized Method of Moments (System GMM) estimator developed by [Arellano and Bover \(1995\)](#) and [Blundell and Bond \(1998\)](#):

$$LLPR_{it} = \alpha + \rho LLPR_{(it-1)} + \beta_1 ESG_{(it-1)} + \beta_2 (ESG_{(it-1)} \times EPU_t) + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

To further examine whether the main findings remain robust when credit risk is measured using realized rather than expected credit risk, the same dynamic specification is estimated using the non-performing loan ratio (NPLR) as an alternative dependent variable:

$$\text{NPLR}_{it} = \alpha + \rho \text{NPLR}(it - 1) + \beta_1 \text{ESG}(it - 1) + \beta_2 (\text{ESG}(it - 1) \times \text{EPU}_t) + \gamma \text{Controls}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (6)$$

The System GMM estimator accounts for potential endogeneity, unobserved heterogeneity, and the dynamic persistence of bank credit risk. The inclusion of the lagged dependent variable captures the dynamic nature of bank risk, while the GMM framework mitigates simultaneity and reverse-causality concerns. To avoid instrument proliferation, the instrument matrix is collapsed, and a restricted lag structure is employed. Instrument validity is assessed using the Hansen test of overidentifying restrictions, while the Arellano–Bond AR(2) test is used to examine the absence of second-order serial correlation.

3.4. Estimation Technique

The empirical analysis is conducted using complementary panel-data estimation techniques. The baseline models are estimated using the fixed-effects (FE) estimator with bank-clustered robust standard errors. The fixed-effects approach controls for unobserved time-invariant bank characteristics that may be correlated with both ESG performance and bank credit risk, while year-fixed effects account for common macroeconomic shocks, regulatory changes, and other time-specific factors affecting the banking sector.

Bank-clustered robust standard errors are employed to account for potential heteroskedasticity and within-bank serial correlation, thereby improving the reliability of statistical inference.

The dynamic models are estimated using the two-step System Generalized Method of Moments (System GMM) estimator with Windmeijer (2005) finite-sample corrected robust standard errors. The two-step estimator provides more efficient parameter estimates than the one-step estimator, while the Windmeijer correction improves finite-sample inference. Lagged levels and differences in the endogenous variables are used as internal instruments to address endogeneity and the persistence of bank credit risk. To avoid instrument proliferation, the instrument matrix is collapsed, and a restricted lag structure is employed. The empirical analyses were conducted using Stata 18.0.

The validity of the dynamic panel estimates is evaluated using the Hansen test of overidentifying restrictions and the Arellano–Bond AR(2) serial-correlation test. A statistically insignificant Hansen test supports instrument validity, while the absence of second-order serial correlation indicates the consistency of the System GMM estimator.

Overall, the combined use of fixed-effects and System GMM estimators provides complementary evidence by addressing unobserved heterogeneity, dynamic persistence, and potential endogeneity, thereby strengthening the credibility of the empirical findings.

4. Empirical Results

This section presents the empirical findings of the study. The analysis begins with descriptive statistics and correlation analysis, followed by the baseline fixed-effects estimations and the dynamic System GMM results. Additional analyses are subsequently conducted through ESG pillar decomposition and robustness tests using the non-performing loan ratio (NPLR) as an alternative measure of realized credit risk. Throughout the analysis, the loan loss provision ratio (LLPR) serves as the primary measure of forward-looking expected credit risk.

4.1. Descriptive Statistics

Table 2 reports the descriptive statistics for the main variables employed in the empirical analysis, including measures of bank credit risk, ESG performance, economic policy uncertainty, and bank-specific control variables.

Table 2. Descriptive Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
LLPR	2160	0.003	0.004	−0.003	0.031
NPLR	1738	0.007	0.006	0	0.038
ESG	2207	34.18	13.48	2.955	81.38
ENV	2207	17.50	19.46	0	95.44
SOC	2207	33.10	16.50	0.914	93.77
GOV	2207	48.10	20.28	0.18	94.68
EPU	5550	160.95	95.10	83.25	384.1
SIZE	4235	21.71	1.79	11.51	29.11
CAP	4227	0.176	0.069	0.074	0.426
LDR	2147	0.874	0.19	0.351	1.78
OER	4182	0.024	0.009	0.006	0.065

Note: All continuous variables were winsorized at the 1st and 99th percentiles.

