

The Impact of ESG Performance on Solvency Risk: The Moderating Roles of Female Directors and External Assurance

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ABSTRACT

This study examines the relationship between environmental, social, and governance (ESG) performance and solvency risk in Taiwanese financial and insurance firms, focusing on the moderating roles of female board representation and external assurance. Using an unbalanced panel of 52 firms from 2015 to 2022, we employ pooled OLS regressions with year fixed effects and firm-clustered standard errors. The results show that the relationship between ESG performance and solvency risk varies across ESG dimensions and measures of financial stability. Environmental and social performance exhibit heterogeneous associations with solvency risk. Female board representation and external assurance significantly moderate the ESG–solvency relationship in selected specifications, indicating that governance characteristics and disclosure credibility condition the financial implications of ESG performance. These findings contribute to the sustainable finance literature by highlighting the contingent relationship between ESG performance, governance mechanisms, and financial stability in financial and insurance firms.

JEL Classifications: G21, G2, G34, M14

Keywords: ESG performance, solvency risk, female director, external assurance

I. INTRODUCTION

Whether ESG engagement enhances financial stability remains an open empirical question. Although ESG has evolved into a comprehensive framework for evaluating corporate sustainability, its implications for firm-level risk outcomes—particularly solvency risk—remain inconclusive. Prior research provides mixed evidence. While some studies suggest that superior ESG performance mitigates financial risk and enhances resilience (e.g., Albuquerque et al., 2019; Shakil, 2021), others indicate that ESG engagement may entail operational costs, complexity, or sector-specific exposures that increase firm risk (Amel-Zadeh and Serafeim, 2018). This ambiguity is particularly relevant to financial and insurance institutions, where capital adequacy and solvency are central to financial stability (Bernal et al., 2014). Although recent research has begun to examine the relationship between ESG performance and corporate solvency (e.g., Yu and Su, 2024), less is known about the conditions under which ESG performance translates into improved solvency outcomes, particularly in financial institutions. This study addresses this gap by examining two potential boundary conditions: female board representation and external ESG assurance. From a governance perspective, female board representation may influence board monitoring, risk oversight, and decision-making (Eagly and Carli, 2003; García and Herrero, 2021), thereby shaping how ESG initiatives are incorporated into firms' risk-management decisions. However, existing evidence regarding female board representation and financial distress or solvency remains mixed (García & Herrero, 2021; Garcia-Blandon et al., 2024), suggesting that its role in the ESG–solvency relationship warrants further investigation. From an information perspective, external assurance can enhance the credibility of ESG disclosures by reducing information asymmetry and concerns about greenwashing (Simnett et al., 2009; Casey and Grenier, 2015), potentially enabling stakeholders to assess more effectively the financial implications of ESG activities. Accordingly, rather than treating ESG performance as a standalone determinant of solvency risk, this study investigates whether and how female board representation and external assurance condition the ESG–solvency relationship.

This study contributes to the literature in three ways. First, it extends ESG–risk research by focusing specifically on solvency risk in listed financial and insurance institutions, complementing prior studies that have primarily examined broader measures of firm value, financial performance, or risk (e.g., Jin and Lei, 2023; Tang et al., 2024). Second, it examines female board representation as an internal governance mechanism through which the relationship between ESG performance and solvency risk may vary, thereby extending prior research beyond the direct effects of ESG performance. Third, it investigates external assurance as an information mechanism that may condition the ESG–solvency relationship by enhancing disclosure credibility and reducing information asymmetry. Using an unbalanced panel of 52 listed financial institutions in Taiwan from 2015 to 2022 and two complementary measures of solvency risk—the Z-score and the standard deviation of return on equity (SDROE)—this study provides evidence on when and under what governance and disclosure conditions ESG performance is associated with solvency outcomes.

The remainder of this paper is organized as follows. Section 2 reviews the related literature and develops the hypotheses. Section 3 describes the data, variables, and empirical methodology. Section 4 presents and discusses the empirical results. Section 5

concludes and discusses the practical implications, limitations, and directions for future research.

II. RELATED LITERATURE AND RESEARCH HYPOTHESES

A. Theoretical Framework

Agency theory suggests that conflicts between shareholders and managers may lead to value-destroying decisions and excessive risk-taking, thereby increasing firms' bankruptcy and solvency risks. Strong ESG performance can help align managerial and shareholder interests, promote long-term sustainability, and reduce agency costs. Empirical evidence shows that firms with superior ESG performance are better able to mitigate agency problems and consequently exhibit lower bankruptcy risk (Aydoğmuş et al., 2022). From a signaling and moral capital perspective, ESG engagement can generate reputational benefits and goodwill that function as an insurance-like mechanism during adverse events. Financial institutions that actively implement ESG practices send positive signals to stakeholders regarding their commitment to environmental protection, social responsibility, and sound governance, thereby enhancing stakeholder trust (Crawford et al., 2024). As a result, investors and other stakeholders are more willing to provide financial support, reducing the likelihood of financial distress. Regarding board characteristics, agency theory posits that female directors enhance board monitoring effectiveness and reduce agency costs, which in turn lowers firm risk. Ain et al. (2020) provide evidence that female board representation significantly reduces agency costs. Moreover, resource dependence theory suggests that gender-diverse boards bring heterogeneous knowledge, skills, and external networks, improving decision-making quality and firms' ability to cope with uncertainty (Hillman et al., 2007). These advantages contribute to more prudent risk management and improved solvency outcomes.

B. ESG Performance and Solvency Risk

Prior literature suggests that ESG performance plays a crucial role in corporate risk management and solvency. From a risk mitigation perspective, ESG engagement generates an insurance-like effect by enhancing reputational capital, stakeholder trust, and information transparency, thereby buffering firms against adverse shocks (Jo and Na, 2012). Firms with strong ESG practices face lower risks of legal penalties and stakeholder conflicts, fostering stable relationships with key external parties (McGuire et al., 1988; Oikonomou et al., 2012). Empirical studies largely support this view, showing that superior ESG ratings correlate with reduced default probabilities, lower financing costs, and enhanced capital access (Li et al., 2022; Yu and Su, 2024; Miani et al., 2026). Conversely, from a shareholder value and agency perspective, ESG activities may impose operational costs, absorb scarce resources, or reflect overinvestment, potentially increasing cash flow volatility and credit risk (Goss and Roberts, 2011). Some studies also report neutral effects during economic expansions (Fandella et al., 2023; Habermann and Fischer, 2023). Despite these mixed findings, the prevailing consensus grounded in Stakeholder Theory and the Insurance-like Effect indicates that the risk-shielding benefits of ESG performance generally outweigh its costs. By suppressing information

asymmetry and lowering debt costs, superior ESG engagement enhances financial resilience. Accordingly, we propose:

H1: Higher ESG performance is negatively associated with solvency risk.

