

Does Sustainability Lower Financing Costs? Evidence from a Dynamic System GMM Analysis

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Abstract: This study provides a comprehensive examination of the non-linear relationship between environmental, social, and governance (ESG) performance and firms' cost of debt. Using a balanced panel dataset of 461 U.S. non-financial firms for the period 2019–2023, the analysis employs the dynamic System-GMM estimator to address potential endogeneity, lagged dependence, and unobserved firm-level heterogeneity. The empirical findings reveal a clear U-shaped relationship between ESG performance and the cost of debt. Moderate ESG engagement enhances creditworthiness and reduces borrowing costs, whereas excessive or unbalanced ESG commitments can increase firms' financing burdens. Robustness analyses confirm the presence of similar non-linear effects across the environmental, social, and governance dimensions, with environmental performance emerging as the strongest driver of the observed pattern. The social and governance pillars also exert significant, albeit relatively weaker, influences on borrowing costs. Overall, the results demonstrate that ESG functions as a dual-purpose strategic resource with the potential to either create value or impose financial pressures depending on its intensity. By highlighting the importance of maintaining a balanced and optimal level of ESG engagement to improve financing conditions, this study offers a meaningful contribution to the corporate finance and sustainability literature.

Keywords: ESG, Cost of Debt, System GMM

Jel Codes: G30, G32, Q56

Sürdürülebilirlik Uygulamaları Finansman Maliyetlerini Azaltır mı? Dinamik Sistem GMM Analizinden Bulgular

Öz: Bu çalışma, çevresel, sosyal ve yönetim (ESG) performansı ile firmaların borçlanma maliyeti arasındaki doğrusal olmayan ilişkiyi kapsamlı biçimde incelemektedir. 2019–2023 döneminde ABD’de faaliyet gösteren 461 finans dışı firmadan oluşan dengeli panel veri seti, potansiyel içsellik sorunlarını, gecikmeli bağımlılıkları ve firma düzeyindeki gözlemlenemeyen heterojenliği kontrol edebilmek amacıyla dinamik System-GMM yöntemiyle analiz edilmiştir. Ampirik bulgular, ESG performansı ile borçlanma maliyeti arasında belirgin bir U-şekilli ilişki olduğunu ortaya koymaktadır. Buna göre, orta düzeyde ESG uygulamaları kredi değerliliğini artırarak borçlanma maliyetlerini düşürürken, aşırı ve dengesiz ESG taahhütleri firmaların finansman yükünü artırmaktadır. Sağlık analizleri, çevresel, sosyal ve yönetim boyutlarının her birinde benzer eğrisel etkilerin ortaya çıktığını doğrulamış; özellikle çevresel performansın borçlanma maliyeti üzerindeki etkinin en güçlü belirleyicisi olduğu tespit edilmiştir. Sosyal ve yönetim boyutları da anlamlı, ancak daha düşük düzeyde etkiler üretmektedir. Genel olarak bulgular, ESG'nin firmalar için hem değer yaratma hem de maliyet oluşturma potansiyeli taşıyan çift yönlü bir stratejik kaynak olduğunu göstermektedir. Bu çalışma, firmaların finansman koşullarını iyileştirebilmeleri için ESG uygulamalarını dengeli, gerçekçi ve optimal bir seviyede yönetmeleri gerektiğini vurgulayarak literatüre önemli bir katkı sunmaktadır.

Atf: Zengin, B. (2026). Does sustainability lower financing costs? Evidence from a dynamic system GMM analysis. *Fiscaoeconomia*, 10(1), 1-16.

<https://doi.org/10.25295/fsecon.1762645>

Geliş Tarihi: 12.08.2026

Kabul Tarihi: 18.12.2026



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Anahtar Kelimeler: ESG, Borç Maliyeti, Sistem GMM

Jel Kodları: G30, G32, Q56

1. Introduction

In recent years, the growing recognition of global environmental degradation, climate-related financial risks, and widening social inequalities has elevated Environmental, Social, and Governance (ESG) performance to the forefront of business and financial decision-making. Investors, regulators, and other stakeholders increasingly expect firms to demonstrate responsible and transparent practices, not only to safeguard long-term value creation but also to ensure resilience against sustainability-related risks. As a result, ESG has evolved from a voluntary corporate initiative into a strategic imperative that influences investment decisions, risk assessment, and overall firm valuation. Driven by regulatory pressures, investor expectations, and broader sustainability concerns, firms have increasingly integrated ESG considerations into their operations and disclosures. While the ethical rationale for ESG adoption is widely acknowledged, its financial implications—particularly in terms of firms' access to capital and cost of financing—remain subject to ongoing academic debate.

A growing body of empirical literature supports the argument that ESG performance enhances firm value by lowering perceived risk and improving stakeholder relations. From the perspective of the resource-based theory (RBT), ESG-related activities function as intangible strategic resources that bolster legitimacy, reduce information asymmetry, and enhance firms' reputational capital (Zheng et al., 2025; Tawfiq et al., 2024; Biswas et al., 2025). Consequently, firms with stronger ESG credentials are viewed as more creditworthy, often enjoying better financing terms and lower borrowing costs. This view has found support in studies highlighting the positive role of ESG in improving credit access, reducing risk premiums, and fostering long-term value creation. However, recent research challenges the assumption that ESG engagement is uniformly beneficial. According to the trade-off theory, firms must weigh the costs and benefits of strategic investments, including ESG initiatives (Friedman, 2007; Li et al., 2024). Beyond a certain threshold, ESG expenditures may result in diminishing marginal returns, inefficient capital allocation, or symbolic compliance—thereby undermining financial performance. The overinvestment hypothesis further posits that excessive ESG engagement may reflect managerial self-interest or misalignment with shareholder value, potentially increasing a firm's risk profile in the eyes of creditors (Liu et al., 2020; Nguyen et al., 2022).

