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The Role of Green Bonds in Driving ESG Performance and Green Innovation in Europe

Amanda Zetzsche de Abreu Gomes

Final Version (This version includes the review and suggestions of the examination committee.)

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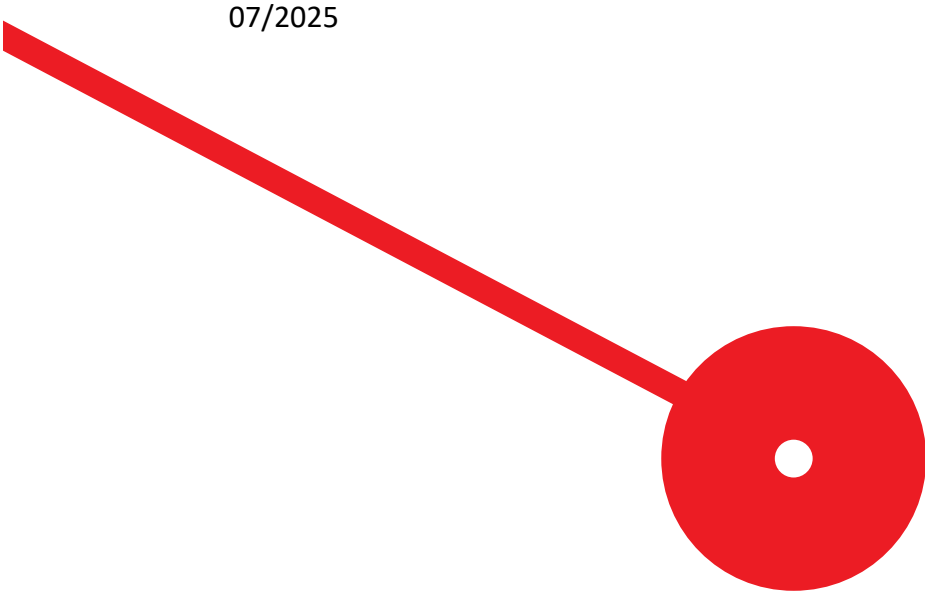

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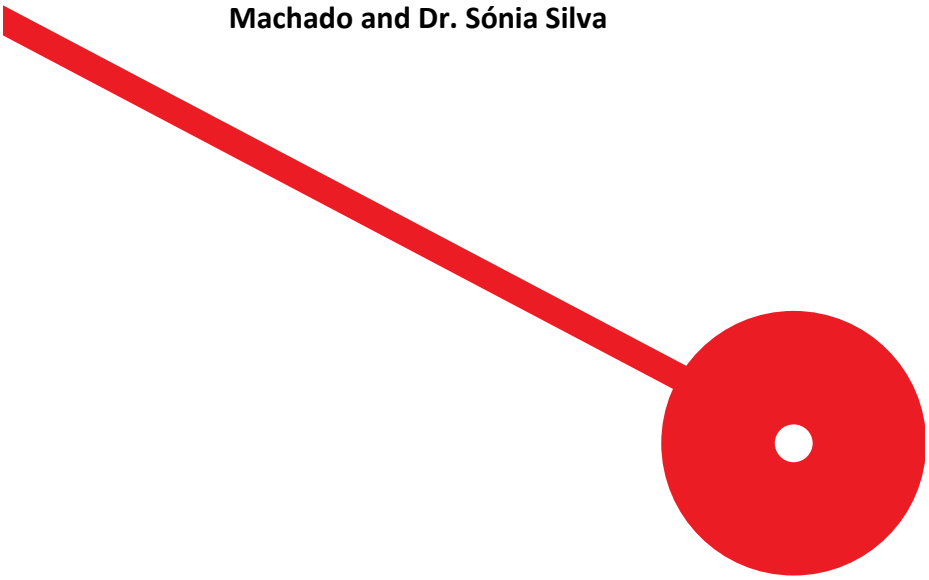
Master's Dissertation submitted to the Porto Accounting and Business School (ISCAP) for the attainment of the master's degree in Corporate Finance, under the supervision of Dr. Ricardo Bahia Machado and Dr. Sónia Silva



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Dedication

In loving memory of my grandmothers, Any Zetzsche Gomes and Nilza Caldas da Silva, whose wisdom continues to guide me.

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Abstract

This dissertation explores the role of green bonds as instruments of sustainable finance and their impact on corporate environmental performance and innovation. Motivated by increasing global commitments to achieve net-zero carbon emissions by 2050, the study investigates whether the issuance of green bonds leads to measurable improvements in Environmental, Social, and Governance (ESG) metrics and stimulates corporate green innovation. To address concerns regarding the credibility of these instruments, the analysis also includes an implied test for potential greenwashing. Furthermore, it examines whether these effects differ across market-based and bank-based financial systems, focusing on the European context.

Using a panel dataset covering the period from 2011 to 2023, this research employs Propensity Score Matching (PSM) to mitigate selection bias, along with a multi-period panel data Difference-in-Differences (DID) model to estimate causal effects. The findings indicate that firms issuing green bonds tend to demonstrate stronger Environmental, Social, and Governance (ESG) performance and greater environmental innovation, regardless of the timing of the issuance event. While the green bond issuance is positively associated with environmental expenditures, emission reduction, and resource efficiency, no statistically significant post-issuance improvements were observed. Furthermore, the analysis finds no consistent evidence about the differences in the economic systems enhancing ESG performance and green innovation.

Importantly, the findings indicate no evidence of greenwashing behavior, reinforcing the notion that companies utilise green bond proceeds for legitimate environmental purposes rather than for reputational enhancement. Overall, the results suggest that green bonds are effective instruments for financing environmentally focused initiatives; however, they may primarily reflect pre-existing corporate sustainability strategies rather than act as catalysts for change. These insights carry significant implications for advancing both the academic and practical understanding of assessing the true impact of green finance in facilitating the transition to a low-carbon economy.

Keywords: ESG, Green Bonds, Green Innovation, Greenwashing

Resumo

Esta dissertação explora o papel das obrigações verdes como instrumentos de financiamento sustentável e o seu impacto no desempenho ambiental e na inovação das empresas. Motivado pelos compromissos globais para alcançar emissões nulas de carbono até 2050, o estudo investiga se a emissão de obrigações verdes conduz a melhorias mensuráveis nos indicadores ambientais, sociais e de governação (ESG), e se estimula a inovação ambiental nas empresas. Para avaliar a credibilidade desses instrumentos, a análise inclui um teste preliminar para identificar possíveis práticas de *greenwashing.* Adicionalmente, examina-se se esses efeitos variam entre sistemas financeiros orientados para o mercado e sistemas baseados na banca, com foco no contexto europeu.

Recorrendo a um conjunto de dados em painel, no período de 2011 a 2023, a investigação aplica a técnica *Propensity Score Matching* (PSM) para corrigir possíveis enviesamentos de seleção e utiliza-se Dados em Painel com múltiplos períodos e a metodologia de *Difference-in-Difference* (DID) para estimar efeitos causais. Os resultados indicam que as empresas que emitem obrigações verdes já apresentam, antes da emissão, um desempenho em ESG superior e uma maior propensão para a inovação ambiental, sugerindo um efeito de auto-seleção. Embora a emissão de obrigações verdes esteja positivamente associada a despesas ambientais, à redução de emissões e eficiência no uso de recursos, não foram observadas melhorias estatisticamente significativas após a emissão. Além disso, a análise não encontra evidências consistentes sobre as diferenças nos sistemas econômicos que promovem a inovação verde.

Os resultados não indicam qualquer evidência de *greenwashing*, reforçando que as empresas utilizam os fundos das obrigações verdes para fins ambientais, e não apenas para ganhos reputacionais. De forma geral, os resultados sugerem que as obrigações verdes são instrumentos eficazes para financiar iniciativas ambientais, embora sirvam como estratégias de sustentabilidade corporativa já existentes, em vez de atuarem como catalisadores de mudança. Estas conclusões contribuem para um entendimento académico e prático aprofundado sobre o impacto real do financiamento sustentável na promoção da transição para uma economia de baixo carbono.

Palavras chave: ESG, Green Bonds, Green Innovation, Greenwashing

TABLE OF CONTENTS

List of Tables

Abbreviation list

ABS – Asset-backed Securities

ATT – Average Treatment Effect on Treated

CB – Conventional Bonds

COP21 – 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC)

CSR – Corporate Social Responsibility

DID – Difference-in-Differences

EIB – European Investment Bank

ESG – Environmental, Social, and Governance

EU – European Union

GB – Green Bonds

GMM – Generalized Method of Moments

LSEG – London Stock Exchange Group

MBS – Mortgage-backed Securities

NFR – Non-Financial Reporting

OLS – Ordinary Least Squares

PSM – Propensity Score Matching

R&D – Research and Development

SIC – Standard Industrial Classification

TCFD – Task Force on Climate-related Financial Disclosures

UK – United Kingdom

USA – United States of America

CHAPTER I – INTRODUCTION

Many countries, cities, and companies have been committed to achieving net-zero carbon emissions by 2050 (Wu, 2022). In line with this target, green bonds are an instrument specifically issued to fund projects with positive environmental or climate-related benefits. Green bonds are part of the broader sustainable finance movement and have gained significant popularity as a means of raising capital for initiatives that support climate goals, such as carbon neutrality and net-zero emissions (Löffler et al. 2021).

Green bonds contribute to the transition to a sustainable economy by channelling capital into projects that directly address climate-friendly initiatives (Flammer, 2021). The funds raised support large-scale shifts toward projects that include renewable energy, energy efficiency, sustainable transportation, and other carbon-reducing measures (Tang & Zhang, 2020). In this way, green bonds mobilise capital for environmentally sustainable projects, accelerating the transition to a green economy (Agliardi & Agliardi, 2019; MacAskill et al., 2021).

Green finance has been shown to accelerate the advancement of green technologies (Yu et al., 2021; Yang et al., 2022), yet further investigation is required to understand the impact of green financial products on the market. The analysis seeks to provide insights into the emerging field of green finance and the demand for further research into country-specific factors and the long-term performance of green bonds.

To achieve this goal, this study will examine three main aspects using a multi-period difference-in-differences (DID) model. Firstly, if the companies improve their environmental performance post-issuance by assessing their sustainability ratings, such as ESG Scores. Secondly, testing changes in green innovation before and after the issuance of green Bonds. It is expected that the proceeds of the green bonds are earmarked for investment in projects that increase the company's R&D expenditure, for instance, the company's innovative capacity directed towards sustainable projects. Thirdly, we examine whether ESG performance and green innovation have increased more in countries with a market-based financial system than in those with a bank-based financial system. Our rationale is grounded in the premise that market-based economies are often associated with greater dynamism in capital markets.

The findings from Dong et al. (2024), which show the positive impact of green bonds on green innovation in China, provide a compelling rationale for expanding this line of research to Europe. While China's green bond market is one of the largest globally, it operates under

specific definitions, use of proceeds, and information disclosure standards that may differ from those in Europe. Given Europe's regulatory frameworks, standardised practices, and diverse economic landscape, it is essential to explore how green bonds influence green innovation within this context. Investigating the effectiveness of green bonds in driving sustainability and innovation in Europe could offer beneficial insights, especially considering the region's environmental goals and its increasing role in global green finance.

To investigate these research questions, the dissertation adopts a quantitative empirical methodology using a longitudinal panel data from 2011 to 2023. The analysis applies a Propensity Score Matching (PSM) technique and subsequently, a Difference-in-Differences (DID) model to estimate the causal effects of green bond issuance on ESG performance and green innovation. By leveraging this multi-period panel data structure, the study can capture changes over time and account for unobserved heterogeneity across firms. The econometric approach allows for conclusions about the relationship between green bond issuance and corporate sustainability outcomes.

This dissertation is organised into five chapters, of which the present Chapter I serves as the introduction. Chapter II presents a literature review of the green bonds, organised around the three central themes of the research. Chapter III outlines the research methodology, detailing the data sources and econometric techniques employed in the analysis. Chapter IV presents the results of the empirical investigation, accompanied by a discussion of the key findings. Finally, Chapter V provides the main conclusions and implications of the study.

