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Environmental Practices and Corporate Cost of Debt: Evidence from European Listed Firms

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ABSTRACT

This paper examines the relationship between firms' environmental sustainability and the cost of debt, with a specific focus on how firms' transition efforts are taken into account. Using a dataset of large European listed companies covering the period from 2015 to 2023, we provide evidence that better environmental practices on polluting emissions, energy sources and waste management reduce firms' cost of debt. This result remains robust when environmental metrics are combined into a unique composite indicator and after testing for endogeneity. Further analysis shows that the reduction in the cost of debt is stronger for less sustainable firms engaged in environmental transition. Our findings shed light on the importance of considering firms' transition needs and efforts for effective transition finance.

1. Introduction

Over the past few years, climate change and its repercussions on the global economy have become central concerns on the agenda of policymakers, prompting institutions to encourage individuals and firms to adopt greener behaviors. Among the most influential global responses, in 2015, the United Nations introduced the 2030 Agenda for Sustainable Development (United Nations, 2015), highlighting the importance of promoting well-being through principles of equity and sustainability. That same year, the Paris Agreement acknowledged the urgent need for prompt and comprehensive economic decarbonization, alongside environmental conservation, to safeguard the interests of both present and future generations (United Nations Framework Convention on Climate Change, 2015). Europe has earmarked achieving carbon neutrality by 2050 as a pivotal objective in its prospective strategies. The European Union's Green Deal (European Commission, 2019) includes an investment strategy designed to accelerate the transition from fossil fuels to renewable energy sources (Antimiani et al., 2023; Arzaghi & Squalli, 2023).

However, translating environmental ambitions into effective progress requires active commitment from private actors as well. In this context, the financial system is expected to play a particular role in contributing to environmental sustainability through effective actions and instruments within the green finance domain (Alharbi et al., 2023; Fan et al., 2024; Ma et al., 2024). Furthermore, it is widely acknowledged that banks can play a crucial role in this transition process by channeling resources towards more sustainable projects and imposing costs on companies that fail to meet environmental standards (Buchetti et al., 2024; de Moraes et al., 2024). At the same time, interest groups and stakeholders are increasingly scrutinizing the financing of activities that hinder the environmental transition. Such scrutiny may result in intensified reputation and litigation risks for banks, ultimately harming their value (Galletta

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et al., 2025).

Starting from these premises, this paper examines how firms' environmental metrics and their transition efforts – as improvements in their overall environmental sustainability – are incorporated into firms' debt financing conditions. From this perspective, it extends the literature on the implications of firms' environmental impact on their financing costs. Accordingly, the analysis focuses on the accounting cost of debt, computed as the ratio between the firm's financial expense and its interest-bearing debt (Eliwa et al., 2019; Gracia & Siregar, 2021). In this way, it complements the previous literature's examination of syndicated loan terms (Chen et al., 2021; Degryse et al., 2023; Delis et al., 2024; Ehlers et al., 2021; Erten & Ongena, 2024; Kleimeier & Viehs, 2018) by providing a more comprehensive perspective that captures the entire cost firms incur to obtain debt financing.

Using a dataset of European listed firms, we document a statistically significant negative relationship between firms' environmental performance and their cost of debt across the three primary domains of sustainability: direct polluting emissions, energy sources, and waste management. We further explore the underlying dynamics of this relationship, finding it to be more pronounced for less sustainable firms that have exhibited a past improvement in their environmental performance.

The contribution of our study to previous literature is twofold. *First*, we enrich prior research by employing more objective, direct, and specific measures to evaluate firms' environmental footprint. This enables a more granular assessment of how firms' environmental performance shapes borrowing costs, highlighting the extent to which each environmental dimension contributes. Furthermore, this approach prevents the adoption of widely used scores (Eliwa et al., 2019; Gracia & Siregar, 2021), which may be inconsistent over time, incomparable across firms and divergent across raters, reflecting significant discretion in their construction (Carbone et al., 2021; Berg, 2022). In doing so, this study also complements previous research that has focused on broader or non-standardized metrics to address this issue, such as companies' sustainability disclosure (Degryse et al., 2023; Zheng & Shen, 2024), as well as indicators of environmental strength, costs, and benchmarks (Erragragui, 2018; Erten & Ongena, 2024) or single-focus measures on chemicals or emissions (Jung, Herbohn, & Clarkson, 2018; Kleimeier & Viehs, 2018; Chen et al., 2021; Delis et al., 2024; Ehlers et al., 2021). *Second*, we contribute to the existing literature by examining how the relationship between corporate environmental sustainability and the cost of debt is shaped by firms' transition dynamics.

Previous studies on the financial effects of firms' environmental sustainability have typically treated it as a static corporate attribute, assuming that a snapshot of the environmental performance at a given point in time may adequately represent the organization's environmental profile. This approach also carries significant practical implications regarding both the perceived distinction between green finance and transition finance and the importance attributed to the latter (G20, 2022; European Commission, 2023). While green finance concerns the financing of what is already environmentally sustainable, transition finance specifically focuses on supporting the process of transition over time. Although in the short-term transition finance may not result in the achievement of green performance targets, it represents a crucial primary step in greening the economy (European Commission, 2023). Otherwise, there is a risk of creating barriers for currently more environmentally-intensive companies, generating a disorderly and less inclusive transition, and ultimately compromising the attainment of a whole-of-economy transition (G20, 2022; Organization for Economic Co-operation and Development, 2022).

The contribution of our study lies in approaching sustainability as a dynamic, transitional process, rather than a simple state. Examining its effect on the cost of debt provides insights into its economic implications on how lenders assess and price credit risk. This framework allows us to evaluate whether the financial system is effectively incorporating elements of environmental transition or selectively favoring more environmentally advanced companies. To date, this dimension has received little attention, and we aim to address this gap by differentiating among firms with higher and lower levels of environmental sustainability while also accounting for their engagement in transition.

The remainder of the paper is structured as follows. Section 2 reviews the literature and develops the hypotheses. Section 3 describes the data. Section 4 is dedicated to the methodology for the Environmental Composite Indicator. Section 5 presents preliminary analysis and results. Section 6 provides further analysis. Section 7 performs an endogeneity test. Section 8 discusses the results. Section 9 concludes.