This underscores the necessity of investigating the ESG–finance relationship in greater detail, particularly through the use of nonlinear models. Several recent studies suggest a U-shaped relationship between ESG scores and financial outcomes such as cost of capital, firm value, or debt structure. These findings imply that while moderate ESG engagement can reduce financing costs, excessive efforts may lead to adverse outcomes due to overcommitment or market skepticism. Despite these insights, empirical studies specifically focusing on the nonlinear impact of ESG performance on the cost of debt remain limited. Moreover, the role of individual ESG pillars—Environmental, Social, and Governance—has not been fully disentangled in the context of borrowing costs.

To address these gaps, this study employs a balanced panel dataset comprising 461 non-financial firms operating in the United States over the period 2019–2023. The focus on non-financial companies reflects the need to avoid distortions arising from the distinct regulatory, capital structure, and accounting characteristics of financial institutions. The U.S. context is selected due to its mature capital markets, diverse corporate governance structures, and the availability of firm-level ESG disclosure data from standardized databases, which enhance the reliability and comparability of ESG assessments across firms and industries.

The United States was chosen because it has (i) deep and mature capital markets, (ii) strict and standardized ESG disclosure frameworks (such as S&P Global and Refinitiv), and (iii) substantial cross-firm variation in ESG practices. This variation is essential for empirically identifying non-linear ESG effects, as it provides sufficient dispersion across firms' sustainability engagement levels. In addition, U.S. non-financial firms follow

relatively comparable financial reporting structures, which reduces accounting heterogeneity bias and enhances the reliability of cross-firm comparisons.

Following this justification, the dependent variable is the cost of debt (CD), while the key explanatory variable is the ESG score, measured both in aggregate form and by its three subcomponents (E, S, and G) for robustness checks. Control variables include firm profitability (ROA), leverage (debt-to-equity ratio), firm size (logarithm of total assets), and firm age, each justified by their established influence on firms' credit conditions and financing costs in prior literature.

This study seeks to fill these gaps in the literature by empirically examining the U-shaped relationship between ESG and the cost of debt—both in aggregate and disaggregated forms—through dynamic panel GMM estimation. This study investigates whether ESG engagement—when calibrated at optimal levels—serves as a value-generating asset that improves credit conditions, or conversely, if excessive ESG efforts raise concerns among creditors and increase borrowing costs. The findings contribute to the literature providing a perspective of ESG's financial consequences and emphasizing the strategic importance of aligning ESG initiatives with firm capacity and stakeholder expectations. By integrating both RBT and trade-off theory perspectives, this study sheds light on the dual nature of ESG as both an opportunity and a constraint in corporate finance. The results have practical implications for managers, investors, and policymakers seeking to optimize ESG strategies in a way that supports financial sustainability.

The study continues with the literature review, methodology, empirical results, discussion, policy implications and limitations, and future research sections.

2. Literature Review

The relationship between ESG performance and firms' cost of debt has been widely examined in prior research. Studies arguing that environmental, social, and governance practices enhance firm value often base this claim on improved risk management. Successful ESG practices contribute to a perception of lower risk among investors and creditors, leading to reduced borrowing costs. Empirical findings also suggest that effective corporate social responsibility (CSR) strategies improve firms' access to finance. These improvements are attributed to enhanced stakeholder engagement, reduced agency costs, and lower information asymmetry through greater transparency (La Rosa et al., 2018; Zheng, 2021). Accordingly, when examined from a long-term value creation perspective, firms with stronger sustainability performance are believed to be better positioned in capital markets to secure funding. This view is shared by lenders, investors, and corporate managers. The shared perception, particularly among lenders, is that firms with high ESG scores are more stable and better equipped to withstand unexpected disruptions (Liu, 2024). As firms benefit from easier access to finance and lower risk premiums, their overall creditworthiness improves, thereby reducing their cost of debt (Amarna et al., 2023). In this context, ESG serves as a key mechanism for the efficient allocation of scarce financial resources (Cheng et al., 2014).

Recent empirical studies reinforce the inverse relationship between ESG performance and cost of debt (Biswas et al., 2025; Rong & Kim, 2024; Eliwa et al., 2021). These studies show that credit agencies now consider non-financial factors such as ESG initiatives, not just profitability, when making lending decisions (Manhath, 2024). This perspective supports resource-based theory, which views ESG performance as a strategic, intangible asset that enhances a firm's competitive advantage (Zheng et al., 2025; Tawfiq et al., 2024; Biswas et al., 2025). According to this framework, resources fall into three categories: (1) physical assets and the technologies or skills required to utilize them, (2) human and organizational capabilities such as culture, commitment, integration, and communication, and (3) intangible resources like reputation and political acumen (Russo & Fouts, 1997).

In this context, ESG practices act as intangible resources that support sustainable firm growth by providing access to critical resources. As such, ESG performance signals stronger management quality, more robust risk mitigation, and long-term growth

potential—attracting investors who prioritize sustainability. For example, a company with a strong environmental management system may be better positioned to comply with future regulations, reducing the risk of costly non-compliance. This favorable perception may increase investor demand for the firm's securities, lowering its cost of capital (Wang, 2025).

Some studies further investigate the conditions under which the ESG-cost of debt relationship becomes stronger or weaker. According to Manhath (2024), the strength of this negative relationship can vary across the firm's life cycle. The effect is generally negative across all stages but is more pronounced during the growth and maturity phases. Additionally, the findings suggest that environmental and social factors play a greater role than governance factors in reducing borrowing costs. This suggests that creditors may be more willing to provide lower-interest funding to companies with higher environmental and social performance. Similarly, governance structures can moderate this relationship. Zhu et al. (2024) finds that larger and more independent boards have a regulatory effect that enhances the impact of ESG on cost of debt. Furthermore, board diversity strengthens this effect, reinforcing the role of governance in shaping the ESG-financing relationship. These findings support the argument that ESG should be seen as a source of value creation, with various internal and external factors influencing the strength of its impact on borrowing costs.

Evidence from Turkey also aligns with these conclusions. Empirical studies indicate that higher ESG performance not only increases firms' profitability but also reduces their cost of debt, reflecting improved access to external finance and enhanced creditor confidence. In particular, environmental and social performance appear to play a more pronounced role in lowering borrowing costs, while governance shows a smaller or less consistent effect (Güngör Karyağdı & Şit, 2022; Atasel & Güneysu, 2023). These findings support the view that ESG engagement can strengthen financial stability and signal operational resilience to stakeholders.