C. ESG Component Performance and Solvency Risk

Firms engaging in effective environmental management experience fewer operational failures and lower credit default risk (Atif and Ali, 2021; Gangi et al., 2019; Cohen, 2023). Although short- and long-term compliance costs can temporarily strain financial resources (Saidane and Abdallah, 2021), overall environmental proactive engagement is expected to reduce solvency risk. Thus, we hypothesize:

H2: Environmental performance is negatively associated with solvency risk.

Corporate social engagement strengthens stakeholder trust and market confidence, enhancing stability and lowering financial distress risks (Chiaramonte et al., 2022; Cooper and Uzun, 2019; Zheng et al., 2019). While certain studies find that social expenditure may increase bankruptcy likelihood during favorable business cycles or show insignificant effects (Habermann and Fischer, 2023; Saidane and Abdallah, 2021), the dominant view posits a risk-mitigating role for social performance in financial institutions. Accordingly, we hypothesize:

H3: Social performance is negatively associated with solvency risk

Strong governance mechanisms enhance monitoring, curb managerial opportunism, and encourage prudent risk-taking, thereby fostering financial stability (Atif and Ali, 2021; Saidane and Abdallah, 2021). However, governance structures strictly oriented toward shareholder wealth maximization may trigger excessive risk-taking (Ali et al., 2021), and its impact can be context-dependent (Cohen, 2023). Nevertheless, effective overall governance quality is generally anticipated to mitigate solvency risk. Thus, we propose:

H4: Governance performance is negatively associated with solvency risk.

D. The Moderating Effect of Female Directors on Solvency Risk

Board gender diversity strengthens board monitoring, reduces agency costs, and improves financial transparency (Adams and Ferreira, 2009; La Rosa et al., 2018). Female directors also tend to exhibit lower overconfidence and greater risk aversion, which may promote more prudent risk management (Faccio et al., 2016; La Rocca et al., 2020). From an Agency Theory perspective, female directors enhance monitoring independence and help constrain opportunistic ESG practices, thereby directing ESG investments toward substantive risk reduction. From a Resource Dependence Theory perspective, female directors bring diverse perspectives, stakeholder networks, and resources that facilitate the integration of ESG strategies into corporate risk management. Accordingly, greater female board representation is expected to strengthen the risk-reducing effect of ESG performance. Thus, we propose:

H5: Female board representation strengthens the negative relationship between ESG performance and solvency risk.

E. The Moderating Effect of External Assurance

External assurance of sustainability or ESG reports has become increasingly common as firms seek to enhance the credibility of non-financial disclosures. Prior studies show that externally assured sustainability reports are perceived as more reliable and credible by stakeholders, particularly for larger or higher-risk firms (Simnett et al., 2009). Empirical evidence further suggests that external assurance enhances the credibility of CSR and ESG disclosures, improves financial performance, and reduces financing costs, including the cost of debt (Kim et al., 2019; Du and Wu, 2019; Kordsachia, 2021). Recent studies also document that the positive relationship between ESG performance and financial outcomes is stronger when sustainability reports are externally assured (Darsono et al., 2025). Beyond merely improving report credibility, the moderating effect of external assurance on solvency risk operates through concrete economic mechanisms explained by Signaling Theory and Moral Capital Theory. Under Signaling Theory, unassured ESG metrics represent "noisy" signals that financial market participants—such as creditors, rating agencies, and underwriters—may discount due to information asymmetry and fears of greenwashing. External assurance serves as a costly, credible signal that significantly reduces information asymmetry. The direct economic consequence of this reduced uncertainty is a lower cost of debt, expanded access to sustainable financing, and more favorable credit terms from capital providers. These tangible economic benefits directly bolster the firm's liquidity buffer and financial flexibility, thereby strengthening the solvency-enhancing capacity of ESG performance. Additionally, viewed through Moral Capital Theory, externally assured ESG performance builds verifiable, authentic "moral capital" among key financial stakeholders. In times of financial strain, this verified moral capital generates an insurance-like protection, encouraging lenders and creditors to maintain credit lines rather than demanding immediate debt liquidation. Therefore, external assurance converts abstract ESG performance into functional financial resilience.

H6: External assurance positively moderates the negative relationship between ESG performance and solvency risk, such that the solvency-enhancing effect of ESG is stronger for assured reports.

III. DATA SOURCES, VARIABLES, AND METHODOLOGY

A. Sample and Data Sources

This study employs an unbalanced annual panel dataset of listed companies in Taiwan's financial and insurance sector. The final sample comprises 52 listed financial institutions observed over the period 2015–2022, including 16 financial holding companies, 21 banks, 11 insurance companies, and 4 other financial institutions. Data are obtained from the Taiwan Economic Journal (TEJ), including the TESG sustainability development index (TESG Rating), as well as the Insurance Open Information Observatory and the Market Observation Post System (MOPS), including financial statistics and annual reports of listed financial holding companies and banks. Annual firm-level data are used for the empirical analysis. The maximum number of potential firm-year observations is 416 (52

firms $\times$ 8 years). Because the panel is unbalanced, the actual number of observations varies across firms and years. Observations with missing values for variables required in a given regression specification are excluded, and no missing values are imputed. The main baseline and moderation specifications contain 415 firm-year observations. After aligning the one-period lagged ESG variables in year ($t-1$) with the corresponding solvency-risk measures in year (t), the lagged robustness specifications contain 414 usable firm-year observations. The number of observations used in each model is reported in the corresponding regression tables.