2. Theoretical background & hypotheses

2.1. Firms' environmental sustainability and cost of debt

Previous research on the relationship between firms' environmental sustainability and their financing conditions has provided mixed evidence. Some studies show that more polluting firms, given their greater exposure to climate transition risk, suffer from greater credit rating deterioration and loan spreads (Carbone et al., 2021; Chen et al., 2021). Chabowski et al. (2019) find that firms with higher levels of environmental inefficiency receive low bond ratings. Conversely, higher transparency and lower carbon emissions lead to more favorable loan conditions, such as reduced loan spreads (Kleimeier & Viehs, 2018; Zheng & Shen, 2024). Degryse et al. (2023) provide evidence that, following the Paris Agreement, green banks have rewarded firms for being environmentally friendly by offering them more favorable loan terms. Delis et al. (2024) focus on the risk of stranded fossil fuel reserves, that has been priced since 2015. Indeed, if these reserves were to become unburnable or “stranded” due to policy shifts, firms holding them would face considerable losses. Likewise, Altavilla et al. (2024) suggest that banks should consider their clients' exposure to climate risk, as this affects their default risk. They provide the example of financing an oil company, while future environmental regulation could force it into default. Their evidence shows that European banks price the climate risk of their clients and charge lower rates to those committed to reducing their future emissions. These findings are also supported by Ehlers et al. (2021), who suggest that carbon risk has been incorporated among the risks priced in a loan. However, they report mixed evidence because the carbon premium is small, indirect

emissions (Scope 2 and Scope 3) are not priced, and green banks do not charge carbon risk differently from other banks. [Erten and Ongena \(2024\)](#) document that the environmental risk sensitivity is not universally observed in the US syndicated loan market, but only arises in “green” states, driven by local beliefs and regulatory enforcement.

Prior literature has also gone beyond the credit risk dimension of sustainability, emphasizing a more strategic interpretation of how environmental sustainability influences firm financing. The reward granted by banks could be seen as a catalyst to align their clients' actions with their environmental commitments. In this regard, a large body of research has investigated firms' environmental strategies and practices through the lens of the stakeholder theory ([Garriga & Melé, 2004](#); [Delmas & Toffel, 2004](#); [Schrettle et al., 2014](#); [Freeman & Dmytriiev, 2017](#)). Recognizing that a corporation is a constellation of cooperative and competitive interests among multiple interacting stakeholders, this theory emphasizes the importance of cultivating favorable relationships and creating value for stakeholders to achieve more successful outcomes ([Donaldson & Preston, 1995](#)). Building on this perspective, [Gracia and Siregar \(2021\)](#) suggest that firms should aim to address their debtholders' interests since they are among their most crucial stakeholders. Indeed, lenders may benefit from firms' environmental sustainability, with respect to reputation ([Di Tommaso et al., 2025](#)), ratings ([Chen et al., 2025](#)) and competitiveness ([Wu, 2025](#)). As a result, by adopting sustainable practices – thereby embracing debtholders' sustainability concerns – firms would be rewarded with a lower cost of debt. Beyond that, they also refer to the legitimacy theory, which postulates that firms are often driven to perform socially desired actions in return for approval. Therefore, by aligning with their debtholders' climate priorities, they can gain legitimacy and trust, which may translate into a reduced cost of debt. In the same vein, [Eliwa et al. \(2019\)](#) invoke legitimacy theory to reach similar conclusions, arguing that failure to comply with green societal expectations may lead to sanctions, such as higher debt costs.

Nevertheless, other studies point to different conclusions. [Buchetti et al. \(2024\)](#) highlight that banks may actually perceive exposures to “green” firms as riskier than those to “brown” firms. They observe this phenomenon – known as green-transition risk – as a negative relationship between a firm's probability of default and its GHG emissions. Green financing entails inherent risk primarily stemming from informational asymmetries and future uncertainties concerning green innovation. Green projects often rely on emerging and unproven technologies, characterized by radical change, uncertain outcomes and subject to rapid advancement and potential replacement ([Barbieri et al., 2020](#); [Taghizadeh-Hesary & Yoshino, 2019](#)). The uncertain viability of such initiatives may result in implementation delays or even abandonment, hence eroding expected returns ([Buchetti et al., 2024](#)). Consequently, financial institutions may approach green investments with greater skepticism and caution. Finally, these uncertainties are further amplified by broader economic instability ([Bettarelli et al., 2024](#)) and the unpredictability of shifting climate policies ([Alharbi et al., 2025](#); [Ji et al., 2024](#)).

[Giannetti et al. \(2024\)](#) find that banks emphasizing environmental sustainability lend more to brown industries, without evidence of considering borrowers' emissions or imposing higher interest rates or reducing debt maturity. Additionally, [Degryse et al. \(2020\)](#) show the existence of barriers to entry for innovative green firms in the form of credit rationing by banks with legacy positions. The activity of these firms in polluting industries risks devaluing banks' legacy positions held with incumbent clients. As a result, they may be reluctant to finance green firms, preferring instead technological conservatism by favoring firms with an established technology, which also preserves their expertise in that field ([Minetti, 2011](#)).

Amid mixed evidence, we aim to shed further light on the relationship between firms' environmental performance and their financing conditions by testing the following first hypothesis:

H1. Firms' environmental sustainability leads to a lower (higher) cost of debt.

Building on the two contrasting perspectives on the financial system's attitude towards green investments, hypothesis **H1** investigates whether firms' environmental sustainability translates into a lower or higher cost of debt financing. This hypothesis is aimed at testing whether firms' environmental performance influences their cost of debt across the three core dimensions of direct polluting emissions, energy sources, and waste management. These capture different and complementary facets of firms' environmental footprint and constitute the main pillars in most environmental assessment frameworks (e.g., EU Taxonomy; [European Union, 2020](#)), while also providing standardized and materially relevant data across firms. Furthermore, this allows for a more refined assessment of how key environmental dimensions relate to firms' cost of financing, thereby contributing to a more granular understanding of the underlying relationship.

2.2. Transition and cost of debt: catching-up theory, path dependency and signaling

Drawing from economic growth theory, the “catch-up” hypothesis posits that economies with lower productivity levels possess a greater potential for rapid growth and improvement. As explained by [Abramovitz \(1986\)](#), the key point relates to the level of technology incorporated in capital stocks. For advanced first movers, this technology was already at the frontier at the time of investment, while followers, whose productivity level is lower, possess an outdated capital stock. However, when it comes to replacing the stock of capital, those who are behind can benefit from a larger leap in both technological advancement and its related productivity growth. Therefore, poor economies tend to grow faster than rich ones in per capita terms and there is a force that promotes convergence ([Barro & Sala-i-Martin, 1992](#)). Expanding on this idea, [Narula \(2004\)](#) invokes the concept of “absorptive capacity” and asserts that, through their ability to acquire and exploit knowledge developed elsewhere, laggard economic units – both countries and firms – can “catch up”.

In light of this, we aim to test whether a similar catch-up dynamic applies in the context of corporate environmental sustainability. The urgency to foster a transition process necessitates considering firms' current level of environmental action and their advancement, since less sustainable firms require more immediate intervention and can potentially improve rapidly, thereby exhibiting a faster

transition. The reward in terms of a lower cost of debt may be more effectively targeted at them than at companies already at the forefront of environmental performance.