However, an alternative view considers ESG costs as the result of a negotiation between firms and society over who bears them (Goss & Roberts, 2011). The company's incurring of implementation costs implies a costly transfer of limited resources to external stakeholders and may lead firms to diverge from the objective of maximizing shareholder wealth. Excessive ESG investments may reflect managerial pursuit of prestige or personal goals, leading to inefficient decisions that fail to benefit creditors, investors, or the firm itself (Jo & Harjoto, 2012; Barnea & Rubin, 2010). According to this view, known as overinvestment theory, ESG expenditures may be seen as a wasteful allocation of resources, resulting in higher debt costs and risk premiums (Liu et al., 2020; Nguyen et al., 2022). Rational agents value ESG investments only when their marginal benefits exceed their marginal costs (Stellner et al., 2015). However, these perceptions may vary across stakeholder groups, making it essential to adopt a multi-stakeholder perspective when designing ESG strategies.

Sustainability practices can also yield different outcomes for investors and creditors. While ESG initiatives may reduce information asymmetry and facilitate risk assessment for creditors, they may be seen as reducing short-term profitability for investors. It is also possible that creditors may respond to sustainability practices outside the general trend in the literature. Some creditors might even view ESG initiatives as unnecessary costs or risky ventures (Magnanelli & Izzo, 2017). Therefore, the trade-off theory also deserves attention. According to this perspective, a firm's primary objective is to maximize profitability, and all activities should be aligned with this goal by balancing associated costs and benefits (Friedman, 2007). ESG initiatives should also be implemented by taking this balance into account. Higher ESG commitment could raise compliance costs, which may negatively affect short-term profitability (Dua & Sharma, 2024).

To explain these complex and sometimes contradictory effects, recent studies have turned to non-linear models (Wang, 2025; Zheng et al., 2025; Tawfiq et al., 2024; Bellavite Pellegrini et al., 2019; Li et al., 2024). Wang (2025) notes that ESG improves firm

performance up to a certain score threshold (65) by reducing risk and enhancing reputation, but beyond that point, the benefits diminish. Excessive ESG efforts may misallocate resources, distract from core operations, and raise skepticism among market participants. Similarly, Zheng et al. (2025) find that excessive ESG activities reduce firm value, with high costs and misallocated capital cited as potential drivers. In comparing U.S. and Chinese banks, their study shows that the adverse impact of excessive ESG investment is more prominent in the U.S., where ESG practices are more mature and scrutinized. In contrast, investors in less developed ESG markets like China may not interpret high ESG scores negatively.

Tawfiq et al. (2024) propose a U-shaped relationship, where both very low and very high ESG scores are associated with higher capital costs. Low ESG scores may signal poor risk management, while overly high scores may imply overemphasis on ESG at the expense of other strategic concerns. This supports the idea that firms should pursue moderate levels of ESG engagement to optimize firm value and meet shareholder expectations. Bellavite Pellegrini et al. (2019) similarly find a U-shaped relationship between ESG scores and cost of equity. Li et al. (2024), analyzing the relationship between ESG and firms' debt structure, found evidence supporting the trade-off theory by documenting a non-linear relationship between ESG scores and long-term debt. Their results suggest that ESG scores are negatively associated with long-term debt at the early stages of ESG engagement but positively associated when ESG scores are relatively high, corresponding to more advanced ESG implementation stages. Zhang & Xiong (2024) also underscore that the relationship between ESG and financial performance is non-linear and that the costs and benefits of ESG engagement must be carefully assessed. They emphasize the importance of determining whether ESG represents a strategic asset or a cost burden during the process of long-term value creation. In their analysis, short-term input costs are evaluated alongside long-term potential gains such as enhanced brand image, investor appeal, regulatory compliance, and risk mitigation, offering a comprehensive view of the impact of sustainability initiatives on firm performance.

In light of these findings, this study tests a non-linear hypothesis, exploring whether ESG engagement follows a U-shaped pattern:

H₁: The relationship between ESG performance and the cost of debt is U-shaped, such that moderate ESG engagement lowers borrowing costs, whereas excessive ESG engagement increases them.

To summarize the theoretical foundation of this study, the figure below illustrates how the relationship between ESG performance and the cost of debt, representing the core research question, varies across different levels of ESG engagement.

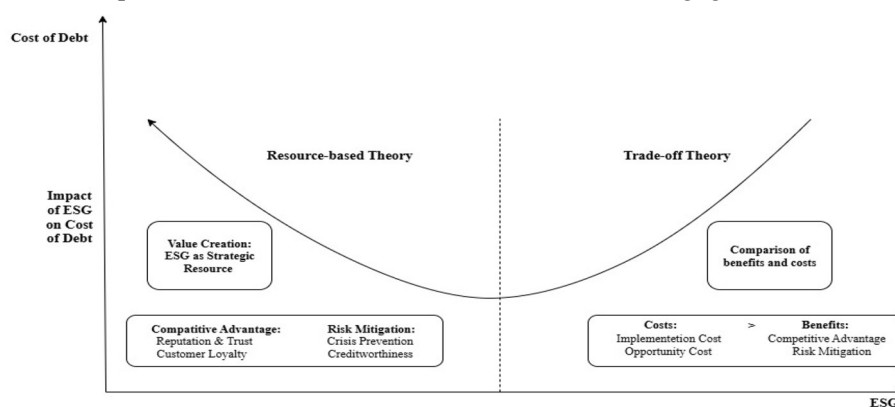


Figure 1. ESG - Cost of Debt Relationship (Source: own elaboration.)

3. Methodology

The primary purpose of this study is to investigate how corporate sustainability practices affect firms' cost of debt. Grounded in the resource-based theory, it has been

widely hypothesized in the literature that firms with strong ESG performance tend to benefit from lower costs of debt. However, this study questions the realism of that assumption by investigating whether, conversely, ESG initiatives may increase the cost of already limited resources. Accordingly, this paper aims to provide a detailed analysis of the overall ESG–cost of debt relationship, offering novel insights into the non-linear dynamics between corporate sustainability performance and borrowing costs.