B. Variables Measuring Solvency Risk

1. Dependent Variables

This study employs two complementary measures of solvency risk. The primary measure is the Z-score, which captures the probability of insolvency for banks and insurers (Lepetit et al., 2008). A higher Z-score indicates a lower probability of failure and greater financial stability, and therefore lower solvency risk. The Z-score is calculated as follows: $Z\text{-score} = (100 + \text{average ROE}) / \text{SDROE}$, where ROE and SDROE are expressed in percentage terms. Following prior studies, SDROE is computed using a three-year rolling window. To mitigate skewness in the distribution of the Z-score, we normalize the measure by taking its natural logarithm (Houston et al., 2010). As an alternative proxy for solvency risk, this study uses the standard deviation of return on equity (SDROE). Prior research has widely employed earnings volatility as a measure of firm-specific risk (Woo, 1987; Adem, 2022). A higher SDROE reflects greater volatility in earnings, indicating lower financial stability and higher solvency risk. Accordingly, the two measures capture solvency risk from complementary perspectives. A higher Z-score represents greater financial stability and lower solvency risk, whereas a higher SDROE represents greater earnings volatility and higher solvency risk. Therefore, the expected signs of the explanatory variables may differ across the two measures. For the Z-score, a positive coefficient indicates greater financial stability and lower solvency risk, whereas for SDROE, a negative coefficient indicates lower earnings volatility and lower solvency risk.

2. Independent Variables

This study uses independent variables, namely the ESG combined score and the environment, social, and governance score. All ESG scores are from TEJ databases (Cheng et al., 2023). TEJ databases, developed by a well-known business database company in Taiwan, constructed and released the TES sustainability development index for Taiwan publicly traded firms in 2015.

3. Moderating Variables

Female board representation is measured by the proportion of female directors on the board, calculated as the number of female directors divided by the total number of board members. External assurance can signal that the released information is accurate and reliable and can assure investors and other stakeholders of the trustworthiness of corporate CSR performance (Braam et al., 2016). Chen and Wu (2024) proposed that

issuing external assurance can also help reduce the cost of debt funds and thus reduce risks, which shows that the content of the sustainability report confirmed by a third party is reliable. This is a dummy variable, which is 1 if the sustainability report is external assurance and 0 if not.

4. Control Variables

Following the relevant literature, we included firm-specific control variables that could potentially affect financial and insurance firm solvency risks.

(1) Firm Size

We employed the natural logarithm of total assets as a proxy for size (Shim, 2017; Korzeb et al., 2025). Larger companies benefit from a more diversified business than can smaller companies (Cheng and Weiss, 2013). Moreover, regulators are less likely to liquidate large companies, thereby reducing the insolvency risk (Chen and Wong, 2004).

(2) Firm Age

Firm age is included as a control variable to account for potential differences in organizational maturity and accumulated managerial experience across financial institutions.

(3) Profitability

According to Esteve-Pérez and Mañez-Castillejo (2008), high profitability can also be a sign of greater efficiency and a better positioning of the firm in the market, both of which contribute to increased solvency. In addition, Atif and Ali (2021) also indicated that increased profitability is expected to decrease bankruptcy risk.

(4) Board Size

Brédart (2014) found that board size is negatively correlated with the likelihood of a company getting into financial distress. The main reason may be that the board has more skills, knowledge, and transparency, which reduces information asymmetry (Alves et al., 2015), leverage, and financing costs (Fields et al., 2012). However, Fich and Shivdasani (2008) showed that the size of the board of directors is positively correlated with the probability of corporate bankruptcy, because insufficient coordination will weaken corporate governance and lead to high leverage, which affects the probability of bankruptcy. Therefore, there is no consistent conclusion at present.

(5) Independent Director

Li et al. (2008) study non-financial firms listed in China and report that higher board independence constitutes a lower probability of financial distress and that the effect of independent directors is more significant during financial crises. Adams and Mehran (2008) observe that independence director is essential, arguing that strengthening their role as independence director can reduce risky decision-making and improve banks' financial performance and stability. Maier and Yurtoglu (2022) find that board

independence is associated with a lower risk of bankruptcy. Table 1 presents the definitions of the variables.

Table 1
Variables Definitions

Variable	Definition
Dependent Variables	
Z- score	The Z-score is calculated as $\frac{(100 + \text{average ROE})}{\{\text{SDROE}\}}$, where ROE and SDROE are expressed as percentages, and SDROE is the standard deviation of the three-year rolling average of net asset returns
SDROE	Standard deviation of three-year return on equity.
Independent Variables	
ESG score (ESG)	The TESG score is ranged from 0 to 100 points, with 0 being the worst and 100 being the best
Environmental score (E)	TESG sustainability index environmental protection rating score
Social score (S)	TESG sustainability index social responsibility rating score
Governance score (G)	TESG sustainability index corporate governance rating score
Moderating variables	
Percentage of female directors (PFD)	Total number of female directors serving on the board of directors divided by the total number of board members
External assurance (EA)	This is a dummy variable, which is 1 if the sustainability report has external assurance and 0 if not.
Control Variables	
Firm size (FS)	Logarithm of total assets of the companies
Firm age (FA)	Number of years since a financial institution was established
ROA	Pre-tax income (losses) /average asset
Board size (BS)	The total number of board members
Independent directors (ID)	Percentage of independent directors on the board
Year dummy (Year)	Assigned as one if it belongs to that year; otherwise assigned to zero

C. Methodology

To estimate the proposed relationships, we employ pooled ordinary least squares (OLS) regression models with year fixed effects. The pooled OLS approach is adopted as the baseline specification because the study focuses on the average associations between ESG performance and firms' solvency risk and on the moderating roles of female directors and external assurance across firms and over time. The key explanatory and moderating variables also exhibit substantial cross-sectional variation across firms.

