MASTER OF SCIENCE IN
FINANCE

MASTER´S FINAL WORK
DISSERTATION

THE IMPACT OF SUSTAINABLE INNOVATION ON THE COST OF DEBT

KYLIAN DE LEEUW

JUNE - 2025

MASTER OF SCIENCE IN

FINANCE

MASTER´S FINAL WORK

DISSERTATION

THE IMPACT OF SUSTAINABLE INNOVATION ON THE COST OF DEBT

KYLIAN DE LEEUW

SUPERVISION:

VICTOR BARROS

JUNE - 2025

Abstract

This dissertation investigates the relationship between sustainable innovation and the cost of debt. Fixed Effect estimation are employed while using a sample of 747 unique firms owning sustainable patents in the European Union from 2003 until 2024. The initial analysis revealed that there is no direct relationship between sustainable innovation and the cost of debt. Further analysis by including additional sustainability measures showed that there is a positive association between sustainable innovation and the cost of debt. Conversely, there is a negative relationship between current sustainability performance and the cost of debt. The different relationship of sustainable innovation and sustainability performance with the cost of debt suggest that lenders prioritize current sustainability efforts over future-oriented ones. Additional analysis highlights that the relationship remains to exist over time, and that bigger firms, more leveraged firms and firms who are able to cover their debt obligations better are perceived as less risky and are expected to benefit from investments in sustainable innovation. This study contributes to the sustainable finance literature as it explains the effects of sustainable innovation on financing costs.

JEL: D92, G21, G32, O31, Q55

Keywords: Sustainable Innovation, Cost of Debt, ESG, Sustainability

Resumo

Esta dissertação investiga a relação entre inovação sustentável e o custo da dívida. Estimações com efeitos fixos são empregadas, utilizando uma amostra de 747 empresas únicas detentoras de patentes sustentáveis na União Europeia entre 2003 e 2024. A análise inicial revelou que não há uma relação direta entre inovação sustentável e o custo da dívida. Uma análise adicional, incluindo medidas complementares de sustentabilidade, mostrou que existe uma associação positiva entre inovação sustentável e o custo da dívida. Por outro lado, há uma relação negativa entre o desempenho atual em sustentabilidade e o custo da dívida. A diferença na relação entre inovação sustentável e desempenho em sustentabilidade com o custo da dívida sugere que os credores priorizam os esforços sustentáveis atuais em detrimento dos voltados para o futuro. Análises adicionais destacam que os efeitos persistem ao longo do tempo, e que empresas maiores, mais alavancadas e com melhor capacidade de cobrir suas obrigações de dívida são percebidas como menos arriscadas e tendem a se beneficiar de investimentos em inovação sustentável. Este estudo contribui para a literatura de finanças sustentáveis ao explicar os efeitos da inovação sustentável sobre os custos de financiamento.

JEL: D92, G21, G32, O31, Q55

Palavras-chave: Inovação Sustentável, Custo da Dívida, ESG, Sustentabilidade

Acknowledgements

This dissertation marks the conclusion of an important chapter in my academic journey, one that would not have been possible without the support and guidance of certain people.

First, I would like to express my sincere gratitude to my supervisor, Professor Victor Barros, for his invaluable support throughout this process. His insightful feedback and expert guidance were essential in overcoming challenges, particularly in the more complex stages of data analysis. Second, I want to thank all the professors I encountered during my studies, whose teaching and dedication greatly enriched my learning experience.

Next to that, I wish to thank to my family, for their unwavering support and encouragement for my choice to pursue my masters degree abroad. Finaly, I want to thank my friends as this experience would have not been the same without you.

Table of Contents

Abstract i

Resumo ii

Acknowledgements iii

List of Tables v

Table of Appendices vi

AI Disclaimer vii

Glossary viii

1. Introduction: 1

2. Literature Review 3

3. Sample and Methodology 9

   3.1 Sample Construction 9

   3.2 Methodology 10

4. Empirical Results 13

   4.1 Descriptive Statistics and Correlation 13

   4.2 Baseline Results 14

   4.3 Sustainability Effects 17

   4.4 Additional Analyses: Timing Effects 19

   4.5 Sustainable Patents and the Cost of Debt: Channels 22

   4.6 Robustness Tests 24

5. Conclusion 26

References 29

Appendices 32

List of Tables

Table 1 – Descriptive Statistics……………………………………………………………13

Table 2 – Baseline Results…………………………………………………………………...15

Table 3 – Sustainability Effects……………………………………………………………18

Table 4 – Delayed Effects…………………………………………………...………………..20

Table 5 – Forward Effects…………………………………………………………….……...21

Table 6 – Size, Leverage and Interest Coverage Effects…………………………………..23

Table 7 – System GMM………………………………………………………………………25

Table of Appendices

Appendix 1: Correlation matrix……………………………………………………………...32

Appendix 2: Sample composition per industry………………………………………………33

Appendix 3: Sample composition per country……………………………………………….33

Appendix 4: Description of variables…………………………………………………...…...34

AI Disclaimer

This dissertation was developed in strict adherence to the academic integrity policies and ethical guidelines of ISEG – Lisbon School of Economics and Management. In the interest of transparency, I disclose that artificial intelligence (AI) tools were ethically used to support the literature review, assist with improving the clarity and coherence of the written content, and aid in the development of Stata code and data visualization. The use of AI was carefully managed to ensure that the originality, scientific rigor, and integrity of the work were fully preserved.

All sources, whether identified through traditional or AI-assisted methods, have been properly cited in accordance with academic standards. The responsible use of AI was a guiding principle throughout the preparation of this dissertation.

Glossary

CPC – Cooperative Patent Classification

CSP – Corporate Social Performance

CSR – Corporate Social Responsibility

EC – European Commission

ECB – European Central Bank

EPO – European Patent Office

ESG – Environmental, Social and Governance

EU – European Union

FE – Fixed Effects

GMM – Generalized Method of Moments

IPC – International Patent Classification

OECD – Organization for Economic Cooperation and Development

OLS – Ordinary Least Squares

SFDR – Sustainable Finance Disclosure Regulation

TCFD – Task Force on Climate-Related Financial Disclosures

RE – Random Effects

USPTO – United States Patent and Trademark Office

VIF – Variance Inflation Factor

1. Introduction:

In prior research there is no consensus if sustainable practices increase or decrease the cost of debt. Some prior studies on the effect of sustainability on the cost of debt found a negative relationship between sustainability and the cost of debt (Goss & Roberts, 2011; Oikonomou, Brooks, & Pavelin, 2014; La Rosa, Liberatore, Mazzi, & Terzani, 2018), whereas others found a positive relationship (Menz, 2010; Magnanelli & Izzo, 2017; Gonçalves et al., 2022).

This dissertation aims to further investigate the relationship between sustainability and the cost of debt by developing the channel of sustainable innovation as a driver of the cost of debt. Specifically, it studies the relationship between sustainable innovation, sustainability performance and the cost of debt.

Climate change is a main concern of the 21st century with far reaching impact on society. Discussions about the impact of human activities on the environment started around 50 years ago leading to the first formal climate protocols of Montreal in 1987 and Kyoto in 1997. In 2015, the Paris Agreement on fighting climate change is the first-ever universal, legally binding global climate deal. The objective of the agreement is to maintain the increase in global temperatures well below two degrees Celsius above pre-industrial levels, whilst making efforts to limit the increase to 1.5 degrees. The European Green Deal (2019) aims to make Europe climate neutral by 2050 (Climate negotiations timeline, 2025).

These ambitious goals can only be achieved with disruptive green technologies, which requires heavy investments. Global financing needs to mitigate climate change are estimated at 5 trillion USD yearly until 2030 (OECD, 2025).

The need to increase investment in adaptation is taking place against a challenging and uncertain macroeconomic context. In many countries, high levels of public debt, high inflation and low near-term prospects for economic growth are putting pressure on public finances. These broader trends are also pushing up the cost of capital, creating challenges for private investment (OECD, 2024).

In September 2024 a report addressing European competitiveness was published by Mario Draghi, former president of the European Central Bank (ECB), on behalf of the European Commission. The report highlights the innovation gap with the US and China, especially in advanced technologies. According to the author Europe is stuck in a static industrial structure with few new companies rising up to disrupt existing industries or to develop new growth engines, and fails to translate innovation into commercialization (Draghi, 2024).

The global decarbonization drive is a growth opportunity for EU industry. The EU is a world leader in clean technologies like wind turbines and low-carbon fuels, and develops more than one-fifth of clean and sustainable technologies worldwide. If Europe is able to match its ambitious climate targets with a plan to achieve them, decarbonization will be an opportunity (Draghi, 2024).