CHAPTER II – LITERATURE REVIEW

Sustainable finance has become crucial in addressing current needs while ensuring future generations can meet their own (Ren et al., 2023). One of the key financial instruments driving this movement is green bonds. Löffler et al. (2021) state that green bonds (GB) are defined as bonds whose proceeds are exclusively allocated to financing or refinancing new and existing eligible green initiatives. These instruments are essential in the global effort to combat climate change, as emphasised by the International Capital Market Association (ICMA, 2018).

According to Tang and Zhang (2020), the green bond market was initiated in 2007 with the issuance of the first "Climate Awareness Bond" by the European Investment Bank (EIB). This was followed by Poland's issuance of the first green sovereign bond in 2016 and France's in 2017. Although green bonds initially experienced slow growth, the market has expanded significantly since 2013, driven by the large-scale entry of private sector companies (Flammer, 2021). Inderst and Stewart (2018) state that green bonds can be categorised into four types: standard recourse-to-the-issuer debt obligations, non-recourse-to-the-issuer debt obligations, green project bonds, and green securitised bonds, which include covered bonds, asset-backed securities (ABS), and mortgage-backed securities (MBS). The funds raised through green bonds are directed toward renewable energy initiatives, such as wind farms, or sustainable public transportation systems, among others.

Despite the challenges posed by the pandemic, 2020 marked a new record of $300 billion in green bond issuance in 52 countries, with a strong third quarter compensating for earlier slowdowns (Climate Bonds Initiative, 2024). Although the green bonds market is smaller than the conventional bonds market, it continues to grow, driven by rising environmental awareness and the urgent need for sustainable financial solutions. Yang et al. (2022) find that green finance significantly boosts green innovation, and environmental regulations also positively impact green innovation, and this effect is amplified when paired with strong green finance.

Fatica and Panzica (2021) suggest that corporate green bond issuance is linked to a reduction in carbon emissions, especially when bonds used for refinancing are excluded. This decrease in emissions was observed for up to two years, indicating increased environmentally friendly activities from new projects. While a direct causal relationship is challenging to establish, the findings support the idea that green bonds signal a firm's commitment to climate-friendly

behaviour. Following the 2015 Paris Agreement[1], companies that either experienced external reviews or issued bonds achieved larger emission reductions compared to other companies (Agliardi & Agliardi, 2019). Furthermore, Fatica and Panzica (2021) conclude that companies engaging in greenwashing do not exhibit a stronger decarbonisation trend compared to conventional bond issuers.

The findings of Alamgir and Cheng (2023) further reinforce the hypothesis that green bond issuance contributes to reduced carbon emissions, providing quantitative evidence of a negative correlation between green bond issuance and carbon footprints. The authors employed the Generalized Method of Moments (GMM) model that identifies a significant negative correlation between green bond issuance and carbon emissions, showing that countries and firms issuing more green bonds tend to experience lower carbon footprints. Additionally, confirming the positive role of green bonds in promoting renewable energy production, with stronger effects observed post-2015 Paris Agreement (COP21), may have stimulated global commitment to climate action.

Thus, this study aims to address the following research questions: (1) Do companies improve their Environmental Social Governance (ESG) metrics after the issuance of green bonds? (2) Does corporate green innovation rise after Green Bond issuance? (3) Has green innovation increased more in the economies of market-based countries than in those of bank-based countries? By exploring these questions, this paper aims to understand the factors influencing green bond issuance and its impact on corporate sustainability and innovation.

2.1 The Growth and Development of the Green Bond Market

The green bond market has grown fast, driven by global climate goals and sustainable finance initiatives. The 2015 United Nations Climate Change Conference (COP21) observed a significant milestone in international climate policy, with 196 countries agreeing to keep global temperature increases below 2°C (Agliardi & Agliardi, 2019). This global commitment, combined with the European Union's goal of achieving carbon neutrality by 2050, has stimulated growth in the green bond market, particularly in Europe (Wu, 2022). Europe has led the way in issuing green bonds, with companies adopting more socially responsible practices (Ge & Liu, 2015).

[1]Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104.

The European Commission's 2018 "Action Plan: Financing Sustainable Growth" provided a significant boost to the market by introducing a unified EU green asset taxonomy, which has facilitated the standardisation of the criteria for green investments, increasing investor confidence (Gianfrate & Peri, 2019). Additionally, the implementation of the Task Force on Climate-related Financial Disclosures (TCFD) in 2017 has provided a framework for consistent risk and opportunity disclosures, further encouraging financial institutions to engage in green bond issuance.

The pricing of green bonds has been one of the central themes in the literature, with several studies identifying a price premium, often referred to as greenium, i.e., a lower yield compared to conventional bonds, due to the demand for sustainable investments (Flammer, 2021). Löffler et al. (2021) show that green-labelled bonds tend to be traded at higher prices, particularly for investment-grade bonds (AA, A, BBB), where the difference in yield can offset the cost of obtaining external certifications. Zerbib (2019) identifies a smaller negative premium, suggesting a limited impact of environmental preferences in the period between 2013 and 2017.

The difference in findings between Löffler et al. (2021) and Zerbib (2019) reflects the evolving nature of the green bonds market. As this market matures, more investors become aware of the financial and environmental benefits of green bonds. Moreover, corporate environmental performance also influences pricing dynamics and impacts the value of green bonds (Wang et al., 2019). Green bonds not only enhance shareholder returns (Tang & Zhang, 2020) but also support companies in improving their environmental performance, such as by reducing CO2 emissions (Flammer, 2021).

2.1.1 ESG Performance Post-Issuance

As green bonds continue to gain traction, their growth is increasingly driven by investor demand for more sustainable and responsible business practices, aligned with Environmental Social and Governance (ESG) principles (Flammer, 2021). ESG integration into financial decision-making reshapes investment strategies, enhancing corporate transparency and long-term value creation (Chang et al., 2022). The integration of ESG into financial decision-making has led investors to favour companies with strong environmental credentials, further propelling the demand for financial instruments like green bonds (Khan et al., 2016; Inderst & Stewart, 2018).

Mohy-ud-Din (2024) demonstrates that strong ESG practices attract responsible investors, while Li et al. (2023) show that high ESG ratings can drive corporate innovation, particularly in developing economies. Tan and Zhu (2022) argue that managers with environmental awareness enhance the connection between ESG ratings and green innovation, particularly in developing countries.

Studies from multiple researchers indicate that the relationship between ESG practices and corporate performance is an evolving topic, and the literature is beginning to signal a responsible approach to the environment, society, and governance (Li et al., 2023; Mohy-ud-Din, 2024; Tan & Zhu, 2022). Agliardi and Agliardi (2019) and Elbannan and Löffler (2023) show that as interest in sustainable investment options increases, companies need to align their practices with ESG criteria to engage with the growing green bond market effectively. Studies of, e.g., Hartzmark and Sussman (2019) and Flammer (2021) indicate that ESG practices attract responsible investors while potentially enhancing long-term shareholder value. Yu et al. (2021) and Yang et al. (2022) further demonstrate that the relationship between ESG performance and corporate success continues to progress, particularly in developing economies.

The issuance of green bonds has a positive impact on corporate green transformation, primarily through three functions: green investment and financing, green social regulation, and green corporate governance (Cheng & Wu, 2024). Studies by Flammer (2021), Fatica and Panzica (2021), and Elbannan and Löffler (2023) present evidence of the relationship between green bonds and environmental performance. While Flammer, Fatica, and Panzica find that green bond issuance is associated with reduced carbon emissions, Elbannan and Löffler note that this effect varies based on firm characteristics, particularly for financially constrained and higher-risk firms, for which there is a limited amount of carbon emissions independent of green bond issuance level. These findings collectively suggest that while green bonds can drive environmental improvements, their effectiveness depends on company-specific factors.

Fatica and Panzica (2021) further emphasise that external reviews strengthen this environmental commitment signal. These reviews, including second-party opinions, verifications, and certifications, assess alignment with industry standards and demonstrate transparency. Companies undertaking these assessments show a willingness to bear

associated costs and reputational risks, indicating genuine long-term dedication to sustainability beyond mere fundraising.

Investors with pro-environmental preferences seem willing to accept lower returns in exchange for supporting environmentally sustainable projects (Agliardi & Agliardi, 2019; MacAskill et al., 2021). Tang and Zhang (2018) explore the factors contributing to positive market reactions following the issuance of green bonds, identifying three potential channels: the financing cost channel, the investor attention channel, and the company fundamental channel. The financing cost channel suggests that demand from socially responsible investors could lower issuers' capital costs, but the study found no significant yield difference between green and conventional bonds. In contrast, the investor attention channel proves more influential, with green bonds attracting increased media coverage and improved stock liquidity. The firm fundamental channel indicates that green bond issuance signals a firm's commitment to sustainability, but improved stock liquidity post-issuance points to investor behaviour as the key driver.

Fatica and Panzica (2021) state that green bonds, particularly those not used for refinancing and those with external reviews, are associated with a reduction in carbon emissions. This finding implies that green bonds may serve as a credible signal of a company's commitment to environmental sustainability, thereby contradicting the "greenwashing" argument. However, recent research by Shi et al. (2023) presents a contrasting view, suggesting that some companies in China may indeed be engaging in greenwashing, prioritizing appearance over real innovation. While green bond issuance leads to a 59.48% increase in patent applications, there is a 37.61% drop in granted patents, indicating that many innovations lack substance. Moreover, citation rates for these patents show no significant increase, suggesting these innovations may not have a genuine scientific impact. This greenwashing effect is particularly pronounced in heavily polluting companies and those with lower human capital, which, despite facing regulatory pressure, lack the resources for substantial innovation.

The literature demonstrates that green bond issuance typically results in improved environmental performance, evidenced primarily through reduced carbon emissions. While concerns about greenwashing exist, external reviews and certifications help validate issuers' environmental commitments, showing sustainability improvements post-issuance.

2.1.2 Corporate Green Innovation: Intangible Investment and R&D

Research suggests that proceeds from green bond issuance can significantly influence research and development (R&D) expenditure and drive green innovation (Yang et al. 2022). Aligned with the United Nations 2030 agenda, the primary objective of corporate tangible investment and R&D expenditures should be to enhance economic performance through sustainable growth (United Nations, 2015). This approach can result in increased R&D spending, fostering greater green innovation, particularly in sectors such as energy and waste management. A further critical consideration is the role of financial constraints, which, while they may initially limit green innovation, may also encourage companies to allocate their R&D resources more efficiently, accelerating the development of environmentally sustainable solutions (Zhang & Yin, 2021).

Dong et al. (2024) state that green bond issuance boosts green innovation through two main channels: alleviating financial constraints and increasing R&D investment. This effect is especially pronounced in regions with weaker climate regulations, industries with stronger environmental performance, and firms with concentrated ownership. The study emphasises that green innovation enhances environmental sustainability and improves financial performance. Additionally, the authors suggest that the long-term, stable funding provided by green bonds helps mitigate financial uncertainties, encouraging firms to redirect resources toward green innovation. According to Zhang and Yin (2021), when companies have financial constraints, they have a strong incentive to use their R&D funds for green innovation, as this can lead to better environmental and economic performance. This means that investing in green innovation is an effective way for companies to improve their sustainability. Besides, a recent study by Alamgir and Cheng (2023) finds that countries with high green bond issuances exhibit a significant reduction in carbon emissions and an increase in renewable energy production, reflecting their progress toward sustainability.