Given the panel structure of the dataset, standard errors are clustered at the firm level to account for potential heteroskedasticity and within-firm serial correlation over time. Year fixed effects are included to control for common time-specific shocks, macroeconomic conditions, and other factors that may affect firms simultaneously during the sample period. Accordingly, the pooled OLS coefficients are interpreted as average

associations across firms and over time rather than as purely within-firm effects. We acknowledge that this specification does not explicitly control for unobserved, time-invariant firm-specific characteristics, which represents a limitation of the empirical design. The basic regression model is specified as follows:

$$\text{Financial stability}_{it} = \alpha + \beta_1 \text{ESG}_{it} + \beta_2 \text{FS}_{it} + \beta_3 \text{FA}_{it} + \beta_4 \text{ROA}_{it} + \beta_5 \text{BS}_{it} + \beta_6 \text{ID}_{it} + \beta_7 \text{Year}_{it} + \varepsilon_{it} \quad (1)$$

$$\text{Financial stability}_{it} = \alpha + \beta_1 E_{it} + \beta_2 S_{it} + \beta_3 G_{it} + \beta_4 \text{FS}_{it} + \beta_5 \text{FA}_{it} + \beta_6 \text{ROA}_{it} + \beta_7 \text{BS}_{it} + \beta_8 \text{ID}_{it} + \beta_9 \text{Year}_{it} + \varepsilon_{it} \quad (2)$$

$$\text{Financial stability}_{it} = \alpha + \beta_1 \text{ESG}_{it} + \beta_2 \text{PFD}_{it} + \beta_3 \text{FS}_{it} + \beta_4 \text{FA}_{it} + \beta_5 \text{ROA}_{it} + \beta_6 \text{BS}_{it} + \beta_7 \text{ID}_{it} + \beta_8 \text{ESG}_{it} \times \text{PFD}_{it} + \beta_9 \text{Year}_{it} + \varepsilon_{it} \quad (3)$$

$$\begin{aligned} \text{Financial stability}_{it} = & \alpha + \beta_1 E_{it} + \beta_2 S_{it} + \beta_3 G_{it} + \beta_4 \text{PFD}_{it} + \beta_5 \text{FS}_{it} \\ & + \beta_6 \text{FA}_{it} + \beta_7 \text{ROA}_{it} + \beta_8 \text{BS}_{it} + \beta_9 \text{ID}_{it} + \beta_{10} E_{it} \times \text{PFD}_{it} + \beta_{11} S_{it} \times \text{PFD}_{it} \\ & + \beta_{12} G_{it} \times \text{PFD}_{it} + \beta_{13} \text{Year}_{it} + \varepsilon_{it} \end{aligned} \quad (4)$$

$$\text{Financial stability}_{it} = \alpha + \beta_1 \text{ESG}_{it} + \beta_2 \text{EA}_{it} + \beta_3 \text{FS}_{it} + \beta_4 \text{FA}_{it} + \beta_5 \text{ROA}_{it} + \beta_6 \text{BS}_{it} + \beta_7 \text{ID}_{it} + \beta_8 \text{ESG}_{it} \times \text{EA}_{it} + \beta_9 \text{Year}_{it} + \varepsilon_{it} \quad (5)$$

$$\begin{aligned} \text{Financial stability}_{it} = & \alpha + \beta_1 E_{it} + \beta_2 S_{it} + \beta_3 G_{it} + \beta_4 \text{EA}_{it} + \beta_5 \text{FS}_{it} \\ & + \beta_6 \text{FA}_{it} + \beta_7 \text{ROA}_{it} + \beta_8 \text{BS}_{it} + \beta_9 \text{ID}_{it} + \beta_{10} E_{it} \times \text{EA}_{it} + \beta_{11} S_{it} \times \text{EA}_{it} \\ & + \beta_{12} G_{it} \times \text{EA}_{it} + \beta_{13} \text{Year}_{it} + \varepsilon_{it} \end{aligned} \quad (6)$$

where i indexes firms, t represents years, and ε_{it} is the error term; α is the intercept; β_j is the estimated regression coefficient of the independent variable; $j = 1, 2, 3, \dots, 13$.

Solvency risk is measured using Z-score and SDROE. The moderating variables are female directors and external assurance. In the above, equations 1 and 2 mainly represent the impact of ESG and ESG dimensions on the firm's solvency risk, while equations 3-6 represent the moderating effect of female directors and external assurance on ESG and its components on solvency risk.

IV. EMPIRICAL RESULTS

A. Descriptive Statistics

As shown in Table 2, the mean values of Z-score and SDROE are 9.2483 and 0.0189, respectively. The relatively large standard deviation of the Z-score (1.2923) suggests substantial variation in financial stability across firms in the financial insurance sector.

The average overall ESG score is 56.0899, with mean scores of 57.6938, 57.2057, and 55.2094 for the environmental, social, and governance dimensions, respectively. Among these, the governance score is comparatively lower. In addition, the standard deviations of ESG and its sub-dimensions indicate considerable dispersion in ESG performance across firms. Furthermore, the average proportion of female directors is 0.1561, suggesting that female representation on corporate boards remains relatively limited within the sample.

Table 2
Descriptive Statistics of Variables

Variable	Mean	Median	Std. dev.	Min	Max
Z-score	9.2483	9.1250	1.2923	5.3565	14.3264
SDROE	0.0189	0.0110	0.0277	0.0002	0.2440
ESG	56.0899	55.0100	8.5736	37.9800	79.2700
E	57.6938	58.7300	14.0054	29.9300	87.5300
S	57.2057	55.9700	13.3828	31.2200	86.3100
G	55.2094	55.4000	9.4042	32.4100	77.4700
PFD	0.1561	0.1429	0.1215	0.0000	0.5714
FS	20.1262	20.6994	1.7160	16.4594	23.2141
FA	30.1856	23.0000	18.2252	5.0000	77.0000
ROA	0.0114	0.0063	0.0193	-0.0709	0.149
BS	11.7157	12.0000	3.4643	6.0000	22.0000
ID	0.3011	0.2727	0.0897	0.1818	0.6000
EA	0.5566	1.0000	0.4974	0.0000	1.0000

B. Correlation Matrix and VIF Values

This study employs Pearson correlation analysis to examine the linear relationships among variables and to provide a preliminary assessment of multicollinearity. As reported in Table 3, ESG performance and the proportion of female directors are not significantly correlated with either the Z-score or SDROE. However, the social dimension is negatively and significantly correlated with SDROE ($r=-0.131$), suggesting that stronger social performance is associated with lower solvency risk. External assurance is positively correlated with overall ESG performance and its individual dimensions. Except for the correlations between ESG and the social dimension, and between board size and the proportion of independent directors—both exceeding 0.7—all other correlation coefficients are below the conventional threshold, indicating moderate to weak correlations. To further assess multicollinearity, this study conducts variance inflation factor (VIF) tests. Consistent with Gujarati and Porter (2009), all VIF values are below 4, suggesting that multicollinearity is unlikely to affect the regression results.