The growing focus on environmental, social, and governance (ESG) factors has raised many unanswered questions in the financial markets. Creditors may consider a firm’s sustainability performance in their pricing decisions based on their assessment of the firm's overall risk (Gillan, Koch, & Starks, 2021). This study investigates the relationship between sustainability and the cost of debt by developing the channel of sustainable innovation as a driver of the cost of debt.

The study uses a sample of 8,862 firm-year observations including 747 unique firms owning sustainable patents in the European Union from 2003 until 2024. The model used is an extension of models used by La Rosa et al. (2018) and Gonçalves et al. (2022) to explicitly account for sustainable innovation through sustainability related patents. Sustainable innovation was measured trough sustainable patent data retrieved from Orbis IP and sustainability performance was measured trough sustainability scores retrieved from Refinitiv.

The baseline results provide weak to no evidence regarding the impact of sustainable innovation on the cost of debt. The relationship is generally weak and statistically insignificant. This can be explained by the fact that benefits of sustainable innovation, such as improved reputation or regulatory alignment, are long-term and not easily measurable, whereas lenders focus on short- to medium-term financial metrics. Additionally, the high upfront costs and uncertain returns of innovation may offset any perceived credit risk reduction, leading credit markets to overlook it when pricing debt.

Additional analysis when considering different measures of sustainability performance shows that sustainable patents become positively associated with the cost of debt. This indicates that companies investing more in sustainable innovation are viewed as riskier by lenders, which leads to a marginally higher cost of debt. This is in line with Sharfman and Fernando (2008), Menz (2010), Magnanelli & Izzo (2017), and Gonçalves et al. (2022) who all found that higher sustainability performance leads to an increase in the cost of debt. The results here provide new insights as the other studies named above used sustainability ratings instead of sustainable patents. A potential explanation for this result is that lenders view investments in sustainable innovation as risky as future returns are uncertain. Conversely, the environmental innovation and ESG score show a negative relationship with the cost of debt. This suggests that firms with stronger sustainability performance tend to secure lower financing costs, leading to a reduction in the cost of debt in line with results found by Oikonomou et al. (2014) and La Rosa et al. (2018).

The different relationship of sustainable innovation and sustainability performance with the cost of debt suggests that lenders prioritize current sustainability efforts over future-oriented ones. This likely reflects lenders' short-term focus, as debt is typically repaid within a few years, making current sustainability performance more relevant than long-term innovation.

Next to that timing effects are studied by including lagged and forward variables. The results of the analysis indicate that the above discussed effects remain to exist over time, especially for the forward values. These findings collectively suggest that lenders differentiate between the immediate costs of sustainable innovation and the long-term value of environmental leadership. Additional analysis is performed to test channels through which sustainability performance may affect the cost of debt. This provides insights that sustainable innovation can be seen as beneficial in specific cases. Bigger firms, more leveraged firms and firms who are able to cover their debt obligations better are perceived as less risky and are expected to benefit from investments in sustainable innovation, which could lead to a reduction in the cost of debt.

The dissertation continues with a literature review in chapter 2, where the concepts related to sustainable innovation, sustainability performance and the cost of debt are discussed. Chapter 3 discusses the sample and methodologies used, followed by chapter 4 where the results are shown. Lastly, chapter 5 discusses the conclusions.

2. Literature Review

Businesses feel the increasing pressure from stakeholders to adapt to the changing environment and to make their operations more sustainable. Investor interest in ESG/CSR is evidenced by the growth in mutual funds with ESG mandates and the increasing number of signatories to the Principles of Responsible Investment (PRI) (Gillan, Koch, & Starks, 2021).

The growing focus on environmental, social, and governance (ESG) factors has raised many unanswered questions in the financial markets. While a company's ESG/ Corporate Social

Responsibility (CSR) profile and activities are clearly linked to its market dynamics, leadership, ownership traits, risk, performance, and value, there remain conflicting hypotheses and results, leading to continued questions and a need for more research (Gillan, Koch, & Starks, 2021).

This dissertation explores the link between sustainable innovation and financial performance, specifically by measuring the impact of the level of sustainable innovation on the cost of debt.

To define sustainability performance and innovation it is important to understand the development of the concepts. Corporate governance is a widely recognized concept considered crucial for enhancing shareholder value, and can be defined as the system of laws, rules, and factors that control operations at a company (Gillan & Starks, 1998). Next to that there is the concept of corporate social responsibility (CSR), which can be defined as the commitment of businesses to contribute to sustainable economic development. Environmental, Social, and Governance (ESG) can be described as the broad concept of social responsibility and governance actions covering most of a companies sustainability efforts (Starks, 2009).

The use of the term sustainable innovation has been increasing over the past years, but so far the academic literature offers only a few definitions. Carrillo-Hermosilla et al. (2010) reviewed various definitions of innovation related to ecological sustainability and defined eco-innovation as "innovation that improves environmental performance." This definition is in line with the idea that the reduction in environmental impacts is the main distinguishing feature of eco-innovation.

In (2007) the European Commission, in its competitiveness and innovation framework, linked eco-innovation to sustainability, stating: "Eco-innovation is any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of natural resources, including energy." Using above definitions, Boons et al. (2012) described sustainable innovation as innovation improving sustainability performance, where performance includes ecological, economic, and social criteria.

Previous research shows that climate change increases risks within the financial system and these climate risks can be divided in two types: physical and transition risks (Battiston, Dafermos, & Monasterolo, 2021). Physical risks include damage of extreme events on assets and can be event driven (acute) or longer term shifts (chronic) in climate patterns. The impacts are already visible with acute events like floods and chronic changes like rising sea levels. Transition risks are expected to arise as a result of policy, legal, technology, and market changes. In a fast changing world new regulations and developments will follow each other quickly, which pressures firms to be agile and adaptive (TCFD, 2017).

Default risk is the primary factor influencing a firm’s cost of debt. A comparable rationale holds for negative corporate and social practices, as lenders face reputational risks from their clients' behavior. As a result, lenders may expect borrowers to take steps to address these sustainability-related risks. Since 2021 financial institutions are forced to disclose detailed sustainability information about their operations by the Sustainable Finance Disclosure Regulation (SFDR, 2021). Underscoring the importance of transparent disclosure of sustainability performance and highlighting the fact that lenders are forced to include sustainability measures in their lending decisions (Gonçalves, Dias, & Barros, 2022).

Empirical evidence indicates that increased voluntary public disclosure by firms has significant positive impacts on capital market dynamics and financial outcomes. Expanded disclosures help reduce information asymmetry between firms and investors, improving transparency in the market. Firms that provide more informative disclosures tend to have better access to external financing at lower costs and experience a lower average cost of both equity and debt capital (Healy, Hutton, & Palepu, 1999).

In prior research there is no consensus if sustainable practices increase or decrease the cost of debt. Advocates for sustainability argue, in line with risk mitigation theory, that there is a negative relationship between sustainable practices and the cost of debt, as socially responsible companies have a lower risk profile, which should allow them to secure more favorable financing terms. Conversely, critics of sustainability believe that these practices are a misallocation of limited resources, leading to an increase in the cost of debt, and propose that this indicates a positive relationship between sustainability efforts and the cost of debt (Gonçalves, Dias, & Barros, 2022).

Greater CSR/ESG performance is expected to lead to better firm financial performance. This indicates that firms that effectively execute legitimate ESG practices and report their ESG performance can anticipate improved financial outcomes. Thus, higher ESG ratings from independent agencies can translate into increased revenues or profits, reinforcing the significance of ESG performance for financial success (Lee & Raschke, 2023). Additionally, this implies that investment in CSR is beneficial for firms, contradicting the agency theory argument that suggests that investment in CSR negatively affects financial performance (Jo & Harjoto, 2012).

Next to that there is evidence that firms with good CSR are rewarded with higher credit ratings. This indicates that CSR performance provides valuable non-financial insights that credit rating agencies are likely to consider when assessing a company's creditworthiness, especially when CSR efforts go beyond basic compliance and align with broader societal expectations. In line with the idea that firms with higher credit ratings are less risky, this can lead to a lower cost of debt (Attig et al. 2013). Firms in the United States with substantial environmental concerns face greater loan spreads, as lenders factor in the potential risks associated with these concerns. In addition, firms with strong environmental performance tend to have lower loan interest rates (Chava, 2014).

Improved environmental risk management is associated with a higher cost of debt, likely due to market perceptions that view such investments as inefficient. However, firms engaging in strong environmental practices may experience increased leverage, as reduced risk makes lenders more willing to offer financing. This increased leverage can provide tax benefits which partially offset the increase in cost of debt (Sharfman & Fernando, 2008).

Some previous studies found a positive relationship between sustainability performance and the cost of debt. Menz (2010) found that CSR does not positively impact corporate bond pricing as socially responsible firms often face higher risk premiums than non-socially responsible firms. A potential explanation by the author is that credit ratings already incorporate various non-financial factors, which could lead to the fact that many bond investors may disregard CSR ratings, viewing them as having limited benefits. Additionally, the findings suggest that the corporate bond market may not efficiently price CSR risks.