The average loan loss provision ratio (LLPR) is 0.3%, ranging from −0.3% to 3.1%, indicating considerable cross-sectional variation in expected credit losses across banks. The average non-performing loan ratio (NPLR) is 0.7%, suggesting relatively moderate levels of realized credit deterioration during the sample period.

The mean ESG score is 34.18, with substantial cross-sectional variation across banks. Among the ESG pillars, governance (GOV) records the highest average score, followed by the social (SOC) and environmental (ENV) dimensions. These descriptive statistics indicate substantial cross-sectional differences in ESG performance across the sampled banks.

Economic policy uncertainty (EPU) also exhibits considerable variation over the sample period, ranging from 83.25 to 384.10, reflecting substantial fluctuations in the U.S. policy environment. Regarding the control variables, the average loan-to-deposit ratio (LDR) is 87.4%, indicating relatively high lending intensity, while the average capital ratio (CAP) suggests that banks are generally well capitalized.

Overall, the descriptive statistics indicate substantial cross-sectional variation in ESG performance, bank characteristics, economic policy uncertainty, and credit risk measures, providing preliminary support for the subsequent panel-data analyses.

4.2. Correlation Matrix and Multicollinearity Diagnostics

Table 3 reports the pairwise correlation matrix among the main variables used in the empirical analysis. The correlation analysis provides preliminary evidence on the relationships between ESG performance, economic policy uncertainty, bank-specific characteristics, and both forward-looking and realized measures of bank credit risk. In addition, the correlation matrix serves as a diagnostic tool for assessing potential multicollinearity before multivariate estimation.

The pairwise correlations indicate no evidence of severe multicollinearity, as the highest correlation among the explanatory variables is 0.539 (between ESG and SIZE), which is well below levels typically associated with multicollinearity concerns.

A positive and statistically significant correlation is observed between LLPR and NPLR (0.271), suggesting that forward-looking expected credit risk and realized credit deterioration are related but capture different dimensions of bank credit risk. ESG performance exhibits a weak positive correlation with LLPR and an insignificant correlation with NPLR,

indicating that the relationship between ESG performance and bank credit risk cannot be fully explained by simple bivariate associations.

Table 3. Pairwise Correlations.

Variables	LLPR	NPLR	ESG	EPU	SIZE	CAP	LDR	OER
LLPR	1.000							
NPLR	0.271 *** (0.000)	1.000						
ESG	0.095 *** (0.000)	−0.018 (0.475)	1.000					
(EPU	0.189 *** (0.000)	0.049 ** (0.040)	0.028 (0.181)	1.000				
SIZE	0.140 *** (0.000)	−0.032 (0.189)	0.539 *** (0.000)	0.051 *** (0.001)	1.000			
CAP	0.096 *** (0.000)	0.002 (0.920)	0.038 * (0.071)	−0.072 *** (0.000)	0.093 *** (0.000)	1.000		
LDR	−0.108 *** (0.000)	−0.050 ** (0.038)	−0.128 *** (0.000)	−0.070 *** (0.001)	−0.215 *** (0.000)	0.382 *** (0.000)	1.000	
OER	0.461 *** (0.000)	0.264 *** (0.000)	0.012 (0.570)	−0.038 ** (0.013)	−0.153 *** (0.000)	−0.031 ** (0.048)	−0.006 (0.774)	1.000

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Among the control variables, the operational efficiency ratio (OER) exhibits the strongest positive correlation with both credit risk measures, whereas the loan-to-deposit ratio (LDR) is negatively correlated with both LLPR and NPLR. In addition, ESG performance is positively correlated with bank size (SIZE), suggesting that larger banks generally report higher ESG scores.

To further assess potential multicollinearity, variance inflation factor (VIF) tests were conducted for all explanatory variables included in the baseline model.

Table 4 presents the variance inflation factor (VIF) results. All VIF values remain well below the conventional threshold of 10, with the highest VIF equal to 1.87 and a mean VIF of 1.51. These results indicate that multicollinearity is unlikely to affect the reliability of the estimated coefficients or the subsequent regression analyses.

Table 4. Variance Inflation Factor (VIF) Results.