In addition to the catch-up theory, further insights are provided by Schrettle et al. (2014), who offer an explanatory framework for corporate strategies and decision-making regarding the climate challenge. Their interpretation of the relationship between environmental management and firms' performance proposes an inverted U-shaped curve. Sustainability commitment is advantageous unless it is pushed too far. Overinvesting in green initiatives can be detrimental when additional costs exceed the marginal benefits. Furthermore, the authors also refer to the concept of path dependency. A firm's current environmental profile reflects past efforts and investments in green technologies, and the same applies to present decisions and future outcomes. Consequently, a lack of early and present investments can make it costly to align in a subsequent period. Therefore, the threat of being left behind in subsequent technological progress may be another reason to provide greater support to currently less sustainable firms.

Finally, according to the signaling theory (Spence, 1973), the environmental transition may be considered a substantive action conveying the information of an active and observable effort toward environmental improvement (Truong et al., 2021). This, in turn, may translate into reputational gains, particularly benefiting environmentally lagging firms, for which improvements represent a greater and clearer departure from past behavior and therefore a more powerful signal.

Building on these theories and considerations, we test the following hypothesis:

H2. The impact of environmental sustainability on the cost of debt is stronger for environmentally lagging firms in transition.

3. Data description

To investigate the relationship between companies' environmental sustainability and their cost of debt, we employ a dataset of large European listed firms covering the period from 2015 to 2023. Data are collected from three primary sources: Orbis Europe, Refinitiv Eikon, and the CRI database. Table 1 contains detailed information on the variables used in the analyses, while Table 2 displays their summary statistics. The sample of companies is restricted to firms with data available for all the key dimensions considered.

Following Eliwa et al. (2019) and Gracia and Siregar (2021), we employ the accounting cost of debt as the dependent variable in our models. According to Orlitzky et al. (2003), accounting-based measures of corporate financial performance are more appropriate and more strongly correlated with corporate environmental performance than market-based measures. The former are seen as an outcome of internal decision-making capabilities and managerial performance, whereas the latter reflect market reactions to the firm's activities.

To measure companies' emissions, we rely on direct CO₂ equivalent emissions,¹ thus avoiding redundancy between Scope 2 and Scope 3 metrics and the other environmental variables. The use of renewable energy and the share of recycled waste are employed to cover the energy source and waste management domains, respectively. We also include control variables at the firm level, referring to the governance and social pillars to mitigate concerns related to omitted variables that are likely to affect both firms' cost of debt and their environmental sustainability (Bigelli et al., 2023).

As one of the key determinants of the cost of debt, the probability of default is incorporated as a crucial control variable in the analysis. Provided by the Credit Reporting Initiative (National University of Singapore, 2022), this variable is defined as the output of a forward intensity function with two classes of inputs, macro-financial factors and firm-specific attributes: $p_{i,t}(\tau) = P_{\tau}(X_t, Y_{i,t})$. This last category includes variables related to firms' distance to default, liquidity (both the level and trend of the ratio Current assets/Current liabilities), profitability (both the level and trend of Net income/Total Assets), the relative market-to-book ratio, and idiosyncratic volatility. Therefore, controlling for this variable in the model captures the effect of all those dimensions.

All variables are winsorized to mitigate the effect of outliers, and the environmental variables of CO2EM and RENEWEN are scaled by revenues to make them comparable across companies with different scales.

Before proceeding with the formulation of the models, we inspect the correlation structure of the variables, as reported in the correlation matrix in Table 3. The majority of statistically significant coefficients fall below 0.5, indicating weak to moderate correlations and consequently suggesting that multicollinearity is not a substantial concern within the dataset.

4. Methodology: The Environmental Composite Indicator

Our empirical framework involves the construction of an ECI, that aggregates the environmental measures presented in Section 3 using the sigma-mu approach in the field of stochastic multicriteria acceptability analysis (SMAA) (Greco et al., 2019a). This synthetic measure is then employed to examine how companies' environmental profile affects borrowing costs in a world transitioning towards sustainability. By capturing firms' overall environmental standing and allowing the tracking of their progress in transition processes, it deepens our understanding of the role of ecological transition in the relationship between companies' environmental practices and their financing costs.

¹ Refinitiv Eikon follows the Greenhouse Gas Protocol which sets the standard for measuring firms' emissions, distinguishing between different sources of GHG emissions: direct GHG emissions from sources owned or controlled by the company (Scope 1); indirect GHG emissions from the generation of purchased electricity consumed by the company (Scope 2); indirect GHG emissions as a consequence of the company's activity but from sources not owned or controlled by it (World Business Council for Sustainable Development & World Resources Institute, 2004).

Table 1
Variables description.

Variable	Definition	Description	Source
Dependent variable			
CoD	Cost of Debt	Ratio between the firm's financial expense and interest-bearing debt	Orbis Europe (2024)
Independent variables: Environmental impact			
CO2EM	CO ₂ Equivalent Emissions Scope1 over Revenue	Direct CO ₂ and CO ₂ equivalent emissions divided by revenue	CO ₂ emissions from Refinitiv Eikon (2024); Revenue from Orbis Europe (2024)
RENEWEN	Renewable Energy over Revenue	Total renewable energy (purchased and produced) divided by revenue	Renewable energy from Refinitiv Eikon (2024); Revenue from Orbis Europe (2024)
WASTEREC	Waste Recycled to Total Waste	Total recycled and reused waste divided by total waste produced	Refinitiv Eikon (2024)
Control variables: Firm Characteristics			
SIZE	Total Assets	Sum of the book values of all assets owned by a firm	Orbis Europe (2024)
PD	Probability of Default (60)	Probability of default – 60 months	CRI database (2024)
BSIZE	Board Size	Total number of board members at the end of the fiscal year	Refinitiv Eikon (2024)
BGENDER	Board Gender Diversity	Percentage of females on the board	Refinitiv Eikon (2024)
SOCIAL	Social Pillar Score	Weighted average relative rating of a company based on the reported social information	Refinitiv Eikon (2024)
ECI	Environmental Composite Indicator	Composite Indicator aggregating the three main environmental dimensions of emissions, energy, and waste.	Authors' calculations based on Refinitiv Eikon

Notes: This table describes the variables employed in the analyses. Data are collected from Orbis Europe, Refinitiv Eikon, and the CRI database.

Table 2
Summary statistics.

Variable	Unit of measurement	Observations	Mean	Median	Sd	Min	Max
CoD	%	1743	5.48	4.34	3.98	1.50	17.91
Log (CO2EM)	Log (Tonnes/Million \$)	1743	2.98	2.71	2.25	-2.55	8.58
RENEWEN	Terajoule/Million \$	1743	0.62	0.09	1.34	0	5.42
WASTEREC	%	1743	68.17	75.60	27.25	0.35	100
SIZE	Billion \$	1743	25.39	7.90	46.04	0.21	256.76
PD	%	1743	1.18	0.96	0.91	0.08	4.75
BSIZE	Number	1743	11.19	11	3.61	4	21
BGENDER	%	1743	33.94	33.33	11.25	0	60
SOCIAL	Number	1743	73.11	76.39	15.79	25.13	96.27
ECI	Number	1743	42.99	45.04	13.66	2.97	94.87

Notes: This table presents the main summary statistics of the distribution of variables employed in the analyses, including mean, median, standard deviation, minimum, and maximum values. Log(CO2EM) is the natural logarithmic transformation of CO2EM.

