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Signaling with Green Bonds

The Role of Green Bond Exchanges in Europe

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Acknowledgments

This master thesis marks the completion of our Master of Science in Economics and Business Administration at the Norwegian School of Economics (NHH).

The experience of coordinating and writing this thesis has certainly been challenging, but ultimately very rewarding. Our thesis has been inspired by the growing body of research on the role of firms and the investment community in contributing to a sustainable future. We saw the opportunity to further shed light on how green exchanges can facilitate investment in eco-friendly projects.

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Abstract

A key challenge in further developing the green bond market is establishing the "green credibility" of such bonds. While a number of studies have investigated the effectiveness of third-party certification as a credibility signal, little scholarly attention has been dedicated to green bond exchanges. Such exchanges bear great signaling potential as they combine strict listing requirements for issuers with heightened visibility for green bonds.

In an empirical analysis based on a sample of 592 green bonds issued by public European firms between 2013 and 2021, we find that investors on average do not respond positively to the announcement of green bond issuance, but do so if the green bond is listed on a dedicated green exchange. Moreover, we show that the stock market reaction to green-exchange-listed bonds is greater in countries with high levels of asymmetric information. In the second part of our analysis, our results indicate that firms do not exhibit improved environmental or financial performance after issuing a green bond, regardless of the presence of green exchange listing or certification. Lastly, we do not find a significant correlation between the stock market reaction to green bond announcements and issuers' subsequent environmental improvements.

Overall, our findings are inconsistent with the signaling argument. While investors perceive green-exchange-listed bonds as an effective signal of firms' commitment to green practices, issuers of such bonds fail to deliver tangible environmental improvements post-issuance.

Keywords – Corporate Sustainability, Impact Investing, Climate Finance, Green Bonds

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List of Acronyms

AAR	Average abnormal return
AR	Abnormal return
AT	Asset turnover
BMP	Boehmer, Mucumeci and Poulsen
CAAR	Cumulative average abnormal return
CAR	Cumulative abnormal return
CBI	Climate Bonds Initiative
CBS	Climate Bonds Standard
CSR	Corporate social responsibility
EM	Equity multiplier
EMH	Efficient Market Hypothesis
EPI	Environmental Performance Index
ESG	Environmental, Social, and Governance
EU	European Union
EU-GBS	EU Green Bond Standard
DiD	Difference-in-differences
DS	Debt-to-sales
GBP	Green Bond Principles
GHG	Greenhouse gas
GICS	Global Industry Classification Standard
ICMA	International Capital Markets Association
IFC	International Finance Corporation
OM	Operating margin
ROA	Return on assets
SSE	Sustainable Stock Exchanges
UN	United Nations
UoP	Use of Proceeds

1 Introduction

The stakes of funding the climate transition are high. It is estimated that we must invest an extra EUR 180bn annually in order to meet the European Union's Paris Agreement targets, of which a substantial amount will need to come from the private sector (EU TEG on Sustainable Finance, 2019). Green bonds have emerged in the past 15 years as an innovative tool to redirect financial flows towards environmentally friendly projects – the third aim of Article 2.1 in the Paris Agreement (UNFCCC, 2015). While the role of governments is pivotal in setting the right regulatory and fiscal landscape for the transition to a low-carbon economy (Carney, 2015; Ehlers and Packer, 2017), multiple researchers have highlighted the important function that financial market instruments, such as green bonds, can play in redirecting finance toward green investments and raising awareness around climate-related financial risks (Baker et al., 2018; Ehlers and Packer, 2017; Flammer, 2021; Zerbib, 2019).

From an estimated USD 37bn in 2014, global annual green bond issuance has grown almost 14-fold to reach USD 509bn in 2021 (CBI, 2022). By the end of 2021, cumulative green bond market volume was estimated between USD 1.1trn and 1.4trn (CBI, 2020). Despite these impressive growth rates, green bonds today only account for 0.4% of the global bond market and thus have the potential to take up further market share (European Commission, 2021a).

1.1 Research objective

This thesis seeks to contribute to a deeper understanding of green bonds. Specifically, we aim to shed light on the signals that investors use to identify credible green bonds and investigate whether such signals indeed help to identify issuers that achieve substantial improvements in their environmental and/or financial performance.

Findings of previous research suggest that financial markets view certified green bonds as a credible signal of firms' commitment to improving their sustainability efforts, whether manifested in terms of a greater "green bond premium" or a greater stock market reaction to the issuance of certified bonds (compared to non-certified bonds) (Bachelet et al., 2019; Baker et al., 2018; Flammer, 2021; Kapraun et al., 2021). Beginning in 2015, multiple

stock exchanges have started to establish separate listing platforms specifically for green bonds. Such "green exchanges" potentially bear a high level of signaling power due to the comprehensive listing requirements and heightened visibility for green bonds. Nevertheless, the implications of green exchange listings have, to date, been the focus of only a small body of scholarly work.

Moreover, determining whether green bond issuance improves the environmental and/or financial performance of issuers is critical to understanding whether green bond issuance constitutes a form of greenwashing or provides credible signals for improvements in firm-level outcomes (Fatica and Panzica, 2020; Flammer, 2021; Yeow and Ng, 2021). Certified or green-exchange-listed bonds should be expected to amplify the improvements in issuers' environmental and financial performance, considering the greater effort and resources spent to meet strict pre- and post-issuance criteria (Fatica and Panzica, 2020; Flammer, 2021).

Finally, there have been no studies to our knowledge directly investigating the link between the stock market reaction to green bonds and issuers' subsequent environmental performance. Yet, understanding this relationship is crucial to uncovering whether investors are capable of identifying green bonds whose issuers successfully achieve tangible improvements in their environmental efforts.

This line of research bears strong ties to the theories of asymmetric information and agency issues. Investor reactions to green bond issuance may be strongly influenced by how much new information the bond issuance provides. A key question to establish the credibility and signaling effect of the green bond label is thus how much green bond issuance mitigates information asymmetries and whether it leads to true environmental or financial benefits for issuers.

We therefore contribute to the literature on green bonds by investigating (i) whether green bond exchange listing is perceived to be an equally or even more credible signal of firms' environmental commitment compared to green bond certification, (ii) whether stock market reactions to these green credibility signals are justified, considering subsequent environmental and financial performance improvements by green bond issuers, and (iii) whether the size of the stock market reaction is linked to the subsequent change in issuers' environmental performance.

Accordingly, we pose the following research questions:

1. *Does the stock market react to the signal sent by green bond issuance, and is this effect amplified for bonds that are listed on green exchanges and/or certified by third parties? Is the reaction stronger in countries with more pronounced information asymmetries?*

2. *Does issuers' environmental and/or financial performance improve following green bond issuance and thus validate the signal? Are the improvements in environmental and/or financial performance more pronounced for bonds that are listed on green exchanges and/or certified?*

3. *Is the stock market reaction to green bond announcement linked to post-issuance environmental performance, thus confirming an effective interpretation of signals by investors?*

1.2 Main findings

The findings of our thesis suggest that green exchange listings are indeed perceived as stronger signals of issuers' environmental commitment than third-party certification. We show that the stock market reaction is positive and significant for green bonds listed on dedicated green exchanges, while it is small and insignificant for certified green bonds. Moreover, we show that the stock market reaction to green-exchange-traded bonds is particularly high in countries with strong levels of asymmetric information between investors and firms, which we proxy using the Environmental Performance Index (EPI) score of the issuer's home country. This indicates that the information-aligning attributes of green exchanges are particularly valued in countries with high levels of asymmetric information.

Yet, our results do not provide sufficient evidence supporting the actual credibility associated with such signals. Firms are not found to exhibit significant improvements in environmental or financial performance after issuing a green bond – a finding that does not vary depending on the presence of green exchange listing or certification.

Lastly, we do not find significant evidence for a link between the stock market reaction to green bond announcements and issuers' subsequent changes in environmental performance.

This supports our previous (non-)finding, as it suggests that investors are not capable of identifying those issuers that will in fact prove their environmental integrity by substantially reducing their carbon footprint, for instance.

1.3 Structure of the thesis

The body of this thesis is structured as follows. Chapter 2 provides background insights on the green bond market and signaling theory. Chapter 3 summarizes the literature to date on the stock market reaction to green bond issuance, and on the relationship between green bond issuance and firms' environmental and financial performance. We describe the data used in Chapter 4, before presenting and discussing our empirical analysis in Chapter 5, detailing the methodology and results pertaining to our three respective research questions. Finally, we summarize the implications of our findings in Chapter 6.

2 Background

2.1 Development of the green bond market

The first green bonds were issued by supranational financial organizations, notably by the European Investment Bank in 2007 and the World Bank in 2008, before the first corporate green bonds were issued in Europe by Swedish property company Vasakrona and French utility company EDF in 2013 (Rosembuj and Bottio, 2016; Baker et al., 2018). While sovereigns and development banks represented 53% of green bond issuance in 2016, compared to 36% for financial and non-financial corporates, by 2021 the roles had reversed and corporates represented 54% of issuance compared to 38% for sovereign issuers (CBI, 2022).[1] Since 2016, the majority of green bond proceeds have been allocated to projects related to energy, buildings, and transport (CBI, 2022).

In Table 1, we present the evolution of European corporate green bonds since 2013.

Table 1: European corporate green bonds over time

This table shows the number of European corporate green bonds, as well as the total issuance amount (in $bn) on an annual basis. The sample consists of all green bonds issued by public European firms from 2013 to 2021. The data has been retrieved from Bloomberg's green bond database.

Year	# Bonds issued	Amount ($bn)
2013	2	2.29
2014	12	5.84
2015	17	6.88
2016	19	8.38
2017	36	14.55
2018	50	20.28
2019	99	34.94
2020	120	50.36
2021	237	82.78
Total	592	226.30

As shown, the European market for corporate green bonds has grown sharply in recent years. Since its emergence in 2013, the total issuance amount increased from a mere USD 2.3bn to USD 82.8bn in 2021. Europe now constitutes the center of the green bond

[1] According to CBI (2022), the remaining issuances are categorized as Asset-Backed Securities and Loans.

market, forming the largest source of green debt in 2020 (48%), followed by the U.S. (18%), Asia Pacific (18%), Latin America (3%), and Africa (0.4%) (CBI, 2020). This status quo is likely to persist since the European Commission expressed its dedication to "reorient capital flows towards sustainable investment" in its 2018 Action Plan (EU TEG on Sustainable Finance, 2019, p. 14). Moreover, the European Union (EU) plans to borrow 30% of the total EUR 225bn required for the Next Generation EU (NGEU) recovery plan through green bonds (CBI, 2020). The euro is the most popular currency for green bond issuance (48%), alongside the US dollar (28%) and the Chinese yuan (6%) (CBI, 2020).

Interestingly, the tremendous growth in the European green bond market has been driven by financials, including banking and real estate corporations. Table 2 shows an overview of European corporate green bonds by sectors, which are divided according to two-digit Global Industry Classification Standard (GICS) codes.