Flammer (2021) explores the market dynamics and implications of corporate green bonds' effectiveness as instruments of sustainable finance. The study finds that green bond issuance, particularly when the projects are certified by independent third-party entities to verify their environmental credentials and ensure compliance with established green bond principles, or when undertaken by first-time issuers, generates a positive stock market response, signalling credible environmental commitment. To be considered a "certified green bond", companies must have their projects verified by independent third parties, and this process entails a

significant amount of administrative work and resource allocation, which makes it expensive for the issuer. Besides, if a bond fails to meet the Climate Bonds Standard[2], the issuer must notify the Climate Bonds Initiative board within one month of becoming aware of the non-compliance. Moreover, Flammer's research indicates that companies issuing green bonds show improved environmental performance and attract a long-term, environmentally conscious investor base.

Emerging sectors such as green technologies and renewable energy may find uncertainties that affect bond pricing, potentially leading to a reduction in the greenium (Löffler et al., 2021). Furthermore, critics argue that the performance of green bonds often mirrors that of conventional bonds, which might pose a challenge for investors seeking more distinct environmental benefits (Wang et al., 2019). Based on the descriptive evidence from Wulandari et al. (2018), green bonds have exhibited improved liquidity since 2016. The study indicates a maturing green bond market, as the influence of liquidity risk on yield spreads has diminished over time, suggesting enhanced tradability. Furthermore, a recent study by Tomczak (2024) on the sovereign green bond market finds that green bond liquidity tends to increase with maturity, providing evidence that longer-term bonds offer liquidity premiums to compensate investors for higher illiquidity risks.

Green bonds are an attractive option for investors seeking to hedge against future environmental and regulatory risks, such as carbon taxes and regulatory shifts, which could be a potential way to finance green innovation to fund projects that boost R&D spending towards sustainable projects (Agliardi & Agliardi, 2019). Despite challenges in emerging sectors and liquidity risks, green bonds remain attractive for financing sustainable innovation. Financial constraints can incentivize more efficient allocation of R&D resources toward sustainable solutions (Li et al., 2023). While the impact of green bonds on corporate innovation and R&D is apparent, the effectiveness of these instruments may vary depending on the financial system in which they operate. This brings us to consider how different financial structures, specifically, market-based versus bank-based systems, influence the innovation and effectiveness of green bonds.

[2]See the terminology in Climate Bonds Initiative, "Climate Bonds Standard" 2024, page 6 (https://www.climatebonds.net/files/files/climate-bonds-standard-v4-1-202403.pdf).

2.1.3 The Market-Based vs. Bank-Based System Performance

The financial systems can be viewed through two primary perspectives: market-based and bank-based systems (Demirgüç-Kunt & Levine, 1999). The structure of a country's financial system, whether market-based or bank-based, is a key factor in understanding the performance of green bonds. This distinction plays a role in determining how effectively green bonds can be issued, traded, and used to finance sustainable projects. Given the importance of green finance in addressing global environmental challenges and understand the particularities of the financial systems and their performance. Levine (2002) defends that stock markets and banking systems play significant roles in providing access to capital. Allen and Gale (2001) argue that banks play a critical role in acquiring and processing proprietary information, thereby improving capital allocation and risk management. In contrast, the market-based view emphasises the efficiency of liquid markets in aggregating information and managing risks through diversification (Holmstrom & Tirole, 1993).

Banks play a pivotal role in gathering proprietary information about firms and managers, which enhances both capital allocation and corporate governance. Ramakrishnan and Thakor (1984) point out that banks' ability to acquire and analyse detailed firm-specific information improves the efficiency of capital allocation and strengthens governance structures. Moreover, banks excel at managing diverse types of risk, such as cross-sectional, intertemporal, and liquidity risks, thereby boosting investment efficiency and supporting economic growth (Allen & Gale, 2001).

In transparent markets, individual investors often face little incentive to gather independent information, relying instead on publicly available data, leading to a "free rider" problem (Wang & Ma, 2009). Holmstrom and Tirole (1993) argue that large liquid markets create incentives for investors to conduct research, as they can profit from trading based on their findings. This continuous scrutiny ensures that managers act in the best interests of shareholders, thereby enhancing overall corporate efficiency and performance. Furthermore, Bhide (1993 as cited in Levine, 2002) argues that liquid markets tend to foster short-termism, where investors prioritise immediate returns over long-term value creation. In contrast, banks, due to their long-term engagements with firms, encourage sustainable corporate practices and investments that support the firm's growth and the broader economy.

La Porta et al. (1997) underline the role of legal and institutional frameworks in shaping financial markets and their impact on economic outcomes. Their research suggests that

countries with stronger investor protections and more developed capital markets, typically those with common law traditions, perform better in terms of external financing and market development. Building on this, Levine (2002) notes that cross-country comparisons of financial systems can be challenging due to country-specific factors, yet such analyses offer valuable insights. For instance, similar long-term growth rates observed in countries like Germany, Japan, the USA, and the UK indicate that the structure of a financial system may not be the primary determinant of growth. Instead, the level of development and efficiency within a financial system, whether bank-based or market-based, appears to have a greater influence on economic performance (Demirgüç-Kunt and Levine, 1999; Levine, 2002). While market-based economies such as Sweden and the USA show impressive performance in leveraging well-developed capital markets to drive green finance, bank-based economies like China, France, and Germany are also making strides in green bond issuance.

In summary, the literature suggests that bank-based systems offer significant advantages in terms of information acquisition, risk management, and capital allocation. On the other hand, market-based systems provide liquidity and transparency, supported by strong accounting standards that supply essential corporate information for equity markets. It is also associated with lower levels of government corruption and facilitates market entry and access for firms and investors (Levine, 2002).

2.2 Research Hypotheses

Building on the theoretical foundations discussed in the literature, this study investigates three key hypotheses. First, we hypothesize that companies issuing green bonds demonstrate measurable improvements in their sustainability metrics, particularly their Environmental, Social, and Governance (ESG) scores. Second, we predict that Green Bond issuance catalyses increased corporate innovation, as companies leverage these financial instruments to develop new sustainable technologies and practices. Third, we propose that the innovation effects of green bonds are more pronounced in market-based economies compared to bank-based economies, suggesting that market structures influence how effectively green financing translates into innovative outcomes.

This study tests three hypotheses empirically that explore green bonds as sustainability financing instruments in the European market, focusing on their impact on corporate environmental performance and innovation across different financial systems. Through

empirical analysis, this research will contribute to the growing body of literature on sustainable finance by providing insights into how green bonds shape corporate environmental behaviour and drive technological advancement across different European economic systems.

H1: The issuance of green bonds leads to improved corporate sustainability performance, proxied by ESG pillar scores, reflecting enhanced commitment to sustainability.

H2: The issuance of green bonds positively impacts corporate innovation, proxied by different ESG outcomes.

H3: Following green bond issuance, Market-based economies exhibit a greater uplift in ESG performance and outcomes than bank-based economies.

CHAPTER III – METHODOLOGY AND DATA

The methodological framework of this dissertation examines the impact of corporate green bond issuances through two complementary empirical approaches: Panel Data Analysis (Klevmarken, 1989) and Difference-in-Differences (DID) estimation (Schiozer et.al., 2021). To systematically investigate the hypotheses, this research addresses three corresponding research questions. First, we examine whether companies improve their Environmental, Social, and Governance (ESG) metrics following Green Bond issuance. Second, we investigate whether corporate green innovation increases after Green Bond issuance. Third, we analyse whether green innovation has grown more in market-based economies compared to bank-based economies. The aim is to understand how green bond issuance influences corporate sustainability and innovation, and how it affects their behaviour across different financial systems.

3.1 Research Design

This research employs a panel data approach, which analyses data from multiple firms over time, allowing an investigation of the relationship between green bond issuance and ESG variables. Panel data enables the control of individual heterogeneity, ensuring more precise results compared to cross-sectional or time-series analysis (Baltagi, 2005). Additionally, this approach allows for testing more complex behavioural models and a better understanding of dynamic adjustments (Baltagi & Griffin, 1988; Klevmarken, 1989).

This empirical longitudinal study employs panel data methodologies using a pooled data structure to analyse data from 2011 to 2023. It addresses potential econometric challenges such as heteroscedasticity and multicollinearity and ensures robustness through matching procedures and by lagging independent variables. A two-sample Student's *t-test* with unequal variances is used to test for statistically significant differences in key variables between treatment and control groups. This is particularly relevant for ESG scores and firm-level characteristics, allowing us to verify the effectiveness of the matching procedure and assess treatment effects. Furthermore, Pearson correlation analysis is conducted to explore the relationships between ESG dimensions (Environmental, Social, Governance) and key firm-level quantitative control variables, including firm size, leverage, R&D intensity, capital expenditures, profitability, and Tobin's Q, as only these variables are suitable for Pearson correlation, which requires continuous firm-level data. This helps identify patterns and potential multicollinearity issues among explanatory variables.

Klevmarken (1989) says that panel data allows for controlling individual heterogeneity, recognising that individuals, firms, states, or countries are naturally heterogeneous. Without accounting for this, cross-sectional and time-series studies may yield biased results (Moulton, 1987). Baltagi (2005) adds that panel data provides informative data, offering variability, less collinearity among variables, increased degrees of freedom, and greater efficiency. Panel data can identify and measure effects that would be undetectable in purely cross-sectional or time-series data. In addition, panel data models allow the construction and testing of more complex behavioural models than what is possible with cross-section or time-series data alone (Baltagi & Griffin,1988; Kumbhakar & Lovell, 2000). Finally, micro-panel data collected at the individual, firm, or everyday level tends to be more accurately measured than similar variables gathered at the macro level, reducing biases that may arise from aggregation (Blundell, 1988; Klevmarken, 1989).

By adopting a panel data approach, this study will use methodologies specifically adapted to this data structure, allowing for an analysis of green bond issuance across various companies over time. The methodology uses a Pooled Ordinary Least Squares (OLS) approach to initially assess unobserved heterogeneity across companies (Angrist & Pischke, 2008). The Pooled OLS estimation provides statistical tests that allow the data users to observe the heterogeneity degree across observations. In this study, we observe individual effects that must be properly treated.

The dataset used in this research comprises a group of firms that issued green bonds during our sample timespan, and a group of firms that never issued green bonds. To properly address the differences between issuers and non-issuers, we applied the Propensity Score Matching (PSM) technique proposed by Rosenbaum and Rubin (1983, 2023). The PSM was designed to address bias selection and causal inference, thus identifying the average treatment effect on treated (ATT) of green bond issuers on ESG performance (Wooldridge, 2010). Firms in the treatment group (EU-based firms issuing green bonds) are matched with firms in the control group (EU-based firms that never issue green bonds) based on observed characteristics - the so-called covariates - using the nearest-neighbour matching with a calliper threshold.

The Difference-in-Differences (DID) methodology is commonly used with panel data analysis to assess the causal effect of a treatment or intervention, particularly when randomisation is not feasible. This method is used for analysing continuous data through

linear models and helps control for unobserved characteristics that may introduce bias (Schiozer et al., 2021).

In this study, the Difference-in-Differences (DID) method is used to estimate the causal impact of green bond issuance on ESG outcomes. By comparing pre-issuance and post-issuance periods for treatment and control firms, this isolates the effect of the treatment group on outcome variables, controlling for time-invariant unobserved heterogeneity.

3.2 Data and Estimation Models

The empirical investigation draws upon data sources provided by LSEG (London Stock Exchange Group) Workspace. Market data and green bond issuance information are sourced from Datastream, while accounting data is extracted from Worldscope, and macroeconomic indicators were retrieved from the World Bank Group. Additionally, Refinitiv Eikon provides ESG criteria information, enabling detailed analysis of sustainability metrics. The analysis distinguishes between bank-based and market-based financial systems, following the classification methodology established by Levine (2002), allowing us to examine how different financial structures influence the effectiveness of green bonds.

Following the initial definition of the sample criteria, a data-cleaning process was conducted, and firms were excluded when reported missing or questionable values for financial indicators, such as total assets, sales, or market capitalisation. Specifically, observations were removed when these values were either unavailable, negative, or represented economically abnormal conditions. Furthermore, following the Fama and French (1997) industry classification methodology, firms with Standard Industrial Classification SIC Code codes between 6000 and 6999, which typically include financial and insurance activities, were excluded to maintain comparability across firms operating in similar economic environments.