Variable	VIF	1/VIF
ESG L1	1.87	0.535
SIZE	1.76	0.567
CAP	1.49	0.669
ESG L1 × EPU	1.48	0.674
LDR	1.42	0.703
OER	1.01	0.991
Mean VIF	1.51	

Overall, the correlation and VIF analyses indicate that multicollinearity is unlikely to bias the estimated coefficients, supporting the reliability of the subsequent fixed-effects and System GMM estimations.

4.3. Main Fixed Effects and Dynamic GMM Results

The main empirical results are presented in two stages. The analysis begins with the baseline fixed-effects (FE) estimation, which examines the relationship between ESG performance and forward-looking bank credit risk while controlling for unobserved bank-

specific heterogeneity. The robustness of these findings is subsequently evaluated using the dynamic System GMM estimator to account for potential endogeneity and the persistence of bank credit risk.

4.3.1. Fixed Effects Results

Table 5 presents the baseline fixed-effects estimation results for the relationship between ESG performance and forward-looking expected credit risk, measured by the loan loss provision ratio (LLPR).

Table 5. Fixed Effects Results.

	LLPR (FE)
ESG($t - 1$)	−0.00003602 *** (0.00001129)
ESG($t - 1$) $\times$ EPU	0.00000015 *** (0.00000005)
SIZE	0.00268134 *** (0.00050394)
CAP	0.00403468 (0.00297530)
LDR	−0.00338483 *** (0.00110633)
OER	0.38881863 *** (0.06242799)
Year Fixed Effects	Yes
Banks	237
Observations	1693
Within R ²	0.435

Notes: Bank-clustered robust standard errors are reported in parentheses. Year fixed effects are included but not reported. *** indicates statistical significance at the 1% levels.

Table 5 reports the baseline fixed-effects (FE) estimation results for the relationship between ESG performance and bank credit risk, measured by the loan loss provision ratio (LLPR). The fixed-effects model controls for unobserved bank-specific heterogeneity and year-fixed effects, thereby exploiting within-bank variation over time.

The coefficient on ESG($t - 1$) is negative and statistically significant at the 1% level, suggesting that banks with stronger ESG performance exhibit lower forward-looking expected credit risk. This finding supports H1 and is consistent with the view that stronger ESG practices contribute to more prudent risk management and lower expected credit losses.

The interaction term between ESG($t - 1$) and economic policy uncertainty (EPU) is positive and statistically significant, indicating that heightened policy uncertainty weakens the beneficial effect of ESG performance on expected credit risk. This result supports H2 and suggests that the effectiveness of ESG-related risk-management practices declines under periods of elevated macroeconomic uncertainty.

Among the control variables, SIZE is positively and significantly associated with LLPR, indicating that larger banks maintain higher expected loan loss provisions. LDR exhibits a negative and statistically significant coefficient, whereas OER remains positively associated with expected credit risk, suggesting that operationally inefficient banks tend to report higher expected credit losses. In contrast, CAP is statistically insignificant, indicating that capital adequacy does not exert an independent effect on expected credit risk after controlling for other bank characteristics.

4.3.2. System GMM Results

To examine whether the baseline findings remain robust after accounting for potential endogeneity and the dynamic nature of bank credit risk, the models are re-estimated using the two-step System GMM estimator.

Table 6 reports the dynamic System GMM estimation results, providing complementary evidence to the baseline fixed-effects estimates after accounting for potential endogeneity and the dynamic nature of bank credit risk.

Table 6. System GMM Results.

	LLPR (System GMM)
L.LLPR	−0.19482709 (0.18858930)
ESG($t - 1$)	−0.00004528 * (0.00002459)
ESG($t - 1$) $\times$ EPU	0.00000015 * (0.00000009)
SIZE	0.00079234 *** (0.00017828)
CAP	0.00593370 * (0.00335118)
LDR	−0.00183732 ** (0.00082672)
OER	0.26716632 *** (0.05395118)
Banks	234
Instruments	22
Observations	1646
Hansen p -value	0.203
AR(2) p -value	0.219

Notes: Two-step System GMM estimates are reported with Windmeijer-corrected robust standard errors in parentheses. Year fixed effects are included but not reported. Hansen and Arellano–Bond AR(2) test statistics are reported as specification diagnostics. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

The System GMM results are broadly consistent with the baseline fixed-effects estimates. The coefficient on ESG($t - 1$) remains negative and statistically significant, although its statistical significance is weaker than in the fixed-effects specification. This finding provides additional support for H1, indicating that stronger ESG performance is associated with lower forward-looking expected credit risk even after accounting for potential endogeneity and dynamic persistence. The smaller estimation sample relative to the fixed-effects model reflects the additional data requirements of the System GMM estimator, particularly the use of lagged variables as internal instruments.