Table 2: European corporate green bond issuers by sector

This table shows the number of European corporate green bonds as well as the total issuance amount (in $bn) by sector. The sample consists of all green bonds issued by public European firms from 2013 to 2021. Sectors are divided according to Global Industry Classification Standard (GICS) codes. The data has been retrieved from Bloomberg's green bond database.

GICS sector	# Bonds issued	Amount ($bn)
Financials	381	127.91
Utilities	115	67.49
Consumer Discretionary	16	8.72
Materials	15	5.45
Energy	14	5.10
Industrials	26	5.05
Consumer Staples	16	2.72
Communications	6	2.68
Health Care	3	1.17
Total	592	226.30

As can be seen, financial corporations dominate the European green bond market with a total issuance amount of USD 127.9bn, making up roughly 57% of the overall market. Utility companies constitute the second largest group of issuers and account for 30% of the European green bond market.

Table 3 presents a breakdown of corporate green bond issuances by country.

Table 3: European corporate green bond issuers by country

This table shows the number of European corporate green bonds as well as the total issuance amount (in $bn) by country. The sample consists of all green bonds issued by European corporations from 2013 to 2021.

GICS sector	# Bonds issued	Amount ($bn)
France	90	58.8
Germany	83	30.7
Italy	35	20.7
Netherlands	27	19.7
Spain	35	19.0
Sweden	150	16.3
United Kingdom	19	10.4
Norway	47	8.5
Finland	22	7.4
Denmark	13	7.4
Austria	22	5.5
Portugal	7	5.3
Belgium	8	3.7
Ireland	4	3.6
Luxembourg	3	2.2
Rest of Europe	27	7.3
Total	592	226.3

As shown, the green bond market is especially large in France, Germany, and Italy. Together, the three countries account for nearly 50% of the total issuance amount in the European market. Other countries, such as Sweden and Norway, are found to issue large numbers of green bonds with relatively small issuance amounts.

In order to further increase the volume of capital flows into the green bond market, the green bond label must be established as credible and trustworthy. Notably, it needs to be demonstrated that the financial instrument is associated with positive environmental and/or financial outcomes for issuers.

2.2 Signals of green bond credibility

Since there is no universal green bond standard, investors are reliant on third-party certification and other credibility signals like green exchange listing to verify bond issuers' environmental credentials. Certification and green exchange listing reduce information

asymmetries by providing investors with transparent and comparable information on the type of projects funded with the bonds' proceeds.

2.2.1 Certification

The majority of green bonds issued to date have some sort of certification, also called "second party opinion" (SPO) or "external review". Certification confirms that the issued green bond is aligned with an industry standard, such as the Green Bond Principles (GBP), Climate Bonds Standard (CBS), or EU Green Bond Standard (EU-GBS), which prescribe requirements for project eligibility, Use of Proceeds (UoP), and reporting. Approximately 86% of global green bond issuance between 2018 and 2020 are estimated to have been certified, with CICERO, Sustainalytics, Vigeo Eiris, and ISS-oekom being the most popular non-financial rating agencies used (CBI, 2019b, 2020). Other players in the certification market include major audit firms, credit rating agencies, and other certification bodies, such as Deloitte, Moody's, and DNV-GL respectively (EU TEG on Sustainable Finance, 2019).

2.2.2 Green exchanges

The Sustainable Stock Exchanges (SSE) initiative was launched by various agencies of the United Nations (UN) in 2009, with the aim to explore how stock exchanges "can enhance performance on ESG issues and encourage sustainable investment" (Grabski et al., 2019, p. ii).[2] Since the Oslo Børs, Nasdaq Stockholm, and the London Stock Exchange (LSE) became the first financial exchanges to provide separate listing platforms for green bonds in 2015, the number of stock exchanges with a dedicated green or sustainable bond segment had grown to 26 by 2021 (CBI, 2022).[3] To qualify for such segments, issuers must meet the "green listing requirements" of the exchange, generally based on the GBP, as well as standard bond listing requirements for these exchanges (Erhart, 2018).

To list a bond on a conventional exchange, issuers typically must obtain regulatory permission to raise capital and must disclose detailed audited financial statements and other material information to the market (LSE, 2022). For a green bond listing on a

[2]The project was jointly launched by the United Nations Conference on Trade and Development (UNCTAD), United Nations Global Compact (UNGC), United Nations Environment Finance Initiative (UNEP FI) and the UN-led Principles for Responsible Investment (PRI).

[3]Appendix Table A.1 shows a list of all European exchanges with dedicated segments for ESG bonds.

dedicated green exchange, issuers must further "provide information about the intended and actual use of proceeds", which should "inform investors about how funds are being allocated to projects and, where possible, about the expected environmental, social and sustainability impacts" (LGX, 2022, para. 7). Given these strict requirements, we expect that bonds listed on such exchanges signal greater environmental integrity of issuers, or at least entail fewer greenwashing concerns than conventional green bonds (Kapraun et al., 2021). The stock market reaction could thus be influenced by the fact that a firm has the will and ability to list a bond on such an exchange, implying that it is already capable and prepared to comply with various legal requirements and regulatory standards. Hence, green exchange listings carry the potential to provide an effective signal of issuers' environmental and financial commitments to investors.

Moreover, proponents have argued that listing a green bond on a specialized green exchange allows issuers to access a wider investor base, boost firm visibility, and benefit from better feedback on asset valuation (Meng et al., 2017; Erhart, 2018). Green exchange listing may thus signal not only more financially stable issuers ex-ante, but also financial benefits ex-post.

Interestingly, green exchange listing has been undertaken mainly by larger issuers who can more easily meet exchanges' listing criteria: out of a sample of 747 green bonds issued between 2015 and 2017, 50% of the accumulated face value but only 30% of the bonds had been admitted to trading on European green exchanges (Erhart, 2018). In our European sample of green bonds issued between 2013 and 2021, 71% of the total face value, compared to 63% of the total number of bonds, are listed on a green exchange.

Figure 1 illustrates how certification and green exchange listings have become increasingly common practices in the European green bond market. As can be seen, certification and green exchanges started to gain considerable momentum in 2017. Green exchange listings in particular have experienced tremendous growth since 2019. By 2021, the share of bonds listed on such exchanges reached 68.4%, and for the first time surpassed the share of certified green bonds (63.3%). This development indicates that firms increasingly recognize the importance of green exchanges in enhancing the credibility and visibility of their green bond issuances.

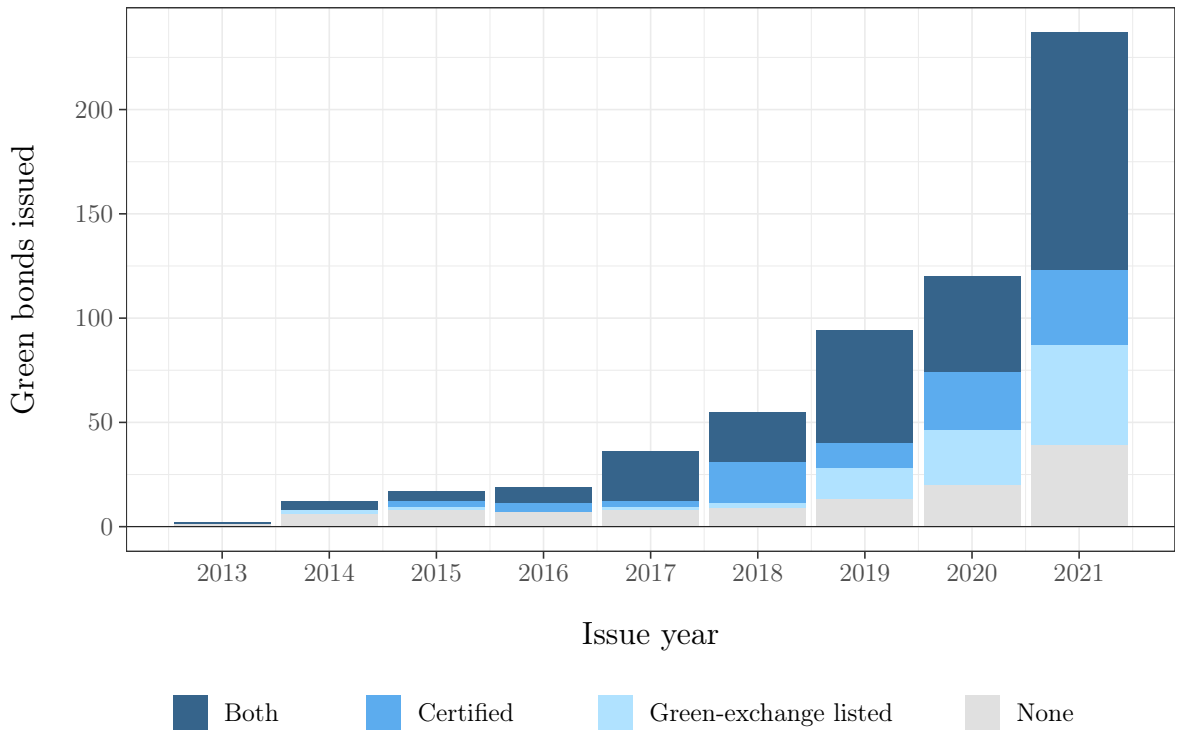

Figure 1: Evolution of certification and green exchange listing in Europe

2.3 Green bonds vs greenwashing

Even 15 years after the first green bond issuance, there is still no universal or legal definition of a green bond. According to the International Finance Corporation (IFC), green bonds are much the same as standard fixed income instruments except that their proceeds are "dedicated to climate or environmental projects" (Rosembuj and Bottio, 2016). In most cases, they are backed by the issuer's balance sheet and are thus assigned the same credit rating as the issuer's other liabilities (Antoniuk and Leirvik, 2021).

While Inderst and Stewart (2018) affirm that it would be too difficult to implement a global green bond standard, Hyun et al. (2020) and Dembele et al. (2021) argue that the lack of a universally accepted definition or standard for green bonds presents a major hindrance to the further development of the green bond market and to the most efficient allocation of funds to assets and projects with positive environmental impacts. Identifying projects with credible environmental or climate-related benefits can be costly and difficult for investors and issuers alike without a universal standard (Ehlers and Packer, 2017). Issuers and investors further face reputational risk if the projects or bonds invested in turn out not to have the environmental benefits originally claimed (EU TEG

on Sustainable Finance, 2019; Bancel and Glavas, 2018). Accusations of "greenwashing", defined as the practice of making unsubstantiated claims about an organization or project's environmental credentials, can be costly for issuers, with consequences including widening credit default swap spreads, a fall in stock price, or a decline in revenues due to contract cancellations or customer boycotts (Henisz and McGlinch, 2019). Therefore, Hyun et al. (2020) argue that information asymmetry on the quality of green projects pushes investors towards a limited universe of green bonds with reliable green information (such as those certified or listed on green exchanges), which increases demand and depresses yields specifically for this subgroup. Improved transparency is thus key to increasing the flow of investment to green projects by limiting search costs for investors and making clear the tangible impacts of sustainable investment (European Commission, 2021a; Bancel and Glavas, 2018).