Table 3
Pairwise correlations.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) CoD	1.000									
(2) Log(CO2EM)	0.117*	1.000								
(3) RENEWEN	0.008	0.376*	1.000							
(4) WASTEREC	-0.095*	-0.274*	-0.009	1.000						
(5) SIZE	-0.036	0.355*	0.072*	0.018	1.000					
(6) PD	0.273*	0.165*	-0.015	-0.059*	0.112*	1.000				
(7) BSIZE	0.002	0.219*	0.042*	0.020	0.327*	0.047*	1.000			
(8) BGENDER	-0.065*	-0.176*	-0.146*	0.052*	0.094*	-0.018	-0.067*	1.000		
(9) SOCIAL	-0.036	0.110*	0.025	-0.026	0.303*	-0.008	0.256*	0.122*	1.000	
(10) ECI	-0.115*	-0.437*	0.425*	0.793*	-0.116*	-0.128*	-0.067*	0.031	-0.056*	1.000

Notes: This table presents the pairwise correlations of the variables used in our analyses. * denotes significance at the 10 % level. Log(CO2EM) is the natural logarithmic transformation of CO2EM.

The number and the use of composite indicators are growing year by year in academic circles, media and among policy makers, thanks to their perks as “big picture” tools: summarizing complex phenomena; facilitating interpretation and communication instead of a multitude of separate metrics; enabling comparisons among different units (Organization for Economic Co-operation and Development, 2008). This growing adoption is grounded on the premise that individual components alone fail to fully capture the multidimensional complexity of a given phenomenon (Angilella et al., 2024). Instead, composite indicators facilitate a more comprehensive assessment by considering its various constituent dimensions.

The construction of a composite indicator involves several steps, with the most crucial being the process of weighting and aggregating the underlying constituents. The Handbook on Constructing Composite Indicators (Organization for Economic Co-operation and Development, 2008) outlines all the main existing approaches and refers to the additive aggregation of equally weighted indicators as the most widely used, due to its simplicity. Nevertheless, it is also the most criticized, as equal weights represent the set of preferences of a single representative agent, assigning equal importance to all the dimensions considered. However, in many decision-making processes, the actors involved may assign different relevance to the underlying dimensions, and such diversity of existing viewpoints must be considered to obtain a meaningful composite indicator (Greco et al., 2019a).

Beyond the criticisms of equal weighting, further concerns regard the assignment of weights to the underlying components. Participatory approaches, which rely on weighting schemes subjectively determined by the experts developing the index, may be sensitive to arbitrariness (Greco et al., 2019b). More objective approaches include statistical techniques, such as correlation analysis, principal component analysis (PCA) or factor analysis (FA). However, they are not free from criticism, since statistical relationships do not necessarily capture the actual influence of each component on the phenomenon under investigation (Saisana & Tarantola, 2002).

The stochastic multicriteria acceptability analysis (SMAA) has become a popular approach to address these issues of traditional weighting schemes, providing a statistical solution based on simulated weight vectors. It overcomes the single-viewpoint issue by considering the full space of weight vectors reflecting multiple decision makers' preferences, while also addressing the shortcomings of subjective and purely statistical techniques. In the so-called sigma-mu method, for each unit i under analysis, a distribution of composite indicators is generated, each resulting from a different weight vector, then summarized by its mean value (μ_i). By doing so, we transition from a single and equally weighted preference to considering several potential points of view and their corresponding relative weighting schemes. This is derived through Monte Carlo simulations, with the quality of the approximation improving as the number of iterations increases (typically 10,000 or more). The two main tools required for estimating a composite indicator are the following two matrices. The former (W) collects, by column, q different weight vectors, while the latter (ECI) exhibits the units' composite indicators obtained for each weight vector:

$$ECI(i, w_h) = \sum_{j=1}^n x_{ij} w_{hj} \tag{1}$$

where i denotes the observed unit, j the dimension, x_{ij} is the value assumed by unit i in dimension j , and w_{hj} is the weight assigned to dimension j in weight vector h , among the q different weight vectors.

$$W = \begin{pmatrix} w_{1,1} & w_{1,2} & \dots & w_{1,q} \\ w_{2,1} & w_{2,2} & \dots & w_{2,q} \\ \vdots & \vdots & \dots & \vdots \\ w_{m,1} & w_{m,2} & \dots & w_{m,q} \end{pmatrix} \tag{2}$$

$$ECI = \begin{pmatrix} ECI(1, w_1) & ECI(1, w_2) & \dots & ECI(1, w_q) \\ ECI(2, w_1) & ECI(2, w_2) & \dots & ECI(2, w_q) \\ \vdots & \vdots & \dots & \vdots \\ ECI(n, w_1) & ECI(n, w_2) & \dots & ECI(n, w_q) \end{pmatrix} \tag{3}$$

Based on this framework, the synthetic environmental score is constructed by linearly aggregating the environmental metrics previously presented in Section 3. The most common aggregation technique is the summation of weighted indicators as shown in Equation (1) (Organization for Economic Co-operation and Development, 2008; Angilella et al., 2024; Dias, 2024). Unlike geometric aggregation, the linear (additive) approach avoids excessive penalization for units with lower scores in some components. Even in the extreme case of a zero in any dimension, the overall score is not nullified. By comparison, other techniques, such as non-compensatory multicriteria approaches, have seen limited diffusion, due to their computational burden and their typical output consisting of a ranking rather than a score suitable for further analyses (Greco et al., 2019b).

The aggregation of different variables into a unique score also requires a preliminary phase of data normalization to avoid scale issues caused by variables with varying scales and ranges. Accordingly, the above-described process has been applied to the min-max normalized version of the original variables, as resulting from the following equation:

$$E_{norm} = \frac{E - E_{min}}{E_{max} - E_{min}} \tag{4}$$

The procedure of subtracting the minimum and then dividing by its range rescales each variable to range from 0, corresponding to the minimum value in the distribution, to 1, corresponding to the maximum value in the distribution. However, since the three variables exhibit different directional relationships with sustainability – i.e., they would point in different directions when aggregated – the direction of $CO2EM_{norm}$ must be reversed. In other words, if left as it is, an increase in the value of CO_2 equivalent emission would lead to an increase in the ECI, which is inconsistent with the purpose of the index. For this reason, the variable applied in the score calculation has been $CO2EM'_{norm} = 1 - CO2EM_{norm}$. This preserves the main characteristics of the distribution while aligning its polarity with the other sustainability-enhancing variables, thus allowing for meaningful aggregation.