In total, 18 firm-level variables were constructed for the empirical analysis. The winsorization technique was applied at the 1st and 99th percentiles of each continuous variable's distribution, as commonly recommended in the empirical finance literature (Campbell, Lo, & MacKinlay, 1997).

Additionally, all explanatory variables were lagged by one year to mitigate endogeneity concerns and better capture pre-treatment dynamics. The treatment variable is a binary indicator assuming 1 if a firm issues green bonds during the timespan of this analysis. The

Post variable is a binary indicator reflecting the period after the issuance of a Green Bond. This variable takes the value of 1 for the year of issuance and subsequent years, and 0 otherwise, allowing us to isolate potential post-issuance effects in the empirical models. It is important to note that the UK and Norway are part of the sample because they are geographically within Europe and adopted European Union (EU) directives on sustainability, aligning their regulatory frameworks with broader EU standards.

In relation to Green Bond issuance, two distinct subsamples of European firms were constructed. The treatment group comprises firms that issued green bonds during the sample period. In contrast, the control group includes firms that, while operating in the same markets and timeframes and possessing the financial and structural capacity to issue green bonds, chose not to do so. This enables a comparison of firms with different financing decisions under similar contextual conditions.

The Propensity Score Matching (PSM) technique proposed by Rosenbaum and Rubin (1983) was used to compare the treatment and control groups' firms. Given the imbalance between the two groups, matching becomes necessary to reduce selection bias and create comparable groups. The propensity score is estimated as the conditional probability of a firm issuing a Green Bond, given a set of observed characteristics. Specifically, the propensity score was estimated based on the same industry, year, and using the closest firm size, as described in Appendix II.

Matching is performed using the nearest neighbour method with replacement, ensuring that each treated firm is matched with a control firm that is most similar in terms of the estimated score. Additionally, a calliper constraint establishes an interval within which the nearest neighbour could be positioned. Matches were only considered valid when the deviation was limited to 1%[3]providing a significant advantage for this methodology. The resulting matched sample consists of 2,664 observations between treatment and control firms.

3.3 Data Overview

The observations in this study were collected across countries, industries, and years. The treatment sample (Green Bonds = 1) consists of 1,175 observations, and the control group (Green Bonds = 0) includes 901 observations. The study adopts the 17-industry portfolios

[3]The balancing property is satisfied. The Likelihood-Ratio (LR) test results show a *p*-value higher than 5%, indicating an adequate model fit.

framework developed by Fama and French (1997) to classify the industries. That offers a more nuanced alternative to traditional industry groupings, enabling more precise analysis of return variation across sectors (Fama & French, 1997). The Fama & French (1997) industry classification (FF17 Industry Portfolios) is presented in Table I in Appendix I.

3.3.1 Sample Description

The dataset used in this study comprises a collection of firm-year observations categorized by country, industry, and year, as detailed in Table 1. The sample is divided into treatment and control groups, with the treatment group consisting of firms that have issued green bonds and the control group comprising comparable firms that have not.

Table 1: Sample Description by Country, Industry, and Year

Panel A reports the distribution of firm-year observations by country for both the treatment and control samples. Panel B presents the distribution of firm-year observations across industries, classified as the Industry Portfolios. Panel C displays the yearly distribution of firm-year observations for both samples.
Source: Author's elaboration.

Panel A: *Sample description by country*

Treatment Sample		**Control Sample**	
Country	*No Obs.*	*Country*	*No Obs.*
Austria	63	Austria	20
Belgium	41	Belgium	22
Denmark	21	Czechia	3
Finland	85	Denmark	20
France	136	Finland	31
Germany	90	France	131
Greece	20	Germany	133
Ireland	7	Greece	31
Italy	92	Hungary	7
Netherlands	85	Ireland	20
Norway	112	Italy	43
Poland	13	Luxembourg	23
Portugal	23	Netherlands	55
Spain	80	Norway	14
Sweden	172	Poland	56
United Kingdom	135	Portugal	15
		Spain	66
		Sweden	28
		United Kingdom	183
Total	**1175**	**Total**	**901**

Panel B: *Sample description by industry*			
Industry	*No Obs.*	*Industry*	*No Obs.*
Food	56	Food	40
Oil and Petroleum Products	20	Oil and Petroleum Products	20
Consumer Durables	14	Consumer Durables	12
Chemicals	56	Chemicals	56
Construction and Construction Materials	155	Construction and Construction Materials	133
Steel Works Etc	51	Steel Works Etc	46
Machinery and Business Equipment	97	Machinery and Business Equipment	77
Automobiles	33	Automobiles	24
Transportation	73	Transportation	56
Utilities	284	Utilities	161
Retail Stores	58	Retail Stores	55
Other	278	Other	221
Total	**1175**	**Total**	**901**
Panel C: *Sample description by year*			
Year	*No Obs.*	*Year*	*No Obs.*
2011	74	2011	55
2012	72	2012	57
2013	73	2013	54
2014	79	2014	62
2015	81	2015	68
2016	70	2016	61
2017	86	2017	62
2018	95	2018	77
2019	105	2019	74
2020	109	2020	86
2021	109	2021	83
2022	115	2022	94
2023	107	2023	68
Total	**1175**	**Total**	**901**

Panel A shows the geographical distribution of the sample. In the treatment group, Swedish firms contribute the largest segment with 172 firm-year observations; conversely, Irish firms represent the smallest with only 7 observations. In the control group, United Kingdom-based firms dominate with 183 observations, whereas firms from Hungary and Czechia provide minimal representation, with just 7 and 3 observations, respectively.

The industry composition, presented in Panel B, shows that both treatment and control groups exhibit strong representation in the Utilities sector (Industry 14), with 284 and 161 observations, respectively, in the "Other" category (Industry 17), with 278 and 221 observations. Notably, the Construction and Materials sector (Industry 8) shows substantial

representation with 155 observations in the treatment group and 133 in the control group. In contrast, the Consumer Durables sector (Industry 5) is the least represented, with only 14 and 12 observations in the treatment and control groups, respectively. This concentration aligns with expectations, as utilities are traditionally capital-intensive and environmentally impactful, making them natural candidates for green financing initiatives.

Panel C illustrates the temporal evolution of the sample. The treatment group demonstrates a consistent upward trajectory since 2011, growing from 74 observations to a peak of 115 in 2022, which reflects the inclusion of more firms that have issued green bonds over time. The control group follows a similar pattern, with peak representation in 2022 (94 observations) and 2021 (83 observations). In 2023, the number of observations in the control group (68 observations) nearly matches the level observed in 2011 (55 observations), suggesting a potential stabilization or slight decline in the non-green bond issuing segment. This temporal pattern captures the dynamic nature of the green finance market during the study period.

3.3.2 Descriptive Analysis

Table 2 presents descriptive statistics for all variables used in this study. The treatment sample (Panel A) shows slightly higher Environmental, Social, and Total ESG Scores than the control group. Firms in the treatment group are generally larger, older, and more leveraged, with an average firm age of 71 years and leverage of 0.31, compared to 65 years and 0.22 in the control group (Panel B). Profitability (ROA and ROE) and R&D investment are similar across groups, while Tobin's Q is marginally higher in the control group. The treatment group is associated with stronger institutional environments, reflected in higher regulatory quality and rule of law scores. However, the control group shows slightly higher GDP growth of 1.64 compared to 1.42 in the treatment group.

Table 2: Descriptive Analysis

Table 2 presents descriptive statistics for the treatment and control samples, based on data from the LSEG Workspace for firm-level variables and country-level indicators. For each variable, we report the number of observations, the standard deviation, the mean, the median, and the 25th and 75th percentiles. ESG scores are reported on a scale from 0 to 1. Variable definitions are provided in Appendix II. Source: Author's elaboration.

Panel A: Treatment Sample

Variable	*n*	Mean	*S.D.*	*P25*	Median	*P75*
ESG Gov Score	1175	0.57	0.21	0.42	0.59	0.75
ESG Env Score	1175	0.70	0.19	0.59	0.72	0.84
ESG Social Score	1175	0.70	0.19	0.60	0.75	0.85
ESG Total Score	1175	0.66	0.16	0.58	0.69	0.78
Size	1175	16.25	1.26	15.54	16.22	16.98
Tobins'Q	1175	1.44	0.80	1.05	1.24	1.52
Capex Ratio	1174	0.05	0.04	0.02	0.04	0.06
R&D Ratio	1175	0.01	0.02	0	0	0.01
ROA	1175	0.06	0.06	0.04	0.06	0.09
ROE	1175	0.11	0.22	0.06	0.11	0.17
Leverage	1175	0.31	0.16	0.19	0.30	0.43
Age	921	71	233	19	28	67
Total Assets *(EUR)*	1175	2.50×10^7	3.90×10^7	5.60×10^6	1.10×10^7	2.40×10^7
Market Cap *(EUR)*	1175	1.30×10^7	1.60×10^7	3.10×10^6	7.10×10^6	1.40×10^7
Ln GDP Capita	1175	10.75	0	11	10.77	10.89
GDP Growth	1175	1.42	3.24	0.48	1.62	2.66
Regulatory Quality	1068	89.72	8.65	85.24	93.33	96.23
Rule Law	1068	89.72	11.24	87.62	93.13	97.61

Panel B: Control Sample

Variable	*n*	Mean	*S.D.*	*P25*	Median	*P75*
ESG Gov Score	901	0.57	0.21	0.42	0.58	0.74
ESG Env Score	901	0.62	0.21	0.48	0.65	0.79
ESG Social Score	901	0.65	0.21	0.51	0.70	0.82
ESG Total Score	901	0.62	0.17	0.51	0.65	0.75
Size	901	16.14	1.21	15.39	16.13	16.92
Tobins'Q	901	1.48	0.93	1.01	1.24	1.62
Capex Ratio	901	0.04	0.03	0.02	0.03	0.06
R&D Ratio	901	0.01	0.02	0	0	0.01
ROA	901	0.06	0.06	0.03	0.06	0.09
ROE	901	0.10	0.32	0.04	0.10	0.16
Leverage	901	0.22	0.14	0.11	0.20	0.29
Age	755	65	226	16	25	53
Total Assets *(EUR)*	901	2.10×10^7	3.20×10^7	4.80×10^6	1.0×10^7	2.20×10^7
Market Cap *(EUR)*	901	1.30×10^7	1.80×10^7	2.30×10^6	6.0×10^6	1.50×10^7
Ln GDP Capita	901	10.62	0.41	10.51	10.69	10.81
GDP Growth	901	1.64	3.75	0.83	1.65	2.78
Regulatory Quality	833	88.24	9.05	81.9	92.38	95.24
Rule Law	833	87.03	11.06	84.91	90.48	93.81

To assess the effectiveness of the treatment, a two-sample Student's t-test with unequal variances was conducted, following standard statistical practice, to compare the means between the treatment and control groups (Bruce & Bruce, 2019). The Environmental score is around 8 percentage points higher in the treatment group (69.6%) compared to the control group (62%), with a *p*-value < 0.01, indicating strong statistical significance. The Social score also shows a significant difference, with the treatment group averaging 70.3% and the control group 65.1% ($p<0.01$). These findings reinforce that firms issuing green bonds demonstrate a greater commitment to environmental and social dimensions. Additionally, the *t*-test results support the comparability of the groups, as most control variables show no major differences, indicating that the matching process was effective.

Table 3: Univariate Analysis

Table 3 shows the results of a two-sample *t*-test with unequal variances in scores between the treatment and control groups. Differences in means are tested using the *t*-statistic test.***,**,* mean statistical significance at the 1%, 5% and 10% respectively. Source: Author's elaboration.