In the absence of market regulation, three main voluntary standards have become vital to establishing the credibility of green bonds and avoiding accusations of greenwashing. Until recently, the two main standards consisted of the Climate Bonds Standard (CBS), launched by the non-profit organization Climate Bonds Initiative (CBI) in 2010, and the Green Bond Principles (GBP), published by a group of 13 investment banks coordinated by the International Capital Markets Association (ICMA) in 2014 (CBI, 2019a; ICMA, 2021). Currently being examined by the European Parliament, the EU Green Bond Standard (EU-GBS) is anticipated to become dominant in the European market and beyond (European Commission, 2021b).

These three green bond standards share many similarities in their specifications for proceeds to be dedicated to eligible green projects, certification by an approved verifier, and publication of update reports on the bond's impact and UoP. Nevertheless, while the GBP outline general recommendations, the CBS provides sector-specific criteria to evaluate the suitability of an asset or project for green bond issuance (CBI, 2019a; ICMA, 2021).

Ehlers and Packer (2017) put forward two main criticisms of existing standards. Firstly, none of the standards require yearly verification by an external reviewer, which they argue is necessary to maintain confidence in the green label. Even if a green label that has been certified at issuance or immediately afterward signals good intentions, the

researchers highlight that "the information value of those labels can depreciate over time as technology evolves or policies of the issuer change" (Ehlers and Packer, 2017, p. 101). Secondly, they criticize the "binary nature" of current standards, with bonds being classed as either green or brown, which does not allow investors to distinguish between different levels of environmental impact (Ehlers and Packer, 2017, p. 94). For example, climate research institute and second-opinion provider CICERO allocates three "shades of green" to determine the extent of a green bond's alignment with a low-carbon and climate-resilient future, ranging between "light green" for only short-term improvements and "dark green" for long-term impact (CICERO, 2022).

Several jurisdictions have established their own national taxonomies for green bond eligibility, including China and India; however, researchers have highlighted that "domestic guidelines run the risk of limiting the value of any particular green certification scheme to the domestic investor base" (Ehlers and Packer, 2017, p. 93). Conversely, the European Green Bond label will be attainable for all issuers within or outside the EU that meet the EU-GBS's requirements (European Commission, 2021b).

2.4 Signaling theory vs greenwashing

Signaling theory is a key concept for understanding the information asymmetries between bond issuers and investors. Issuers hold information that investors do not, and so investors depend on signals to deduce positive or negative attributes about a firm. Stiglitz (2000) has highlighted that signals about intent and quality are particularly sought after: for example, investors want to know whether an issuer intends to implement a sustainable strategy and whether it will be effective. The "green" label on green bonds is thus a critical differentiating signal that a firm plans to invest in a more environmentally friendly strategy. The label makes the bond's intended UoP more noticeable, meaning its non-pecuniary attributes are more distinct for investors and issuers can consequently benefit from higher demand and potentially a lower cost of capital (European Commission, 2021a).

Connelly et al. (2011) define the two main characteristics of an effective signal as its observability, i.e., how noticeable it is, and its cost, which should put off dishonest signalers. Kirmani and Rao (2000) state that the signal cost should be sufficiently high to put off low-quality firms from signaling, but low enough to make signaling attractive for high-quality

firms. In our case, the signal is the issuance of a green bond: low-quality firms would attempt to greenwash, while high-quality firms would have truly green intentions. Hyun et al. (2020) argue that the pre- and post-issuance costs of the green bond requirements in terms of reporting and management of proceeds can put off small and medium-sized issuers, although they concede that certification costs can be partly compensated with a lower yield due to higher demand for higher quality certified green bonds. Baker et al. (2018) and Ehlers and Packer (2017) also argue that the cost of certification is minimal for larger bonds compared to the total issuance value, the cost of a normal credit rating, and an expected lower yield. Nevertheless, there are costs associated with not achieving the green bond's objectives, affecting the reputation of both the issuer and the green bond market in general. Lack of improved environmental performance following green bond issuance will inevitably undermine the signal's credibility, unless investors differentiate between the environmental improvements associated with the bond's project and the firm as a whole. The issuer may fulfill the bond's KPIs (i.e., use the bond's proceeds as intended), but not achieve large-scale environmental improvements overall, especially when the bond funds small-scale green projects. Hence, the credibility of a green bond would ideally be assessed by analyzing the environmental impact of the project(s) for which the green bond is issued. Since project-specific data for green bonds typically is not available, such an analysis is unfeasible. At present, green bond credibility can therefore be more easily evaluated based on a signaling perspective, which focuses on issuers' overall environmental performance.

Provided that green bond issuance is observable and costly, and thus an effective signal which allows the identification of high-quality firms truly dedicated to corporate sustainability, investors should react to green bond issuance on the stock market. If, however, the green label cannot be trusted as a credible signal of an issuer's intentions to truly improve their environmental performance, investors may react negatively or not at all on the stock market. In the case that the green label alone is not a credible signal due to the lack of standardization around the definition of a green bond, certification or green exchange listing could allow the emergence of a separating equilibrium between those issuers truly dedicated to sustainability and those merely attempting to create noisy market signals or "greenwashing". Applying signaling theory to the green bond context, firms truly dedicated to eco-friendly practices (high-quality firms) can differentiate

themselves as greener by self-selecting into certification or green exchange listing, which demand a higher cost and increased effort compared to standard green bond issuance. Indeed, while green exchange listings and certification entail similar costs for issuers (e.g., due to reporting requirements), green exchanges also provide greater visibility for listed bonds, allowing environmentally-aware investors to find green bonds more easily (Meng et al., 2017; Erhart, 2018; Kapraun et al., 2021). Kirmani and Rao (2000) highlight that signaling may be especially effective in relatively new markets where participants lack relevant knowledge, which could be applied to the green bond market as a relatively new financial instrument. However, they also highlight that signals may not be seen as credible in noisy signaling channels, meaning that signal receivers fail to recognize the cost or credibility of the signal.

The green bond label represents a signal that issuers send to investors that the firm intends to improve its corporate sustainability. Investigating the stock market reaction and the issuer's environmental and financial performance following green bond issuance thus allows us to understand: a) whether this signal is positively viewed by the market, and b) whether the market's reaction is justified considering the subsequent changes in the issuer's environmental and financial performance. Our line of research can also be linked to the financial theory on agency issues. For example, Bancel and Glavas (2018) propose a theoretical framework distinguishing between green bond issuers with agency issues, who prioritize corporate social responsibility (CSR) activities over shareholder interests, and those with a stakeholder motive to enhance firm value. However, while Bancel and Glavas focus on measuring proxies for agency issues and information asymmetries between green bond issuers and shareholders, we are interested in using this theory in the context of signaling credibility in the stock market in general.

3 Literature review

The environmental and social impact of fixed income investment has been the focus of a much smaller body of research compared to equity investment (Inderst and Stewart, 2018). Despite the fact that global bond markets are considerably larger than global equity markets, with the former valued at USD 123.5trn in 2020 compared to USD 105.8trn for the latter (Klochin et al., 2021), academics and industry practitioners first concentrated on Environmental, Social, and Governance (ESG) considerations in equity investment, since bondholders do not have the same voting rights and do not share in the "upside" of firms as equity investors do (Schoenmaker and Schramade, 2019).

Initial research on the applications of ESG in fixed income investment focused on the links between CSR and various measures of financial performance, such as the relationship between issuers' ESG ratings and credit ratings (Henisz and McGlinch, 2019; Hsu and Chen, 2015) or general bond performance (Desclée et al., 2016). For instance, Hsu and Chen (2015) find that firms with high ESG ratings usually have better credit ratings.

The idea of a "green bond premium" or "greenium", defined as the difference in yield between green bonds and equivalent conventional bonds, has received considerable attention from academics and practitioners alike. A negative premium would indicate that investors are willing to accept lower returns due to non-pecuniary preferences for the green label, allowing issuers to benefit from lower financing costs. Despite multiple studies, results remain mixed, with some researchers finding evidence of a premium (Ehlers and Packer, 2017; Baker et al., 2018; Zerbib, 2019; Bachelet et al., 2019) and others no premium (Fossum and Teigland, 2020). Some studies seem to reach no definite conclusion (Harrison, 2017) or only find a premium for green bonds with certain characteristics (Hyun et al., 2020; Kapraun et al., 2021). While early studies looked at conventional bond attributes such as sector, credit rating, or issue amount to try to explain variations in the premium size or significance, two of the most convincing factors proposed to date have been high demand from investors motivated by sustainability concerns (Baker et al., 2018; Zerbib, 2019), and the "green-credibility" or "greenness" of the bond (Hyun et al., 2020; Kapraun et al., 2021). The studies by Hyun et al. (2020) and Kapraun et al. (2021) find no significant evidence of a premium between green and conventional bonds, but they do find a significant premium

of 4-6 basis points (bps) for certified green bonds. Indeed, this premium increases to 15-26 bps for green bonds certified by CBI-approved verifiers (Baker et al., 2018; Hyun et al., 2020). Kapraun et al. (2021) further find a significant premium for green bonds which are traded on a green bond exchange with strict listing requirements (4 bps) and from issuers with high environmental ratings (7-9 bps). One explanation proposed is that indicators signaling the "greenness" of a green bond (such as green exchange listing or certification) can reduce investors' information costs, incurred while gathering the information needed to make an investment. Credible green bonds therefore attract greater demand from environmentally-motivated investors, which consequently lowers issuers' financing costs (Baker et al., 2018; Hyun et al., 2020).

We are thus interested in investigating whether these indicators of "greenness", that is green exchange listing and certification, produce a comparable reaction on the stock market to that seen on the bond market (the "greenium"). Furthermore, we aim to investigate whether investor reactions to green bond issuance are justified considering subsequent improvements in issuers' environmental and/or financial performance.

3.1 Stock market reaction to green bond issuance

In previous scholarly work, researchers have investigated the stock market's reaction to the announcement of green bonds, notably whether investors view green bond issuance as a positive signal of environmental or financial outcomes. A firm's equity value reflects the market's assessment of current firm value and expected future performance, compared to other assets of comparable risk. According to the semi-strong form of the Efficient Market Hypothesis (EMH), new public information is continuously assessed, valued, and incorporated into the stock price. Therefore, a change in the stock price suggests that an event (such as green bond issuance) changes the market's assessment of the firm's future cash flows (Klassen and McLaughlin, 1996; Parlour and Rajan, 2020). Baulkaran (2019) theorizes that the stock market will react to green bond issuance if it is seen as value-enhancing, for example if green bonds allow firms to cut costs and increase efficiency while reducing their environmental impact, but not if green bond issuance is merely used to diversify a firm's investor base.