Table 3
Pearson's Correlation Matrix VIF Values

	Z-score	SDROE	ESG	E	S	G	PFD	FS	FA	ROA	BS	ID	EA
Z-score	1												
SDROE	-0.674***	1											
ESG	0.056	-0.086	1										
E	-0.104	0.024	0.623***	1									
S	0.106	-0.131***	0.842***	0.515***	1								
G	-0.015	-0.009	0.679***	0.223***	0.227***	1							
PFD	0.086	0.004	0.026	-0.088	-0.073	0.166***	1						
FS	0.100	-0.124	0.473***	0.408***	0.434***	0.270***	0.019	1					
FA	-0.114	0.070	0.050	0.002	0.128***	-0.081	-0.111	-0.381***	1				
ROA	-0.090	-0.100	-0.095	0.082	-0.102	-0.103	-0.010	-0.258***	0.149***	1			
BS	0.166***	-0.181***	-0.033	-0.069	0.085	-0.134***	0.154***	0.008	0.014	-0.216***	1		
ID	-0.189***	0.224***	0.040	0.145***	-0.040	0.076	-0.136***	0.182***	-0.176***	0.174***	-0.714***	1	
EA	0.019	-0.087	0.568***	0.501***	0.566***	0.238***	0.014	0.436***	0.006	0.095	-0.061	0.087	1
VIF			1.84	1.79	2.10	1.27	1.17	2.37	1.51	1.32	2.46	2.54	1.95

Notes: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

PFD=Percentage of female directors, FS= Firm size, FA= Firm age, BS= Board size, ID= Independent directors, EA= External assurance

C. Regression Results

1. The Effects of ESG Performance and Its Dimensions on Solvency Risk

Table 4 reports the results of the pooled OLS regressions with year fixed effects and firm-clustered standard errors. The dependent variables are the Z-score and SDROE, which capture financial stability and earnings volatility, respectively. Columns (1) and (3) report the results for overall ESG performance. ESG performance is not significantly associated with the Z-score but is positively associated with SDROE at the 10% significance level. Given that a higher SDROE indicates greater earnings volatility and higher solvency risk, the results do not support the hypothesized negative relationship between ESG performance and solvency risk. Therefore, H1 is not supported. One possible explanation is that ESG investments may involve upfront costs and uncertain short-term payoffs, potentially increasing performance volatility (McWilliams and Siegel, 2000). Columns (2) and (4) report the results for the individual ESG dimensions. Environmental performance is negatively and significantly associated with the Z-score and positively and significantly associated with SDROE. Because a lower Z-score and a higher SDROE both indicate greater solvency risk, these results are contrary to the hypothesized risk-reducing effect of environmental performance. Therefore, H2 is not supported. This finding is consistent with Oikonomou et al. (2012), who document a positive association between environmental performance and firm-level systematic risk. One possible explanation is that environmental investments may involve substantial upfront costs and delayed financial returns, thereby placing short-term pressure on firms' financial positions. In contrast, social performance is positively and significantly associated with the Z-score and negatively and significantly associated with SDROE. Both results indicate lower solvency risk and are therefore consistent with the hypothesized direction. Accordingly, H3 is supported. This finding is consistent with Lee and Koh (2024) and suggests that stronger social performance may enhance stakeholder trust and strengthen relationships with customers, employees, and other stakeholders, thereby contributing to greater financial stability. Governance performance is not significantly associated with either the Z-score or SDROE. Therefore, H4 is not supported. One possible explanation is that the effects of governance mechanisms on financial stability may take time to materialize and may therefore not be immediately reflected in short-term solvency outcomes (Li and Hu, 2025). Regarding the control variables, the proportion of independent directors is negatively and significantly associated with the Z-score and positively and significantly associated with SDROE, suggesting that greater board independence is associated with higher solvency risk in the sample. One possible explanation is that independent directors may have less firm- or industry-specific knowledge, potentially limiting the effectiveness of board monitoring in complex financial institutions (Lu and Boateng, 2018). Firm size is negatively associated with SDROE, suggesting that larger financial institutions experience lower earnings volatility, potentially reflecting greater diversification and economies of scale.

Table 4
The Effects of ESG Performance and Its Dimensions on Solvency Risk

Variable	Z-score (1)	Z-score (2)	SDROE (3)	SDROE (4)
Constant	9.1043*** (4.17)	9.3265*** (4.19)	0.0616 (1.64)	0.5961 (1.48)
ESG	0.0045 (0.37)		0.0001* (1.75)	
E		-0.0165** (-2.55)		0.0003** (2.15)
S		0.0166** (2.27)		-0.0003*** (-2.42)
G		-0.0046 (-0.44)		-0.0001 (-0.09)
FS	0.0446 (0.54)	0.0601 (0.79)	-0.0029* (-1.74)	-0.0031* (-1.95)
FA	-0.0107 (-1.39)	-0.0115 (-1.64)	0.0001 (1.47)	0.0002* (1.77)
ROA	-1.5924 (-0.37)	0.3138 (0.08)	-0.2966 (-1.58)	-0.3319 (-1.65)
BS	-0.0011 (-0.03)	-0.0068 (-0.17)	-0.0002 (-0.03)	0.0004 (0.05)
ID	-3.5258** (-2.18)	-3.3007** (-2.11)	0.0979** (2.26)	0.0932** (2.12)
Year	Yes	Yes	Yes	Yes
Observations	415	415	415	415
Adj. R ²	0.1474	0.1749	0.1712	0.1892

Notes: t-statistics based on firm-clustered standard errors are reported in parentheses. Year fixed effects are included in all specifications. *p < 0.10; **p < 0.05; ***p < 0.01.

2. Moderating Effect of Female Directors

This study adopts Villa et al.'s (2003) research method and uses a hierarchical regression analysis to examine the moderating effect of female directors and external assurance on the ESG performance and the firm's solvency risk. Table 5, Columns (1) and (3), report the moderating effect of female board representation on the relationships between ESG performance and the Z-score and SDROE, respectively. The interaction term ESG $\times$ PFD is negative and statistically significant for the Z-score ($\beta = -0.1083$, $p < .05$), but insignificant for SDROE. Given that a higher Z-score indicates greater financial stability and lower solvency risk, the negative interaction coefficient indicates that greater female board representation weakens the positive association between ESG performance and financial stability. Thus, although female board representation has a statistically significant moderating effect on the ESG–Z-score relationship, the direction of this effect is contrary to our initial expectation. Table 5, Columns (2) and (4), further report the moderating effect of female board representation on the relationships between environmental performance and the Z-score and SDROE, respectively. The interaction term E $\times$ PFD is negative and statistically significant for the Z-score but insignificant for SDROE, indicating that the relationship between environmental performance and the Z-score becomes more negative as female board representation increases. This unexpected finding suggests that the moderating role of female board representation may vary across ESG dimensions and risk measures, consistent with recent evidence that the effects of

board gender diversity on ESG–risk relationships are context- and dimension-dependent (Antari et al., 2025; Al-Shaer et al., 2026). As shown in Figure 1, the relationship between ESG performance and the Z-score is slightly positive at low levels of female board representation but becomes negative at high levels. This pattern is consistent with the negative and significant ESG $\times$ PFD interaction ($\beta = -0.1083$, $p < .05$), confirming that female board representation significantly moderates the ESG–solvency relationship, but in a direction contrary to H5. Therefore, H5 is not supported.