Ultimately, for each company in each year, a distribution of 10,000 scores is obtained via Monte Carlo simulations in MATLAB and by applying Equation (1) to our normalized environmental variables:

$$ECI(i, w_h) = w_{1,h}CO2EM'_{norm} + w_{2,h} WASTEREC_{norm} + w_{3,h} RENEWEN_{norm} \quad (5)$$

By taking the mean of these distributions, we obtain a synthetic measure of firms' overall environmental performance, which serves as the basis for identifying the transition status in the subsequent analysis.

5. Baseline model and preliminary results

To test how firms' environmental practices affect their cost of debt across the three domains of GHG emissions, renewable energy, and recycled waste, we employed a multiple linear regression model with year-, country-, and industry-fixed effects. All independent variables are lagged by one year to mitigate endogeneity arising from potential reverse causality and simultaneity issues (Neitzert & Petras, 2022). This first model is specified as follows:

$$CoD_{it} = \beta_j E_{it-1} + \beta_k Z_{it-1} + \eta_{year} + \lambda_{industry} + \mu_{country} \quad (6)$$

where E_{it-1} denotes the vector of environmental variables for each company, Z_{it-1} is the vector of control variables, while η_{year} , $\lambda_{industry}$, and $\mu_{country}$ represent the fixed effects that control for unobserved heterogeneity at the time, industry and country levels. Industry-fixed effects are defined according to the North American Industry Classification System (NAICS), which identifies 112 groups of firms within our sample, each belonging to a different sector. Table 4 depicts the results of the preliminary regressions. Column 1 presents the baseline OLS regression without fixed effects. Columns 2 and 3 report the results of the fixed-effect model in Equation (6), based on the original and standardized² regressors, respectively. The use of standardized variables in Column 3 facilitates a direct comparison of their impact on the cost of debt. The resulting estimates represent the effect of a one-standard-deviation change in each regressor on firms' cost of debt. All the coefficients related to firms' environmental performance are statistically significant and economically meaningful in the fixed-effect regressions. In absolute terms, the magnitude of the coefficients for the environmental variables is comparable to that of other traditional determinants of the cost of debt, such as firm size (proxied by total assets) and default probability.

The output of this regression model confirms the existence of a negative relationship between environmental sustainability and the cost of debt. Specifically, firms' cost of financing declines with decreasing CO₂ equivalent emissions and increasing adoption of renewable energy and waste recycling. Furthermore, from the standardized coefficients in Column 3, it can be observed that, among the environmental variables, the logarithm of CO2EM has the greatest impact, resulting in a 0.679 percentage point variation in the cost of debt for a one-standard-deviation change.

6. Further analysis

Before proceeding with further investigations involving the ECI to define environmental transition, its empirical validity is tested by substituting it in place of the three environmental variables in the baseline model in Equation (6):

$$CoD_{it} = \beta_j ECI_{it-1} + \beta_k Z_{it-1} + \eta_{year} + \lambda_{industry} + \mu_{country} \quad (7)$$

where ECI_{it-1} substitutes the vector of environmental variables (E_{it-1}) for each firm-year observation. The estimation results are presented in Column 1 of Table 5. The statistically significant negative coefficient for ECI corroborates the inverse relationship between companies' environmental sustainability and their cost of debt. This finding also serves as a robustness check for the regression model in Equation (6), where the three environmental variables were included separately. Column 2 of Table 5 provides the standardized coefficients estimated from Equation (7). The impact of environmental sustainability on the cost of debt is comparable in magnitude to that of the other financial controls. For a standard-deviation increase in companies' ECI, their cost of debt decreases by 0.555 percentage points. To provide further robustness, we re-estimate the model in Equation (7) using standard errors clustered at the firm level, which accounts for potential within-firm correlation of residuals in panel data sets (Cameron & Miller, 2015; Petersen, 2009). The results confirm the negative relationship between firms' ECI and their cost of debt (Column 3 of Table 5).

The adoption of the ECI into our analysis enables a deeper investigation of the dynamics underlying the relationship between banks and companies in a world transitioning towards sustainability. Therefore, we turn to test hypothesis H2, which focuses on less environmentally sustainable firms and their engagement in transition. Firstly, we set up a regression model to assess whether the negative relationship between firms' environmental sustainability and their cost of debt is pronounced differently depending on their level of sustainability. To this end, the ECI interacts with a dummy variable, which is equal to 1 if the company's ECI is above its annual median value, and 0 otherwise:

$$CoD_{it} = \beta_j ECI_{it-1} + \beta_w D_{it-1} + \beta_z ECI_{it-1} \times D_{it-1} + \beta_k Z_{it-1} + \eta_{year} + \lambda_{industry} + \mu_{country} \quad (8)$$

where D_{it-1} is the dummy variable identifying the two groups of Environmentally Lagging (EL) and Environmentally Advanced (EA) firms, with the threshold set at the median value of the ECI for each year. This interaction enables us to assess the extent to which the

² Standardization is obtained by applying the formula $Z = \frac{X - \mu}{\sigma}$ to a variable X with mean μ and standard deviation σ . The result is a rescaled variable having a mean of zero and a standard deviation of one.

Table 4
Environmental variables and the cost of debt.

VARIABLES	(1)	(2)	(3)
	CoD	CoD	CoD
Log(CO2EM) _{t-1}	0.170*** (0.051)	0.301*** (0.086)	0.679*** (0.194)
RENEWEN _{t-1}	-0.069 (0.066)	-0.220** (0.097)	-0.294** (0.130)
WASTEREC _{t-1}	-0.007* (0.004)	-0.010** (0.004)	-0.267** (0.119)
SIZE _{t-1}	-0.008*** (0.002)	-0.009*** (0.003)	-0.437*** (0.122)
PD _{t-1}	1.144*** (0.116)	0.825*** (0.139)	0.749*** (0.127)
BSIZE _{t-1}	0.002 (0.027)	-0.181*** (0.039)	-0.653*** (0.141)
BGENDER _{t-1}	-0.012 (0.008)	-0.012 (0.010)	-0.138 (0.115)
SOCIAL _{t-1}	-0.004 (0.007)	0.0002 (0.007)	0.003 (0.107)
Obs	1743	1730	1730
Adj-R ²	0.089	0.330	0.330
Year FE	No	Yes	Yes
Industry FE	No	Yes	Yes
Country FE	No	Yes	Yes

Notes: This table presents the results of the base regression model. Column 1 reports the OLS baseline model; Column 2 reports the fixed-effects regression model, as in Equation (6); Column 3 reports the fixed-effects regression model with standardized regressors. *, **, and *** denote p-values smaller than 10 %, 5 %, and 1 %, respectively. Robust standard errors in parentheses.

Table 5
ECI and the cost of debt.