Similarly, the interaction term between ESG($t - 1$) and economic policy uncertainty (EPU) remains positive and statistically significant, thereby providing further support for H2. This result indicates that heightened economic policy uncertainty weakens the beneficial effect of ESG performance on expected credit risk, consistent with the baseline fixed-effects findings.

Among the control variables, SIZE and OER remain positively and statistically significantly associated with LLPR, while LDR continues to exhibit a negative and significant relationship with expected credit risk. CAP becomes marginally significant in the dynamic specification, suggesting that stronger capitalization may contribute to lower expected credit risk once dynamic adjustments are taken into account.

The coefficient on the lagged dependent variable is statistically insignificant, suggesting that forward-looking expected credit risk does not exhibit strong persistence over time. This result contrasts with the robustness analysis based on realized credit risk (NPLR), where greater persistence is observed.

The diagnostic tests support the validity of the dynamic specification. The Hansen test does not reject the null hypothesis of instrument validity ($p = 0.203$), indicating that the selected instruments are appropriate. Similarly, the Arellano–Bond AR(2) test does not reject the null hypothesis of no second-order serial correlation ($p = 0.219$), supporting the consistency of the System GMM estimator. Furthermore, the number of instruments (22) remains substantially below the number of cross-sectional units (234), indicating that instrument proliferation is unlikely to affect the estimation results.

Collectively, the System GMM results corroborate the baseline fixed-effects estimates, indicating that the study’s main conclusions remain robust after accounting for potential endogeneity and dynamic persistence.

4.4. ESG Pillar Analysis

Table 7 reports the fixed-effects estimation results obtained by replacing the aggregate ESG score with its environmental (ENV), social (SOC), and governance (GOV) pillars. Decomposing the aggregate ESG score into its three dimensions allows the analysis to identify which ESG components primarily drive the relationship between ESG performance and forward-looking expected credit risk.

Table 7. ESG Pillar Results.

	ENV	SOC	GOV
ENV($t - 1$)	−0.00002079 * (0.00001058)		
ENV($t - 1$) × EPU	0.00000013 *** (0.00000004)		
SIZE	0.00275419 *** (0.00052133)	0.00275432 *** (0.00050894)	0.00270007 *** (0.00050911)
CAP	0.00356620 (0.00299405)	0.00389839 (0.00299128)	0.00387562 (0.00298489)
LDR	−0.00318366 *** (0.00109139)	−0.00337569 *** (0.00109273)	−0.00336545 *** (0.00112397)
OER	0.38915889 *** (0.06234457)	0.38968293 *** (0.06254369)	0.38816010 *** (0.06260592)
SOC($t - 1$)		−0.00003186 *** (0.00001053)	
SOC($t - 1$) × EPU		0.00000013 *** (0.00000004)	
GOV($t - 1$)			−0.00001967 ** (0.00000806)
GOV($t - 1$) × EPU			0.00000009 ** (0.00000004)
Year Fixed Effects	Yes	Yes	Yes
Banks	237	237	237
Observations	1693	1693	1693
Within R-squared	0.438	0.436	0.434

Notes: Bank-clustered robust standard errors are reported in parentheses. Year fixed effects are included but not reported. ENV, SOC, and GOV represent the environmental, social, and governance ESG pillars, respectively. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

The results indicate that all three ESG pillars are negatively associated with the loan loss provision ratio (LLPR), although the magnitude and statistical significance of the estimated effects differ across the three dimensions.

The coefficient on $ENV(t - 1)$ is negative and statistically significant at the 10% level, indicating that stronger environmental performance is associated with lower forward-looking expected credit risk. However, the interaction between ENV and economic policy uncertainty (EPU) is positive and statistically significant, suggesting that heightened policy uncertainty weakens the beneficial effect of environmental performance.