	Control	Treatment						
	Obs1	Obs2	Mean1	Mean2	dif (Obs1-Obs2)	*t* test	*p* value	
ESG Gov Score	901	1175	0.573	0.572	0.001	0.15	0.897	
ESG Env Score	901	1175	0.62	0.696	-0.076	-7.6	0	***
ESG Social Score	901	1175	0.651	0.703	-0.052	-5.8	0	***
ESG Total Score	901	1175	0.619	0.664	-0.045	-6.15	0	***
Size	901	1175	16.137	16.252	-0.115	-2.1	0.036	**
Tobins'Q	901	1175	1.485	1.444	0.041	1.05	0.291	
Capex Ratio	901	1174	0.041	0.049	-0.008	-5.2	0	***
R&D Ratio	901	1175	0.01	0.009	0.001	1.45	0.153	
ROA	901	1175	0.061	0.065	-0.004	-1.3	0.192	
ROE	901	1175	0.096	0.106	-0.010	-0.8	0.42	
Leverage	901	1175	0.22	0.314	-0.094	-13.9	0	***
Age	755	921	65	71	-6.3	-0.55	0.578	
Total Assets *(EUR)*	901	1175	2.10×10^7	2.50×10^7	-3.96×10^6	-2.55	0.011	**
Market Cap *(EUR)*	901	1175	1.30×10^7	1.268×10^7	3.211×10^5	0.4	0.672	
Ln GDP Capita	901	1175	10.623	10.746	-0.123	-7.3	0	***
GDP Growth	901	1175	1.637	1.415	0.222	1.4	0.158	
Regulatory Quality	833	1068	88.243	89.717	-1.474	-3.6	0.001	***
Rule Law	833	1068	87.029	89.717	-2.688	-5.2	0	***

To complement the descriptive analysis, the Pearson correlation coefficients were estimated to explore the relationships among the three ESG dimensions: environmental, social, the total ESG scores, and the control variables used in the regression analysis. Table 4 show the results that disclose strong positive correlations between the environmental and social scores

(r = 0.685), as well as between each of these pillars and the total ESG score (r = 0.841 for environmental, r = 0.873 for social), which does not represent an issue because those variables correspond to the dependent variables in regression analysis. Firm size is moderately and positively correlated with all ESG scores (r ≈ 0.42–0.49), suggesting that larger firms tend to achieve higher ESG performance.

In contrast, capital expenditure shows negative correlations, particularly with the social score (r = -0.155), while R&D spending has a positive relationship with the social dimension (r = 0.160). Profitability and leverage display weak or negligible correlations with ESG scores. The findings suggest that firm size and innovation (proxied by R&D) are more closely linked to ESG performance than profitability or capital structure.

Table 4: Pearson Correlation

Table 4 shows Pearson correlation coefficients for the ESG pillar scores and control variables. All variable definitions are provided in Appendix II. * Mean statistical significance at least 5% level. Source: Author's elaboration.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) ESG Env Score	1								
(2) ESG Social Score	0.685*	1							
(3) ESG Total Score	0.841*	0.873*	1						
(4) Size	0.476*	0.423*	0.487*	1					
(5) Tobin's Q	-0.015	0.068*	0.031	-0.159*	1				
(6) Capex Ratio	-0.089*	-0.155*	-0.131*	-0.084*	0.054*	1			
(7) R&D Ratio	0.074*	0.160*	0.164*	0.062*	0.245*	-0.106*	1		
(8) ROA	0.014	0.028	0.011	-0.130*	0.536*	0.116*	0.079*	1	
(9) Leverage	0.018	0.025	0.03	0.059*	-0.120*	0.154*	-0.193*	-0.190*	1

CHAPTER IV – RESULTS AND DISCUSSION

This chapter presents the findings of the study and discusses the results from the statistical analysis using panel data, followed by an interpretation of their significance in the broader context of green bond issuance and economic systems. The following analysis begins by testing whether the issuance of green bonds has a measurable impact on companies' ESG performance, with a focus on the environmental and social pillars. Furthermore, Hypothesis 2 tests whether companies that demonstrate higher levels of green innovation also tend to be more innovative overall. Additionally, key comparisons between market-based and bank-based economies are highlighted, along with an evaluation of firms in market-based economies that exhibit higher levels of green innovation compared to those in bank-based economies, followed by the issuance of green bonds.

Although the ESG framework includes Governance, the variable will not be the focus of the analysis. Governance practices are already well-established, extensively regulated, and subject to separate mandatory reporting requirements for firms. In contrast, the Environmental and Social components are more dynamic and central to green bond issuance, which typically requires clear, intentional investment in sustainability-related initiatives, particularly environmental ones.

Therefore, this study focuses on the environmental and social dimensions, which more directly reflect the objectives and use of proceeds associated with green bonds. The empirical strategy employed a fixed effects regression model, integrating fixed effects for country, industry, and year, while clustering at the firm level. This approach is appropriate for a cross-country study, where firm-level clustering controls for intra-firm correlation and fixed effects capture unobserved heterogeneity across broader structural dimensions.

4.1 The impact of green bond financing on ESG performance

This section presents the results for testing Hypothesis 1, which posits that the issuance of green bonds leads to an improvement in corporate sustainability metrics, as reflected in the company's ESG scores. Additionally, a placebo test was conducted as a robustness check. Equation (1) was modelled to test Hypothesis 1.

$$Y_{i,t} = \alpha_i + \beta_1 Green\ Bonds_{i,t} + \beta_2 Post_{i,t} + \beta_3 Post_{i,t} \times Green\ Bonds_{i,t} + \delta_1 X_{i,t-1} + \delta_2 Z_{c,t-1} + \lambda_c + \eta_j + \gamma_t + \varepsilon_{i,c,t} \quad (1)$$

$Y_{i,t}$ is the outcome variable, representing the firm's ESG pillar scores proxied for ESG performance. α_i is the firm-specific fixed effect, which captures individual heterogeneity.

β_1 corresponds to the variable Green Bonds, a dummy that takes the value of 1 if the firm has issued green bonds at time *t*, and 0 otherwise. β_2 is associated with the variable Post**,** a dummy that equals 1 in the post-treatment period, capturing the period after the Green Bond issuance. β_3 is the interaction term between Green Bonds and Post**,** which captures the Difference-in-Differences (DID) effect. It also included a set of firm-level variables represented by $X_{i,t-1}$, as follows: *Size*, the natural logarithm of total assets; *Tobin's Q*, measured as total assets minus book value of equity plus (market capitalization) divided by total assets; *ROA* is measured as net income before extraordinary items divided by total assets; *Leverage* is the total (short plus long-term) debt divided by total assets; *Capex Ratio* is measured as capital expenditures divided by total assets; *R&D Ratio* is the research and development expenses divided by lagged total assets. The vector $Z_{c,t-1}$ of country-level variables were included as follows: *Ln GDP* is the logarithm of gross GDP per capita, measured at constant 2024 prices; *GDP Growth* is the annual percentage growth rate of real gross domestic product; *Regulatory Quality* is a proxy for institutional quality based on the ability of governments to formulate and adopt regulations that promote private sector development; and, *Rule of Law* is a proxy that captures the enforcement of the law measured by the quality of contract enforcement, property rights, confidence in law, forces, and courts. All variable definitions are described in Appendix II.

Due to perfect multicollinearity between the Post variable and its interaction with the Green Bond indicator, the $\beta_3 Post \times Green\ Bonds_{i,t}$ variable was dropped from the model, as expected. This does not affect the interpretation, since the redundancy is a known limitation in such interaction setups. Table 5 presents the results. Regressions (1), (2), and (3) exclude investment-related and country-level controls; models (4), (5), and (6) incorporate country-level variables; while the final models (7), (8), and (9) include all controls.

The regression results presented in Table 5 consistently indicate that firms issuing green bonds are associated with higher ESG scores, particularly in the Environmental Pillar, where the coefficients' magnitudes are higher across all specifications. As an example, in model (7), green bond issuance corresponds to a rise of 5.7 percentage points in the ESG Environmental Pillar score of the treatment group compared to the control group. Overall, green bond issuers display ESG scores 3 percentage points above their counterparts as displayed in model (9). The consistency of the results across these specifications reinforces the validity of the findings.

Across all model specifications, firms that issued green bonds demonstrated significantly higher environmental scores, with increases of approximately 5.7 percentage points, statistically significant at the 1% level. Social and overall ESG scores also improved, albeit the economic magnitude of the coefficient estimates is lower than that of the Environmental Pillar score. This suggests that green bonds contribute not only to environmental improvements but also to broader corporate responsibility enhancements.

The absence of a significant effect for the post-issuance variable indicates that these gains are not driven by external time trends but are directly linked to the issuance of green bonds. These results support existing literature that emphasises the role of green bonds in enhancing sustainability outcomes (Flammer, 2021; Cheng & Wu, 2024). Control variables behaved largely as expected: firm size and profitability exhibited a strong positive relationship with ESG scores. Leverage and capital expenditure did not show significant impacts, while macroeconomic or institutional variables were mostly insignificant in relation to ESG performance. On the other hand, R&D expenditure appears to positively influence Social and ESG scores; these results reinforce our belief that R&D serves as a proxy for corporate innovation.

Overall, these findings suggest that the issuance of green bonds is a credible mechanism for promoting corporate ESG performance, particularly in environmental areas. While concerns regarding greenwashing persist, the consistent positive association observed in our results indicates that, on average, green bonds represent more than mere symbolic commitments; they are associated with measurable and substantive changes in corporate behaviour.

Based on the evidence presented in Table 5, the hypothesis that green bond issuance has a positive impact on ESG performance - Hypothesis 1 - is supported. The findings indicate that companies or institutions engaging in green bond issuance tend to show measurable improvements in key ESG indicators, particularly in the environmental dimension and social responsibility practices. Empirical evidence from the analysed cases demonstrates that the allocation of funds raised through green bonds directly contributes to environmentally sustainable projects, thereby enhancing the environmental scores of the issuers.

Our evidence suggests that green bond issuance functions as both a financing mechanism and a strategic tool for enhancing ESG performance. This conclusion is consistent with previous studies indicating that financial instruments linked to sustainability, such as green bonds, effectively promote more responsible corporate behaviour and improve non-financial

performance metrics. In summary, the analysis confirms that the issuance of green bonds has a tangible and positive impact on the ESG performance of organisations, thereby validating Hypothesis 1 proposed in this study.

Table 5: Results of Hypothesis 1

Table 5 presents the results for Hypothesis 1. It is important to note the following model specifications: Models (1), (2), and (3) exclude investment-related and country-level controls; Models (4), (5), and (6) incorporate country-level variables; and Models (7), (8), and (9) include all controls. Variable descriptions are provided in Appendix II. Robust *t*-statistics in parentheses. *** *p<0.01,* ** *p<0.05,** *p<0.1.* Source: Author's elaboration.