VARIABLES	(1)	(2)	(3)
	CoD	CoD	CoD
ECI _{t-1}	-0.041*** (0.008)	-0.555*** (0.115)	-0.041*** (0.012)
SIZE _{t-1}	-0.007*** (0.002)	-0.319*** (0.106)	-0.007* (0.004)
PD _{t-1}	0.824*** (0.138)	0.749*** (0.126)	0.824*** (0.174)
BSIZE _{t-1}	-0.173*** (0.039)	-0.623*** (0.140)	-0.173*** (0.061)
BGENDER _{t-1}	-0.014 (0.010)	-0.158 (0.116)	-0.014 (0.013)
SOCIAL _{t-1}	-0.00002 (0.007)	-0.0003 (0.106)	-0.00002 (0.010)
Obs.	1730	1730	1730
Adj-R ²	0.329	0.329	0.329
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes

Notes: This table presents the results of the regression model in Equation (7), where the three environmental variables—CO2EM, RENEWEN, and WASTEREC—have been aggregated into the ECI. Column 1 reports the estimates from the fixed-effects regression model. Column 2 outlines the results of the same model with standardized regressors. Column 3 provides estimations with standard errors clustered at the firm level. *, **, and *** denote p-values smaller than 10 %, 5 %, and 1 %, respectively. Robust standard errors in parentheses.

relationship persists across firms with varying levels of environmental performance. Table 6 presents the results of the regression in Equation (8), while Table 7 shows the estimated marginal effects for the two different groups. The negative relationship between environmental performance and the cost of debt is stronger for companies with an ECI falling below the annual median (EL), indicating that this effect is more pronounced among firms that lag in environmental sustainability.

To assess hypothesis H2 regarding less sustainable firms in transition, we propose a final analysis that incorporates this feature. The model in Equation (7) is now extended to include a triple interaction among the ECI, the dummy variable (D) that distinguishes between less and more sustainable firms, as in Equation (8), and a dummy variable (T) that accounts for firms' transition. The latter equals 1 if the firm's ECI increased in the previous year of observation compared to the year before that, and 0 otherwise. As a result,

Table 6
ECI, sustainability level, and the cost of debt.

VARIABLES	CoD
ECI _{t-1}	-0.083*** (0.016)
1.D _{t-1}	-1.116 (1.221)
ECI _{t-1} #1.D _{t-1}	0.044* (0.025)
SIZE _{t-1}	-0.007*** (0.002)
PD _{t-1}	0.814*** (0.138)
BSIZE _{t-1}	-0.169*** (0.039)
BGENDER _{t-1}	-0.012 (0.010)
SOCIAL _{t-1}	0.0003 (0.007)
Obs.	1730
Adj-R ²	0.333
Year FE	Yes
Industry FE	Yes
Country FE	Yes

Notes: This table presents the results of the regression model in Equation (8). Here, the ECI, obtained by aggregating the three environmental variables, interacts with the dummy variable D, which classifies companies as having an above-median environmental score (*Environmentally Advanced*) and a below-median environmental score (*Environmentally Lagging*). *, **, and *** represent p-values smaller than 10 %, 5 %, and 1 %, respectively. Robust standard errors in parentheses.

Table 7
Marginal effects for sustainability level.

ECI _{t-1}	CoD
EL	-0.083*** (0.016)
EA	-0.039** (0.019)

Notes: This table exhibits the marginal effects of the ECI on the cost of debt for the two groups of Environmentally Lagging (EL) and Environmentally Advanced (EA) firms. *, **, and *** denote p-values smaller than 10 %, 5 %, and 1 %, respectively. Delta-method standard errors in parentheses.

four groups of firms emerge: Non-transitioning Laggards, Non-transitioning Leaders, Emerging Transitioners, and Transitioning Leaders. This enables us to examine the relationship between environmental sustainability and the cost of debt, while distinguishing between environmentally lagging and advanced firms, and considering their involvement in the transition process. Therefore, we set the following regression model:

$$\begin{aligned}
 \text{CoD}_{it} = & \beta_j \text{ECI}_{it-1} + \beta_w \text{D}_{it-1} + \beta_t \text{T}_{it-1} + \beta_h \text{ECI}_{it-1} \times \text{D}_{it-1} + \beta_s \text{ECI}_{it-1} \times \text{T}_{it-1} + \beta_r \text{D}_{it-1} \times \text{T}_{it-1} + \beta_z \text{ECI}_{it-1} \times \text{D}_{it-1} \times \text{T}_{it-1} + \beta_k \text{Z}_{it-1} \\
 & + \eta_{\text{year}} + \lambda_{\text{industry}} + \mu_{\text{country}}
 \end{aligned} \tag{9}$$

where D_{it-1} is the dummy variable distinguishing between firms with an above- or below-median environmental performance, while T_{it-1} is the dummy variable indicating whether there was a transition from t-2 to t-1. Column 1 in Table 8 contains the regression results, while Column 1 in Table 9 displays the related estimates of marginal effects, with a coefficient for each of the four groups. The already established negative relationship between environmental sustainability and the cost of debt holds stronger for firms that are less sustainable but have shown a past improvement in their environmental performance (Emerging Transitioners). Consistently with the theoretical framework of hypothesis H2, this coefficient is greater than that relating to firms with stronger environmental

Table 8
ECI, sustainability level, transition, and the cost of debt.

VARIABLES	(1)	(2)
	CoD	CoD
ECI _{t-1}	-0.072*** (0.025)	-0.117*** (0.026)
1.D _{t-1}	-2.263 (2.032)	-3.220* (1.945)
1.T _{t-1}	1.102 (1.038)	-0.009 (1.848)
ECI _{t-1} #1.D _{t-1}	0.059 (0.042)	0.090** (0.040)
ECI _{t-1} #1.T _{t-1}	-0.033 (0.029)	-0.016 (0.050)
1.D _{t-1} #1.T _{t-1}	0.768 (1.959)	0.608 (2.697)
ECI _{t-1} #1.D _{t-1} #1.T _{t-1}	0.006 (0.042)	0.015 (0.060)
SIZE _{t-1}	-0.005* (0.003)	-0.006* (0.003)
PD _{t-1}	0.697*** (0.167)	0.639*** (0.195)
BSIZE _{t-1}	-0.142*** (0.047)	-0.097* (0.056)
BGENDER _{t-1}	-0.011 (0.013)	-0.018 (0.016)
SOCIAL _{t-1}	0.004 (0.009)	-0.002 (0.012)
Obs.	1261	884
Adj-R ²	0.348	0.361
Year FE	Yes	Yes
Industry FE	Yes	Yes
Country FE	Yes	Yes

Notes: This table presents the results of the regression model in Equation (9). Here, the ECI interacts with the dummies D and T. In both Column 1 and 2, Dummy D classifies companies as having an above-median ECI ($D=1$) or a below-median ECI ($D=0$). In Column 1, Dummy T signals an environmental transition in the year before: $T=1$ if the firm's ECI increased from $t-2$ to $t-1$ and $T=0$ if it did not. In Column 2, Dummy T signals an environmental transition over two consecutive years: $T=1$ if the firm's ECI increased both from $t-3$ to $t-2$ and from $t-2$ to $t-1$, and $T=0$ if it failed to increase in either of the two intervals. *, **, and *** denote p-values smaller than 10 %, 5 %, and 1 %, respectively. Robust standard error in parentheses.

performance and a recent environmental transition (Transitioning Leaders). In other words, the marginal effect of an ECI increase is greater for Emerging Transitioners than for environmentally advanced firms.