Similarly to findings regarding the green bond premium, results on the stock market

reaction to green bond issuance have been mixed and certain bond characteristics remain important differentiators. Baulkaran (2019) finds a positive significant cumulative abnormal return (CAR) of 1.48% for the 21-day window around the announcement of green bond issuance. Flammer (2021), Pedersen and Thun (2019), and Tang and Zhang (2020) find that the stock market reaction is only significant for first-time green bond issuances, but not for seasoned issuances. They argue that an issuer's debut green bond attracts market attention for its first demonstration of commitment to improving its sustainability performance, while subsequent issuances show a renewed commitment but do not communicate as much new information as the first issuance. Flammer (2021) and Pedersen and Thun (2019) also find a large and significant reaction to the issuance of green bonds that are certified by a third party, but no significant reaction to the issuance of non-certified bonds. Baulkaran (2019), on the other hand, does not find any significant impact of certification on the stock market reaction to green bond announcements.

In his seminal article, Akerlof (1970) proposed a theoretical perspective on how buyers attempt to distinguish between good quality and bad quality products ("lemons") due to information asymmetry with sellers. He highlights that a "certifying establishment", such as guarantees or brand names, can help to reassure buyers that they are not paying for a "lemon". However, such certification must be credible, otherwise a buyer will view the whole market as a market for "lemons". Indeed, among the conflicting findings on the green bond premium and the stock market reaction to green bond issuance, the importance of the credibility of the green label stands out. For example, while Baker et al. (2018) find that municipal green bonds are priced at a premium of 5-7 bps compared to ordinary bonds, they find that the premium doubles or triples for externally verified green bonds. Hyun et al. (2020) and Kapraun et al. (2021) find that only credible corporate green bonds, certified by a third party or listed on the dedicated green bond segment benefit from a premium. A premium for certified green bonds suggests that investors are willing to pay for environmental sustainability, lower exposure to stakeholder risk and for the greater transparency, reduced asymmetric information, and guarantees against greenwashing conferred by certification (Bachelet et al., 2019), which reassures them that they are not investing in a "lemon". Similarly, Flammer (2021) and Pedersen and Thun (2019) find that stock market investors respond positively to certified green bond issuances, but did not investigate the effect of green exchange listings on the stock market

reaction. Therefore, most research on credible green bond signals to date has focused on certification but has not considered other possible signals of green bond credibility.

If exchange listing and certification are indeed credible signals and reduce information asymmetry between investors and issuers, a stronger reaction by the stock market to the announcement of green-exchange-listed and certified bonds would be justifiable. Given the strict listing requirements and heightened visibility conferred by dedicated green exchanges, we would expect the stock market to show a greater reaction to the announcement of green-exchange-listed bonds than that shown towards the issuance of non-listed green bonds. First-time issuances are expected to result in a greater stock market reaction than subsequent issuances due to the new information on the firm's commitment to the environment, reducing the sustainability-related information asymmetry between investors and issuers.

Overall, we formulate the following hypotheses:

Hypothesis 1. *Green bond announcements have a positive effect on issuers' stock prices.*

Hypothesis 1.1. *Green exchange listing has a positive impact on the relationship between green bond announcements and issuers' stock prices.*

Hypothesis 1.2. *Third-party certification has a positive impact on the relationship between green bond announcements and issuers' stock prices.*

Hypothesis 1.3. *First-time green bond issuances have a greater positive effect on issuers' stock prices than seasoned issuances.*

As discussed in section 2.2, green bonds help to reduce the level of asymmetric information between issuers and investors. The same applies to green exchange listing and certification, which aim to mitigate information asymmetries by virtue, inter alia, of the associated reporting requirements. Therefore, it can be argued that green bonds are an especially valuable signaling tool for firms operating in contexts with particularly high levels of asymmetric information.

An important determinant of firms' informational asymmetry with investors is the country in which the firm is domiciled (Reddy and Fabian, 2020). Interestingly, Li and Yang (2021) find that greater public attention to environmental issues reduces asymmetric

information between firms and investors, especially for firms that have high environmental ratings. They argue that higher "green taste" induces investors to learn more about firms' environmental credentials. Hence, higher levels of asymmetric information between green bond issuers and investors are more likely to be found in countries with low public attention to the environment, compared to countries with stronger environmental attention. We thus expect the information-aligning benefits of green bonds to be particularly valuable to investors in countries with lower environmental attention.

We will therefore test the following hypothesis:

Hypothesis 1.4. *The stock market reaction to green bond announcements is stronger in countries with low levels of public environmental attention.*

3.2 Impact of green bonds on environmental performance

Moreover, there has been limited research conducted on the relationship between green bond issuance and the environmental performance of issuers. Environmental performance refers to a firm's impact on the environment, in terms of the resources it uses, the waste it generates, and its carbon footprint. Since environmental performance is a nebulous concept, researchers have used various proxies to measure it, including a firm's ESG rating or specifically the rating's environmental pillar, absolute emissions, or carbon intensity (e.g., of revenues or assets). For example, Flammer (2021) finds that green bond issuers experience an upgrade in their environmental rating and a decrease in CO_2 emissions within two years after issuance. Yeow and Ng (2021) find that only issuers of certified green bonds reduce their greenhouse gas (GHG) emissions within a year of issuance. This finding is coherent since issuers of certified green bonds can be more credibly expected to reduce their emissions and follow through on their proposed green investments due to the pre- and post-issuance requirements associated with receiving certification.

Since green-exchange-listed green bonds have to fulfill similar requirements to those for certified green bonds, we would also expect the environmental performance of issuers to show a more marked improvement than those of non-green-exchange-listed bonds. The costs, both financial and in terms of managerial effort, incurred to list and certify green

bonds send a signal that issuers of listed and certified green bonds are more dedicated to truly improving their environmental performance. While the aforementioned researchers have looked at the effect of certification on green bond issuers' environmental performance, we build on their research by investigating the effect of green exchange listing on issuers' subsequent environmental performance (as measured in terms of environmental scores and GHG emissions).

As discussed in section 3.1, the level of political and societal pressure to transition towards green corporate practices varies from country to country. Yet, there have been no studies to our knowledge investigating the relationship between green bond issuers' environmental performance and the environmental context of the issuer's country of domicile. Ortas et al. (2015) find that French, Spanish and Japanese firms have differing social, corporate and environmental practices and Ferrat (2021) shows that firms' environmental and financial performance is affected by regional environmental regulations and investor awareness. Neither, however, analyze green bonds in particular. Bond issuers in countries with a strong environmental focus are likely to already be driven toward green practices by strict national environmental policies, such as carbon taxes and environmental protection laws. Firms domiciled in countries with weaker green regulation are likely faced with less pressure to turn green. Hence, we expect the added environmental commitment associated with green bond issuance – and the resulting environmental improvements – to be greater in countries with less developed environmental standards.

Overall, we examine the following hypotheses:

Hypothesis 2. *Firms' environmental performance significantly improves following the issuance of green bonds.*

Hypothesis 2.1. *Green exchange listing has a positive influence on the relationship between green bond issuance and issuers' environmental performance.*

Hypothesis 2.2. *Third-party certification has a positive influence on the relationship between green bond issuance and issuers' environmental performance.*

Hypothesis 2.3. *The effect of green bond issuance on environmental performance is greater for firms domiciled in countries with lower levels of public environmental pressure.*

3.3 Impact of green bonds on financial performance

Multiple studies have established a link between firms' CSR efforts and credit risk. For example, Hsu and Chen (2015) show that firms with good CSR performance, as measured by social performance ratings, benefited from reduced credit and bankruptcy risk, as well as tightened bond spreads between 1991 and 2012. Fiandrino et al. (2019) and Bancel and Glavas (2018) equally find a two-way positive relationship between CSR and corporate financial performance, with Bancel and Glavas (2018) affirming that green bond issuers that "do well" financially consequently have the ability to "do good". While Klassen and McLaughlin (1996) highlight that the direction of causality between higher profits allowing improved future social responsibility or strong CSR performance resulting in higher future profits, is not clear-cut, various researchers argue that a causal relationship between ESG performance and credit risk is plausible. Negative environmental management events, such as oil spills, can incur high costs, including clean-up, legal or regulatory liabilities, or lost revenues following damage to public and consumer trust (Henisz and McGlinch, 2019; Klassen and McLaughlin, 1996). On the other hand, Ehlers and Packer (2017) find that green bonds are more exposed to climate-related financial risks than conventional corporate bonds. They find that, among corporate debt rated by Moody's for exposure to environmental risks at a sectoral level, 13% was issued by firms in industries with moderate levels of environmental credit risk and 3% in industries with elevated risk, compared to 22% and 14% for green bond issuers respectively.

Klassen and McLaughlin (1996) theorize that environmental performance affects financial performance through two main channels: (1) a market (revenue) channel whereby more environmentally-oriented companies are able to attract more customers and displace competitors; and (2) a cost channel whereby stronger environmental performance allows to avoid costs related to environmental crises and liabilities and to minimize costs from waste and inefficient processes. Flammer (2018) finds that firm profitability, as measured by return on assets (ROA), increases following green bond issuance. Yeow and Ng (2021), on the other hand, find insufficient evidence to conclude that green bond issuers outperform conventional bond issuers in terms of ROA or asset turnover (AT).

Bancel and Glavas (2018) propose two frameworks to understand why firms issue green bonds despite their greater costs and reputational risks (if accused of greenwashing)

compared to conventional bond issuance. On the one hand, an agency motive would mean that green bond issuance is primarily a CSR activity that is undertaken in the interest of the CEO to be viewed as a good corporate citizen, rather than in the interests of shareholders. On the other hand, under a stakeholder motive, CSR activities would be seen as value-enhancing (leading to a higher credit rating or lower cost of capital, for example). Under this scenario, green bond issuance sends a positive signal to investors and stakeholders that the firm will undertake future CSR practices that will lead to superior environmental and financial performance.

If green bonds allow issuers to enter new markets (e.g., for more sustainable or green products), cut regulatory and operational costs, and attract new customers and investors, financial performance should improve in the wake of green bond issuance. Green exchange listing and certification should have an even more pronounced effect on green bond issuers' financial performance, as the proposed green projects should more credibly lead to improved environmental performance and, in turn, generate even greater efficiency gains and cost reductions.

Furthermore, we hypothesized that the effect of green bond issuance on firms' environmental performance is greater in countries with low levels of political and societal pressure to transition towards a sustainable economy. If improved green practices indeed boost financial performance through the channels described above, then issuers in countries with lower environmental standards might equally have more room to improve their financial performance. There have been no studies to our knowledge investigating the relationship between the financial performance of green bond issuers and the environmental context of the latter's country of domicile. While Friede et al. (2015) and Ferrat (2021) find regional differences for the relationship between firms' ESG practices and corporate financial performance, they do not study green bonds.

We investigate how firms' financial performance evolves subsequent to the issuance of green bonds by testing the following hypotheses:

Hypothesis 3. *Firms' financial performance significantly improves following the issuance of green bonds.*

Hypothesis 3.1. *Green exchange listing has a positive influence on the relationship*

between green bond issuance and issuers' financial performance.