To address this research question, the empirical analysis relies on a dynamic System-GMM estimation. The main specification focuses exclusively on the overall ESG index, which constitutes the core explanatory variable of the study. The Environmental (E), Social (S), and Governance (G) pillars are examined separately only as robustness checks, in order to assess whether the non-linear relationship observed for the composite ESG score persists across its individual components. Accordingly, the empirical framework consists of one primary model, supported by three supplementary robustness estimations, rather than four alternative main models.

The empirical analysis covers a panel of 461 U.S. firms for the period 2019–2023. ESG data are sourced from S&P Global, while all other financial variables are retrieved from the Refinitiv Eikon database. The dependent variable is the cost of debt (CD), which captures the financial burden of external resources. Following prior literature, a firm-specific, accounting-based measure is employed, calculated as the ratio of interest expense to average debt (Eliwa et al., 2021; Li et al., 2024; Malik & Kashiramka, 2024; Shi et al., 2024).

The key explanatory variable is the overall ESG score, reflecting a firm’s composite sustainability performance. In this study, the contemporaneous ESG score (ESG_{it}) is used, as the primary goal is to assess how current sustainability practices influence current borrowing costs. The squared term of ESG is included to test for possible nonlinearities in the ESG–cost of debt relationship. This specification allows the investigation of varying marginal effects, such as diminishing returns or rising costs beyond a certain ESG engagement threshold. Prior studies (Zhang & Xiong, 2024; Tawfik et al., 2024; Çetenak et al., 2023; Zheng et al., 2025) have documented similar U-shaped relationships, suggesting that while moderate ESG activity reduces financing costs, excessive ESG investment may lead to higher financial burdens due to operational inefficiencies or skepticism about the firm’s motives.

Control variables include return on assets (ROA), leverage ratio (debt/equity), firm size (log of total assets), and firm age. These were selected based on existing literature to capture firm-specific characteristics that may influence the cost of debt and ensure a more robust estimation. The variables used in the model are explained in the table below.

Table 1. Variable Definitions

Variable	Obs	Mean	Std. Dev.
Cost of Debt	cd	Ratio of interest expense to average debt	Refinitiv Eikon
ESG Score	esg	Composite ESG index measuring overall sustainability performance	S&P Global
Return on Assets	roa	Net income / total assets, proxy for profitability	Refinitiv Eikon
Leverage	de	Debt-to-equity ratio, proxy for financial risk	Refinitiv Eikon
Firm Size	log_asset	Natural logarithm of total assets	Refinitiv Eikon
Firm Age	age	Number of years since firm establishment	Refinitiv Eikon

The baseline model investigates the relationship between ESG performance and firms’ cost of debt using both the linear and non-linear terms of ESG. The equation is specified as follows:

$$CD_{it} = \beta^0 + \beta^1 CD_{i,t-1} + \beta^2 ESG_{it} + \beta^3 (ESG_{it})^2 + \beta^4 ROA_{it} + \beta^5 DE_{it} + \beta^6 \log(Assets_{it}) + \beta^7 Age_{it} + \varepsilon_{it} \quad (1)$$

Equation (1) represents a dynamic panel data model, where $CD_{(i,t-1)}$ (the one-period lag of the dependent variable) captures the persistence of borrowing costs over time. Including the lagged dependent variable controls for the possibility that firms with historically high or low debt costs tend to maintain similar financing structures in

subsequent periods. This adjustment also mitigates potential endogeneity by accounting for unobserved firm-specific factors affecting both past and current cost of debt.

The primary explanatory variable, ESG, reflects a firm's overall sustainability performance. The squared term, $(ESG)^2$, captures potential nonlinearities—allowing the identification of diminishing or reversing effects (e.g., a U-shaped relationship). A negative and significant β_2 followed by a positive and significant β_3 would indicate that moderate ESG engagement reduces debt costs, whereas excessive ESG commitment increases them.

Control variables such as profitability (ROA_{it}), leverage (DE_{it}), firm size ($\log(\text{Assets}_{it})$), and firm age (Age_{it}) are incorporated to account for financial characteristics that could independently influence debt pricing. This model tests the hypothesis that ESG performance is associated with lower financing costs up to a certain level, beyond which the effect may reverse due to diminishing returns or overinvestment.

The Generalized Method of Moments (GMM) model is used to estimate these equations. The GMM is particularly well-suited for panel data analyses characterized by potential endogeneity, unobserved firm-specific heterogeneity, and omitted variable bias. In the ESG-cost of debt relationship, bidirectional causality is a reasonable concern. Firms with lower borrowing costs may be more capable of allocating resources toward ESG-related activities, while strong ESG performance can, in turn, enhance access to capital and reduce financing costs. To mitigate such endogeneity concerns, GMM utilizes internal instruments, typically lagged values of explanatory variables, which serve as valid instruments under specific moment conditions (Blundell & Bond, 1998; Arellano & Bond, 1991). Moreover, the dynamic nature of the relationship, whereby historical ESG performance may affect present financial outcomes, further justifies the use of lagged independent and/or dependent variables. Accordingly, this study employs the system GMM estimator, which offers efficiency gains and improved instrument validity, particularly in cases involving small time dimensions.

In this context, Difference-GMM was not preferred because the dataset has (i) a short time dimension ($T=5$), (ii) highly persistent variables, and (iii) weak lagged instruments in levels. Under such circumstances, Difference-GMM suffers from weak instrumentation bias. System-GMM resolves this by combining equations in differences and levels, providing stronger instruments and improving estimator efficiency (Blundell & Bond, 1998). Hence, System-GMM is theoretically and empirically the more appropriate choice for this dataset.

To ensure the robustness of the findings, additional models are estimated using the Environmental (E), Social (S), and Governance (G) pillars separately. These supplementary estimations serve as robustness checks and are discussed in Section 5.