Among the three ESG dimensions, $SOC(t - 1)$ exhibits the largest negative coefficient and the strongest statistical significance, indicating that social performance has the strongest association with lower expected credit risk. The positive and statistically significant interaction between SOC and EPU further indicates that this beneficial effect diminishes under periods of elevated economic policy uncertainty.

Similarly, $GOV(t - 1)$ is negatively and significantly associated with LLPR, while the interaction between GOV and EPU remains positive and statistically significant. These findings suggest that stronger governance practices are likewise associated with lower expected credit risk, although their effectiveness is moderated by economic policy uncertainty.

Collectively, the pillar-level analysis provides support for H3, indicating that the social and governance dimensions exert largest reduction in expected credit risk compared to the environmental dimension. The consistently positive interaction terms across all three models further reinforce the conclusion that economic policy uncertainty weakens the effectiveness of ESG-related risk-management practices regardless of the ESG dimension considered.

4.5. Robustness Analysis Using NPLR

Table 8 reports the robustness analysis based on the dynamic System GMM specification using the non-performing loan ratio (NPLR) as an alternative measure of realized credit risk. Unlike the loan loss provision ratio (LLPR), which captures forward-looking expected credit risk, NPLR reflects realized loan deterioration. Re-estimating the baseline specification using NPLR allows the robustness of the main findings to be evaluated when credit risk is measured using realized rather than expected outcomes.

The results differ from those obtained using the baseline LLPR specification. The coefficient on $ESG(t - 1)$ remains negative but is no longer statistically significant, indicating that ESG performance is not significantly associated with realized credit deterioration after accounting for dynamic persistence and potential endogeneity. Accordingly, H4 is not supported.

Similarly, the interaction term between $ESG(t - 1)$ and economic policy uncertainty (EPU) is statistically insignificant, indicating that the moderating effect observed under the forward-looking LLPR specification is not replicated when realized credit risk is used as the dependent variable.

The coefficient on the lagged dependent variable is positive and highly significant, indicating substantial persistence in non-performing loans over time. This finding suggests that realized credit deterioration evolves gradually and is strongly influenced by past loan performance. Among the control variables, OER remains positively and significantly associated with NPLR, whereas the remaining control variables are statistically insignificant.

The diagnostic tests support the validity of the dynamic specification. The Hansen test does not reject the null hypothesis of instrument validity ($p = 0.653$), while the Arellano–Bond AR(2) test does not reject the null hypothesis of no second-order serial correlation ($p = 0.538$). Furthermore, the number of instruments (22) remains substantially below the

number of cross-sectional units (201), indicating that instrument proliferation is unlikely to affect the estimation results.

Table 8. Robustness Results Using NPLR.

	NPLR (System GMM)
Lagged NPLR	0.59229455 *** (0.13250265)
ESG($t - 1$)	−0.00004181 (0.00005321)
ESG($t - 1$) $\times$ EPU	−0.00000018 (0.00000024)
SIZE	0.00053167 * (0.00031524)
CAP	−0.00372882 (0.00376620)
LDR	0.00026237 (0.00110076)
OER	0.11464645 *** (0.03126131)
Banks	201
Observations	1335
Instruments	22
Hansen p -value	0.653
AR(2) p -value	0.538

Notes: Robust standard errors are reported in parentheses. Year fixed effects are included but not reported. Hansen and Arellano–Bond AR(2) test statistics are reported as specification diagnostics. ***, and * indicate statistical significance at the 1%, and 10% levels, respectively.

Overall, the robustness analysis indicates that the beneficial effect of ESG performance is confined to forward-looking expected credit risk, rather than realized credit deterioration. These findings reinforce the use of LLPR as the primary measure of bank credit risk in this study and suggest that ESG performance primarily influences banks' expectations of future credit losses rather than contemporaneous non-performing loans.

5. Discussion

5.1. Interpretation of the Main Findings

The findings provide consistent evidence that stronger ESG performance is associated with lower forward-looking expected credit risk among publicly listed U.S. banks. Across both the baseline fixed-effects and dynamic System GMM estimations, banks with higher ESG scores exhibit lower loan loss provision ratios (LLPR), suggesting that sustainability performance is associated with more favorable expectations regarding future credit losses. Importantly, because the analysis relies on observational data, these findings should be interpreted as associations rather than definitive causal relationships.