Column 2 of Table 8 refers to a regression model that adopts the same triple interaction framework as in Equation (9). However, the

Table 9
Marginal effects for sustainability level and transition.

	(1)	(2)
	CoD	CoD
ECI _{t-1}	-0.072*** (0.025)	-0.117*** (0.026)
NTL _a	-0.013 (0.033)	-0.027 (0.032)
NTL _e	-0.105*** (0.023)	-0.133*** (0.047)
ET	-0.040 (0.026)	-0.028 (0.046)
TL		

Notes: In Column 1, this table exhibits the marginal effects of the ECI on the cost of debt for the groups of Non-transitioning Laggards (NTL_a), Non-transitioning Leaders (NTL_e), Emerging Transitioners (ET), and Transitioning Leaders (TL). Column 2 reports the same marginal effects but considers the transition over two consecutive years, with $T=1$ if ECI increased in both intervals from $t-3$ to $t-2$ and from $t-2$ to $t-1$, and $T=0$ if it failed to increase in either of the two intervals. *, **, and *** denote p-values smaller than 10 %, 5 %, and 1 %, respectively. Delta-method standard errors are in parentheses.

dummy variable employed to capture firms' transition is now set to 1 if the firm's ECI increased over two consecutive years before that of observation (from $t-3$ to $t-2$ and from $t-2$ to $t-1$), and 0 if it failed to increase in either of the two intervals. Hence, we apply a stricter criterion, allowing for a more robust assessment of transition efforts. The previous findings are corroborated under this definition, confirming the robustness of our results. Once again, in Column 2 of Table 9, the greatest coefficient in absolute terms is associated with companies that have lower ECI but have shown a past tendency to improve it for two consecutive years (Emerging Transitioners). Furthermore, it is worth noting that for Emerging Transitioners, the relationship is stronger in the case of a two-consecutive-year transition (-0.133 , in Column 2 of Table 9) than in a one-year transition (-0.105 , in Column 1 of Table 9). This finding further reinforces the relevance of transition efforts for environmentally lagging firms. Applying a more stringent definition in terms of consistency of environmental improvement yields an even more pronounced effect.

7. Endogeneity

Estimations in dynamic panel data analyses may be biased by endogeneity issues, mainly caused by reverse causality and omitted variables. To overcome this challenge, we use a system Generalised Method of Moments (GMM) estimation. Dynamic panel data analysis offers several advantages over static modeling, particularly in addressing concerns about endogeneity. Following Roodman (2009), we employ a two-step system GMM estimator that involves building a system of two equations using delayed and instrumental variables. This estimator is designed for situations with “small T, large N” panels.

In our two-stage system GMM, the model in Equation (7) is augmented with a delayed dependent variable as an additional regressor. Furthermore, the variable ECI is considered endogenous, and its delayed values from $t-2$ to $t-4$ are used as internal instruments (GMM instruments). Beyond that, concerning our variable of interest, other internal instruments were created lagging the dependent variable CoD and the firms' characteristics control variables of SIZE, PD, and BSIZE from $t-2$ on, thereby adding more information and improving efficiency (Anderson & Hsiao, 1982). Additionally, an exogenous variable is incorporated as an instrumental variable (IV) to further enhance the model's efficiency. To select a suitable exogenous instrumental variable, we use an environmental indicator at the firm's country level. Some authors refer to the institutional theory to highlight the influence that the country's sustainability characteristics have on firms' sustainability practices (Baldini et al., 2018; Dhaliwal et al., 2014; Eliwa et al., 2019). Indeed, in the relationship between companies and society, rather than viewing CSR as the outcome of purely voluntary actions, institutional theory addresses the social structures that influence the nature of firms' behavior (Brammer et al., 2012; Campbell, 2007). Therefore, the countries' SDG13 score is incorporated into the model. This variable measures countries' progress toward achieving the 13th Sustainable Development Goal (Climate action) and is part of the SDG indexes sourced from the SDG Transformation Center (Sustainable Development Solutions Network, 2024). Beyond the theoretical dimension encompassing the institutional theory, following Baum et al. (2003), the validity of this instrument, as well as the others cited above, is tested through the “difference-in-Hansen” statistic, which allows for testing a subset of the orthogonality conditions. Table 10 reports the results of the specified

Table 10
Two-step system GMM.

VARIABLES	CoD
CoD _{t-1}	0.365** (0.148)
ECI _{t-1}	-0.141* (0.076)
SIZE _{t-1}	-0.014 (0.024)
PD _{t-1}	-2.654*** (0.987)
BSIZE _{t-1}	-0.580 (0.382)
BGENDER _{t-1}	-0.059 (0.144)
SOCIAL _{t-1}	0.084 (0.068)
Year FE	Yes
Obs.	1273
AR(1): p-value	0.000
AR(2): p-value	0.890
Hansen test: p-value	0.425

Notes: This table presents the results of the two-step system GMM estimation, which addresses potential endogeneity issues related to the ECI. CoD_{t-1} is the lagged dependent variable. *, **, and *** represent p-value smaller than 10 %, 5 %, and 1 %, respectively. Robust standard error in parentheses. P-values concerning the autocorrelation tests and Hansen's test for the validity of the estimation are also reported.

GMM estimation, with particular emphasis on the Arellano-Bond tests for autocorrelation, AR(1) and AR(2), as they constitute essential conditions for the estimation's validity, detecting the existence of, respectively, autocorrelation of first order and second order. To check for potential overidentification issues due to instrument proliferation, we rely on the Hansen test, which is particularly appropriate for two-step GMM estimations. Its p-value, together with that of AR(1) and AR(2) tests, is reported in [Table 10](#). According to [Roodman \(2009\)](#), it should remain far from 1.000, a value that can be artificially reached and thus is a symptom of extreme overidentification.

Another important result, which also serves as a check of the dynamic estimation, is the coefficient associated with the lagged dependent variable. Persistence in the cost of debt is present as indicated by the statistically significant coefficient on its lagged value. Furthermore, since the value is below 1, the stationary assumption for system-GMM ([Arellano & Bover, 1995](#)) is not violated. We also include time dummies – both in the model and as IV instruments – and apply the [Windmeijer \(2005\)](#) correction for robust standard errors. The coefficient associated with ECI in [Table 10](#) is statistically significant and consistent with the respective hypothesis. The results from this estimation confirm that the previously observed relationship between firms' environmental performance and their cost of debt remains significant in a dynamic panel analysis, as demonstrated by the GMM estimator.