4. Empirical Results

The GMM model was used in the estimation of the primary model (overall ESG-cost of debt relationship). The ESG explanatory variable and control variables such as ROA (return on assets), DE (debt/equity), firm size (\log_asset), and age were used to explain the dependent variable, CD (cost of debt). The table below presents summary statistics for these key variables used in the empirical analysis.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
cd	2305	0.042	0.03	0.001	0.221
esg	2305	35.687	14.741	13	79
roa	2305	5.547	5.415	-8.15	24.16
de	2305	1.169	3.825	-18	18.83
log asset	2305	15.561	1.447	12.533	19.294
age	2305	76.65	48.778	6	205

The dependent variable, cost of debt (CD), has a mean of 4.2%, with values ranging from 0.1% to 22.1%. This suggests moderate variation in firms' cost of debt. The main explanatory variable, ESG score, exhibits substantial cross-sectional variation, with an average of 35.7 and a standard deviation of 14.7, ranging between 13 and 79. These values suggest meaningful cross-sectional variation in environmental, social, and governance performance across firms. Profitability measured by return on assets (ROA) has an average of 5.55%, which is in line with typical firm-level financial performance. Leverage, proxied by the debt-to-equity ratio (DE), shows a mean of 1.17 but a high standard deviation (3.83). Firm size, proxied by the logarithm of total assets (log_asset), has a mean of approximately 15.56, consistent with mid-to-large firms. Firm age also shows considerable variability, ranging from 6 to 205 years, with a mean of 76.65 years. This indicates that the sample includes both relatively new and very mature firms.

Table 3. Matrix of Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) cd	1.000					
(2) esg	-0.061*** (0.004)	1.000				
(3) roa	-0.033 (0.109)*	0.023 (0.260)	1.000			
(4) de	-0.061*** (0.003)	0.042** (0.042)	-0.087*** (0.000)	1.000		
(5) log_asset	-0.189*** (0.000)	0.599*** (0.000)	-0.024 (0.259)	0.089*** (0.000)	1.000	
(6) age	-0.085*** (0.000)	0.257*** (0.000)	-0.025 (0.238)	0.053** (0.010)	0.285*** (0.000)	1.000

*** p<0.01, ** p<0.05, * p<0.1

Table 3 presents the Pearson correlation coefficients among the main variables used in the empirical analysis. As shown in Table 3, the cost of debt is weakly but significantly negatively correlated with ESG ($r=-0.061$, $p<0.01$), suggesting that firms with higher sustainability performance tend to face slightly lower borrowing costs. It should be noted, however, that this linear correlation does not indicate a U-shaped relationship; the non-linear effect is formally tested through regression analysis. The cost of debt also exhibits significant negative correlations with leverage ($r=-0.061$, $p<0.01$), firm size ($r=-0.189$, $p<0.01$), and firm age ($r=-0.085$, $p<0.01$), implying that larger, more mature, and less leveraged firms generally enjoy lower borrowing costs.

Overall, the correlation coefficients are moderate and below common multicollinearity thresholds ($r<0.80$), indicating that the variables can be included in the same regression specification without serious multicollinearity concerns.

To examine the link between firms' ESG performance and their cost of debt, this study applies the GMM. The choice of GMM is primarily motivated by concerns regarding endogeneity, the dynamic nature of the relationship and unobserved heterogeneity. Specifically, ESG scores may be endogenous due to reverse causality, whereby firms with lower financing costs may have more resources or stronger incentives to engage in ESG practices (Goss & Roberts, 2011; Cheng et al., 2014). Moreover, time-invariant firm-specific effects and omitted variable bias may confound the estimates if not properly addressed (Wintoki et al., 2012). Additionally, the cost of debt is likely to be persistent over time, implying a dynamic structure that standard estimators like OLS or fixed effects may fail to capture efficiently (Blundell & Bond, 1998).

To mitigate these concerns, this study applies the dynamic panel GMM estimator, specifically the system GMM approach developed by Blundell & Bond (1998), which uses lagged levels and differences of the explanatory variables as internal instruments. This method yields reliable and efficient parameter estimates even when the model includes endogenous variables, serial correlation, and unobserved firm-specific effects, making it particularly appropriate for panel data analyses in corporate finance research. Therefore, GMM offers a robust empirical framework for assessing the causal impact of ESG performance on firms' borrowing costs.

Table 4 presents the results of dynamic panel estimations using the two-step System GMM method, where the dependent variable is the cost of debt (cd). The model evaluates the impact of overall ESG scores, along with its squared term, to capture potential non-linear effects.

Table 4. System GMM Estimation of ESG on Cost of Debt

	cd
cd_lag	0.312 (0.506)
esg	-0.057*** (0.000)
esg^2	0.010*** (0.000)
roa	-0.000 (0.126)
de	-0.000* (0.073)
log_asset	-0.005** (0.021)
age	-0.000 (0.234)
Constant	0.194*** (0.000)
Observations	1844
Hansen p-value	0.621
Sargan p-value	0.662
AR(1) p-value	0.073
AR(2) p-value	0.386

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Primary model investigates the impact of ESG performance on firms' borrowing costs. The coefficient for the ESG score ($\beta_2 = -0.057$, $p < 0.01$) is negative and statistically significant, indicating that higher ESG performance is associated with lower cost of debt. This suggests that firms engaging in sustainability practices are perceived as less risky by creditors, leading to reduced financing costs. However, the squared term ($\beta_3 = 0.010$, $p < 0.01$) is positive and significant, implying that the ESG–cost of debt relationship is U-shaped. This means that while moderate ESG engagement initially lowers borrowing costs, excessive ESG investment eventually leads to higher costs of debt. This finding challenges the traditional assumption that “more ESG is always better.” It supports the overinvestment hypothesis (Jo & Harjoto, 2012), which argues that beyond an optimal threshold, ESG spending may become inefficient or even detrimental to firm value. From a trade-off theory perspective, the result highlights that firms must balance the benefits of sustainability with the associated compliance and opportunity costs.