Similarly, Magnanelli and Izzo (2017) found that corporate social performance (CSP) does not play a pivotal role in the cost of debt's definition process and documented a positive correlation between cost of debt and CSP after applying a linear regression model, which suggests a higher cost of debt. Gonçalves et al. (2022) also found a significant positive relationship between the cost of debt and ESG performance among European firms from 2002 to 2018 while using OLS regression models, suggesting that more socially responsible firms are penalized by lenders through an increase in interest rates. In addition, the study found that during periods of financial crisis, sustainability and the degree of under- and overinvestment in sustainability activities become irrelevant to lenders.

On the other hand, there are studies that suggest a negative relationship between sustainability performance and the cost of debt. La Rosa et al. (2018) argues that a negative relationship exists between corporate sustainability performance and interest rates, indicating that higher social performance correlates with lower borrowing costs. In line with that, the authors found that improved CSP has a positive impact on credit ratings. Results were obtained by employing a multi-theoretical framework combining economics with social theories to analyze data through multivariate regressions to explore relationships between CSP and the cost of debt and debt access among European firms from 2005 to 2012.

Similarly, Oikonomou et al. (2014) found a clear inverse relationship between corporate social performance (CSP) and the cost of corporate debt. Strong CSP leads to lower corporate bond yield spreads and improved credit ratings, while bad performance results in higher yield spreads and penalties in the credit markets. Various dimensions of CSP significantly influence debt pricing, with long-term bonds particularly benefiting from responsible practices. Goss and Roberts (2011) were able to quantify the relationship between CSR and bank debt and found that firms with social responsibility concerns pay between 7 and 18 basis points more than firms that are more responsible. Next to that the authors found mixed results related to CSR investments. Low-quality borrowers that spend more on CSR face higher loan spreads and shorter maturities, but lenders are indifferent to CSR investments by high-quality borrowers. The results support the overinvestment theory idea that lower-quality borrowers may overinvest in CSR initiatives that do not yield sufficient returns, leading lenders to increase loan costs to account for the increased risks.

Overinvestment theory is supported by agency theory and in line with this, Bénabou and Tirole (2010) discussed the concept of delegated philanthropy to explain an underlying reason of overinvestment. Delegated philanthropy can be defined as a scenario where stakeholders are willing to give up financial gains to support social goals, effectively asking companies to undertake philanthropic activities on their behalf. This delegation is seen as more efficient than individuals directly engaging in philanthropy due to lower transaction costs and existing financial relationships with corporations. Another argument to explain overinvestment theory is that managers may spend too much on philanthropy and sustainability to boost their own image, since acting responsibly can enhance their personal reputation (Barnea & Rubin, 2010).

All above discussed studies focused on the linear relationship between sustainability and the cost of debt. Ye and Zhang (2011) are the first researchers to document a U-shaped relationship between CSR and the cost of debt. Based on risk mitigation theory, the study explores if better social performance can lower the cost of debt for companies in China. The findings show that CSR improvements help reduce the cost of debt when CSR spending is below a certain optimal level. Once a firm's CSR investment goes beyond that point, the cost of debt starts to rise again. In other words, companies with very low or very high CSR investments face higher borrowing costs. The study also finds that small firms require a higher optimal level of CSR compared to large firms.

Bae et al. (2018) found a similar relationship between CSR and bank loans in the US. The authors used data from syndicated bank loans and found that the advantages of strong CSR are not consistent, but declining at a decreasing rate, relative to the loan spread of private bank loans. This suggests there is an optimal level of CSR when it comes to minimizing the cost of debt. The findings provide evidence of a non-linear relationship between CSR and the cost of debt, indicating that CSR spending beyond the optimal point may be seen as inefficient and unnecessary by lenders.

Green finance initiatives are expected to promote green technology innovation and to have an incentive effect on the application of sustainable patents. Yuan et al. (2024) found that green finance supports green technology innovation in a selected group of European countries and Zeng et al. (2023) found that green financial policies significantly promote green technology innovation and have an incentive effect on the application of green invention patents and green utility model patents innovation in China. This is particularly true for large-scale enterprises, state-owned enterprises, and non-heavy polluting enterprises (Zeng et al. 2023). In line with this, Zhao et al. (2024) found that environmental investments significantly promote enterprise green technology innovation in China. Additionally, digital transformation improves ESG development with the effect being the strongest in environmental aspects of ESG performance. The impact varies notably across industries and different levels of market competition and government subsidies (Chen & Ren, 2024).

Climate change regulatory shocks generally increase the cost of debt. However, this scenario is reversed for firms that find greater opportunities within climate change regulations, suggesting that the regulatory risk premium associated with climate change may not always be positive. The negative impact of regulations is stronger in companies with a higher beta, greater asset tangibility, and weaker environmental innovation performance (Jin & Wang, 2025). These findings highlight the potential benefits of strong sustainable innovation performance.

For Chinese companies proof is found that digital transformation reduces a companies default risk, helps businesses secure more bank loans and reduces financial distress. Digital transformation significantly reduces debt default risk by easing financing constraints and boosting productivity. Companies with higher returns on assets, higher R&D investment, larger scale, higher leverage, and higher information transparency experience an even stronger risk mitigation effect from digital transformation (Chen et al. 2024). Additionally, proof was found that digital transformation helps businesses secure more bank credit loans by boosting operational efficiency, strengthening external supervision, and lowering default risk. The impact is especially strong for firms with weaker competitiveness, fewer institutional investors, and lower solvency (Chen et al. 2025). In line with that, digital transformation significantly reduces financial distress, and its positive effect is even stronger under higher economic policy uncertainty. This reduction occurs mainly by lowering operational risk and easing financing constraints (Cui & Wang, 2023).

The objective of this dissertation is to answer the research question: "What is the impact of sustainable innovation on the cost of debt?" To answer the research question the following hypothesis is constructed:

Hypothesis I: There is an association between the level of sustainable innovation and the cost of debt.

In this hypothesis the relationship between sustainable innovation and the cost of debt will be investigated. It will add value to the literature as it is new to study the effect of sustainability and innovation combined on the cost of debt. The expected outcome is hard to predict as in prior research there is no consensus about how sustainability practices affect the cost of debt. Some studies found a negative relationship (Goss & Roberts, 2011; Oikonomou et al., 2014; La Rosa, Liberatore et al., 2018), whereas others found a positive relationship (Menz, 2010; Magnanelli & Izzo, 2017; Gonçalves et al., 2022).

3. Sample and Methodology

3.1 Sample Construction

The initial sample of this study consists of 1,221 unique firms that own sustainable patents in the European Union (EU). All owners are European subsidiaries, but firms can be part of a group headquartered outside of the EU. The data ranges from 2003 until 2024. Companies operating in the financial industry were left out as their capital market decisions are heavily influenced by industry-specific regulations, which differ significantly from those affecting non-financial firms (Pittman & Fortin, 2004). Observations with missing financial or ESG data are excluded from the sample and to account for extreme outliers, financial variables are winsorized at the 1st and 99th percentiles.

The sample after exclusions consists of 747 firms belonging to 38 countries and 9 industry sectors, totaling 8,862 firm-year observations. Appendices 2 and 3 present the sample composition by industry and by country.

To measure sustainable innovation a sample of sustainable patents is constructed with data from Orbis IP. To define sustainable patents the Cooperative Patent Classification (CPC) is used. CPC is a patent classification managed by European Patent Office (EPO) & United States Patent and Trademark Office (USPTO) with the purpose to provide a more detailed and modern classification system derived from the International Patent Classification (IPC). CPC adds a Y-section for emerging technologies for sustainability related patents. For the purpose of this research all patents belonging to this CPC Y-category are considered as sustainable. The dataset includes all patents classified as sustainable with owners in the European Union in the timeframe of 2003 to 2024. The variable sustainable patents is presented as a count of sustainable patent applications per year for every firm.

ESG scores are retrieved from Refinitiv to measure sustainability performance. Refinitiv ESG scores are calculated based on a company's performance in the Environmental, Social, and Governance areas. Companies are scored on these metrics relative to their industry peers. The final ESG score reflects a weighted average of the three pillars, aiming to provide a comprehensive view of a company's sustainability performance. Additionally, Refinitiv's Environmental Innovation Score, which is part of the broader ESG score system is retrieved. The Environmental Innovation Score assesses a company's performance in using innovation to address environmental issues. This score reflects a company's ability to innovate in areas like product, process, and business models to mitigate environmental impact.

The cost of debt is calculated, in line with previous research on the topic, as the ratio of a companies interest expense over its total debt outstanding (Gonçalves, Dias, & Barros, 2022) (La Rosa, Liberatore, Mazzi, & Terzani, 2018).