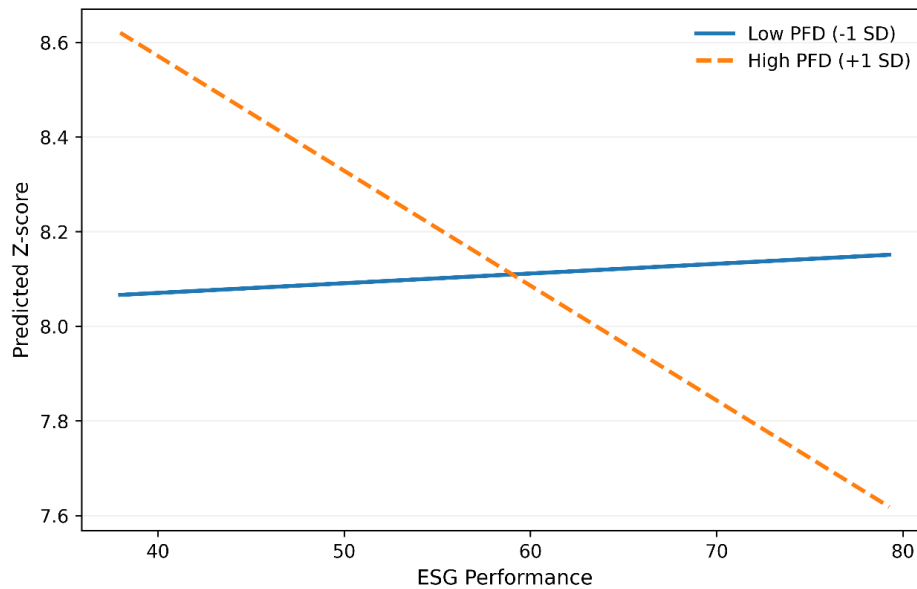
Table 5
Moderating Effect of Female Director on ESG Performance and Solvency Risk

Variable	Z-score (1)	Z-score (2)	SDROE (3)	SDROE (4)
Constant	8.9026*** (4.34)	9.6390*** (4.60)	0.0573 (1.56)	0.0565 (1.41)
ESG	0.0058 (0.70)		-0.0001 (-0.62)	
E		-0.0180*** (-3.32)		0.0003** (2.57)
S		0.0211*** (2.77)		-0.0003** (-2.51)
G		-0.0048 (-0.45)		-0.0001 (-0.05)
PFD	0.3184 (0.49)	0.4507 (0.68)	0.0172 (0.78)	0.0161 (0.77)
FS	0.0636 (0.79)	0.0431 (0.63)	-0.0028* (-1.69)	-0.0033 (-1.81)
FA	-0.0100 (-1.38)	-0.0138** (-1.96)	0.0002 (1.64)	0.0002 (1.99)
ROA	-1.1049 (-0.27)	1.1121 (0.29)	-0.3067 (-1.65)	-0.3508* (-1.75)
BS	0.0003 (0.01)	-0.0103 (-0.26)	-0.0001 (-0.11)	0.0001 (0.12)
ID	-3.6670** (-2.31)	-3.7621** (-2.68)	0.1020** (2.34)	0.1026** (2.22)
ESG $\times$ PFD	-0.1083** (-2.02)		0.0006 (0.43)	
E $\times$ PFD		-0.1183** (-2.09)		0.0010 (1.16)
S $\times$ PFD		0.0222 (0.38)		-0.0009 (-0.62)
G $\times$ PFD		-0.0045 (-0.07)		0.0009 (0.65)
Year	Yes	Yes	Yes	Yes
Observations	415	415	415	415
Adj. R ²	0.1553	0.1948	0.1773	0.1989

Notes: t-statistics based on firm-clustered standard errors are reported in parentheses. Year fixed effects are included in all specifications. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Figure 1

Illustrates the Moderating Effect of Female Board Representation on the Relationship between ESG Performance and Solvency Risk