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variables	ENV	SOCIAL	ESG	ENV	SOCIAL	ESG	ENV	SOCIAL	ESG
Green Bond	**0.0570*** **	**0.0370** **	**0.0308** **	**0.0573*** **	**0.0371** **	**0.0311** **	**0.0573*** **	**0.0379** **	**0.0314** **
	(3.35)	**(2.26)**	**(2.22)**	**(3.37)**	**(2.27)**	**(2.24)**	**(3.40)**	**(2.42)**	**(2.38)**
Post	0.0084	-0.0076	-0.0096	0.0078	-0.0078	-0.0098	0.0080	-0.0075	-0.0096
	(0.46)	(-0.40)	(-0.66)	(0.43)	(-0.41)	(-0.68)	(0.44)	(-0.40)	(-0.68)
Size	0.0865***	0.0808***	0.0746***	0.0865***	0.0803***	0.0746***	0.0859***	0.0784***	0.0734***
	(13.98)	(13.78)	(14.01)	(13.96)	(13.63)	(13.94)	(14.33)	(14.06)	(14.53)
Tobin's Q	0.0059	0.0104	0.0065	0.0061	0.0104	0.0066	0.0036	0.0058	0.0023
	(0.66)	(1.41)	(1.09)	(0.69)	(1.41)	(1.11)	(0.40)	(0.80)	(0.39)
ROA	0.2029**	0.2112**	0.1550**	0.2007**	0.2059**	0.1539**	0.2178**	0.2493***	0.1861**
	(2.12)	(2.08)	(1.99)	(2.12)	(2.03)	(1.97)	(2.31)	(2.64)	(2.53)
Leverage	-0.0443	-0.0337	-0.0154	-0.0441	-0.0329	-0.0160	-0.0301	0.0008	0.0099
	(-0.80)	(-0.65)	(-0.36)	(-0.80)	(-0.63)	(-0.37)	(-0.52)	(0.01)	(0.22)
Capex Ratio							-0.0605	-0.2635	-0.1470
							(-0.24)	(-1.03)	(-0.62)
R&D Ratio							0.5193	1.0457***	0.9173***
							(1.56)	(3.38)	(3.55)
Ln GDP				0.0828	0.1176	0.0303	0.0867	0.1253*	0.0372
				(1.13)	(1.64)	(0.53)	(1.19)	(1.75)	(0.65)
GDP Growth				0.0016	0.0015	-0.0004	0.0017	0.0016	-0.0003
				(0.82)	(0.80)	(-0.26)	(0.84)	(0.86)	(-0.21)
Regulatory Quality				-0.0005	0.0000	0.0004	-0.0005	-0.0001	0.0003
				(-0.21)	(0.00)	(0.20)	(-0.21)	(-0.05)	(0.18)
Rule Law				-0.0051	-0.0002	-0.0024	-0.0050	-0.0000	-0.0022
				(-1.57)	(-0.06)	(-0.97)	(-1.55)	(-0.01)	(-0.93)
Constant	-0.8153***	-0.7957***	-0.6977***	-1.1646	-2.0366**	-0.8248	-1.2034	-2.0871***	-0.8837
	(-6.80)	(-7.76)	(-7.72)	(-1.45)	(-2.55)	(-1.28)	(-1.48)	(-2.60)	(-1.36)
Observations	2,075	2,075	2,075	2,075	2,075	2,075	2,074	2,074	2,074
R-squared	0.395	0.441	0.444	0.398	0.443	0.444	0.400	0.454	0.456
Firm FE	No	No	No	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm

To ensure the robustness of our results, a placebo test was conducted to identify any events that may have occurred simultaneously with the treatment and could have confounded the main findings. For this purpose, we control for the passage of the EU Non-Financial Reporting (NFR) Directive (2014/95/EU). The European Union strategically implemented the Non-Financial Reporting (NFR) Directive 2014/95/EU[4] to synchronise corporate governance with the European Green Deal and the United Nations 2030 Agenda. This regulatory framework requires disclosure of climate and environmental, social, and governance (ESG) considerations, requiring organisations to integrate sustainability metrics into their strategic decision-making processes. By requiring transparent reporting, the directive aims to enhance corporate accountability, promote sustainable practices, and align business strategies with broader global environmental and social objectives (Directive 2014/95/EU, 2014).

The EU Non-Financial Reporting Directive mandates that large public companies with over five hundred employees disclose non-financial information regarding their environmental, social, and governance (ESG) practices. This regulatory framework aims to enhance transparency in corporate sustainability efforts, prioritising climate change and resource management through ESG reporting. The implementation of the NFRD is represented by a dummy variable, which assumes a value of 1 from 2018 onwards (when the directive came into force) and 0 otherwise. This dummy variable was included as a control variable in our previous regression models.

Table 6 presents the results of the placebo analysis. The key findings related to green bonds remained largely consistent, and the variables, including the control variables, remained stable. These results suggest that the increase in ESG commitment observed among firms was not a direct consequence of the directive's implementation. Rather, these firms had already demonstrated strong ESG engagement before the regulation, thereby reinforcing the credibility of their sustainable and social investments. Consequently, these findings reduce the likelihood of greenwashing behaviour. Since firms did not significantly increase their sustainability reporting in response to the directive, this implies they were not simply reallocating funds from green bonds towards unrelated or non-environmental/social projects.

[4] European Parliament & Council of the European Union. (2014). Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU regarding the disclosure of non-financial and diversity information by certain large undertakings and groups. Official Journal of the European Union, L 330, 1-9. https://eur-lex.europa.eu/eli/dir/2014/95/oj/eng

Instead, the evidence supports the conclusion that these firms are genuinely committed to their ESG objectives.

This additional test confirms the consistency of our previous results, reinforcing the argument that the observed improvements in ESG factors are not merely a consequence of regulatory compliance but rather a reflection of firms' commitment to sustainability. These results provide additional support for Hypothesis 1.

Table 6: Hypothesis 1 - The Placebo Test

Table 6 presents the results of a placebo test conducted using the EU Non-Financial Reporting (NFR) Directive (2014/95/EU) and the Corporate Sustainability Reporting Directive as reference points to identify potential confounding events. Variable descriptions are provided in Appendix II. Robust t-statistics in parentheses. *** *p<0.01,* ** *p<0.05,* * *p<0.1.* Source: Author's elaboration.

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variables	ENV	SOCIAL	ESG	ENV	SOCIAL	ESG	ENV	SOCIAL	ESG
Green Bond	**0.0664*** **	**0.0473** **	**0.0348** **	**0.0645*** **	**0.0457** **	**0.0341** **	**0.0647*** **	**0.0467** **	**0.0348** **
	(3.03)	**(2.29)**	**(2.03)**	**(2.94)**	**(2.22)**	**(1.99)**	**(2.96)**	**(2.30)**	**(2.07)**
Post	0.0145	-0.0009	-0.0070	0.0124	-0.0022	-0.0078	0.0128	-0.0018	-0.0074
	(0.74)	(-0.05)	(-0.45)	(0.63)	(-0.11)	(-0.50)	(0.65)	(-0.09)	(-0.49)
NFRD	-0.0198	-0.0217	-0.0083	-0.0151	-0.0182	-0.0065	-0.0157	-0.0186	-0.0071
	(-0.93)	(-1.00)	(-0.51)	(-0.71)	(-0.83)	(-0.39)	(-0.74)	(-0.86)	(-0.43)
Size	0.0865***	0.0807***	0.0746***	0.0864***	0.0802***	0.0746***	0.0859***	0.0784***	0.0734***
	(13.96)	(13.75)	(13.99)	(13.95)	(13.61)	(13.93)	(14.33)	(14.05)	(14.52)
Tobin's Q	0.0059	0.0104	0.0065	0.0061	0.0104	0.0066	0.0036	0.0057	0.0023
	(0.67)	(1.42)	(1.09)	(0.69)	(1.41)	(1.11)	(0.40)	(0.80)	(0.39)
ROA	0.2043**	0.2127**	0.1556**	0.2021**	0.2076**	0.1545**	0.2191**	0.2509***	0.1867**
	(2.13)	(2.10)	(2.00)	(2.13)	(2.05)	(1.99)	(2.32)	(2.66)	(2.55)
Leverage	-0.0441	-0.0335	-0.0153	-0.0439	-0.0327	-0.0159	-0.0299	0.0010	0.0100
	(-0.80)	(-0.65)	(-0.36)	(-0.79)	(-0.63)	(-0.37)	(-0.51)	(0.02)	(0.22)
Capex Ratio							-0.0569	-0.2592	-0.1454
							(-0.22)	(-1.00)	(-0.61)
R&D Ratio							0.5229	1.0500***	0.9189***
							(1.57)	(3.40)	(3.55)
Ln GDP				0.0751	0.1083	0.0270	0.0787	0.1159	0.0336
				(1.02)	(1.49)	(0.47)	(1.07)	(1.60)	(0.58)
GDP Growth				0.0017	0.0016	-0.0004	0.0017	0.0017	-0.0003
				(0.83)	(0.82)	(-0.25)	(0.86)	(0.88)	(-0.20)
Regulatory Quality				-0.0006	-0.0001	0.0003	-0.0006	-0.0002	0.0003
				(-0.24)	(-0.04)	(0.18)	(-0.25)	(-0.10)	(0.16)
Rule Law				-0.0049	0.0001	-0.0023	-0.0048	0.0002	-0.0021
				(-1.53)	(0.02)	(-0.95)	(-1.51)	(0.08)	(-0.90)
Constant	-0.8206***	0.8015***	-0.6999***	-1.0991	-1.9579**	-0.7968	-1.1365	-2.0081**	-0.8534
	(-6.86)	(-7.82)	(-7.76)	(-1.35)	(-2.43)	(-1.23)	(-1.39)	(-2.47)	(-1.30)
	0.0664***	0.0473**	0.0348**	0.0645***	0.0457**	0.0341**	0.0647***	0.0467**	0.0348**
Observations	2,075	2,075	2,075	2,075	2,075	2,075	2,074	2,074	2,074
R-squared	0.396	0.442	0.444	0.398	0.443	0.444	0.401	0.454	0.456
Firm FE	No	No	No	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm

4.2 Does green bond issuance positively affect green innovation?

The literature suggests that green bonds can stimulate corporate green innovation through two primary mechanisms: alleviating financial constraints and increasing R&D investments (Dong et al., 2024). Flammer (2021) further argues that green bonds send a credible signal to investors and the market, particularly when they are certified by a third party. This certification encourages firms to allocate resources more transparently and purposefully towards environmental initiatives. Consequently, this often leads to a prioritisation of green innovation, which can yield both economic and environmental benefits, driving tangible ESG outcomes.

Hypothesis 2 aims to test whether companies with greater green innovation are more innovative overall. To analyse this further, we have identified four environmental scores: environmental expenditures (investments), greenhouse gas (CO2) emission reductions, resource efficiency, and waste management initiatives. These sustainable variables are defined as follows: Environmental Expenditures represent the total value of environmental investments and initiatives, including reported expenditures aimed at reducing environmental risks, pursuing sustainability-related opportunities, and adopting cleaner technologies or processes; CO2 Emissions are determined by the policies and targets set to reduce emissions from operations (air, water, and land); Resource Efficiency refers to the policies implemented to enhance energy and water efficiency, supporting continuous improvement across various processes and operations; Waste encompasses both e-waste reduction and waste reduction initiatives, which provide actions and management strategies to reduce, treat, or phase out e-waste and overall waste.

These variables are binary indicators, taking the value of one when the outcome is positive and zero otherwise. Each score represents the sum of two environmental variables, as detailed in Appendix II. We re-estimate equation (1), substituting the dependent variable with each score to examine the impact of green bond issuance on these scores. The rationale for this analysis is strengthened by measuring indicators that reveal whether companies have invested in green innovation, based on the assumption that green bond proceeds will be allocated to sustainable projects. Table 7 presents the results, indicating that regressions (1), (2), and (3), which correspond to expenditure, emissions, and resources, are statistically significant, except regression (4), which relates to the Waste indicator. This confirms that companies issuing green bonds demonstrate their commitment, independent of the issuance

itself. The post-issuance period shows no statistical significance, suggesting that the commitment does not rely on the emission event. This indicates an absence of greenwashing, with companies genuinely utilising green bond investments for sustainable projects. It is assumed that the more a company invests in these environmental dimensions, the more innovative it is likely to be in terms of sustainable projects and green innovation.

Our results (in Table 7) indicate that green bond issuance is positively and significantly associated with three indicators of corporate environmental innovation: Model 1 environmental expenditures (coefficient = 0.2108, $p<0.05$), Model 2 emission reduction (0.1261, $p<0.01$), and Model 3 resource efficiency (0.1589, $p<0.01$). Moving to Model 2, which focuses on CO2 emissions, the results show a positive and highly significant relationship between green bond issuance and firms' efforts to manage and reduce emissions. The coefficient of 0.1261 ($p<0.01$) suggests that firms issuing green bonds tend to report lower scores in emissions-related initiatives after the issuance. Overall, our results support Hypothesis 2, which posits that the issuance of green bonds positively influences corporate green innovation.

The statistical significance of expenditure, emission, and resource indicators suggests that green bond issuers typically utilise these instruments as financing vehicles for pre-established sustainability strategies, as well as catalysts for new environmental initiatives. Furthermore, this finding implies that green bond issuers are often firms with an intrinsic, long-term commitment to ESG objectives, where the issuance of green bonds forms part of a broader strategic orientation towards sustainability rather than a symbolic or isolated gesture.