3.2 Methodology

Different models are applied to study the relationship between sustainable innovation, sustainable performance and the cost of debt. The models control for firm-specific characteristics. The first equation below presents the base model and is designed to test hypothesis H1:

$$Cost\ of\ Debt_{i,t} = \beta_0 + \beta_1\ \text{SustainablePatents}_{i,t} + \beta_2\ \text{Leverage}_{i,t} + \beta_3\ \text{TobinQ}_{i,t} + \beta_4\ \text{OCF}_{i,t} + \beta_5\ \text{IntCov}_{i,t} + \beta_6\ \text{Performance}_{i,t} + \beta_7\ \text{Tang}_{i,t} + \beta_8\ \text{AssetG}_{i,t} + \beta_9\ \text{Liq}_{i,t} + \beta_{10}\ \text{Size}_{i,t} + \varepsilon_{i,t}$$

Equation 1

where i denotes each firm and t the corresponding year. Sustainable patents serves as the independent variable and is computed as described in the above section. Firm control variables are defined as follows:

Tobin Q ratio (TobinQ): Calculated as the sum of the market value of equity and total debt, divided by total assets. Similar to the market-to-book ratio, Tobin Q serves as a risk control, an indicator of market mispricing, and a measure of growth potential (Goss & Roberts, 2011). Previous studies suggest that Tobin Q is expected to have a negative relationship with the cost of debt (Gonçalves, Dias, & Barros, 2022).

Operating cash flow (OCF): Calculated as the ratio between operating cash flow and total assets. A higher cash flow indicates that a firm is able to generate a sufficient amount of cash to cover its debt payments. This is expected to lead to reduction in the cost of debt, and as a result of that a negative relationship is expected between both variables (Gonçalves, Dias, & Barros, 2022).

Interest coverage ratio (IntCov): Calculated as the sum of net income and interest expenses, divided by interest expenses. A negative relationship is expected between interest coverage and the cost of debt, as a higher interest coverage ratio shows that a firm can earn enough income to cover its debt payments, which helps to lower its cost of borrowing (Gonçalves, Dias, & Barros, 2022).

Performance: Calculated as net income before extraordinary items divided by revenue. Higher profitability shows that a company is better able to generate income, which reduces its default risk. Therefore, a negative relationship between performance and the cost of debt is expected (Gonçalves, Dias, & Barros, 2022).

Asset tangibility (Tang): Calculated as the ratio between property plant and equipment and total assets. Tangible assets can be used as a collateral, and therefore firms with more tangible assets are viewed as less risky by lenders. This reduction of implied risk makes lenders more willing to offer lower interest rates, which suggests a negative relationship between asset tangibility and the cost of debt (Gonçalves, Dias, & Barros, 2022).

Asset growth (AssetG): Calculated as the annual percentual change in total assets. A higher asset growth indicates greater investments in expansion of a firm. There are two different arguments to explain how lenders view this. One explanation is that growth indicates a healthy company as sufficient resources are required to finance the expansion. On the other side, it can also be viewed as riskier as rapid growth can increase the uncertainty around future cash flows. Therefore, it is difficult to predict the relationship between asset growth and the cost of debt, but previous research on the topic suggests a negative relationship (Gonçalves, Dias, & Barros, 2022).

Liquidity (Liq): Calculated as the current ratio by dividing current assets over current liabilities. Higher liquidity indicates that a firm is able to cover its short term obligations, which decreases its default risk. As a result of this a negative relationship is expected between liquidity and the cost of debt (Gonçalves, Dias, & Barros, 2022).

Firm Size (Size): Calculated as the natural logarithm of a firm's total assets. Research shows that larger firms are generally less affected by negative cash flow events, which lowers their risk of default. Moreover, larger firms are able to offer more collateral compared to smaller ones, making them appear less risky to lenders (Goss & Roberts, 2011). Therefore, a negative relationship between firm size and the cost of debt is expected.

Leverage (Lev): Calculated as the ratio between total debt and total assets. Previous research shows two opposite arguments explaining the relationship between leverage and the cost of debt. On one side, a positive relationship is suggested, supported by the argument that increased leverage leads to an increase in default risk (Goss & Roberts, 2011). On the other side, a negative relationship is suggested, supported by the argument that a higher level of leverage can be associated with higher creditworthiness, leading to a reduction in the cost of debt (Ye & Zhang, 2011). Therefore, it is difficult to predict the relationship between leverage and the cost of debt.

4. Empirical Results

4.1 Descriptive Statistics and Correlation

Table 1 presents the descriptive statistics for all variables in the cost of debt models. The descriptive statistics show that the sample consists of 8,862 firm-year observations. The average cost of debt is 4.2%, with a standard deviation of 4.3%, indicating that most firms face relatively low borrowing costs with some variation across the sample. The average number of sustainable patent applications per year is 0.95, with a large standard deviation of 6.35, suggesting that while some firms are highly innovative in sustainability, many others hold few or no new patents on a yearly basis.

The ESG Score has a mean of 56.67 and a standard deviation of 20.51, reflecting substantial differences in firms' environmental, social, and governance performance. The Environmental Innovation score has a mean of 48.59 and a standard deviation of 32.75, indicating wide dispersion in environmental innovation activities among firms.

Tobin’s Q has an average of 1.72 and firms exhibit a positive mean operating cash flow (OCF) of 0.086, though variability is evident with a standard deviation of 0.057. The interest coverage ratio (IntCov) shows a mean of 18.83, though the large standard deviation (48.57) suggests the presence of firms with significantly different abilities to cover their interest obligations. Other variables such as performance, tangibility, asset growth, liquidity, size, and leverage also show a reasonable variability across its distribution, indicating that the sample captures firms with diverse financial and operational profiles.

Table 1 – Descriptive Statistics

	N	Mean	SD	p25	Median	p75
Cost of Debt	8862	4.225	4.339	1.816	3.309	5.187
ESG Score	8862	56.673	20.507	41.832	59.617	72.823
Sustainable Patents	8862	0.950	6.345	0.000	0.000	0.000
Environmental Innovation	8862	48.590	32.752	20.690	50.000	78.571
TobinQ	8862	1.722	1.086	1.073	1.359	1.949
OCF	8862	0.086	0.057	0.057	0.085	0.115
IntCov	8862	18.832	48.565	2.877	6.727	15.364
Performance	8862	0.058	0.100	0.024	0.054	0.096
Tang	8862	0.257	0.160	0.123	0.232	0.355
AssetG	8862	0.079	0.208	-0.023	0.043	0.123
Liquidity	8862	1.626	0.815	1.118	1.420	1.870
Size	8862	23.031	1.475	21.988	23.021	24.089
Leverage	8862	0.253	0.136	0.156	0.243	0.338

Appendix 1 shows the Pearson correlation matrix. There is no significant correlation between sustainable patents and the cost of debt. There is a statistically significant negative correlation of 0.153 between the cost of debt and ESG Score, suggesting that firms with higher ESG performance tend to experience lower borrowing costs. Similarly, the cost of debt is negatively correlated with environmental innovation (-0.169), indicating that firms that invest more in environmental innovation also benefit from reduced financing costs.

The correlation matrix also reveals a statistically significant relationship between several independent variables. In particular, the correlation between firm size and ESG Score is relatively high (0.521), suggesting that larger firms are more likely to have higher ESG ratings. Additionally, a strong positive correlation is observed between operating cash flow (OCF) and performance (0.720), indicating that firms with stronger cash flows tend to exhibit better financial performance.

Furthermore, the negative correlation between firm size and leverage (-0.249) suggests that larger firms may rely less on debt financing compared to smaller firms. The inverse relationship between liquidity and leverage (-0.305) indicates that firms with higher liquidity levels tend to maintain lower debt ratios.

To check for potential multicollinearity a Variance Inflation Factors (VIF) test is performed. All VIF values are below the common threshold of 5, with the highest being 2.59 for OCF, indicating that multicollinearity is not a serious concern in this model. The mean VIF of 1.47 further supports this conclusion, suggesting that the predictors are sufficiently independent from one another for reliable estimation.

4.2 Baseline Results

Table 2 shows the baseline results from the regressions using different estimations. In column 1 is presented the standard pooled OLS. In columns 2 and 3 the approach is constrained to a panel specification, presenting both Random Effects and Fixed Effects specifications. The cost of debt is used as dependent variable and sustainable patents is used as the explanatory variable in all the models. Each model is controlled with a set of control variables. The OLS and Random Effects model controls for industry effects to account for industry specific variability on definition of the cost of debt.