3. Moderating Effect of External Assurance

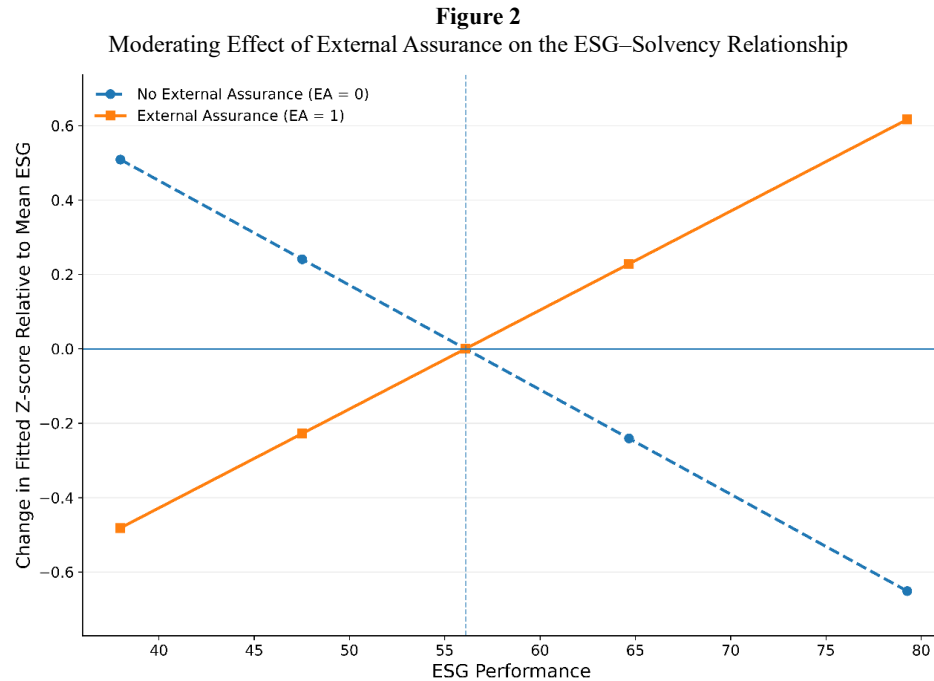
Table 6, Columns (1) and (3), report the moderating effect of external assurance (EA) on the relationship between ESG performance and the Z-score and SDROE, respectively. The interaction term $ESG \times EA$ is positive and statistically significant for the Z-score and negative and statistically significant for SDROE. Given that a higher Z-score indicates greater financial stability and a higher SDROE indicates greater earnings volatility, both interaction effects are consistent with the hypothesized risk-reducing moderating role of external assurance. These results suggest that external assurance strengthens the association between ESG performance and financial stability while reducing earnings volatility. One possible explanation is that third-party assurance enhances disclosure credibility, strengthens stakeholder trust, and reduces information asymmetry, thereby improving firms' financing conditions and solvency positions. For the individual ESG dimensions, $E \times EA$ is positive and statistically significant for the Z-score but insignificant for SDROE, suggesting that external assurance strengthens the association between environmental performance and financial stability, but provides no evidence of a moderating effect on earnings volatility. Similarly, $G \times EA$ is positive and statistically significant for the Z-score but insignificant for SDROE, indicating that its moderating effect is evident for financial stability as captured by the Z-score, but not for earnings volatility. Assurance may enhance the reliability of ESG disclosures and strengthen internal controls and stakeholder confidence (Edgley et al., 2010; Du and Wu, 2019). By contrast, $S \times EA$ is insignificant for both risk measures, possibly because social responsibility practices are already relatively institutionalized in the financial and

insurance industry, limiting the incremental benefits of external assurance (Weber, 2018). To further illustrate the moderating effect, Figure 2 plots the relationship between ESG performance and the Z-score conditional on external assurance. When $EA = 0$, the estimated ESG slope is negative ($\beta = -0.0281$), whereas when $EA = 1$, it becomes positive ($-0.0281 + 0.0547 = 0.0266$). Thus, the positive and statistically significant interaction coefficient ($\beta = 0.0547$, $p < .01$) indicates that external assurance shifts the estimated ESG–Z-score relationship from negative to positive. The lagged-ESG robustness specification shows a similar pattern, with corresponding slopes of -0.0262 and 0.0229 . Taken together, the significant $ESG \times EA$ interaction terms for both the Z-score and SDROE are consistent with the hypothesized moderating role of external assurance. Therefore, H6 is supported. However, the moderating effects for the individual ESG dimensions are not uniform across the two solvency-risk measures.

Table 6
Moderating Effect of External Assurance on ESG Performance and Solvency Risk

Variable	Z-score (1)	Z-score (2)	SDROE (3)	SDROE (4)
Constant	10.9605*** (8.29)	10.9974*** (8.42)	0.0146** (2.34)	0.0154** (2.46)
ESG	-0.0281* (-1.71)		0.0002*** (2.54)	
E		-0.0348*** (-2.95)		0.0001 (1.21)
S		0.0315** (2.29)		0.0001 (1.17)
G		-0.0274*** (-2.70)		0.0001 (1.32)
FS	0.0573 (1.19)	0.0723 (1.49)	-0.0012*** (-5.40)	-0.0013*** (-5.41)
FA	-0.0097** (-2.56)	-0.0116*** (-2.99)	0.0002 (1.20)	0.0001 (1.06)
ROA	0.7518 (0.22)	0.6728 (0.19)	0.0651*** (4.04)	0.0567** (3.33)
BS	-0.0254 (-0.95)	-0.0417 (-1.54)	-0.0003 (-0.29)	-0.0005 (-0.39)
ID	-4.2010*** (-3.94)	-3.8237*** (-3.70)	0.0122** (2.48)	0.0117** (2.35)
EA	-0.0153 (-0.09)	-0.0611 (-0.35)	0.0004 (0.50)	0.0002 (0.19)
ESG×EA	0.0547*** (2.66)		-0.0002** (-2.42)	
E×EA		0.0230* (1.75)		-0.0001 (-0.80)
S×EA		-0.0163 (-1.06)		-0.0001 (-1.50)
G×EA		0.0427*** (3.04)		-0.0001 (-1.12)
Year	Yes	Yes	Yes	Yes
Observations	415	415	415	415
Adj. R ²	0.1325	0.1635	0.2274	0.2247

Notes: t-statistics based on firm-clustered standard errors are reported in parentheses. Year fixed effects are included in all specifications. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.



Note: The figure shows the estimated change in the fitted Z-score relative to the sample mean of ESG performance (56.0899). The estimated ESG slopes are -0.0281 for firms without external assurance ($EA = 0$) and 0.0266 for firms with external assurance ($EA = 1$).

4. Robustness Tests: Addressing Endogeneity Concerns

Potential endogeneity concerns may arise from reverse causality and omitted-variable bias. To mitigate these concerns, we re-estimate the baseline models using one-period lagged ESG variables, with ESG performance measured in year ($t-1$) and solvency risk in year (t). This specification establishes temporal ordering and helps mitigate concerns about contemporaneous reverse causality and simultaneity. The lagged-ESG results, including the estimated coefficients and significance levels, are reported in Tables 7 and 8. The findings are broadly consistent with the baseline results, with the main effects of ESG performance and the moderating effects of female board representation and external assurance exhibiting similar patterns, although some differences in coefficient magnitudes and statistical significance are observed. Importantly, we acknowledge that lagging ESG does not fully address omitted-variable bias or unobserved heterogeneity. Therefore, the lagged specification is interpreted as a robustness check rather than a definitive solution to endogeneity. Overall, the results provide additional evidence regarding the robustness of the main findings.