These results are consistent with previous studies that examine the impact of green bonds on sustainability-oriented investments (Dong et al., 2024; Flammer, 2021). They confirm that green bonds enable firms to increase their investments in green innovation activities, supporting the notion that these financial instruments are effective tools for fostering corporate sustainability. However, the waste management indicator did not demonstrate a statistically significant relationship with green bond issuance. This lack of significance may reflect sector-specific implementation challenges or the measurement complexities inherent in waste management projects. This might reflect sectoral or regulatory variations in how waste projects are managed or reported across different sectors or regulatory frameworks, or

it could be since such initiatives are generally less capital-intensive and, therefore, less reliant on green bond financing.

Table 7: Results of Hypothesis 2

Table 7 presents the results for Hypothesis 2. Each variable included in the regression is a composite score, calculated as the sum of two category-specific indicators: expenditures, emissions, resources, and waste. Robust *t*-statistics in parentheses. Variable descriptions are provided in Appendix II. ****p<0.01, ** p<0.05,* p<0.1.* Source: Author's elaboration.

Model	(1)	(2)	(3)	(4)
Dependent Variables	Environmental Expenditures	CO2 Emissions	Resource Use	Waste
Green Bond	**0.2108****	**0.1261*****	**0.1589*****	**-0.0322**
	(2.28)	**(3.12)**	**(3.01)**	**(-0.66)**
Post	0.1254	-0.0445	-0.0731	0.0347
	(1.11)	(-1.02)	(-1.31)	(0.68)
Size	0.1430***	0.1579***	0.1792***	0.0975***
	(4.09)	(8.76)	(8.30)	(4.73)
Tobin's Q	-0.0588	-0.0020	0.0136	0.0273
	(-1.39)	(-0.11)	(0.52)	(1.11)
ROA	0.1307	-0.2204	0.4397	0.3846
	(0.23)	(-0.67)	(1.38)	(1.29)
Leverage	-0.4636	0.0966	-0.2709	0.0677
	(-1.53)	(0.78)	(-1.60)	(0.39)
Capex Ratio	0.1682	0.4489	0.2947	0.2911
	(0.15)	(0.81)	(0.43)	(0.46)
R&D Ratio	2.6785	0.6451	-0.3359	1.3178
	(1.24)	(1.00)	(-0.21)	(1.50)
Ln GDP	0.3120	0.2517	0.3327	-0.0583
	(0.84)	(0.98)	(1.30)	(-0.22)
GDP Growth	-0.0107	-0.0043	-0.0027	-0.0044
	(-0.99)	(-0.68)	(-0.45)	(-0.74)
Regulatory Quality	0.0064	0.0020	0.0013	0.0028
	(0.55)	(0.27)	(0.16)	(0.41)
Rule Law	-0.0012	-0.0160	-0.0186	-0.0010
	(-0.08)	(-1.54)	(-1.40)	(-0.09)
Constant	-5.0852	-2.3530	-3.1237	-0.4424
	(-1.23)	(-0.89)	(-1.20)	(-0.16)
Observations	1,752	1,931	1,927	1,925
R-squared	0.290	0.258	0.244	0.281
Firm FE	No	No	No	No
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm

Moreover, the insignificance of the "Post" variable across all models suggests that firms' engagement with green innovation was not instigated by the issuance of green bonds. Rather, these firms were already on a sustainability trajectory prior to issuing the bonds. This is a significant insight that reinforces the idea of environmental commitment and minimizes concerns regarding greenwashing, as it appears that firms do not utilise green bonds for reputational gains. The absence of statistical significance in the post-issuance period bolsters the anti-greenwashing argument, indicating that companies exhibit genuine environmental commitment independent of the bond issuance event itself, rather than engaging in performative behaviour following market entry.

In line with this strategic commitment, it is reasonable to infer that firms demonstrating consistent investment across key sustainability areas, such as environmental expenditures, emissions reduction, and resource efficiency, are also more likely to be innovative in implementing and integrating green technologies and practices. This, in turn, reinforces the positive correlation between sustainable finance and corporate innovation capacity, particularly in areas that are directly aligned with ESG goals.

Altogether, our results provide evidence in support of Hypothesis 2, as the results suggest that green bonds act as catalysts, motivating companies to invest in and implement sustainable practices that align with broader environmental objectives. This reinforces the argument that green financing mechanisms can effectively drive corporate behavioural changes towards sustainability. Consequently, the positive relationship observed confirms that the issuance of green bonds encourages corporate investments and initiatives that promote environmental sustainability and innovation. In conclusion, both the theoretical literature and empirical evidence confirm that green bond issuance plays a significant role in fostering corporate green innovation.

4.3 Green Bonds and Market-based versus Bank-based Economies

The objective of Hypothesis 3 is to determine whether companies in market-based economies demonstrate higher levels of ESG performance and ESG outcomes compared to those in bank-based economies following the issuance of green bonds. Using the economic classification established by Demirgüç-Kunt and Levine (1999), the countries classified as market-based in this study include the United Kingdom, the Netherlands, Sweden, Denmark, Finland, and Ireland. All other countries included in the analysis are categorised as bank-based economies.

Equation (1) was extended to include the variable 'Market-Based' to test whether green bond instruments are associated with improved ESG performance and outcomes in market-based economies compared to bank-based economies.

$$Y_{i,t} = \alpha_i + \beta_1 Green\ Bonds_{i,t} + \beta_2 Post_{i,t} + \beta_3 Post_{i,t} \times Green\ Bonds_{i,t} + \beta_4 Market_{c,t} + \beta_5 (Market\ Based_{c,t} \times Post_{i,t}) + \delta_1 X_{i,t-1} + \delta_2 Z_{c,t-1} + \lambda_c + \eta_j + \gamma_t + \varepsilon_{i,c,t} \quad (2)$$

Where $Y_{i,t}$ is the outcome variable that will be replaced by ESG pillar scores (like in Section 4.1 for testing Hypothesis 1) and ESG scores, as in Section 4.2, testing Hypothesis 2. β_4 refers to the variable Market Based, a dummy indicating whether the firm operates in a market-based economy (1 for market-based; 0 for bank-based economies). β_5 captures the interaction between Market-Based and Post, which captures the impact of market-based economies compared to bank-based economies when firms decide to issue green bonds. The remaining variables are as described above. The interaction between $\beta_3 Post_{i,t} \times Green\ Bonds_{i,t}$ was dropped from the model due to perfect multicollinearity, as explained in Hypothesis 1, page 28.

The results presented in Table 8 indicate that, on average, the estimates of the coefficients reveal no significant differences in ESG performance and outcomes between green bond issuers in market-based and bank-based economies. The lack of substantial differences between these two types of economies in promoting green innovation challenges established the financial system theory.

Traditional literature suggests that market-based systems, with their emphasis on liquidity, transparency, and information efficiency, should offer superior mechanisms for pricing environmental risks and allocating capital towards innovative sustainable projects (Holmstrom & Tirole, 1993). It was anticipated that the enhanced capacity of capital markets to incorporate new information and provide diverse funding sources would create competitive advantages for financing green innovation. However, our empirical results do not support this premise, indicating that sustainability finance operates under different dynamics compared to conventional innovation financing.

Table 8: Results of Hypothesis 3

Table 8 reports the estimation results of Equation (2), which tests whether green bond issuance is associated with higher levels of green innovation in market-based economies compared to bank-based economies. Each column corresponds to a different regression specification, using various ESG pillar scores and sustainability-related (scores) dependent variables as described in Appendix II. Robust *t*-statistics in parentheses. *** *p<0.01,* ** *p<0.05,* * *p<0.1.* Source: Author's elaboration.

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variables	ENV	SOCIAL	ESG	ENV	SOCIAL	ESG	Environmental Expenditure	CO2 Emission	Resource	Waste
Green Bond	**0.0574*** **	**0.0373** **	**0.0311** **	**0.0574*** **	**0.0381** **	**0.0315** **	**0.2106** **	**0.1262*** **	**0.1589*** **	**-0.0322**
	(3.37)	**(2.28)**	**(2.24)**	**(3.40)**	**(2.43)**	**(2.38)**	**(2.28)**	**(3.11)**	**(3.01)**	**(-0.66)**
Post	0.0164	0.0091	-0.0054	0.0161	0.0084	-0.0060	0.0070	0.0424	-0.0510	0.0547
	(0.67)	(0.37)	(-0.28)	(0.66)	(0.35)	(-0.32)	(0.05)	(0.89)	(-0.70)	(0.90)
Market	0.0318	-0.0711	0.0140	-0.0359	0.0074	0.0366	-0.3520	0.2079	0.0607	0.0045
	(0.44)	(-1.41)	(0.29)	(-0.37)	(0.10)	(0.64)	(-1.09)	(1.08)	(0.31)	(0.02)
Post Market	-0.0235	-0.0460	-0.0120	-0.0221	-0.0433	-0.0097	0.3214	-0.2390***	-0.0610	-0.0551
	(-0.84)	(-1.49)	(-0.54)	(-0.79)	(-1.42)	(-0.45)	(1.64)	(-3.78)	(-0.70)	(-0.59)
Size	0.0866***	0.0805***	0.0747***	0.0860***	0.0787***	0.0735***	0.1402***	0.1594***	0.1796***	0.0979***
	(13.99)	(13.66)	(13.88)	(14.37)	(14.09)	(14.48)	(3.98)	(8.95)	(8.32)	(4.73)
Tobin's Q	0.0062	0.0105	0.0066	0.0037	0.0059	0.0024	-0.0604	-0.0013	0.0137	0.0274
	(0.69)	(1.43)	(1.11)	(0.41)	(0.82)	(0.39)	(-1.43)	(-0.07)	(0.52)	(1.11)
ROA	0.1986**	0.2018**	0.1528*	0.2157**	0.2452**	0.1852**	0.1913	-0.2527	0.4318	0.3774
	(2.08)	(1.98)	(1.95)	(2.27)	(2.58)	(2.51)	(0.34)	(-0.78)	(1.35)	(1.26)
Leverage	-0.0452	-0.0351	-0.0165	-0.0312	-0.0014	0.0094	-0.4627	0.0912	-0.2722	0.0665
	(-0.81)	(-0.68)	(-0.39)	(-0.54)	(-0.03)	(0.21)	(-1.54)	(0.73)	(-1.60)	(0.38)
Capex Ratio				-0.0604	-0.2632	-0.1470	0.1705	0.4513	0.2963	0.2924
				(-0.24)	(-1.03)	(-0.62)	(0.15)	(0.83)	(0.43)	(0.46)
R&D Ratio				0.5157	1.0386***	0.9157***	2.7486	0.6021	-0.3477	1.3072
				(1.54)	(3.32)	(3.54)	(1.29)	(0.94)	(-0.21)	(1.49)
Ln GDP	0.0837	0.1194*	0.0308	0.0876	0.1270*	0.0376	0.2854	0.2720	0.3379	-0.0535
	(1.16)	(1.70)	(0.55)	(1.21)	(1.81)	(0.66)	(0.76)	(1.08)	(1.32)	(-0.21)
GDP Growth	0.0015	0.0013	-0.0005	0.0016	0.0015	-0.0004	-0.0096	-0.0050	-0.0029	-0.0046
	(0.77)	(0.70)	(-0.30)	(0.79)	(0.77)	(-0.24)	(-0.88)	(-0.79)	(-0.47)	(-0.76)
Regulatory Quality	-0.0004	0.0002	0.0004	-0.0004	0.0001	0.0004	0.0050	0.0026	0.0014	0.0030
	(-0.17)	(0.08)	(0.23)	(-0.18)	(0.02)	(0.20)	(0.42)	(0.35)	(0.18)	(0.43)
Rule Law	-0.0052	-0.0005	-0.0024	-0.0051	-0.0003	-0.0023	0.0000	-0.0167	-0.0188	-0.0012
	(-1.62)	(-0.16)	(-1.02)	(-1.60)	(-0.11)	(-0.96)	(0.00)	(-1.61)	(-1.41)	(-0.10)
Constant	-1.1703	-2.0479***	-0.8278	-1.2084	-2.0970***	-0.8859	-4.7471	-2.5888	-3.1844	-0.4980
	(-1.47)	(-2.62)	(-1.29)	(-1.50)	(-2.66)	(-1.37)	(-1.14)	(-1.00)	(-1.23)	(-0.18)
Observations	2,075	2,075	2,075	2,074	2,074	2,074	1,752	1,931	1,927	1,925
R-squared	0.398	0.444	0.445	0.401	0.455	0.456	0.292	0.263	0.244	0.281
Firm FE	No	No	No	No	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm

This divergence may arise from the characteristics of environmental projects, which frequently involve long-term payments, complex externalities, and non-financial benefits that conventional market pricing mechanisms struggle to capture effectively. The findings imply that the theoretical advantages of market-based systems may not directly translate to the sustainability domain, where success depends more on sustained commitment and stakeholder alignment than on efficient capital allocation mechanisms. This suggests that the economic system, whether bank-based or market-based, does not seem to influence green innovation following the issuance of green bonds.