Table 2 – Baseline Results

	(1) OLS	(2) RE	(3) FE
Sustainable patents	0.00785*	0.00936**	0.00667
	(0.00419)	(0.00461)	(0.00453)
TobinQ	0.45963***	0.10722	0.04715
	(0.08438)	(0.12133)	(0.13657)
OCF	4.94221***	4.74602*	3.39223
	(1.79697)	(2.49067)	(2.58650)
IntCov	-0.00644***	-0.00850***	-0.00836***
	(0.00208)	(0.00258)	(0.00267)
Performance	-3.27753***	-1.50530	-1.05699
	(0.91490)	(1.19702)	(1.25931)
Tang	-0.90151***	-0.57099	-1.58245
	(0.31266)	(0.88952)	(1.39754)
AssetG	-1.06619***	-1.14473***	-0.89514***
	(0.26132)	(0.31822)	(0.33714)
Liquidity	0.18884**	0.46855***	0.51128***
	(0.09007)	(0.16065)	(0.18833)
Size	-0.35996***	-0.91244***	-1.68382***
	(0.03364)	(0.08792)	(0.16578)
Leverage	-8.15121***	-8.93195***	-8.52118***
	(0.46198)	(0.95060)	(1.07681)
Intercept	13.88182***	26.46824***	44.64508***
	(0.86421)	(2.16671)	(3.89928)
Industry effects	Y	Y	N
Observations	8862	8862	8862
Adj R^2	0.12661	-	0.12228
F-stat	34.97728	-	20.96585

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

The goal of the baseline analysis is to investigate if there is a relationship between sustainable innovation and the cost of debt, and to select the most appropriate model for the analysis. In the OLS regression of model 1, the coefficient of sustainable patents shows a positive and statistically significant relationship at the 10% level, suggesting that, firms with more sustainable patents tend to experience a slightly higher cost of debt. This positive relationship remains significant in the Random Effects (RE) model at the 5% level, indicating a weak positive relationship between sustainable innovation and the cost of debt.

In the fixed effects (FE) specification, the coefficient on sustainable patents becomes statistically insignificant, in contrast to the OLS and RE models. This outcome can be explained by the nature of the FE estimator, which isolates within-firm variation over time by eliminating all time-invariant firm-level characteristics. Consequently, the FE model discards any between-firm differences that may explain variation in the cost of debt, focusing only on how changes in sustainable patent activity within a firm influence its borrowing costs. The lack of significance suggests that sustainable patenting varies relatively little within firms across the sample period, limiting the FE model's ability to detect an effect. By controlling for these factors, the FE model provides a more conservative estimate, indicating that sustainable patents may not have an effect on the cost of debt when accounting for firm-specific effects.

To decide whether fixed effects or random effects are more relevant for this study, the Hausman specification test was conducted. The results ($\chi^2(10) = 157.65$, $p < 0.0001$) provide strong evidence that the difference in coefficients between the fixed and random effects models is systematic. This suggests that the random effects assumptions are violated, and the fixed effects model is more appropriate for the analysis.

The results provide weak to no evidence to support Hypothesis I regarding the impact of sustainable innovation on the cost of debt. While sustainable innovation appears to have a marginal positive effect in the OLS and RE models, the relationship is generally weak. Using FE specifications, the effect even becomes statistically insignificant. This may be rationalized by several economic factors. Firstly, sustainable innovation is often associated with long-term strategic benefits, such as enhanced brand value, regulatory compliance, or risk mitigation, which may not be immediately observable or quantifiable. Lenders tend to be more risk-averse and focus on short- to medium-term cash flows, leverage, and credit metrics, which may not be significantly affected by sustainability initiatives in the short run. Second, while sustainable innovation can enhance a firm's reputation and stakeholder trust, it often involves high upfront costs, uncertain payoffs, and long investment horizons, which may offset any perceived reduction in credit risk. As a result, credit markets might not price in these initiatives when determining interest rates or loan terms, particularly if such innovation is not directly linked to improvements in operational efficiency or financial performance.

Most control variables show the expected signs. Interest coverage is negatively related to the cost of debt and statistically significant at the 1% level in all models, suggesting that a higher interest coverage ratio decreases the cost of debt. Asset growth is negative and statistically significant at the 1% level in all models, suggesting that a higher growth rate could lead to a reduction in the cost of debt. Size is negatively related to the cost of debt and statistically significant at the 1% level in all models, suggesting that larger firms are viewed as less risky by lenders. Leverage is negative and statistically significant at the 1% level in all models, in line with the argument that highly leveraged firms are perceived as more creditworthy. Performance and tangibility are in line with the expectations significantly negatively related to the cost of debt in the OLS model, but lose significance in the Fixed and Random Effects estimations.

Liquidity shows an unexpected positive sign and is statistically significant at least at the 5% level. Gonçalves et al. (2022) found the same unexpected relationship. A potential explanation for this could be that lenders view high liquidity as inefficient and a waste of resources. Tobin's Q and operating cash flow show opposed to the expectations a positive and significant relationship with the cost of debt in the OLS model, but this effect diminishes in the Fixed and Random Effects models.

The fit, as indicated by the adjusted R^2, is modest across the models, ranging from approximately 12.2% to 12.7%, suggesting that the models explain a reasonable proportion of the variance in the cost of debt. The F-statistics for the models indicate that the models are statistically significant overall.

4.3 Sustainability Effects

To investigate the relationship between sustainable innovation and the cost of debt further Table 3 shows the results from the FE regressions where additional sustainability effects are added to the model. The cost of debt is used as dependent variable and sustainable patents is used as the explanatory variable in all the models. The Environmental innovation and ESG scores, which are retrieved from Refinitiv are used as additional explanatory variables. Next to that a interaction term between Environmental innovation and sustainable patents is added. Each model is controlled with the same nine control variables as before.

Table 3 – Sustainability Effects

	1	2	3
Sustainable patents	0.00812*	0.00854**	
	(0.00460)	(0.00429)	
Environmental innovation	-0.01253***		-0.01258***
	(0.00291)		(0.00292)
ESG Score		-0.03594***	
		(0.00554)	
Environmental Innovation x Sustainable patents			0.00009*
			(0.00004)
Intercept	40.28459***	31.29975***	40.26962***
	(4.01633)	(3.97299)	(4.01629)
Control variables	Y	Y	Y
Industry effects	N	N	N
Observations	8862	8862	8862
R-squared	0.12919	0.13781	0.12915
Adj R^2	0.12811	0.13674	0.12806
F-stat	19.58553	21.05253	19.34323

Robust standard errors are in parentheses, All estimations use FE
**** p<.01, ** p<.05, * p<.1*

To investigate the relationship between sustainable innovation and the cost of debt further additional sustainability variables are added to the model, which seems to improve the model. The results consistently show that sustainable patents become positively associated with the cost of debt and the relationship is now significant at least at the 10% level across all specifications. This indicates that companies investing more in sustainable innovation are viewed as riskier by lenders, which leads to a marginally higher cost of debt. This is in line with Sharfman and Fernando (2008), Menz (2010), Magnanelli & Izzo (2017), and Gonçalves et al. (2022) who all found that higher sustainability performance leads to an increase in the cost of debt. The results here provide new insights as the other studies named above used sustainability ratings instead of sustainable patents. A potential explanation for this result is that lenders view investments in sustainable innovation as risky as future returns are uncertain. A key addition in this analysis is the environmental innovation score, which shows a statistically significant at the 1% level negative relationship with the cost of debt across all models, suggesting that firms with stronger environmental innovation capabilities tend to secure lower financing costs.

In the second model, the ESG score is introduced as a replacement of the environmental innovation score and shows a negative and highly significant effect on the cost of debt. This suggests that companies showing better sustainability performance are viewed less risky by lenders, which leads to a reduction in the cost of debt. This is in line with results found by Oikonomou et al. (2014) and La Rosa et al. (2018), which suggests that lenders value strong sustainability performance positively.

The third model incorporates the interaction variable Environmental Innovation x Sustainable patents, which combines environmental innovation scores with sustainable patents. The coefficient for this variable is positive and statistically significant at the 10% level, although the effect size is economically small. This suggests that while sustainable innovation individually may increase the cost of debt, its interaction with broader environmental efforts may capture nuanced perceptions of sustainability by lenders.

The fact that sustainable patents, environmental innovation and ESG performance show a different relationship with the cost of debt provides interesting additional insights. All three variables are a measure of sustainability, where sustainable patents are more future focused, environmental innovation and ESG performance are a representation of current performance. This suggests that lenders value current sustainability performance more than future performance. A potential explanation for this is that lenders often are more short-term focused as debt obligations will be paid back in just a couple of years in most cases. The long-term beneficial effects of sustainable innovation are as a result of this not that relevant to lenders.

The findings suggest that policymakers should support mechanisms that make the value of sustainable innovation more transparent and financially attractive, for example with green innovation subsidies or tax incentives, to help lenders better assess and reward long-term sustainability investments. For managers, the results highlight the importance of linking sustainable patenting efforts to clear, measurable environmental outcomes and communicating these effectively to financial stakeholders. Simply investing in green R&D is unlikely to reduce borrowing costs unless it is accompanied by demonstrable performance improvements that signal reduced risk and long-term value.