Table 7
Moderating Effect of Female Directors on the Relationship between ESG Performance and Solvency Risk (ESG Lagged by One Period)

Variable	Z-score (1)	Z-score (2)	SDROE (3)	SDROE (4)
Constant	9.3642*** (4.42)	9.8149*** (4.33)	0.0559 (1.50)	0.0531 (1.28)
ESG	0.0014 (0.11)		-0.0002 (-1.02)	
E		-0.0169*** (-2.81)		0.0002* (1.98)
S		0.0162* (1.97)		-0.0003** (-2.13)
G		0.0004 (0.03)		-0.0001 (-0.30)
PFD		0.7415 (1.03)		
FS	0.0305 (0.38)	0.0118 (1.15)	-0.0024 (-1.34)	-0.0026 (-1.45)
FA	-0.0120* (-1.70)	-0.0236* (-1.91)	0.0002 (1.76)	0.0002* (1.88)
ROA	-3.4993 (-0.78)	-2.3555 (-0.55)	-0.3020 (-1.64)	-0.3200 (-1.64)
BS	-0.0004 (0.041)	-0.0022 (-0.05)	-0.0001 (-0.13)	-0.0004 (-0.05)
ID	-3.1421** (-2.25)	-3.8237** (-2.53)	0.1013** (2.35)	0.0975** (2.17)
ESG×PFD	-0.1295* (-1.93)		0.0005 (0.30)	
E×PFD		-0.1245** (-2.40)		0.0009 (1.11)
S×PFD		-0.0123 (-0.20)		-0.0004 (-0.31)
G×PFD		0.0510 (0.71)		-0.0006 (-0.52)
Year	Yes	Yes	Yes	Yes
Observations	414	414	414	414
Adj. R ²	0.1687	0.2048	0.1804	0.1897

Notes: t-statistics based on firm-clustered standard errors are reported in parentheses. Year fixed effects are included in all specifications. *p < 0.10; **p < 0.05; ***p < 0.01.

Table 8
Moderating Effect of External Assurance on the Relationship between ESG Performance and Solvency Risk (ESG Lagged by One Period)

Variable	Z-score (1)	Z-score (2)	SDROE (3)	SDROE (4)
Constant	11.1377*** (8.80)	11.0272*** (8.57)	0.0396 (0.89)	0.0409 (0.92)
ESG	-0.0262* (-1.74)		0.0002 (0.31)	
E		-0.0287*** (-2.79)		0.0003 (1.51)
S		0.0159 (1.32)		-0.0004 (-1.141)
G		-0.0183* (-1.80)		-0.0001 (-0.05)
FS	0.0399 (0.82)	0.0580 (1.17)	-0.0027 (-1.56)	-0.0029* (-1.79)
FA	-0.0107** (-2.80)	-0.0117 *** (-2.97)	0.0001 (1.57)	-0.0002** (-2.01)
ROA	-1.9188 (-0.55)	-1.5398 (-0.44)	-0.3243 (-1.63)	-0.3167 (-1.48)
BS	-0.0258 (-0.97)	-0.0335 (-1.23)	0.0003 (0.29)	0.0004 (0.41)
ID	-3.6713*** (-3.51)	-3.1749*** (-3.03)	0.1061** (2.56)	0.0982** (2.23)
EA		-0.0680 (-0.40)		
ESG×EA	0.0491** (2.55)		-0.0007* (-1.72)	
E×EA		0.0175 (1.45)		-0.0002 (-0.67)
S×EA		-0.0027 (-0.19)		0.0001 (0.34)
G×EA		0.0335** (2.33)		-0.0005 (-1.31)
Year	Yes	Yes	Yes	Yes
Observations	414	414	414	414
Adj. R ²	0.1383	0.1551	0.1815	0.1901

Notes: t-statistics based on firm-clustered standard errors are reported in parentheses. Year fixed effects are included in all specifications. *p < 0.10; **p < 0.05; ***p < 0.01.

V. CONCLUSION AND PRACTICAL IMPLICATIONS

A. Conclusions

This study contributes to the sustainable finance and corporate governance literature in four ways. First, while prior ESG research has focused on firm value, stock volatility, and credit risk, evidence linking ESG to solvency risk-especially in financial and insurance sectors-is limited. Using Z-score and earnings volatility to measure insolvency probability, this study shifts the focus from market-based risk to accounting-based financial stability, extending ESG-risk research into prudential stability. Second, by

decomposing ESG into environmental, social, and governance dimensions, we show their effects on solvency risk are heterogeneous: environmental performance may increase short-term risk, whereas social performance enhances long-term stability, challenging the assumption that ESG uniformly reduces risk. Third, female board representation emerges as a conditional mechanism in the ESG–solvency relationship; however, the observed moderating pattern does not support the hypothesized risk-reducing role. In the Z-score specification, greater female board representation attenuates rather than strengthens the association between ESG performance and financial stability. This unexpected finding suggests that the governance role of female directors in translating ESG engagement into solvency outcomes may depend on contextual and institutional conditions. Fourth, external assurance conditions the ESG–solvency relationship in selected specifications, particularly for financial stability measured by the Z-score. These findings highlight the role of disclosure credibility as an important boundary condition, although the moderating effects are not uniform across ESG dimensions or solvency-risk measures. Overall, this study integrates ESG performance, board gender diversity, and disclosure assurance into a unified framework explaining solvency dynamics, offering insights for regulators and policymakers on sustainable finance and systemic stability.

B. Practical Implications

This study offers several policy implications. First, ESG investments—particularly in the environmental dimension—may involve short-term costs that increase solvency risk, suggesting that managers should carefully balance sustainability objectives with financial stability considerations. Second, board gender diversity moderates the relationship between ESG initiatives and solvency outcomes, highlighting the importance of effective board oversight in sustainability strategies. Third, external assurance enhances disclosure credibility and mitigates information asymmetry, thereby contributing to improved financial resilience. Furthermore, these findings may serve as a reference for regulatory authorities in designing future financial and insurance policies that promote sustainable finance while maintaining systemic stability.

C. Research Limitations and Future Directions

This study has several limitations. First, the sample size is relatively small, which may limit generalizability; future research could expand the time span or adopt cross-industry comparisons to improve external validity. Second, additional variables related to female directors, such as education level or the participation of female independent directors, could provide a more nuanced understanding of their impact on solvency risk. Finally, future studies could incorporate ESG data from multiple rating agencies, such as MSCI or S&P Global, to enhance measurement accuracy and offer a more comprehensive perspective on ESG performance and financial stability.

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