From a theoretical perspective, these findings are broadly consistent with stakeholder theory, which argues that organizations creating value for a broad set of stakeholders develop stronger governance structures, improve organizational resilience, and enhance their ability to manage risks. Within the banking sector, ESG practices may strengthen internal governance, improve monitoring and screening processes, reinforce stakeholder confidence, and encourage more prudent lending decisions. Collectively, these mechanisms may contribute to lower expected credit risk by improving banks' ability to identify potential credit deterioration before losses become fully realized.

A key contribution of this study lies in distinguishing between forward-looking expected credit risk and realized credit deterioration. While ESG performance remains

significantly associated with lower LLPR, its relationship with the non-performing loan ratio (NPLR) becomes statistically insignificant once dynamic persistence and potential endogeneity are considered. This divergence suggests that ESG performance is more closely associated with banks' forward-looking assessment of credit quality than with contemporaneous measures of realized loan deterioration. Consequently, the findings highlight the importance of selecting credit-risk measures that accord with the underlying research question, particularly when evaluating the role of sustainability in bank risk management.

This distinction extends the existing banking and ESG literature by demonstrating that the relationship between ESG performance and credit risk depends on how credit risk is measured. Much of the previous literature has relied primarily on realized indicators such as non-performing loans, whereas the present study shows that forward-looking provisioning measures capture an additional dimension through which ESG performance is associated with banks' assessment of future credit losses. Rather than suggesting that ESG universally improves all dimensions of bank credit risk, the evidence indicates that its association is stronger for expected credit risk than for realized loan deterioration. In doing so, the study provides a more nuanced understanding of the ESG–credit risk relationship and contributes to the growing literature examining how sustainability influences different dimensions of bank risk.

At the same time, the results should be interpreted in light of the characteristics of loan loss provisions. Although LLPR is widely used as a forward-looking measure of expected credit risk, provisioning decisions may also reflect managerial judgment, accounting discretion, and regulatory considerations. Accordingly, the observed association between ESG performance and LLPR may capture not only differences in expected credit quality but also differences in banks' provisioning behavior. This consideration reinforces the importance of interpreting LLPR as a forward-looking proxy rather than a direct measure of realized credit deterioration and provides additional context for understanding why the results differ from those obtained using NPLR.

5.2. Discussion of the Moderating Effect of Economic Policy Uncertainty

The findings further indicate that economic policy uncertainty (EPU) weakens the beneficial association between ESG performance and forward-looking expected credit risk. The positive and statistically significant interaction between ESG performance and EPU suggests that the risk-reducing association of ESG becomes less pronounced during periods of heightened policy uncertainty. This result implies that while ESG performance remains an important component of banks' risk-management framework, its effectiveness depends partly on the broader macroeconomic and institutional environment in which banks operate.

One possible explanation is that elevated policy uncertainty increases uncertainty regarding future economic conditions, borrower repayment capacity, and regulatory expectations. Under such conditions, banks face greater difficulty in evaluating future credit quality, while borrowers become more vulnerable to adverse macroeconomic shocks. Consequently, the information advantages and governance improvements associated with stronger ESG performance may be insufficient to fully offset the increased uncertainty surrounding lending decisions. Rather than eliminating the benefits of ESG, heightened policy uncertainty appears to reduce the extent to which sustainability-related practices are associated with lower expected credit risk.

These findings contribute to the growing literature examining the interaction between firm-level sustainability and macroeconomic uncertainty. Previous studies have generally examined ESG performance and credit risk independently or have focused primarily on the direct effects of macroeconomic uncertainty. By explicitly incorporating EPU as a mod-

erating factor, this study demonstrates that the ESG–credit risk relationship is conditional rather than uniform across different economic environments. This finding provides a more comprehensive understanding of how internal sustainability practices interact with external macroeconomic conditions in shaping banks' forward-looking assessment of credit risk.