4.4 Additional Analyses: Timing Effects

To further explore the relationship between sustainable innovation and the cost of debt, additional regression analyses were conducted to test timing effects by including lagged independent variables. The models in table 4 account for the potential delayed effects of sustainable activities on firms' cost of debt. Specifically, the first and second lags of Sustainable Patents and Environmental Innovation were introduced as explanatory variables. All models were estimated using FE and controlled for the same variables as in the baseline analysis.

Table 4 – Delayed Effects

	1	2	3	4
L.Sustainable patents	0.00267			
	(0.00476)			
L2.Sustainable patents		0.00274		
		(0.00572)		
Sustainable patents			0.00832*	0.00993*
			(0.00495)	(0.00538)
Environmental innovation	-0.01012***	-0.00843***		
	(0.00295)	(0.00288)		
L.Environmental innovation			-0.01110***	
			(0.00293)	
L2.Environmental innovation				-0.01170***
				(0.00281)
Intercept	43.77505***	45.50149***	42.98713***	43.39811***
	(4.24842)	(4.26608)	(4.26557)	(4.26825)
Control variables	Y	Y	Y	Y
Industry effects	N	N	N	N
Observations	7989	7251	7989	7251
R-squared	0.13405	0.12711	0.13555	0.13137
Adj R^2	0.13285	0.12578	0.13436	0.13005
F-stat	19.63867	18.19101	20.25189	19.35272

Robust standard errors are in parentheses, All estimations use FE
**** p<.01, ** p<.05, * p<.1*

The goal of the analyses is to investigate if there exists a timing effect. The results presented in Table 4, indicate that the lagged values of sustainable patents are not statistically significant in Models 1 and 2, suggesting that past sustainable patenting activity does not have a clear delayed effect on the cost of debt. A potential explanation for the lack of significant lagged effects is that credit markets may respond more strongly to visible, current innovation signals than to past activities. Sustainable patents, while forward-looking indicators of innovation, may not immediately translate into proven technologies, revenue generation, or operational improvements. Lenders might prioritize tangible, near-term outcomes over historical patent filings when assessing risk.

In contrast, the environmental innovation score consistently shows a negative and highly significant relationship with the cost of debt across all model specifications. Both the first and second lags of environmental innovation are significant at the 1% level, indicating that improvements in a firm's environmental innovation performance lead to lower borrowing costs over time. This effect is robust and persistent, reinforcing the interpretation that environmental innovation is perceived by lenders as a signal of improved long-term resilience, regulatory alignment, and reduced credit risk.

In summary, while sustainable patenting appears to be associated with an increase in the cost of debt, its lagged effects are not statistically meaningful. Meanwhile, environmental innovation has a clear and persistent negative impact on borrowing costs. These findings suggest that creditors may differentiate between types of sustainability innovation, viewing patenting as more uncertain or costly in the short term, while valuing environmental innovation as a sign of long-term financial and operational soundness.

To complement the lagged variable analysis, table 5 shows an additional analysis introducing forward values of sustainable patents and environmental innovation into the regression models. This approach aims to explore whether the cost of debt might be influenced by firms' anticipated future innovation activities and sustainability efforts. All models were estimated using FE and are controlled for the same variables as in the baseline analysis.

Table 5 – Forward Effects

	1	2	3	4
F.Sustainable patents	0.00984*			
	(0.00597)			
F2.Sustainable patents		0.01007**		
		(0.00485)		
Sustainable patents			0.00557	0.00509
			(0.00427)	(0.00429)
Environmental innovation	-0.01194***	-0.01153***		
	(0.00294)	(0.00293)		
F.Environmental innovation			-0.01068***	
			(0.00300)	
F2.Environmental innovation				-0.01128***
				(0.00328)
Intercept	42.16071***	42.78119***	43.18199***	43.96678***
	(4.14440)	(4.40140)	(4.12305)	(4.39360)
Control variables	Y	Y	Y	Y
Industry effects	N	N	N	N
Observations	7989	7251	7989	7251
R-squared	0.12617	0.12868	0.12436	0.12707
Adj R^2	0.12497	0.12736	0.12315	0.12574
F-stat	18.77645	19.14851	18.19592	18.12223

Robust standard errors are in parentheses, All estimations use FE
**** p<.01, ** p<.05, * p<.1*

The goal of the analyses is to investigate if there exists a forward-looking timing effect. The results show that both the first and second leads of sustainable patents are positively and significantly, at least at the 10% level, associated with the cost of debt. These findings suggest that lenders may anticipate that firms investing in sustainable patenting activities in the near future will incur additional risks or costs, which are reflected in higher debt pricing even before these innovations are realized. This forward-looking effect indicates that creditors might proactively adjust borrowing costs based on expected sustainability strategies.

Conversely, the forward-looking environmental innovation score consistently shows a negative and highly significant effect on the cost of debt. Both the first and second leads are significant at the 1% level, indicating that firms expected to improve their environmental innovation performance are rewarded with lower borrowing costs in the present. This finding aligns with the idea that lenders perceive firms committed to ongoing environmental innovation as more stable, forward-thinking, and better positioned to manage future risks, thereby justifying a lower cost of debt.

This analysis suggests that lenders not only react to past and current sustainable activities, but also proactively incorporate expectations about future sustainability efforts into credit pricing. The positive association between future sustainable patents and cost of debt likely reflects lender's concern with the potential financial strain of innovation projects. Meanwhile, the negative association with anticipated environmental innovation performance highlights the perceived long-term financial stability and risk mitigation benefits of sustainability leadership.

Taken together, while sustainable innovation efforts may temporarily increase firms' cost of debt due to perceived risks, the overall trajectory of environmental innovation contributes to lower borrowing costs as firms signal their long-term commitment to sustainability. This forward-looking dimension further strengthens the argument that the cost of debt is not just a response to historical performance, but also a reflection of market expectations regarding the sustainability strategies firms intend to pursue.

4.5 Sustainable Patents and the Cost of Debt: Channels

To further explore relationship between sustainable innovation and the cost of debt relevant channels are studied. Table 6 shows the results from the FE regressions where interaction terms are created between sustainable patents and the variables size, leverage and interest coverage. Each model is controlled with the same nine control variables excluding the variable used in the interaction term, to avoid multicollinearity.

Table 6 – Size, Leverage and Interest Coverage Effects

	(1) Size	(2) Lev	(3) IntCov
Sustainable patents	0.28440***	0.03582***	0.01376**
	(0.10849)	(0.01344)	(0.00555)
Environmental innovation	-0.02110***	-0.01174***	-0.01298***
	(0.00284)	(0.00299)	(0.00292)
Size x Sustainable patents	-0.01117***		
	(0.00431)		
Leverage x Sustainable patents		-0.09579**	
		(0.03844)	
IntCov x Sustainable patents			-0.00033*
			(0.00018)
Intercept	6.37679***	43.40533***	40.92009***
	(0.69928)	(4.02514)	(4.12404)
Control variables	Y	Y	Y
Industry effects	N	N	N
Observations	8862	8862	8862
R-squared	0.10299	0.09871	0.12348
Adj R^2	0.10187	0.09759	0.12239
F-stat	16.10939	18.70310	20.21919

Robust standard errors are in parentheses, All estimations use FE
**** p<.01, ** p<.05, * p<.1*

The goal of the first model is to investigate if a firms' size affects the perception of how sustainable innovation is viewed by lenders. The results show a negative, and statistically significant at the 1% level, coefficient for the interaction term between size and sustainable patents. This implies that the beneficial effect of sustainable patents on cost of debt grows stronger as firm size increases. As seen before sustainable innovation by itself increases the cost of debt, but this effect weakens or reverses for larger firms. A potential explanation for this is that larger firms are generally less affected by negative cash flow events, which gives them more opportunities to invest in innovation without increasing their risk profile too much.

The second model investigates the effect of leverage on a companies' sustainable innovation strategies and shows a negative, and statistically significant at the 5% level, coefficient for the interaction term between leverage and sustainable patents. This implies that leveraged firms with more investments in sustainable innovation may be rewarded by lenders with a reduction in the cost of debt. Where sustainable innovation alone raises cost of debt, the interaction between leverage and sustainable innovation flips the effect. A potential explanation for this is that firms with both higher leverage and investments in sustainable innovation may appear more mature or strategically sound to lenders.

The third model investigates the effect of a companies' interest coverage abilities and shows a small negative, and statistically significant at the 10% level, coefficient for the interaction term between interest coverage and sustainable patents. This implies that when a firm has strong interest coverage and invests in sustainable innovation, it may reduce its cost of debt. A potential explanation for this is that innovation is seen as a good thing for financially healthy firms as their general risk profile is lower.