Among the control variables, the leverage ratio (de) is weakly negative and marginally significant ($p = 0.073$), suggesting that firms with higher leverage in this sample may enjoy lower borrowing costs—possibly reflecting better access to credit among mature and stable firms. Firm size (log_asset) shows a negative and statistically significant coefficient ($p = 0.021$), consistent with the expectation that larger firms face lower credit risk and enjoy favorable lending conditions. In contrast, profitability (ROA) and firm age are statistically insignificant, indicating limited explanatory power in this context. The dynamic term (cd_lag) is positive but insignificant ($p = 0.506$), implying limited persistence in borrowing costs once firm-level heterogeneity and endogeneity are controlled for.

Diagnostic statistics confirm the validity of the GMM specification. The Hansen ($p = 0.621$) and Sargan ($p = 0.662$) tests indicate that the instruments are valid and the model is not overidentified. The Arellano–Bond AR(1) test ($p = 0.073$) shows first-order serial correlation, which is expected in first-differenced GMM models, while the AR(2) test ($p = 0.386$) confirms the absence of second-order serial correlation—thus satisfying key GMM assumptions.

Overall, the results demonstrate a nonlinear (U-shaped) relationship between ESG performance and the cost of debt. Moderate ESG engagement enhances firms' creditworthiness and reduces financing costs, but excessive ESG activities may reverse this benefit due to potential overinvestment, inefficiencies, or perceived signaling risks. These findings extend the existing literature by empirically confirming that the financial benefits of ESG initiatives are not unlimited and depend on achieving an optimal balance between sustainability and financial efficiency. The following graphical analysis is presented to examine the link between ESG performance and debt costs. This visualization serves two primary purposes: first, to provide an understanding of the direction and shape of potential relationships among key variables, and second, to identify nonlinearities that may not be immediately apparent in the regression coefficients alone. This graphic was used to more clearly illustrate the nonlinear relationship found in the study's results.

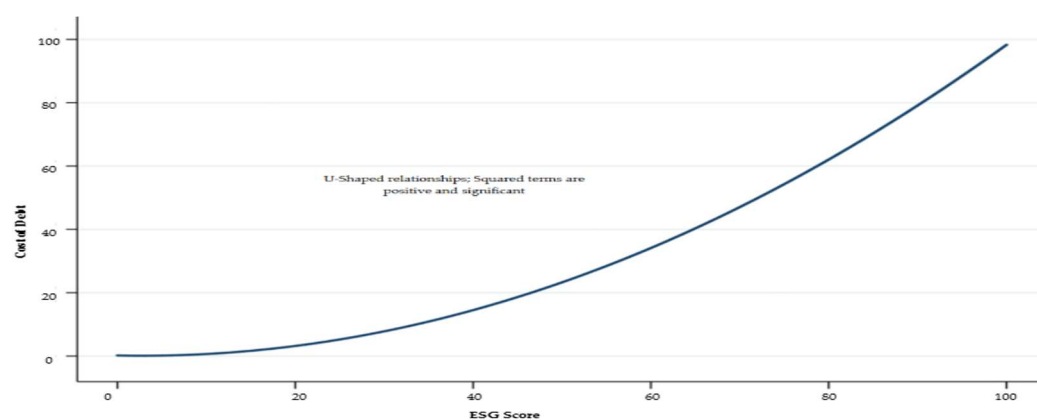


Figure 2. Effect of ESG Overall on Cost of Debt

Figure 2 illustrates the nonlinear relationship between ESG performance and the predicted cost of debt, confirming the U-shaped pattern identified in the regression analysis. The curve indicates that firms with either very low or very high ESG scores face higher borrowing costs, while those maintaining moderate ESG engagement benefit from comparatively lower debt costs. This supports the notion that both insufficient and excessive sustainability efforts can be viewed as risk factors by creditors—either due to weak risk management or potential inefficiencies and overinvestment. Overall, the visualization reinforces the importance of maintaining a balanced ESG strategy to optimize financial outcomes and align sustainability initiatives with credit market expectations.

5. Robustness Analysis

The robustness models using E, S, and G are not alternative main models but complementary tests conducted after estimating the primary ESG model. Their purpose is to assess whether the non-linear relationship identified in the main specification also appears when the ESG dimensions are examined separately.

To ensure the reliability of our results, we conducted several complementary tests. Because the ESG pillars are likely to be highly correlated with each other, three separate models were estimated for the Environmental (E), Social (S), and Governance (G) dimensions. This approach allows the analysis to identify which pillar primarily drives the overall ESG–cost of debt relationship while avoiding potential multicollinearity issues that could arise from including all dimensions simultaneously (Tawfiq et al., 2024).

The robustness check models were estimated using the first difference of the cost of debt (ΔCD) as the dependent variable. This adjustment captures how changes in firms' debt costs respond to variations in ESG pillar performance over time, rather than focusing

solely on their levels. Expressing the dependent variable in first differences also mitigates potential non-stationarity and unobserved firm-specific effects.

The pillar-specific models are formulated as follows:

$$CD_{it} = \beta^0 + \beta^1 CD_{i,t-1} + \beta^2 E_{it} + \beta^3 (E_{it})^2 + \beta^4 ROA_{it} + \beta^5 DE_{it} + \beta^6 \log(Assets_{it}) + \beta^7 Age_{it} + \varepsilon_{it} \quad (2)$$

$$CD_{it} = \beta^0 + \beta^1 CD_{i,t-1} + \beta^2 S_{it} + \beta^3 (S_{it})^2 + \beta^4 ROA_{it} + \beta^5 DE_{it} + \beta^6 \log(Assets_{it}) + \beta^7 Age_{it} + \varepsilon_{it} \quad (3)$$

$$CD_{it} = \beta^0 + \beta^1 CD_{i,t-1} + \beta^2 G_{it} + \beta^3 (G_{it})^2 + \beta^4 ROA_{it} + \beta^5 DE_{it} + \beta^6 \log(Assets_{it}) + \beta^7 Age_{it} + \varepsilon_{it} \quad (4)$$

Equation (2) focuses on the environmental (E) component of ESG to investigate whether environmental initiatives independently exhibit a non-linear relationship with the cost of debt. Similar to the primary model, both the linear and squared terms of the environmental score ($E_{i,t}$ and $(E_{i,t})^2$) are included to capture potential threshold effects. This specification evaluates whether moderate levels of environmental engagement are associated with reduced financing costs, while insufficient or excessive efforts may elevate perceived risks or operational inefficiencies. The control variables are retained as in the primary model to ensure consistency across model specifications.