Hypothesis 3 postulates that green bond issuers based in market-based economies display superior ESG performance and achieve a higher magnitude related to environmental outcomes. However, the results confirm that this is not necessarily the case. The results indicate that firms issuing green bonds tend to exhibit a stronger commitment to sustainability, regardless of whether their country of domicile is classified as a market-based or bank-based economy. This is reflected in their enhanced ESG performance and tangible environmental outcomes.

The evidence suggests that the decision to issue green bonds is linked to a broader corporate strategy centred on sustainability, rather than being solely influenced by external factors such as the country's economic context. In essence, green bond issuers are companies that are inherently more engaged in advancing environmental goals and integrating sustainable practices into their operations.

This analysis builds upon the theoretical distinctions between these two financial systems and their differing impacts on sustainability financing mechanisms. However, even when controlling for these two financial systems, the coefficient estimates presented in Table 8 are remarkably similar in terms of economic magnitude and statistical significance to the evidence provided in Tables 5 and 7. Notably, there is a consistent and significant positive coefficient for the green bond variable across all models, ranging from environmental scores (0.0574, $p<0.01$) to resource efficiency (0.1589, $p<0.01$).

The consistency of these positive coefficients across both market-based and bank-based economies is particularly evident; it indicates that the green bond effect is a fundamental characteristic of the issuing firms rather than a function of the financial system's infrastructure. Furthermore, the statistical significance across all environmental models (except for waste) provides cross-model evidence for the environmental performance of

green bonds. The literature suggests that market-based systems, with their emphasis on liquidity, transparency, and information efficiency (Holmstrom & Tirole, 1993), may be better equipped to facilitate the pricing and allocation of capital towards sustainable projects. However, the empirical evidence does not support this perspective. Instead, the results align with Levine's (2002) observation that the structure of a financial system may not be the primary determinant of economic outcomes. The lack of significant differences between market-based and bank-based economies in promoting green innovation following green bond issuance indicates that firm-specific factors and internal commitments to sustainability may play a more decisive role than the broader financial system architecture.

The only statistically significant difference identified is in the emission reduction model, where bank-based economies seem to have an advantage. However, as this is the sole significant coefficient, it may be influenced by omitted variables or unobserved heterogeneity; therefore, further empirical testing is required to draw definitive conclusions. Consequently, no robust evidence emerges to support a systematic advantage of either financial system in promoting green innovation or emission reduction following the issuance of green bonds.

This suggests that the decision to issue green bonds and the subsequent innovation performance are more dependent on company-specific strategies, governance structures, and commitment to sustainability, rather than the broader financial system in which they operate. Altogether, our results do not support Hypothesis 3.

CHAPTER V – CONCLUSION

This study researched the role of green bonds in enhancing corporate sustainability, focusing on their impact on ESG performance, green innovation, and the differences across financial systems. It revealed that green bonds primarily serve as financing mechanisms for firms with pre-existing sustainability commitments, rather than acting as catalysts for environmental transformation. Addressing three research questions, our findings demonstrate that companies issuing green bonds exhibit superior ESG performance and green innovation; however, these characteristics are not only materialising post-issuance but are also evident beforehand.

Firstly, the analysis revealed that companies issuing green bonds generally demonstrate higher ESG performance. These companies are "pre-aligned" with sustainability principles, suggesting that green bonds may reflect a commitment to ESG rather than catalyze change. The results indicate a positive correlation between green bond issuance and ESG performance indicators. Companies that issue green bonds exhibited a strong orientation towards sustainable practices before issuance.

Furthermore, these companies also showed strong ESG engagement before the implementation of the NFRD regulation, thereby reinforcing the credibility of their sustainable and social investments. The findings have significant implications concerning greenwashing behaviour, as firms did not increase their sustainability reporting in response to the directive. This suggests they were not simply reallocating funds from green bonds to unrelated or non-environmental social projects. Instead, the evidence strongly supports the conclusion that these firms are genuinely committed to ESG goals. In summary, green bond issuance is linked to enhanced corporate sustainability metrics, and this relationship cannot be attributed to regulatory changes or reporting requirements.

Secondly, the research confirms a positive association between green bond issuance and corporate green innovation. Our evidence demonstrates a positive relationship between green bond issuance and indicators of environmental innovation, environmental expenditures, emission reduction, and resource efficiency. These findings challenge the notion that green bonds directly trigger new environmental commitments and instead suggest that companies with existing environmental priorities are more likely to issue such financial instruments. Thus, similar to ESG performance, green bonds appear to reflect rather than instigate environmental innovation. Importantly, the absence of signals indicating greenwashing supports the conclusion that companies utilise the funds from green bond

issuance for genuine sustainable initiatives. The consistent pattern of pre-issuance environmental commitment, combined with the lack of post-issuance performance improvements, demonstrates that European companies are not using green bonds for window-dressing purposes.

Thirdly, contrary to our expectations, the empirical analysis reveals no significant differences between market-based and bank-based economies in fostering green innovation or in ESG performance associated with green bond issuance. The results indicate that the structure of a country's financial system does not influence the effectiveness of green bonds. Companies that issue green bonds consistently demonstrate a statistically significant positive correlation with various sustainability metrics across both economic systems. This suggests that green bonds are an effective financing mechanism for environmental initiatives across different economic frameworks, highlighting their versatility as instruments for advancing corporate sustainability.

In summary, the results contribute to our understanding of how green bonds operate within corporate finance and their role in promoting environmental objectives. The findings indicate that while green bonds are effective instruments for reinforcing existing corporate environmental commitments, they may not independently catalyse new sustainable behaviours. However, as the market for green finance continues to demonstrate maturity, future research, supported by additional data, may uncover different dynamics. Simultaneously, the findings affirm that green bonds serve as a credible mechanism for financing sustainable initiatives, reinforcing their importance in the global transition towards a low-carbon economy. In the coming years, it will be essential to re-examine these relationships to evaluate whether the strategic integration of green finance results in more transformative sustainability outcomes over time.

A limitation of this research is the small sample size of green bond issuances in comparison to the extensive dataset available for conventional bonds and non-green bond issuers. This constraint may affect the statistical power and generalisability of our findings. A follow-up study would be valuable to reassess these relationships as the green bond market matures and more longitudinal data becomes available, potentially revealing evolving patterns or confirming the stability of our current findings.

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APPENDICES

Appendix I

Table I: Fama & French Industry Classification

Table I presents the Fama & French (1997) Industry Classification FF17 Factors. Source: Author's elaboration.

Number	Abbreviation	Category
1	Food	Food
2	Mines	Mining and Minerals
3	Oil	Oil and Petroleum Products
4	Clths	Textiles, Apparel & Footwear
5	Durbl	Consumer Durables
6	Chems	Chemicals
7	Cnsum	Drugs, Soap, Perfumes, Tobacco
8	Cnstr	Construction and Construction Materials
9	Steel	Steel Works Etc
10	FabPr	Fabricated Products
11	Machn	Machinery and Business Equipment
12	Cars	Automobiles
13	Trans	Transportation
14	Utils	Utilities
15	Rtail	Retail Stores
16	Finan	Banks, Insurance Companies, and Other Financials
17	Other	Other

Appendix II

Table II: Variable Definition, Firm Level, Industry Level, and Country Level

Table II presents the definitions of variables at the firm, industry, and country levels as outlined in the study. Source: Author's elaboration.

Variable	Definition	Source
Firm-level		
Age	A firm's age is measured as the natural logarithm of the difference between the current year and its incorporation date.	Worldscope
Capex Ratio	Capital expenditures (CAPEX) divided by total assets.	Worldscope
GDP per capita (Ln)	Natural logarithm of GDP per capita.	Worldscope
Leverage	Total (short plus long-term) debt divided by total assets.	Worldscope
R&D	Research and development expenses are divided by lagged total assets. (R&D is set to zero when it is missing.)	Worldscope
Market Capitalization	Logarithm of the market value of equity (expressed in EUR).	Worldscope
ROA	Net income before extraordinary items divided by total assets.	Worldscope
ROE	Net income is divided by equity.	Worldscope
Tobin's Q	Total assets minus book value of equity plus market capitalization) divided by total assets.	Worldscope
Total Assets	Total Assets expressed in EUR.	Worldscope
Size (Total Assets)	Natural logarithm of total assets.	Worldscope
ESG-Level		
Governance Total Score	The weighted average relative rating of a company based on the reported governance information, resulting from three category scores: Management, Shareholders, and CSR strategy.	LSEG ESG Data
Environment Total Score	The weighted average relative rating of a company based on the reported environmental information, resulting from three category scores: Resource use, Emissions, and Innovation.	LSEG ESG Data
Social Total Score	The weighted average relative rating of a company based on the reported social information, resulting from four category scores: Workforce, Human rights, Community, and Product responsibility.	LSEG ESG Data
ESG Total Score	Refinitiv's ESG Score is an overall company score based on the self-reported information in the environmental, social, and corporate governance pillars.	LSEG ESG Data
Industry-Level		
Industry	Classification scheme proposed by Fama and French (1997), based on 17 Industry Portfolios.	Fama and French (1997)
Country-Level		

Variable	Definition	Source
GDP Growth	Annual percentage growth rate of real gross domestic product (GDP).	World Bank (Development Indicators)
GDP *per Capita*	Logarithm of gross GDP *per capita,* measured at constant 2024.	World Bank (Development Indicators)
Regulatory Quality	Proxy for institutional quality based on the ability of governments to formulate and adopt policies and regulations that promote private sector development.	Kaufmann *et al.* (2009) World Bank (Worldwide Governance Indicators)
Rule of law	Proxy that captures the enforcement of the law measured by the quality of contract enforcement, property rights, confidence in law forces and courts.	Kaufmann *et al.* (2009) World Bank (Worldwide Governance Indicators)
Additional Sustainability Variables		
Environmental Expenditures Investments	Reports on environmental spending or investments to reduce risks/increase opportunities.	LSEG ESG Data
Environmental Investments Initiatives	Reports on proactive environmental investments, new technologies, or cleaner emissions treatment.	LSEG ESG Data
Policy Emission	Has formal policies or mechanisms to reduce emissions (air, water, land) from operations.	LSEG ESG Data
Target Emissions	Sets specific short- or long-term targets for reducing emissions.	LSEG ESG Data
Policy Energy Efficiency	Policies or systems to improve energy efficiency and support continuous improvement.	LSEG ESG Data
Policy Water Efficiency	Policies or systems to improve water efficiency and support continuous improvement.	LSEG ESG Data
e-Waste Reduction	Reports on actions to reduce, treat, or phase out e-waste, including hazardous materials.	LSEG ESG Data
Waste Reduction Initiatives	Reports on initiatives to manage and reduce total waste, including partnerships with waste firms.	LSEG ESG Data