The results also have important practical implications. For bank managers, the findings suggest that ESG initiatives should complement rather than substitute broader risk-management strategies during periods of elevated policy uncertainty. Maintaining strong governance, prudent credit assessment, and effective capital planning remains essential when macroeconomic uncertainty increases. For regulators and policymakers, the results indicate that promoting sustainable banking practices alone may not be sufficient to preserve financial stability during periods of heightened policy uncertainty. Reducing policy uncertainty through transparent and predictable economic policies may enhance the effectiveness of banks' sustainability initiatives and strengthen the resilience of the banking sector.

Overall, the moderating role of EPU suggests that the effectiveness of ESG practices depends not only on banks' internal sustainability performance but also on the stability of the external policy environment. Accordingly, ESG should be viewed as one component of a broader risk-management framework whose association with expected credit risk varies with prevailing macroeconomic conditions.

5.3. ESG Pillars, Contribution to the Literature, and Practical Implications

The pillar-level analysis provides additional insight into the mechanisms through which sustainability performance is associated with forward-looking expected credit risk. Although the environmental, social, and governance dimensions are all negatively associated with LLPR, the magnitude of the estimated coefficients suggests that the social and governance pillars exhibit stronger associations than the environmental pillar. Because the study estimates each pillar separately, these differences should be interpreted as indicative rather than conclusive evidence of heterogeneous effects. Nevertheless, the results suggest that ESG is not a homogeneous construct and that different sustainability dimensions may influence banks' forward-looking risk assessments through distinct organizational channels.

The relatively stronger association observed for the social and governance dimensions is consistent with the characteristics of the banking industry. Banking activities depend heavily on stakeholder confidence, information quality, corporate governance, and effective risk oversight rather than on direct environmental operations. Investments in customer relationships, employee development, transparency, and governance quality may therefore strengthen banks' monitoring capacity and improve the quality of lending decisions, leading to lower expected future credit losses. By comparison, environmental initiatives may influence bank risk more indirectly through portfolio composition, climate-related exposures, and long-term strategic positioning, which could explain their comparatively smaller association with forward-looking provisioning decisions.

Beyond interpreting the empirical results, the study makes several contributions to the existing literature. First, it extends previous research by distinguishing between forward-looking expected credit risk and realized credit deterioration within a unified empirical framework. Rather than relying exclusively on non-performing loans, the analysis demonstrates that the observed association between ESG performance and credit risk depends on whether risk is measured using expected or realized outcomes. This distinction provides a more comprehensive perspective on the role of sustainability in banking and highlights the importance of selecting credit-risk measures that reflect the specific dimension of risk under investigation.

Second, the study contributes by incorporating economic policy uncertainty as a moderating factor rather than examining ESG performance and credit risk in isolation. The results indicate that the relationship between ESG performance and expected credit risk is contingent upon the broader macroeconomic environment, suggesting that firm-level sustainability practices and macroeconomic uncertainty jointly shape banks' forward-looking risk assessments. In doing so, the study broadens the literature by integrating internal governance mechanisms with external sources of uncertainty within a single analytical framework.

Third, by examining publicly listed U.S. banks over the 2016–2025 period, the study provides updated evidence from one of the world's largest banking systems during a decade characterized by substantial regulatory and macroeconomic changes. This institutional context contributes additional evidence to the growing international literature on sustainable banking while extending previous studies that have primarily focused on different countries, alternative institutional settings, or realized measures of credit risk.

The findings also provide several practical implications. For bank managers, the results suggest that ESG initiatives should be integrated into broader enterprise risk-management frameworks rather than being viewed solely as sustainability objectives. Strengthening governance quality, stakeholder engagement, and social responsibility may contribute to more effective forward-looking credit-risk assessment, particularly under relatively stable macroeconomic conditions. For investors, the findings indicate that ESG information may provide additional insights into banks' expected credit quality beyond traditional financial indicators. For regulators and policymakers, the results highlight that promoting sustainable banking practices may enhance financial resilience, while maintaining a stable and predictable policy environment remains important for preserving the effectiveness of ESG-related risk-management strategies.

Overall, the findings suggest that ESG performance should be viewed as an important component of banks' forward-looking risk-management framework rather than as a universal solution to all dimensions of credit risk. Its association with expected credit losses varies across ESG dimensions and depends on the prevailing macroeconomic environment, underscoring the need to evaluate sustainability performance within a broader institutional and economic context.