Overall, there can be concluded that investments in sustainable innovation are viewed as risky by lenders, leading to an increase in the cost of debt. Investigating channels provides additional insights that sustainable innovation can be seen as beneficial in specific cases. Bigger firms, more leveraged firms and firms who are able to cover their debt obligations better are perceived as less risky, and are expected to benefit from investments in sustainable innovation, which could lead to a reduction in the cost of debt.

4.6 Robustness Tests

To ensure the reliability and validity of the baseline results, this section presents robustness tests using the System Generalized Method of Moments (System GMM) estimator. This technique accounts for potential endogeneity, measurement errors, and dynamic relationships by incorporating the lagged dependent variable as a regressor (Blundell & Bond, 1998). By doing so, the analysis corrects for unobserved heterogeneity and simultaneity bias, providing a more reliable estimation framework. However, although System GMM offers advantages in addressing endogeneity and dynamic feedback, it also involves complex assumptions and risks of instrument proliferation. Therefore, FE estimation is used as the baseline due to its interpretability and fewer assumptions, while System GMM serves as a robustness check to validate the stability and reliability of the core findings.

Table 7 – System GMM

	(1) Cost of Debt
L.Cost of Debt	0.557***
	(0.104)
Sustainable patents	0.00434
	(0.00552)
Environmental Innovation	-0.0418*
	(0.0218)
TobinQ	0.0702
	(0.105)
OCF	0.179
	(1.830)
IntCov	-0.00590**
	(0.00273)
Performance	0.538
	(1.386)
Tang	-0.367
	(0.364)
AssetG	-1.875***
	(0.308)
Liquidity	0.125
	(0.106)
Size	0.104
	(0.113)
Leverage	-4.781***
	(0.876)
Intercept	2.604
	(1.728)
Industry effects	N
Observations	7989
F p-value	0.000
AR(1) p-value	0.000
Hansen p-value	0.255
Sargan p-value	0.049
Difference-in-Hansen p-value	0.055

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

The GMM estimation shows a significant positive relationship between past and current cost of debt. This outcome highlights the persistence of financing conditions over time, suggesting that the cost of debt is influenced by its historical levels. The sustainable patent variable does not show a significant direct influence on the cost of debt, while the environmental innovation score is marginally significant with a negative coefficient. Which confirms the reliability of the baseline results.

The Arellano-Bond test for first-order autocorrelation (AR(1)) is significant, which is expected in differenced models. The Hansen test of overidentifying restrictions suggests that the instruments used in the model are valid and not overfitted, while the Sargan test is marginally significant but less reliable in the presence of heteroskedasticity and a large number of instruments. Furthermore, the Difference-in-Hansen tests confirm the exogeneity of instrument subsets, with p-values comfortably above conventional significance levels.

Overall, the diagnostic results indicate that the model is well-specified, the instruments are appropriate, and the GMM estimation provides robust and reliable results.

5. Conclusion

The main goal of this dissertation was to study the relationship between sustainable innovation and the cost of debt. The study uses a sample of 8,862 firm-year observations including 747 unique firms owning sustainable patents in the European Union from 2003 until 2024. The model used is an extension of models used by La Rosa et al. (2018) and Gonçalves et al. (2022) to explicitly account for sustainable innovation through sustainability related patents. FE models were used, while controlling for the following variables: TobinQ, OCF, IntCov, Performance, Tang, AssetG, Liquidity, Size and Leverage.

The baseline results provide weak to no evidence regarding the impact of sustainable innovation on the cost of debt. The relationship is generally weak and statistically insignificant. This can be explained by the fact that benefits of sustainable innovation, such as improved reputation or regulatory alignment, are long-term and not easily measurable, whereas lenders focus on short- to medium-term financial metrics. Additionally, the high upfront costs and uncertain returns of innovation may offset any perceived credit risk reduction, leading credit markets to overlook it when pricing debt.

Additional analysis when considering different measures of sustainability performance shows that sustainable patents become positively associated with the cost of debt. This indicates that companies investing more in sustainable innovation are viewed as riskier by lenders, which leads to a marginally higher cost of debt. This is in line with Sharfman and Fernando (2008), Menz (2010), Magnanelli & Izzo (2017), and Gonçalves et al. (2022) who all found that higher sustainability performance leads to an increase in the cost of debt. The results here provide new insights as the other studies named above used sustainability ratings instead of sustainable patents. A potential explanation for this result is that lenders view investments in sustainable innovation as risky as future returns are uncertain. Conversely, the environmental innovation and ESG score show a negative relationship with the cost of debt. This suggests that firms with stronger sustainability performance tend to secure lower financing costs, leading to a reduction in the cost of debt in line with results found by Oikonomou et al. (2014) and La Rosa et al. (2018).

The different relationship of sustainable innovation and sustainability performance with the cost of debt suggest that lenders prioritize current sustainability efforts over future-oriented ones. This likely reflects lenders' short-term focus, as debt is typically repaid within a few years, making current sustainability performance more relevant than long-term innovation.

Next to that timing effects are studied by including lagged and forward variables. The positive effects of sustainable patents on the cost of debt show the risk associated with pursuing sustainability through innovation. On the other hand, the negative impact of the environmental innovation score underscores the long-term financial advantages of building strong environmental capabilities. The results of the analysis indicate that the effect remains to exist over time, especially for the forward values.. These findings collectively suggest that lenders differentiate between the immediate costs of sustainable innovation and the long-term value of environmental leadership.

Additional analysis is performed to test channels through which sustainability performance may affect the cost of debt. This provides insights that sustainable innovation can be seen as beneficial in specific cases. Bigger firms, more leveraged firms and firms who are able to cover their debt obligations better are perceived as less risky and are expected to benefit from investments in sustainable innovation, which could lead to a reduction in the cost of debt.

To ensure the reliability and validity of the baseline results, robustness tests using the System GMM estimator are performed. Overall, the diagnostic results indicate that the model is well-specified, the instruments are appropriate, and the GMM estimation provides robust and reliable results.

The dissertation provides valuable new insights for policymakers and managers as the study develops the research channel for the effect of sustainable innovation on the cost of debt. The findings suggest that policymakers should support mechanisms that make the value of sustainable innovation more transparent and financially attractive, for example with green innovation subsidies or tax incentives, to help lenders better assess and reward long-term sustainability investments. For managers, the results highlight the importance of linking sustainable patenting efforts to clear, measurable environmental outcomes and communicating these effectively to financial stakeholders. Simply investing in green R&D is unlikely to reduce borrowing costs unless it is accompanied by demonstrable performance improvements that signal reduced risk and long-term value.

This study has a couple of limitations that offer promising directions for future research. First, the use of patent data as a measure for sustainable innovation may not fully capture the economic value or practical implementation of innovation. Second, the analysis is limited to firms owning sustainable patents, which excludes firms without sustainable patents. Third, lender heterogeneity was not accounted for, even though different financing agents may evaluate sustainability signals differently.

Future research could address these limitations by expanding the scope to include different lender types and regions to further enhance understanding of how sustainable innovation is priced in credit markets. Next to that additional measures of sustainable innovation, such as R&D expenses, could be incorporated to provide a more nuanced view of the financial implications of sustainability-driven innovation.

In summary, this dissertation supports the hypothesis that sustainable innovation is associated with the cost of debt. Sustainable innovation in combination with current sustainability performance measures has a positive relationship with the cost of debt. These results are important as it provides information about how sustainable innovation affects a firm's risk profile in the perspective of lenders.

References

Attig, N., El Ghoul, S., Guedhami, O., & Suh, J. (2013). Corporate Social Responsibility and Credit Ratings. *Journal of Business Ethics 117*, 679-94.

Bae, S. C., Chang, K., & Yi, H.-C. (2018). Are more corporate social investments better? Evidence of non-linearity effect on costs of US Bank loans. *Global Finance Journal 38*, 82-96.

Barnea, A., & Rubin, A. (2010). Corporate social responsibility as a conflict between shareholders. *Journal of Business Ethics 97*, 71-86.

Battiston, S., Dafermos, Y., & Monasterolo, I. (2021). Climate risks and financial stability. *Journal of Financial Stability*, 54, 100867.

Bénabou, R., & Tirole, J. (2010). Individual and corporate social responsibility. *Economica 77*, 1–19.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of econometrics, 87(1)*, 115-143.

Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2012). Sustainable innovation, business models and economic performance: an overview. *Journal of Cleaner Production*.

Carrillo-Hermosilla, J., del Río, P., & Könnölä, T. (2010). Diversity of eco-innovations: reflections from selected case studies. *Journal of Cleaner Production 45*, 74-88.

Chava, S. (2014). Environmental externalities and cost of capital. *Management Science, 60*, 2223–2247.

Chen, G., Liu, P., & Jiang, A. (2024). Does digital transformation in enterprises reduce debt default risk? *International Review of Economics and Finance 96*, 103529.