Hypothesis 3.2. *Third-party certification has a positive influence on the relationship between green bond issuance and issuers' financial performance.*

Hypothesis 3.3. *The effect of green bond issuance on financial performance is greater for firms domiciled in countries with lower levels of public environmental pressure.*

3.4 Stock market reaction and environmental performance

While there have been several studies on the stock market reaction to green bond issuance and on issuers' subsequent environmental performance respectively, no studies to our knowledge have looked at the correlation between the two phenomena. Yet, it is important to establish whether investors correctly identify signals indicating that issuers are truly going to improve their environmental performance, as we discuss in section 2.4. Does the stock market react strongest to green bonds issued by firms who go on to markedly improve their environmental performance, suggesting that investors recognize and correctly interpret signals regarding issuers' environmental performance? Or does the stock market reaction to green bond issuance bear no correlation to subsequent environmental performance by issuers? Our line of inquiry builds on previous research undertaken on the stock market reaction to environmental events and performance (Antoniuk and Leirvik, 2021; Flammer, 2021; Klassen and McLaughlin, 1996).

If environmental performance improves the most for firms whose green bond issuance prompted a positive stock market reaction, this would suggest that investors effectively identify companies that deliver tangible environmental improvements following green bond issuances. It would further suggest that the informational quality of green bond issuance is high, allowing investors to reduce their information asymmetries with issuers and to correctly identify high-quality firms (and avoid "lemons"). Conversely, no significant correlation between the stock market reaction to green bond issuance and subsequent environmental performance would suggest that stock market investors are not effective at identifying credible signals of issuers' environmental commitment.

In line with the signaling argument, our final hypothesis is as follows:

Hypothesis 4. *Post-issuance environmental performance is positively correlated with the size of the stock market reaction to green bond announcements.*

4 Data

This section aims to explain the selection of our green bond sample and describes the key data used to conduct our analysis, including bond-level information and indicators of corporate environmental and financial performance. Lastly, we present statistics describing our green bond sample in detail.

4.1 Sample selection

The initial sample of this empirical study consists of 592 green bonds issued by public European firms between 2013 and 2021. This corresponds to 203 unique green bond issuers in our sample.

We look exclusively at European issuers of green bonds. The vast majority of previous research has analyzed samples of all green bonds issued worldwide since 2007 (Fatica and Panzica, 2020; Kapraun et al., 2021; Zerbib, 2019; Flammer, 2021; Antoniuk and Leirvik, 2021; Yeow and Ng, 2021; Baulkaran, 2019). Nevertheless, the perception of green bond issuance by investors and its impact on financial and environmental performance in Europe merits separate investigation due to the specific context of a region that is a pioneer in terms of environmental regulation and sustainable finance initiatives. European companies are already required and expected to follow strict environmental standards which could affect the strength of the signal of environmental commitment sent by green bond issuance. A 2019 survey of 1,000 issuers and investors worldwide by the bank HSBC revealed that European market actors feel the highest societal and regulatory pressure to focus on the environment and society (63% of European respondents vs 48% on average globally) (HSBC, 2019). Many researchers include country fixed effects in their regressions in order to differentiate between the different social and regulatory attitudes towards the environment across regions and how they might affect different reactions to green bond issuance (Fiandrino et al., 2019; Pedersen and Thun, 2019; Flammer, 2021; Kapraun et al., 2021). However, limiting our analysis to Europe allows us to better evaluate the effects of green exchanges and certification on green bond issuance within a region that is already a world leader in terms of environmental regulation and green investment (CBI, 2020).

We restrict the sample to green bonds issued by public firms, as our analysis is based on

detailed stock market and accounting data, which typically are not available for private firms. Moreover, we exclude issuers classified under "Government" from our sample, including development banks and supranational entities, which are not "corporations" in a traditional sense.

4.2 Green bond data

To build a database of European corporate green bonds, we first retrieve all corporate bonds from the Bloomberg Terminal that are issued by European public firms and characterized as green bonds. Bloomberg's fixed income database provides a detailed overview of bond characteristics, as well as relevant information on the bond issuer. Bloomberg labels bonds as green bonds when an issuer "a) self-labels its bond as 'green', or b) identifies it as an environmental sustainability-oriented bond issue with clear additional statements about the commitment to deploy funds towards projects and activities in the Green Bond Principles use of proceeds categories" (The Green Bond Principles, 2017, p. 5). Due to Bloomberg's extensive coverage, we expect that the resulting database is close to exhaustive.

We obtain information on the exchange listing of green bonds. As discussed, several European stock exchanges have established dedicated segments for green bonds. Most of these exchanges provide continuously updated lists of all bonds included in their specialized green bond segments, which we use to identify green-exchange-listed bonds in our sample.[4] The only exchange that does not appear to publish such a list is the Vienna Stock Exchange. However, according to data by CBI, this exchange accounts for only 0.1% of green-exchange-listed bonds (CBI, 2018). Hence, we expect our data on green exchanges to be close to complete. Looking at the combined data, we find that 63.3% of the green bonds in our sample are listed on a green exchange.

Moreover, information on green bond certification is retrieved from the CBI and ICMA. The CBI provides a database of all bonds that have been certified by a CBI-approved verification provider. To extend our definition of certification, we use the ICMA database, which includes all green bonds certified by accredited certification providers, such as

[4]For example, the LGX provides a list of all bonds listed on their dedicated green bond segment: https://www.bourse.lu/lgx-displayed-international-bonds?bonds=green

CICERO and Sustainalytics (ICMA, 2022). Combining these two databases, we find that 65.2% of the green bonds in our sample are certified.

4.3 Firm-level data

4.3.1 Accounting data

All accounting data are obtained from the Refinitiv Eikon database (henceforth "Eikon"). Eikon is a financial markets database and contains, inter alia, comprehensive historical financial data, making it a useful resource for performing economic regressions. The main accounting variables obtained and constructed from Eikon's database are as follows. Firm size represents the natural logarithm of the firm's total assets (in USD). Return on assets (ROA) is the ratio of firms' operating income before taxes to total assets. Asset turnover (AT) is the ratio of net sales to average total assets. Tobin's Q equals the company's market value divided by its assets' replacement costs. Leverage is the ratio of total debt to the value of total assets. To reduce the effect of extreme outliers, we winsorize all accounting ratios at the 1^{st} and 99^{th} percentiles.

4.3.2 Stock market data

We use the Compustat Global database to collect daily stock prices for all green bond issuers in our sample, as well as daily market returns. Compustat Global comprises financial and market data on publicly traded firms, representing more than 90% of the global market capitalization, with coverage on over 96% of market capitalization in Europe (WRDS, 2014).

4.3.3 ESG data

All ESG data are retrieved from Eikon. The database provides information that is collected by ESG specialists based on publicly accessible sources such as corporate websites, annual reports, and CSR reports. Based on this information, companies are rated along three pillars: environmental, social, and governance. For our analysis, the main pillar of interest is the environmental (E) pillar, which we will discuss further in section 5.2. Moreover, we retrieve GHG emissions data from Eikon. As ESG data are available for only a limited

number of public firms, some bond issuers were excluded from the analysis due to missing information.

4.4 Summary statistics

In this section, we present an overview of the European market for green bonds. This includes summaries of the data at the green bond level and bond issuer level.

4.4.1 Summary statistics at the green bond level

In Table 4, we present descriptive statistics for the 592 European corporate green bonds in our sample.

Table 4: Descriptive statistics at the bond level

This table presents summary statistics for all European corporate green bonds. *#Green bonds* refers to the number of green bonds in our sample. *#Green bond issuing-days* refers to the number of distinct days on which a company issues one or multiple green bonds; *#Green bond issuing-years* are the distinct years in which a company issues one or multiple green bonds; *#Green bond issuing-firms* refers to the number of European firms which have issued green bonds. *Green-exchange-listed* is a dummy variable that equals one for green bonds listed on dedicated green exchanges. *Certified* is a dummy variable that equals one if the green bond has obtained third-party certification. *Maturity* refers to the maturity (in years) of the green bond. *Coupon* refers to the coupon rate for (fixed-rate) green bonds. The table provides means and the corresponding standard deviations (in parentheses) for each characteristic.

	Green bond sample
# Green bonds	592
# Green bond issuing-days	502
# Green bond issuing-years	339
# Green bond issuing-firms	203
Amount issued (in $mil)	150.71 (85.47)
Green-exchange-listed (0/1)	0.63 (0.48)
Certified (0/1)	0.65 (0.48)
Maturity (in years)	21.26 (109.82)
Coupon	0.014 (0.011)

As some firms issue multiple green bonds on a given day, our sample of 592 green bonds corresponds to 502 distinct issuing-days. Further, the sample includes 339 distinct green bond issuing-years and 203 distinct issuers. European green bond issuances are fairly large with an average issue amount of approximately USD 150.7m. Roughly 65% of green bonds have obtained a third-party certification, and about 63% are listed on a green exchange.

On average, European green bonds mature after approximately 21.3 years. Fixed-rate green bonds have an average coupon of 1.4%.

4.4.2 Summary statistics at the issuer level

In Table 5, we provide summary statistics for the firm-specific characteristics described in section 4.3.

Table 5: Descriptive statistics at the issuer level

This table presents summary statistics for green bond issuers (column (1)) and conventional bond issuers (column (2)). *Assets* refers to the total value of an issuer's assets (in $bn). *Leverage* is the ratio of total debt to the value of total assets. *ROA* stands for Return on Assets and is calculated as the ratio of operating income before taxes to total assets. *AT* stands for Asset Turnover and is the ratio of net sales to average total assets. *Tobin's Q* equals the firm's market value divided by its asset's replacement costs. *Environmental score* is the environmental pillar score provided by Refinitiv. The conventional bond issuers in column (2) are firms operating in the same country, GICS sector, and year as the green bond issuer. The table reports sample means and the corresponding standard deviations (in parentheses) for each characteristic. Column (3) reports the p-value of the difference-in-means T-test.

	N	Green bond issuers	Conventional bond issuers in same country, sector, and year	p-value (diff. in means)
		(1)	(2)	(3)
Assets ($bn)	110	404.46	117.99	0.004***
		(698.25)	(20.01)	
Leverage	110	1.34	1.25	0.716
		(0.94)	(1.66)	
ROA	110	0.04	0.03	0.356
		(0.05)	(0.04)	
AT	110	0.32	0.40	0.329
		(0.44)	(0.49)	
Tobin's Q	110	1.23	1.25	0.870
		(0.59)	(0.68)	
Environmental score	110	74.49	57.33	<0.001***
		(19.73)	(18.88)	

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

The summary statistics in the table are recorded in the year preceding the bond issuance. Column (1) provides an overview of firm-level characteristics of European green bond issuers. In column (2), we include a comparison with other (conventional) bond issuers. To support the relevance of the comparison, we only consider bond issuers in the same

country, the same GICS, and the same year as the green bond issuers. On average, European green bond issuers are larger in terms of assets than conventional bond-issuing firms. Meanwhile, they are similar in capital structure (leverage), profitability levels (ROA), efficiency rates (AT), and firm value (Tobin's Q). Further, green bond issuers have substantially higher environmental scores.