6. Conclusions

This study examined the association between environmental, social, and governance (ESG) performance and bank credit risk among publicly listed U.S. banks over the period 2016–2025. Using complementary fixed-effects and dynamic System GMM estimations, the analysis investigated whether ESG performance is associated with forward-looking expected credit risk and whether economic policy uncertainty (EPU) conditions this relationship.

The findings indicate that stronger ESG performance is associated with lower forward-looking expected credit risk, measured by the loan loss provision ratio (LLPR), whereas no statistically significant association is observed for realized credit deterioration measured by the non-performing loan ratio (NPLR) after accounting for dynamic persistence and potential endogeneity. The results further show that economic policy uncertainty weakens the beneficial association between ESG performance and expected credit risk, while the pillar-level analysis suggests that the social and governance dimensions exhibit stronger associations with lower expected credit risk than the environmental dimension.

The study contributes to the sustainable finance and banking literature in several respects. First, it demonstrates the importance of distinguishing between forward-looking expected credit risk and realized credit deterioration when evaluating the role of ESG performance in banking. Second, it shows that the relationship between ESG performance

and expected credit risk is conditional on the broader macroeconomic environment by explicitly incorporating economic policy uncertainty as a moderating factor. Third, by examining the environmental, social, and governance pillars separately, the study provides additional insight into the organizational channels through which sustainability performance is associated with banks' forward-looking credit-risk assessments. Collectively, these findings contribute to a more nuanced understanding of how sustainability, macroeconomic uncertainty, and bank risk interact within the U.S. banking sector.

The findings also have practical implications for several stakeholders. For bank managers, integrating ESG considerations into governance frameworks, lending policies, and enterprise risk-management systems may strengthen the assessment of future credit risk, particularly under relatively stable macroeconomic conditions. For investors, ESG performance may provide useful information regarding banks' forward-looking risk profiles in addition to conventional financial indicators. For regulators and policymakers, the findings suggest that promoting sustainable banking practices and maintaining a stable and predictable policy environment may jointly enhance the resilience of the banking sector.

Despite these contributions, several limitations should be acknowledged. First, the analysis focuses exclusively on publicly listed U.S. banks, which may limit the generalizability of the findings to other institutional and regulatory settings. Second, ESG performance is measured using ratings obtained from a single data provider and may therefore be subject to measurement differences and incomplete ESG coverage across banks. Third, although LLPR provides a forward-looking proxy for expected credit risk, loan-loss provisioning may also reflect managerial discretion, accounting judgments, and regulatory considerations. Finally, the analysis relies on a single U.S. economic policy uncertainty index, which may not capture all dimensions of macroeconomic uncertainty affecting bank risk.

Future research could extend this study in several directions. Examining alternative ESG measures, including ESG controversies and disclosure-based indicators, would help assess the robustness of the observed relationships. Future studies could also investigate whether the findings differ across institutional environments, regulatory regimes, or stages of economic development through cross-country analyses. In addition, incorporating alternative measures of macroeconomic uncertainty, climate-related financial risk, or bank-specific governance characteristics may provide further insight into the mechanisms linking sustainability performance and bank credit risk. Finally, future research may employ alternative identification strategies and formal comparisons of ESG pillar effects to further strengthen causal inference and deepen understanding of the heterogeneous channels through which ESG performance influences bank risk.

Author Contributions: Conceptualization, M.A.-D.; data curation, M.A.-D.; formal analysis, M.A.-D. and W.A.; investigation, M.A.-D. and W.A.; methodology, M.A.-D. and W.A.; project administration, M.A.-D.; resources, M.A.-D. and W.A.; software, M.A.-D. and W.A.; supervision, M.A.-D.; validation, M.A.-D. and W.A.; visualization, M.A.-D. and W.A.; writing—original draft, M.A.-D. and W.A.; writing—review and editing, M.A.-D. and W.A. 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: Restrictions apply to the availability of these data. Financial data were obtained from Refinitiv Eikon under a commercial license and are subject to licensing restrictions. Macroeconomic data were obtained from the Federal Reserve Economic Data (FRED) database, which is publicly available. The processed data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to the licensing terms of the data provider.

Acknowledgments: The authors would like to thank the editor and the reviewers in advance for their effort to ensure that this manuscript is of high quality.

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

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