Equation (3) analyzes the social (S) dimension of ESG. This model examines whether social performance—encompassing aspects such as labor practices, workforce diversity, and community involvement—demonstrates a non-linear effect on firms' debt financing conditions. The inclusion of both $S_{i,t}$ and $(S_{i,t})^2$ facilitates the identification of turning points in the relationship. This approach reflects the growing scholarly interest in the strategic versus symbolic implementation of socially responsible practices.

Equation (4) explores the governance (G) dimension of ESG to assess whether corporate governance quality exerts a non-linear influence on the cost of debt. While effective governance structures are typically associated with increased transparency, lower agency risks, and enhanced investor confidence, overly stringent governance mechanisms may impose unnecessary costs. By incorporating both the linear and squared terms of the governance score ($G_{i,t}$ and $(G_{i,t})^2$), this model investigates whether there exists an optimal level of governance from creditors' perspective. As with the previous models, the same set of financial control variables is included to isolate the governance effect.

Table 5 presents the results of dynamic panel estimations using the two-step System GMM method, where the analysis was re-estimated by separately including each ESG pillar (Environmental, Social, and Governance) in the model.

Table 5. System GMM Estimation of ESG Pillars on Cost of Debt

	cd (e)	cd(s)	cd(g)
cd_lag	0.117 (0.589)	0.307 (0.582)	0.337 (0.495)
e/s/g	-0.047*** (0.001)	-0.038*** (0.000)	-0.034*** (0.000)
e ² /s ² /g ²	0.009*** (0.000)	0.007*** (0.000)	0.006*** (0.000)
roa	-0.000** (0.022)	-0.000 (0.254)	-0.000 0.317
de	-0.000* (0.144)	-0.000 (0.125)	-0.000** (0.035)
log_asset	-0.007*** (0.009)	-0.005** (0.014)	-0.004* (0.054)
age	-0.000*** (0.000)	-0.000 (0.220)	-0.000 (0.298)
Constant	0.201*** (0.000)	0.162*** (0.001)	0.139*** (0.001)
Observations	1844	1844	1844
Hansen p-value	0.100	0.154	0.316
Sargan p-value	0.400	0.222	0.290
AR(1) p-value	0.110	0.116	0.131
AR(2) p-value	0.259	0.434	0.278

*** p<0.01, ** p<0.05, * p<0.1

The results of the three pillar-specific robustness models confirm the existence of a nonlinear (U-shaped) relationship between each ESG dimension and the cost of debt. Among the three dimensions, the Environmental (E) pillar exhibits the strongest statistical effect, as indicated by the magnitude and significance of both its linear (-0.0472 , $p < 0.01$) and squared (0.0097 , $p < 0.01$) coefficients. This finding suggests that lenders are particularly responsive to firms' environmental performance, rewarding moderate levels of environmental engagement while penalizing both insufficient and excessive environmental initiatives due to perceived risk or inefficiency. The Social (S) pillar also demonstrates a significant U-shaped pattern (-0.0380 and 0.0077 , $p < 0.01$), though with a milder curvature, implying that social practices exert a more gradual influence on debt pricing. The Governance (G) pillar, while maintaining statistical significance (-0.0349 and 0.0068 , $p < 0.01$), displays the weakest non-linear magnitude among the three. This indicates that although good governance contributes to lower borrowing costs, its marginal effect diminishes more rapidly relative to environmental and social factors. Overall, these results suggest that environmental performance is the primary driver of the ESG–cost of debt relationship, followed by social and governance dimensions.

Importantly, these results are consistent with the main regression model, reinforcing the evidence that the relationship between ESG performance and the cost of debt is nonlinear. The robustness checks thus strengthen confidence in the validity of the primary findings and confirm that the observed patterns are not driven by model specification or multicollinearity concerns. This insight provides a foundation for the subsequent discussion, which explores the mechanisms through which ESG engagement shapes financing conditions and investor perceptions.

6. Discussion

This study examines the nonlinear impact of ESG performance on firms' cost of debt by using a dynamic panel GMM estimation. The empirical findings reveal a U-shaped relationship between ESG scores and borrowing costs, indicating that moderate levels of ESG engagement are associated with lower financing costs, whereas excessive ESG engagement may result in increased debt burdens. This finding is consistent across both the aggregated ESG index and disaggregated Environmental, Social and Governance components.

The results are aligned with the study's underlying theoretical framework and provide empirical support for the hypotheses developed. Drawing on **the resource-based theory (RBT)**, ESG practices are conceptualized as strategic, intangible resources that can enhance a firm's competitive advantage by improving legitimacy, mitigating perceived risks, and fostering stakeholder trust (Tawfiq et al., 2024; Biswas et al., 2025). In accordance with this perspective, the analysis demonstrates that moderate ESG performance contribute positively to reducing the cost of debt, reflecting their role as value-generating assets within the firm's resource portfolio. However, the findings also reveal a threshold effect, whereby ESG engagement beyond an optimal level begins to exert adverse financial consequences. This situation can be explained by another hypothesis on which the study is based. This shift aligns with **the trade-off theory**, which suggests that firms strive to optimize their financial and strategic choices by weighing associated costs against expected benefits. Once ESG practices surpass a certain intensity, the marginal benefits diminish, and the initiatives may be perceived by creditors as instances of resource misallocation, managerial overreach, or symbolic compliance (Biswas et al., 2025). In such cases, the costs associated with ESG may outweigh the perceived benefits, thereby leading to higher borrowing costs.