5 Empirical analysis

In this section, we first describe the methodology of the event study. We then present and discuss our results to answer the research question on how investors react to the announcement of green bond issuances, and whether signals of green bond credibility affect this reaction. Moreover, we examine whether the stock market reaction depends on the level of public environmental attention in the issuer's home country. Next, we describe our difference-in-differences (DiD) regression model for investigating issuers' environmental and financial performance, before presenting and discussing the corresponding regression results. Lastly, we present the regression model used to test whether there is a significant relationship between the stock market reaction and post-issuance environmental performance, and discuss its results.

5.1 Event study

In this section, we begin by describing the event study methodology, before presenting the corresponding results.

5.1.1 Methodology

The event study methodology analyzes whether there is a significant reaction in financial markets around the public announcement of an event. The aim of this particular event study is to investigate how stock markets react to the announcement of green bond issuances by public European companies. For this analysis, we restrict the sample to bonds for which the announcement date is known, and with non-missing information on the returns during the time windows under investigation. Out of the 592 European green bonds, a total of 383 have this information.

5.1.1.1 Event windows

We retrieve the announcement date from the Bloomberg Terminal, which is the first day on which a firm announced the issuance of a green bond. Thus, the announcement date captures the day when the news about green bond issuance is revealed to the market. In contrast, no new information is provided to the market on the actual issue date.

Accordingly, we set the bond's announcement date as the event date ($t = 0$) in our event study. As Flammer (2021) points out, it is possible that part of the information is revealed to investors prior to the issuance announcement. We therefore include the five trading days preceding the announcement. Moreover, in line with MacKinlay (1997), we consider the possibility of a staggered stock market reaction by including the five trading days following the announcement. Thus, our baseline event window is [-5, 5]. To enhance the robustness of our results, we add three alternative event windows: [-10, -6], [-1, 1], and [6, 10].

5.1.1.2 Computing abnormal returns

For each firm i, we calculate the abnormal returns based on the market-adjusted model, which has been used in multiple event studies on the stock market reaction to green bond issuance (e.g., Antoniuk and Leirvik, 2021; Aswani, 2021). In this model, the expected return equals the market return for the same period, and is based on the assumption that, on average, all stocks provide the same rate of return (Ritter et al., 1991; Bruner, 1999). Thus, expected returns are determined as follows:

$$E\left(R_{i,t}\right) = R_{m,t}$$

where $E\left(R_{i,t}\right)$ is the expected return on the stock of firm i on day t, and $E\left(R_{m,t}\right)$ is the market return on day t. To calculate market returns, we use country-specific stock market indices, based on Compustat data. Next, we calculate the abnormal return (AR) of firm i on day t as the difference between the realized return and the expected return estimated by the market-adjusted model:

$$AR_{i,t} = R_{i,t} - E\left(R_{i,t}\right)$$

Cumulating the AR for firm i over the event window gives the CAR:

$$CAR\left(T_1, T_2\right) = \sum_{t=T_1}^{T_2} AR_{i,t}$$

where T_1 is the first day and T_2 the last day of the event window. The average abnormal return (AAR) is calculated for each day within the event window. We aggregate the

abnormal returns for all N stocks to compute the AAR at each time t:

$$AAR_t = \frac{1}{N} \sum_{i=1}^{N} AR_{i,t}$$

Lastly, we sum the average abnormal returns over the T days in the event window to compute the cumulative average abnormal return (CAAR):

$$\text{CAAR}\,(T_1, T_2) = \sum_{T_1}^{T_2} AAR_t$$

5.1.1.3 Hypothesis testing

To draw statistical inference from the resulting CAAR, we test for significance. For this purpose, we use the standardized cross-sectional test, also known as the Boehmer, Mucumeci and Poulsen (BMP) test (Boehmer et al., 1991). As opposed to the ordinary cross-sectional test developed by Brown and Warner (1985), the method is robust against any event-induced variance, supporting the power of the test (Harrington and Shrider, 2007). The Z-statistic for testing $H_0 : E(CAAR) = 0$ is given as follows:

$$Z_{BMP} = \sqrt{N} \frac{\overline{SCAR}}{S_{\overline{SCAR}}}$$

where $\overline{SCAR}$ is the standardized cumulative abnormal return averaged across the N green bond announcements. The corresponding standard deviation is computed based on:

$$S^2_{SCAR} = \frac{1}{N-1} \sum_{i=1}^{N} \left(SCAR_i - \overline{SCAR}\right)^2$$

$$\overline{SCAR} = \frac{1}{N} \sum_{i=1}^{N} SCAR_i$$

$$SCAR_i = CAR_i / S_{CAR_i}$$

where S_{CAR_i} is the forecast-error-corrected standard deviation, as suggested by Mikkelson and Partch (1988). This corrected standard deviation adjusts the test statistic for serial

correlation in the returns, and is computed based on:

$$S^2_{CAR_i} = S^2_{AR_i} L_i$$

where L_i refers to the count of non-missing stock returns in the event window for firm i.

5.1.2 Results

In this section, we present the event study results. Firstly, we investigate the stock market reaction for the entire sample of green bonds. Next, we examine any differences in abnormal returns due to green exchange listing, certification, and first-time issuance respectively. Lastly, we analyze whether the stock market reaction depends on the level of public environmental attention in the issuing firm's home country.

5.1.2.1 Stock market reaction to green bond announcements

In Table 6, we consider the entire sample of green bonds and report the CAARs (as a percentage) and the corresponding Z-score for each event window.

Table 6: CAARs of green bond announcements

This table shows the cumulative average abnormal return (CAAR) for various time windows around the announcement date of green bond issuances. The BMP test (Z_{BMP}) is used to statistically test if the CAARs are significantly different from zero. The sample consists of $N = 383$ green bonds.

Event window	CAAR	Z_{BMP}
[-10, -6]	0.048	0.753
[-5, 5]	**0.486**	**1.554**
[-1, 1]	-0.081	-0.932
[6, 10]	0.209	1.356

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. Results for the baseline event window are highlighted in boldface type.

As shown in the table, we find that green bond announcements on average do not lead to any significant abnormal returns. The CAAR for the baseline event window [-5, 5] is 0.49%, but statistically insignificant. Similarly, all other time windows analyzed yield CAARs that are small and insignificant.

The CAARs are computed by summing the average daily abnormal return for the different

time windows. To test for statistical significance, we apply the standardized cross-sectional test outlined in section 5.1.1.3. Several alternative time windows are analyzed to ensure robustness. As none of these exhibit significant abnormal returns, the results do not appear to be affected by unrelated trends around the announcement date. The results are illustrated in Figure 2, showing the daily AARs around the announcement date.

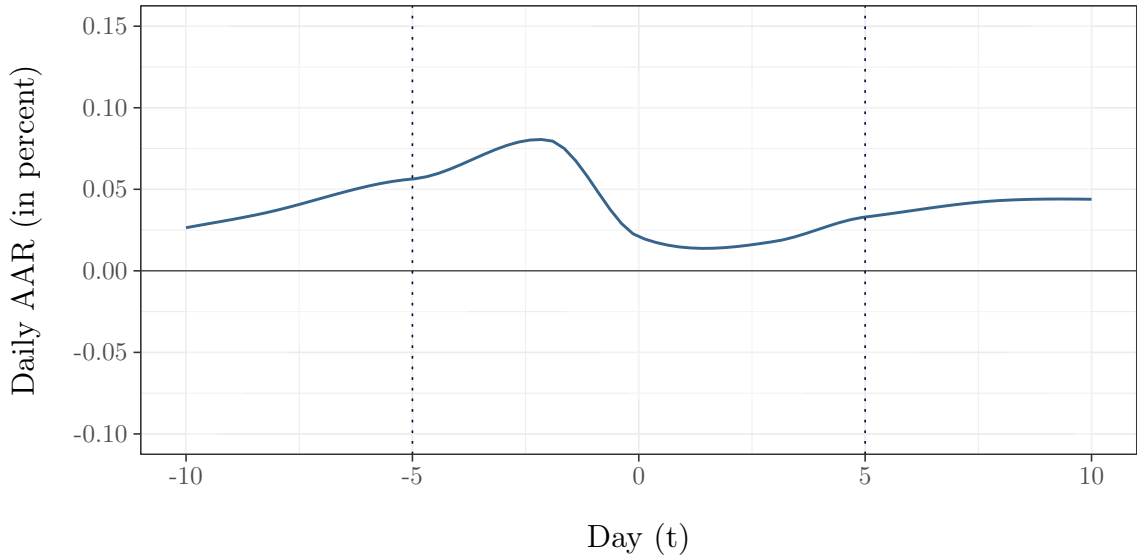

Figure 2: Average abnormal returns (AARs) around the announcement of green bonds

As is shown, the AAR of green bond issuers increases slightly in the lead-up to the announcement date, before diminishing towards the second half of the event window.

Overall, our results do not confirm the findings of prior studies that show positive CAARs in response to green bond announcements (Baulkaran, 2019; Tang and Zhang, 2020; Flammer, 2021). There are several possible explanations for this non-finding. Firstly, corporate green bond issuance in Europe generally may not be seen as a credible enough signal of firms' environmental commitment. For instance, investors may not deem the signal cost to be sufficiently high to put off low-quality (greenwashing) firms from signaling (Kirmani and Rao, 2000). Secondly, the signal may lack observability, i.e., the green bond issuance may not be noticeable enough among the targeted pool of investors (Connelly et al., 2011). Lastly, an explanation for the absence of a substantial stock market reaction could be that the majority of European investors do not have a preference for green investments and, moreover, do not deem green bond issuance to be value-enhancing. However, the latter explanation does not appear to be plausible, given previous studies and surveys revealing that European investors tend to have stronger non-pecuniary preferences for

green assets compared to the global average (HSBC, 2019; Maltais and Nykvist, 2021).

To further investigate the validity of these explanations, it is necessary to conduct analyses on a deeper level. Therefore, we examine the effect of several green bond characteristics, such as green exchange listing and third-party certification, on the stock market reaction.

5.1.2.2 Green bond exchanges

To add to the existing literature analyzing the stock market reaction to green bond issuance, we shed light on the potential signaling effect of green exchange listings. In Table 7, we report the CAARs for the announcement of green bonds listed on dedicated green exchanges, and green bonds that are not.

Table 7: CAARs of green-exchange-listed and non-green-exchange-listed green bonds

This table shows the cumulative average abnormal return (CAAR) for various time windows around the announcement date of green bond issuances. The BMP test (Z_{BMP}) is used to statistically test if the CAARs are significantly different from zero. The table distinguishes between green-exchange-listed and non-green-exchange-listed green bonds.