8. Discussion

A well-established body of literature documents that improvements in firms' environmental practices can generate operational as well as market-based strategic benefits, including efficiency gains, competitive advantage, enhanced regulatory compliance and greater organizational legitimacy ([Eliwa et al., 2019](#); [Golicic & Smith, 2013](#); [Nogueira et al., 2023](#)).

From an operational perspective, improvements in environmental practices reflect the adoption of innovative processes and technologies that enhance firms' operations. Some scholars refer to the “natural resource-based view” of the firm ([Hart, 1995](#)) to argue that environmental sustainability fosters resource productivity and efficiency, leading to cost savings and better production processes ([Hermundsdottir & Aspelund, 2022](#)). When focusing on green practices linked to the circular economy, firms can enjoy enhanced operational performance in cost, time and quality ([Salandri et al., 2022](#)). This represents a win-win situation, in which a more sustainable use of energy and resources both reduces the firm's environmental impact and improves its economic outcome ([Ghisetti & Rennings, 2014](#)).

Environmental activities are also a source of innovation with market and strategic implications. They can drive improvements in sales and revenue, better satisfy customers' needs, enable the development of new products and entry into new markets, expand market share and strengthen competitive positioning ([Golicic & Smith, 2013](#); [Sardana et al., 2020](#); [Xie et al., 2019](#)).

Such operational and market-based gains have implications for credit risk and, from lenders' perspective, higher efficiency, innovation and profitability may translate into greater financial well-being and thus lower probability of default.

The process of upgrading the capital stock and the associated aforementioned gains are likely to be more substantial for Emerging Transitioners. In contrast, for firms that are already environmentally advanced and operate close to the technological frontier, marginal improvements tend to deliver limited additional benefits. Moreover, in this process, Emerging Transitioners may also be less exposed to technological uncertainty. In line with the concept of “absorptive capacity”, their environmental improvements often build upon knowledge developed elsewhere and widely adopted practices ([Narula, 2004](#)). Instead, it is reasonable to expect that further improvements for environmentally advanced firms may rely on superior and unproven technology, exposing them to greater technological, viability and outcome uncertainty ([Buchetti et al., 2024](#)) as well as the risk of green overinvestment ([Schrettle et al., 2014](#)). Accordingly, and consistent with the catch-up dynamic, marginal improvements in lagging firms translate into larger reductions in the cost of debt.

Furthermore, the progress of Emerging Transitioners reduces their risk of being locked into a path dependency, where accumulated gaps could make future alignment with advanced technology more difficult and costly ([Schrettle et al., 2014](#)).

In addition to the aforementioned operational and market-based effects, the stronger impact observed for Emerging Transitioners may also relate to the information conveyed by the transition process itself. Firms that improve their environmental position over time signal an active and observable commitment to sustainability, which can positively influence lenders' perception ([Spence, 1973](#); [Truong et al., 2021](#)). Such information facilitates a more accurate understanding of the firm's behavior and its relatively enduring characteristics, thus mitigating the informational asymmetry that contributes to corporate environmentalism being opaque ([Truong et al., 2021](#)) and perceived as risky ([Buchetti et al., 2024](#)). This transition signal is potentially stronger for environmentally lagging firms, as it reflects a more pronounced and substantive effort to change and advance towards higher levels of environmental sustainability, moving from a relatively less advanced position.

Understandably, beyond the issues related to catching up, overinvestment, and path dependency, financial actions in favor of the ecological transition may prove more beneficial for firms striving to achieve stronger sustainability rather than for those already environmentally advanced.

9. Conclusion

This paper contributes to the literature on the effect of firms' environmental performance on their cost of debt, highlighting the role of the financial system in fostering the environmental transition. Using a sample of large European listed firms from 2015 to 2023, we first examine how the main pillars of environmental sustainability – GHG emissions, renewable energy, and waste management – relate to firms' cost of financing. We then deepen our understanding of this relationship by incorporating the concept of transition into our analytical framework.

Preliminary findings suggest a negative relationship between improved environmental performance, specifically, lower CO₂ emissions, increased use of renewable energy, and higher waste recycling, and firms' cost of financing. This relation suggests that growing sustainability concerns are leading financial institutions to integrate environmental metrics in firms' cost of debt assessment, complementing the traditional measures of companies' creditworthiness.

Another key finding relates to the more dynamic aspect of environmental transition, captured through the firm-level evolution of an Environmental Composite Indicator (ECI), which aggregates the three separate environmental variables. By distinguishing between environmentally lagging and advanced firms and considering their engagement in environmental transition, we uncover a novel dynamic underlying this relationship. Environmental sustainability reduces the cost of debt, with a stronger effect for firms with lower levels of environmental performance that are engaged in transition. Therefore, while the first result shows that firms with weaker environmental performance face a higher CoD, an equal increase in the ECI leads to a greater reduction in the cost of debt for Emerging Transitioners than it does for environmentally advanced firms. This insight suggests that financial institutions are factoring transition efforts into their support for the environmental transformation of the economy. The primary targets are firms that are lagging behind in environmental sustainability but are showing improvement in their climate profile.

Our study carries some practical implications for policymakers. The evidence that lenders prioritize lagging firms engaged in environmental transition suggests a possible direction for public policy. Support schemes aimed at fostering environmental transition could benefit from being targeted similarly, considering firms' transition needs and efforts, rather than being applied uniformly. This recommendation aligns with recent guidance from the [European Commission \(2023\)](#) on transition finance. Although the legal framework is not yet defined, it is acknowledged that firms cannot transition to fully sustainable models in a single step. For an efficient, effective, and inclusive transition, it is essential to consider that economic actors can reach environmental objectives at different paces.

Although our research provides a new perspective on the relationship between firms' environmental impact and their cost of debt, accounting for the transition dimension, it is not without some limitations that future studies could address. First, the relatively short time series of available corporate environmental data limits the ability to observe firms' environmental transition over longer horizons. Observations covering a greater temporal span would allow for a more accurate and extensive tracing of the firm's improvement trajectory. Furthermore, a longer observation period could capture more substantial changes occurring between more distant stages of a given firm's transition. Future research could investigate this relationship in small and medium-sized enterprises as more environmental data becomes available. Finally, our analysis could also be extended geographically to investigate whether environmental transition considerations similarly affect the cost of debt for non-European firms.

Author statement

All authors have contributed substantially to the work reported in this manuscript. All authors were responsible for conceptualization, study design, methodology. Simona Galletta and Lorenzo Fichera conducted data collection, data analysis, software implementation. All authors drafted the manuscript and all authors reviewed and revised it. All authors approved the final version of the manuscript. The authors declare that this manuscript has not been published previously and is not under consideration for publication elsewhere.

Conflict of interest

The authors declare no conflict of interest.

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Data availability

Data will be made available on request.

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