The robustness analysis confirms that the relationship between ESG performance and the cost of debt is nonlinear and dimension-specific. The positive and significant coefficients on the squared terms suggest that creditors may interpret excessively high ESG scores not as indicators of superior firm quality, but rather as signs of inefficient capital allocation or attempts to obscure underlying operational weaknesses (Shi et al.,

2024). Among the three pillars, the Environmental (E) dimension shows the strongest U-shaped effect: moderate environmental engagement enhances credibility, reduces information asymmetry, and lowers borrowing costs, while excessive spending may raise creditor concerns about overinvestment or “greenwashing,” (de Freitas Netto et al., 2020) increasing perceived risk. The Social (S) and Governance (G) dimensions also display significant nonlinear effects. The social pillar has a larger absolute coefficient than governance, suggesting social initiatives—such as better labor conditions, employee retention, and community relations—more strongly influence creditors by improving stability and reputation. Governance remains crucial for transparency and agency risk reduction, though its marginal impact on debt pricing appears smaller. Overall, these results highlight the importance of considering each ESG dimension’s distinct influence rather than assuming a uniform hierarchy.

The positive and significant coefficients on the squared terms of ESG and its dimensions suggest that creditors may interpret excessively high ESG scores not as indicators of superior firm quality, but rather as signs of inefficient capital allocation or attempts to obscure underlying operational weaknesses (Shi et al., 2024). Regarding the control variables, firm size consistently shows a negative and significant association with the cost of debt, implying that larger firms benefit from lower perceived risk and improved access to capital markets. Profitability (ROA) similarly reduces borrowing costs, consistent with expectations that financially healthy firms face lower credit risk. Leverage and firm age exhibit weaker or insignificant effects, suggesting that ESG dynamics play a more decisive role in shaping creditors’ perceptions in the analyzed context.

In conclusion, the primary model demonstrates that ESG performance as a whole has a significant U-shaped relationship with the cost of debt, suggesting that moderate ESG engagement enhances firms’ creditworthiness, while excessive involvement may reverse this benefit. The robustness analysis further confirms these results by showing that each ESG dimension individually exhibits a similar nonlinear pattern, with environmental performance emerging as the most influential driver. Firms aiming to optimize their financing conditions should therefore maintain a balanced level of ESG engagement—prioritizing credible and well-integrated environmental initiatives, while ensuring that social and governance practices remain consistent and strategically aligned to sustain long-term financial efficiency.

These findings contribute to the existing literature by highlighting that the relationship between ESG and the cost of debt is not uniformly negative or linear, as often suggested in prior studies. Instead, the evidence presented here shows that beyond an optimal point, additional ESG investment may generate diminishing or even adverse financial effects. This nuanced interpretation broadens the theoretical understanding of ESG by integrating insights from both resource-based theory and trade-off theory, emphasizing that sustainability practices can function as value-enhancing assets or financial constraints depending on their intensity.

The study can be further improved by extending the analysis to cross-country settings, incorporating sector-specific ESG sensitivities, or applying alternative nonlinear modeling approaches such as threshold regressions or quantile GMM. Such extensions would make it possible to explore whether the turning point in the ESG–cost of debt relationship differs across countries, regulatory settings, or levels of market development, thereby providing a clearer understanding of how institutional conditions shape sustainability–finance dynamics.

7. Policy Implications

This study yields several inferential insights and policy implications for firms, investors, and regulators. The identified nonlinear (U-shaped) relationship between ESG performance and the cost of debt highlights that the financial value of ESG initiatives is contingent on achieving an optimal balance between commitment and efficiency. Moderate ESG engagement strengthens firms’ legitimacy, reduces information

asymmetry, and enhances creditworthiness, whereas excessive or symbolic engagement can generate unintended financial burdens through overinvestment, inefficiency, or signaling risks. These findings suggest that the financial market's response to ESG practices is not purely linear but instead depends on the credibility and proportionality of firms' sustainability strategies.

From a corporate policy perspective, managers should treat ESG as a strategic investment rather than a compliance-driven exercise. ESG practices must align with a firm's operational capacity, stakeholder priorities, and long-term value creation goals. Firms should avoid adopting standardized or imitative ESG frameworks and instead design initiatives that reflect their sectoral realities and risk profiles. Periodic reassessment of ESG efficiency and integration into financial risk management systems would help firms prevent overinvestment and ensure that sustainability efforts contribute to measurable financial performance.

For governments and regulatory bodies, the results underscore the importance of developing differentiated and incentive-based ESG policies. Policymakers should design disclosure standards and tax incentives that promote credible and material ESG activities, while discouraging symbolic or excessively costly initiatives that may distort firms' capital allocation. Regulatory frameworks could also encourage industry-specific ESG benchmarks, enabling firms to compare performance relative to their peers and to internalize sustainability targets without imposing uniform thresholds across all sectors. Integrating ESG sensitivity into public credit guarantee schemes and green bond frameworks could further reduce information asymmetry between borrowers and lenders.

From the financial system's perspective, credit rating agencies and institutional investors should refine their ESG assessment models to incorporate potential nonlinear effects. Traditional linear scoring may underestimate risk at extreme levels of ESG engagement. Instead, more nuanced evaluation systems that distinguish between efficient and excessive sustainability spending would better capture the true relationship between ESG activities and creditworthiness.

In summary, the findings offer actionable insights for both practitioners and policymakers. ESG engagement should be managed as a strategic and context-dependent investment: when properly calibrated, it can serve as a mechanism for reducing financing costs and enhancing resilience; when pursued excessively or symbolically, it may generate financial inefficiencies. Governments, investors, and firms should therefore cooperate to develop balanced ESG ecosystems that promote sustainability without undermining financial stability.

8. Limitations and Future Research

This study has several limitations. First, the dataset covers only U.S. non-financial firms for 2019–2023, which may constrain the generalizability of the results across regions or sectors. Second, while the GMM estimator addresses endogeneity concerns, potential measurement errors in ESG scores remain.

Future research could extend the analysis by incorporating industry-specific ESG effects or exploring threshold models to identify the exact turning points in ESG–finance relationships. Investigating how different institutional or regulatory contexts moderate the ESG–cost of debt link would also provide valuable insights.

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Conflict of Interest: None

Funding: None

Ethical Approval: None

Author Contributions: Burcu ZENGİN (100%)

Çıkar Çatışması: Yoktur.

Finansal Destek: Yoktur.

Etik Onay: Yoktur.

Yazar Katkısı: Burcu ZENGİN (%100)