	CAAR	Z_{BMP}
Panel A: Green-exchange-listed bonds ($N = 263$)		
[-10, -6]	0.125	1.202
[-5, 5]	**0.841*** **	**2.619**
[-1, 1]	0.003	0.461
[6, 10]	0.077	0.230
Panel B: Non-green-exchange-listed bonds ($N = 119$)		
[-10, -6]	-0.119	-0.808
[-5, 5]	**-0.284**	**-0.825**
[-1, 1]	-0.272	-0.991
[6, 10]	0.502	1.406

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. Results for the baseline event window are highlighted in boldface type.

During the baseline event window, green-exchange-listed bonds exhibit a CAAR of 0.84%, which is significant at the 1% level. All other time windows have CAARs that are small and insignificant, indicating that the results are not driven by confounding events around the announcement day. For green bonds that are not listed on such exchanges, abnormal returns are negative and statistically insignificant, regardless of the time window

considered. Figure 3 illustrates the results, showing the development of daily AARs for green-exchange-listed and non-green-exchange-listed green bonds.

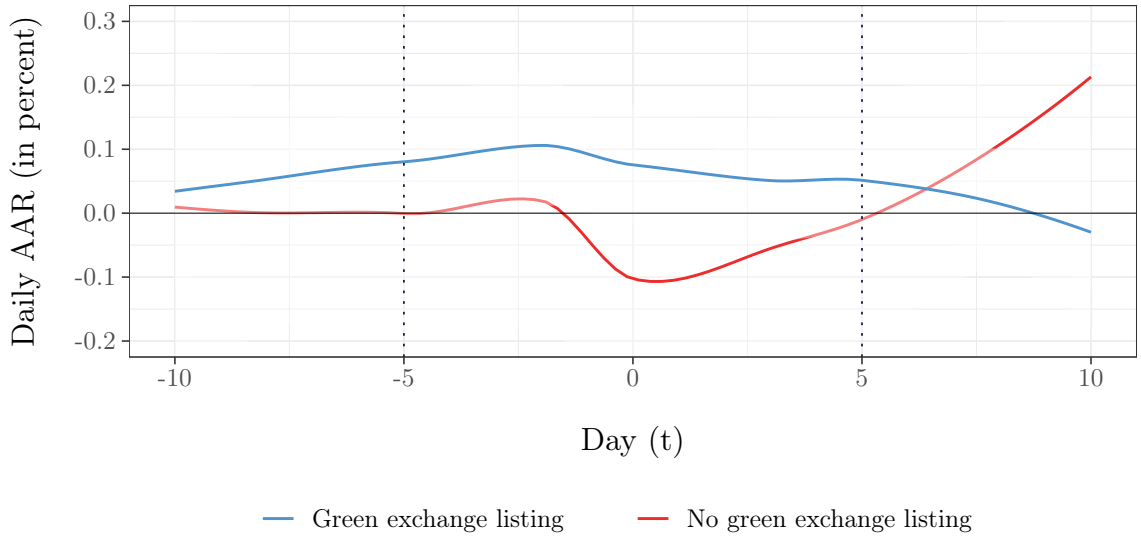

Figure 3: Average abnormal returns (AARs) for the announcement of green-exchange-listed and non-green-exchange-listed green bonds

As depicted, AARs for green-exchange-listed bonds rise in the lead-up to the announcement date, and remain positive throughout the entire event window. Non-green-exchange-listed bonds, on the other hand, exhibit a marked drop in AARs around the announcement date. Curiously, the abnormal returns for these bonds rise substantially between the fifth and tenth day following the announcement. However, as shown in Table 7, the CAAR during this period is statistically insignificant.

In sum, we find significant evidence of a positive stock market reaction to the announcement of green-exchange-listed green bonds. Our findings support the reasoning of Kapraun et al. (2021), who argue that green exchanges provide improved visibility and transparency of green bonds and strengthen the reliability of the green bond label. Hence, green exchange listings fulfill the two key criteria for an effective signal, as proposed by Connelly et al. (2011). Firstly, they facilitate exposure to a wider investor base and thus entail a substantial level of observability. Secondly, through their strict listing requirements, especially those associated with post-issuance reporting, green exchange listing comes at a considerable cost to green bond issuers. Due to this combination of great observability and signaling costs, investors appear to recognize green exchange listing as an effective signal of issuers' environmental commitment, which is reflected in the positive stock market reaction.

5.1.2.3 Certification

In line with previous studies, we analyze the impact of third-party certification on the stock returns of green bond issuers. For each event window, Table 8 reports the CAARs for the announcement of certified and non-certified green bonds.

Table 8: CAARs of certified and non-certified green bonds

This table shows the cumulative average abnormal return (CAAR) for various time windows around the announcement date of green bond issuances. The BMP test (Z_{BMP}) is used to statistically test if the CAARs are significantly different from zero. The table distinguishes between certified and non-certified green bonds.

	CAAR	Z_{BMP}
Panel A: Certified green bonds ($N = 257$)		
[-10, -6]	0.291	1.366
[-5, 5]	**0.049**	**0.911**
[-1, 1]	-0.094	-0.948
[6, 10]	0.091	1.047
Panel B: Non-certified green bonds ($N = 126$)		
[-10, -6]	-0.439	-0.959
[-5, 5]	**1.368**	**1.394**
[-1, 1]	-0.058	0.1651
[6, 10]	0.452	1.224

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. Results for the baseline event window are highlighted in boldface type.

As is shown, we find that the CAAR for certified green bonds is small and insignificant during the baseline event window. Interestingly, the CAAR for non-certified green bonds is markedly higher, but remains statistically insignificant. Similarly, the CAARs for all alternative time windows are insignificant, both for certified and non-certified green bonds.

As illustrated in Figure 4, the AAR for certified green bonds starts falling shortly before the announcement date, and recovers only after the event window. Curiously, non-certified green bonds experience a surge in AARs starting on the announcement date, before dropping towards the end of the event window. However, as shown in Table 8, the CAAR for non-certified bonds is statistically insignificant, which is confirmed by the robustness checks performed in section 5.1.3. Hence, we cannot rule out that this surge in abnormal returns is caused by chance.

In sum, we do not find significant evidence of a positive stock market reaction to the

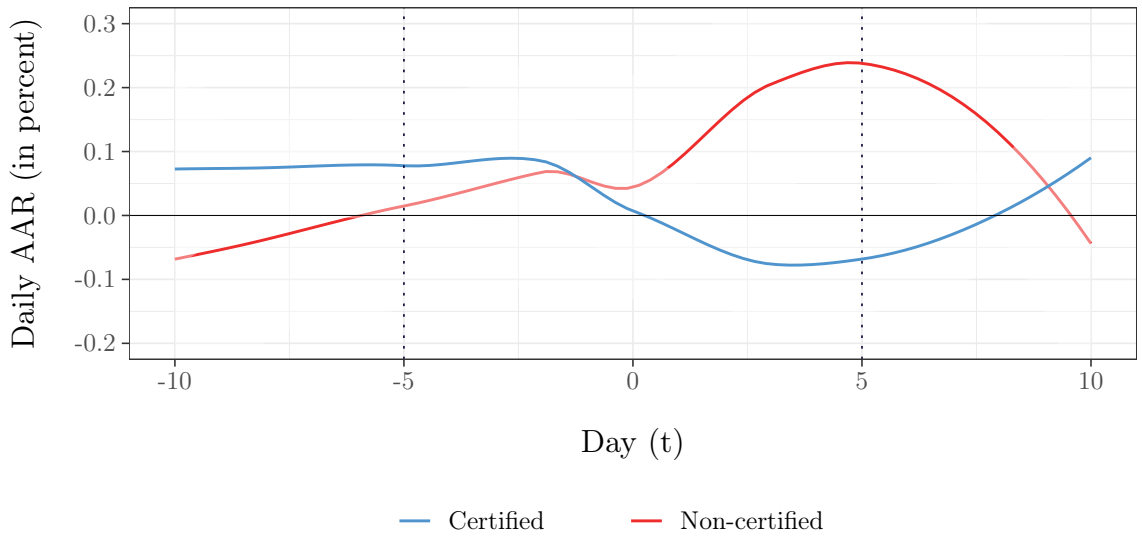

Figure 4: Average abnormal returns (AARs) for the announcement of certified and non-certified green bonds

announcement of certified green bonds. Our findings thus contradict previous studies like Flammer (2021), whose results show that the announcement of certified green bonds entails a significant positive stock market reaction, while announcements of non-certified green bonds do not. A possible explanation for this disparity could be that we exclusively focus on European issuers, while Flammer's results are based on a global sample. Our results indicate that European investors do not discern green bond certification as a strong signal of firms' environmental commitment. This could again be explained based on the argumentation of Connelly et al. (2011): while certification is associated with a substantial signaling cost (e.g., through administrative and compliance burdens), certification lacks the same degree of observability compared to green exchange listings. In contrast to green exchanges, third-party certification does not increase the bond's exposure to a wider investor base. Hence, it can be argued that issuing a certified green bond entails a lower level of signaling power compared to issuing a green-exchange-listed bond. A weaker reaction of the stock market to the announcement of certified green bonds, as found in our analysis, thus supports this line of argumentation.

5.1.2.4 First vs seasoned issuances

Next, we examine whether there is a difference in the stock market reaction to the announcement of first-time versus seasoned green bond issues. As reported in Table 9, we find that the CAAR for first-time issuances is 0.79%, yet statistically insignificant.

Table 9: CAARs of first-time and seasoned green bond issuances

This table shows the cumulative average abnormal return (CAAR) for various time windows around the announcement date of green bond issuances. The BMP test (Z_{BMP}) is used to statistically test if the CAARs are significantly different from zero. The table distinguishes between first-time and seasoned green bond issuances.

	CAAR	Z_{BMP}
Panel A: First green bond issuances ($N = 152$)		
[-10, -6]	-0.137	-0.263
[-5, 5]	**0.788**	**1.263**
[-1, 1]	0.031	0.894
[6, 10]	0.123	1.133
Panel B: Seasoned green bond issuances ($N = 221$)		
[-10, -6]	0.171	0.463
[-5, 5]	**0.288**	**0.259**
[-1, 1]	-0.156	-0.175
[6, 10]	0.268	0.234

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. Results for the baseline event window are highlighted in boldface type.

Similarly, the CAAR for seasoned green-bond issuances is insignificant and notably smaller at 0.29%. The CAARs for all alternative event windows are small and insignificant, both for first and seasoned issues. As depicted in Figure 5, abnormal returns for first-time issuances remain at a positive yet marginal level throughout the entire event window, while abnormal returns are close to zero for seasoned issuances.