Chen, X., Wang, Q., & Wang, S. (2025). Enterprise digital transformation and bank credit loans - Empirical evidence from listed companies in China. *Pacific-Basin Finance Journal 90*, 102672.

Chen, Y., & Ren, J. (2024). How does digital transformation improve ESG performance? Empirical research from 396 enterprises. *International Entrepreneurship and Management Journal*, 21-27.

Climate negotiations timeline. (2025). Retrieved from Europa.eu: https://www.europarl.europa.eu/infographic/climate-negotiations-timeline/index_en.html

Competitiveness and Innovation Framework Programme. (2007). Retrieved from European Commission.

Cui, L., & Wang, Y. (2023). Can corporate digital transformation alleviate financial distress? *Finance Research Letters 55*, 103983.

Draghi, M. (2024). *The future of European competitiveness.* European Commission.

Gillan, S. L., Koch, A., & Starks, L. T. (2021). Firms and social responsibility: A review of ESG and CSR research in corporate finance. *Journal of Corporate Finance, 66*, 101889.

Gillan, S., & Starks, L. (1998). A survey of shareholder activism: Motivation and empirical evidence. *Contemporary Finance Digest 2*, 10–34.

Gonçalves, T. C., Dias, J., & Barros, V. (2022). Sustainability performance and the cost of capital. *International Journal of Financial Studies, 10*, 63.

Goss, A., & Roberts, G. S. (2011). The impact of corporate social responsibility on the cost of bank loans. *Journal of Banking and Finance 35*, 1794–810.

Healy, P. M., Hutton, A. P., & Palepu, K. G. (1999). Stock performance and intermediation changes surrounding sustained increases in disclosure. *Contemporary Accounting Research, 3*, 485-520.

Jin, W., & Wang, Y. (2025). If Money Talks: Climate change-related regulation and firms' cost of debt. *Borsa Istanbul Review*, 2214-8450.

Jo, H., & Harjoto, M. A. (2012). The causal effect of corporate governance on corporate social responsibility. *Journal of Business Ethics 106*, 53–72.

La Rosa, F., Liberatore, G., Mazzi, F., & Terzani, S. (2018). The impact of corporate social performance on the cost of debt and access to debt financing for listed European non-financial firms. *European Management Journal, 36*, 519-529.

Lee, M. T., & Raschke, R. L. (2023). Stakeholder legitimacy in firm greening and financial performance: What about greenwashing temptations? *Journal of Business Research, 155*, 113393.

Magnanelli, B. S., & Izzo, M. F. (2017). Corporate social performance and cost of debt: the relationship. *Social Responsibility Journal, 13*, 250-265.

Menz, K.-M. (2010). Corporate Social Responsibility: Is it Rewarded by the Corporate Bond Market? A Critical Note. *Journal of Business Ethics 96*, 117–34.

OECD. (2024). *Climate Adaptation Investment Framework.* OECD.

OECD. (2025). *Finance and investment for climate goals*. Retrieved from OECD: https://www.oecd.org/en/topics/finance-and-investment-for-climate-goals.html

Oikonomou, I., Brooks, C., & Pavelin, S. (2014). The effects of corporate social performance on the cost of corporate debt and credit ratings. *Financial Review 49*, 49–75.

Pittman, J. A., & Fortin, S. (2004). Auditor choice and the cost of debt capital for newly public firms. *Journal of Accounting and Economics 37*, 113–36.

SFDR. (2021). Retrieved from European Commission: https://finance.ec.europa.eu/sustainable-finance/disclosures/sustainability-related-disclosure-financial-services-sector_en

Sharfman, M. P., & Fernando, C. S. (2008). Environmental risk management and the cost of capital. *Strategic Management Journal 29*, 569–92.

Starks, L. T. (2009). EFA Keynote Speech: "Corporate Governance and Corporate Social Responsibility: What Do Investors Care about? What Should Investors Care about? *Financial Review 44*, 461–68.

TCFD. (2017). *Recommendations of the Task Force on Climate-related Financial Disclosures.* Task Force on Climate-related Financial Disclosures.

Ye, K., & Zhang, R. (2011). Do lenders value corporate social responsibility? Evidence from China. *Journal of Business Ethics 104*, 197-206.

Yuan, J., Ali, S., Nazar, R., & Imdad Ullah, M. (2024). Innovation for a greener future: Disentangling the asymmetric impact of green finance on green technology in european union economies. *Heliyon*.

Zeng, Q., Tong, Y., & Yang, Y. (2023). Can green finance promote green technology innovation in enterprises: Empirical evidence from China. *Environmental Science and Pollution Research, 30*, 87628–87644.

Zhao, M., Fu, X., Du, J., & Cui, L. (2024). Optimal environmental investment strategies for enterprise green technology innovation: An empirical study based on multiple drive models. *Journal of Environmental Management, 370*, 122624.

Appendices

Appendix 1: Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Cost of Debt	1.000												
(2) Sustainable Patents	-0.010	1.000											
(3) ESG Score	-0.153*	0.117*	1.000										
(4) Environmental Innovation	-0.169*	0.095*	0.490*	1.000									
(5) Size	-0.198*	0.129*	0.521*	0.288*	1.000								
(6) TobinQ	0.177*	-0.035*	-0.013	-0.147*	-0.235*	1.000							
(7) OCF	0.080*	-0.005	0.054*	-0.047*	0.001	0.381*	1.000						
(8) IntCov	0.055*	-0.014	0.048*	-0.009	-0.021*	0.266*	0.354*	1.000					
(9) Performance	0.003	-0.005	0.118*	-0.020*	0.126*	0.266*	0.720*	0.322*	1.000				
(10) Tang	-0.075*	-0.016	0.000	0.034*	0.047*	-0.216*	0.112*	-0.052*	-0.038*	1.000			
(11) AssetG	-0.036*	-0.020*	-0.074*	-0.066*	-0.034*	0.135*	0.089*	0.063*	0.163*	-0.075*	1.000		
(12) Liquidity	0.158*	-0.023*	-0.152*	-0.139*	-0.339*	0.248*	0.126*	0.256*	0.107*	-0.119*	0.088*	1.000	
(13) Leverage	-0.277*	-0.002	0.011	0.059*	0.131*	-0.171*	-0.249*	-0.367*	-0.163*	0.131*	-0.004	-0.305*	1.000

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

Appendix 2: Sample composition per industry

Industry	Frequency	Percent
Basic Materials	1,841	20.77%
Consumer Cyclicals	1,186	13.38%
Consumer Non-Cyclicals	558	6.30%
Energy	490	5.53%
Healthcare	976	11.01%
Industrials	1,958	22.09%
Real Estate	12	0.14%
Technology	1,324	14.94%
Utilities	517	5.83%
Total	**8,862**	**100%**

Appendix 3: Sample composition per country

Country	Frequency	Percent
Australia	20	0.23%
Austria	135	1.52%
Belgium	157	1.77%
Bermuda	18	0.20%
Canada	110	1.24%
China	159	1.79%
Cyprus	3	0.03%
Czech Republic	16	0.18%
Denmark	220	2.48%
Finland	265	2.99%
France	635	7.17%
Germany	824	9.30%
Greece	43	0.49%
Hong Kong	26	0.29%
Hungary	13	0.15%
India	85	0.96%
Ireland	178	2.01%
Israel	21	0.24%
Italy	139	1.57%
Japan	1,772	20.00%
Korea; Republic (S. Korea)	212	2.39%
Luxembourg	29	0.33%
Mexico	19	0.21%
Netherlands	269	3.04%
Norway	99	1.12%
Poland	97	1.09%
Portugal	27	0.30%
Russia	16	0.18%
Saudi Arabia	9	0.10%
Slovenia	3	0.03%
South Africa	10	0.11%
Spain	242	2.73%
Sweden	388	4.38%
Switzerland	242	2.73%
Taiwan	43	0.49%
Turkey	12	0.14%
United Kingdom	428	4.83%
United States of America	1,878	21.19%
Total	**8,862**	**100%**

Appendix 4: Description of variables

Dependent variable	
Cost of Debt	Interest expenses / total debt outstanding
Independent variables	
Sustainable Patents	Count of sustainable patent applications retrieved from Orbis IP
ESG Score	ESG score retrieved from Refinitiv database
Environmental Innovation Score	Environmental Innovation Score retrieved from Refinitiv database
Control variables	
TobinQ	(Market value of equity + total debt) / total assets
OCF	Operating cash flow / total assets
IntCov	(Net income + interest expenses) / interest expenses
Performance	Net income before extraordinary items / revenue
Tang	Property plant and equipment / total assets
AssetG	(Total assetst − total assetst-1) / total assetst-1
Liq	Current assets / current liabilities
Size	Natural logarithm of a firm's total assets
Leverage	Total debt / total assets

Variables are motivated by La Rosa et al. (2018) and Gonçalves et al. (2022)