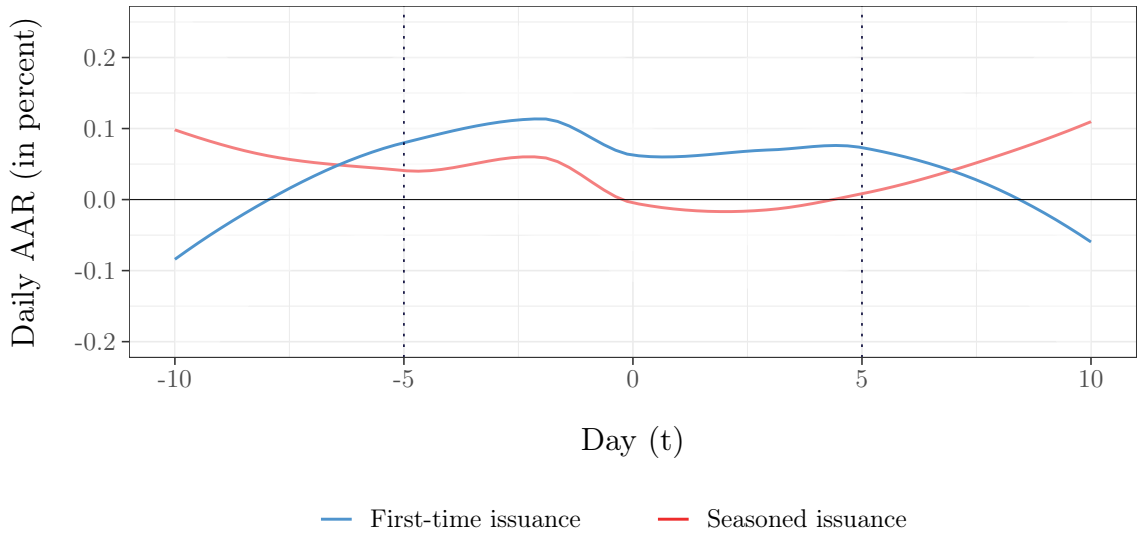

Figure 5: Average abnormal returns (AARs) for the announcement of first and seasoned green bonds issuances

In sum, we do not find sufficient evidence to conclude that first-time green bond issuances induce a greater stock market reaction compared to seasoned issuances. These findings contradict prior studies such as Tang and Zhang (2020) and Flammer (2021), who find that, since more new information is provided to the market, CARs are significantly higher for first-time issues than for seasoned issuances. A possible reason for this disparity in results lies in the time horizon and geographical scope considered in our analysis. As discussed in section 2.2.2, dedicated green bond segments only started to proliferate in Europe in 2019. Hence, it is likely that a large part of European green bonds listed on such segments are seasoned issuances. In fact, 64% of green-exchange-listed bonds in our sample are associated with firms that have issued one or more green bonds before. Hence, it can be argued that this creates an offsetting effect, which could help to explain the lacking difference in abnormal returns between first-time and season issuances.

5.1.2.5 Public environmental awareness and stock market reaction

In line with Kapraun et al. (2021), we use the Environmental Performance Index (EPI) score as a proxy for countries' public attention on environmental issues. The EPI was jointly developed by Yale University and Columbia University and ranks 180 countries on various indicators associated with environmental health and ecosystem vitality (Wendling et al., 2020). Many of Europe's major green bond issuing countries, such as France and Sweden, occupy top ranks in the EPI. Meanwhile, Italy, being Europe's third-largest green bond issuer, ranks only 17$^{\text{th}}$ in the European ranking of the EPI.[5] A low EPI score indicates a need for considerable improvements in national sustainability efforts to address major environmental issues. Hence, investors' trust in green labels and the willingness to contribute to national environmental efforts could be particularly strong in countries with well-developed environmental policies. Green bond issuers in countries with high EPI scores could thus be under stricter legal constraints and regulation and face more severe public pressure on actually implementing green projects (Kapraun et al., 2021). Following Li and Yang's (2021) argumentation, we expect that the level of asymmetric information, especially with regard to environment-related information, is lower in such countries.

Using the EPI score as a proxy for asymmetric information between issuers and investors, we investigate whether the stock market reacts more positively to green bond issuances

[5]Appendix Table A.2 shows a full ranking of European countries based on their 2020 EPI scores.

in countries with high levels of information asymmetry. Moreover, we expect that green exchange listing and certification contribute to information alignment and thus have a more positive effect on the stock market reaction in countries with particularly pronounced information asymmetries.

Table 10 presents the results of this analysis, which distinguishes between countries with particularly high EPI rankings (top 20% of European countries in the EPI) and countries with non-high EPI rankings (outside the top 20%).

Table 10: The effect of public environmental awareness on CAARs

This table shows the cumulative average abnormal return (CAAR) for the time window [-5, 5] for various sub-samples. The associated BMP test statistics are provided in parentheses. *High EPI* refers to green bonds issued in countries ranked in the top 20% of European countries in the Environmental Performance Index (EPI). *Non-High EPI* refers to bonds issued in countries not ranked in the top 20% of the EPI. The table shows results for the entire sample of green bonds, and distinguishes green bonds based on green exchange listing and third-party certification.

	CAAR[-5, 5]	
	High EPI	Non-High EPI
All green bonds (N = 188 | 195)	0.363 (0.746)	0.608 (1.503)
Green-exchange-listed bonds (N = 147 | 117)	0.826 (1.609)	0.861** (2.205)
Non-green-exchange-listed bonds (N = 41 | 78)	-1.255 (-1.092)	0.233 (0.127)
Certified green bonds (N = 142 | 115)	0.098 (0.216)	-0.011 (-0.021)
Non-certified green bonds (N = 46 | 80)	1.165 (0.199)	1.486* (1.754)

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

As can be seen, the CAAR is small and insignificant for the overall sample green bonds, both for those issued in high-EPI as well as non-high EPI countries. This indicates that, in general, the stock market reaction to green bond issuances is not significantly higher in countries with high levels of information asymmetry. However, investors do appear to value the added information alignment associated with green exchange listings. The CAAR of green-exchange-listed bonds is large and statistically significant in non-high EPI countries. Meanwhile, the CAAR is smaller and statistically insignificant in high-EPI countries. Lastly, CAARs of certified green bonds are small and insignificant in both country categories. Interestingly, non-certified bonds exhibit substantially higher CAARs than certified bonds. European investors hence do not seem to recognize and value the information-aligning attributes of certification.

Crucially, the results indicate that investors assign particularly great importance to green exchanges in countries with high levels of information asymmetries. As discussed, green exchanges are effective in increasing the visibility and transparency of green bonds. Moreover, through their strict requirements on post-issuance reporting, they inform investors about how proceeds are allocated to implement green projects, thereby contributing immensely towards information alignment between investors and issuers. This information alignment is especially valuable for investors in countries with high levels of asymmetric information, making green exchange listings particularly beneficial in such countries. By contrast, in countries with great public environmental attention, and thus lower levels of asymmetric information, investors tend to be well-informed about the environmental efforts of green bond issuers. Hence, it can be argued that, in these countries, issuing a green bond provides less "new" information to investors. Overall, the signaling power of green exchange listings therefore appears to be greater in countries with more pronounced information asymmetries between investors and issuers.

5.1.3 Robustness

The event study results presented in the previous sections are based on a *parametric* significance test, namely the standardized cross-sectional (or BMP) test. However, a shortcoming of parametric methods is that they are based on specific assumptions regarding the probability distribution of stock returns (MacKinlay, 1997). *Non-parametric* significance tests, on the other hand, do not require as stringent assumptions about returns distributions. Therefore, it is advisable to additionally estimate the model parameters using non-parametric methods, which allow for the non-normality in the cross section of abnormal returns. By carrying out a non-parametric test, we aim to verify that results are not driven by outliers, and thus support the robustness of our findings. A widely used non-parametric test in event studies is the generalized sign test introduced by Cowan (1992). As this test only uses the sign of the abnormal returns, but not its magnitude, event-induced volatility does not affect the null-rejection rates of the test. To conduct this test, we first compute the estimated fraction of positive returns during the event window:

$$\hat{p} = \frac{1}{N} \sum_{i=1}^{N} \frac{1}{L_1} \sum_{t=T_0}^{T_1} \varphi_{i,t}$$

where $\varphi_{i,t}$ equals 1 if the sign of the abnormal return for stock i on day t is positive, and equals 0 otherwise. L_1 denotes the number of days within the event window. The generalized sign test statistic for testing $H_0 : E(CAAR) = 0$ is given as follows:

$$Z_{Cowan} = \frac{(w - N\hat{p})}{\sqrt{N\hat{p}(1-\hat{p})}}$$

where w denotes the number of stocks in the sample with positive CARs in the event period.

Table 11 presents the results of the event study using the generalized sign test statistics for the baseline event window.

Table 11: Event study results based on the Cowan generalized sign test

This table reports the cumulative average abnormal return (CAAR) for the time window [-5, 5] for various sub-samples. The Cowan generalized sign test (Z_{Cowan}) is used to statistically test if the CAARs are significantly different from zero. Panel A shows results for the entire sample of green bonds. Panel B distinguishes between green bonds listed on dedicated green exchanges and green bonds that are not. Panel C distinguishes between certified and non-certified green bonds. Panel D distinguishes between first-time and seasoned green bond issuances.

	CAAR [-5, 5]	Z_{Cowan}
Panel A: All green bonds ($N = 383$)	0.486**	2.196
Panel B: Green exchange vs. no green exchange		
Green-exchange-listed bonds ($N = 264$)	0.841**	2.150
Non-green-exchange-listed bonds ($N = 119$)	-0.284	0.737
Panel C: Certified vs. non-certified		
Certified green bonds ($N = 257$)	0.049	1.557
Non-certified green bonds ($N = 126$)	1.368	1.605
Panel D: First issuance vs. seasoned issuance		
First green bond issuance ($N = 152$)	0.788	1.199
Seasoned green bond issuance ($N = 221$)	0.288*	1.945

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Crucially, we find that green-exchange-listed bonds (Panel B) exhibit a large and statistically significant CAAR, both when using the Cowan and BMP test (cf. Table 7). Considering the consistency in parametric and non-parametric test statistics, we find robust evidence for a significant positive stock market reaction to the announcement of green bonds listed on a green exchange.

Moreover, CAARs are positive and significant when looking at green bonds in general

(Panel A) and for seasoned green bond issues (Panel D). However, these results are inconsistent with the corresponding parametric statistics based on the BMP test (cf. Tables 6 and 9). Therefore, our findings do not provide sufficient evidence to conclude that there is a significant stock market reaction for green bonds in general or for seasoned green bond issues. All remaining test results are statistically insignificant for both the Cowan and BMP test, thus being consistent for parametric and non-parametric methods.

5.2 Green bonds and corporate performance

In this section, we begin by describing the methodology applied for analyzing green bond issuers' environmental and financial performance, before presenting and discussing the results of our analysis.

5.2.1 Methodology

For this analysis, we account for the fact that some firms issue multiple green bonds in a year by considering firm-year observations, which are the distinct years in which a firm issues one or multiple green bonds. After restricting the sample to observations with nonmissing information on the key variables of our regression models, the sample consists of 56 firm-year observations.

5.2.1.1 Measuring environmental and financial performance

Environmental performance. To gauge issuers' environmental performance, we consider two outcome variables. Firstly, we look at the environmental pillar of the ESG score provided by Refinitiv (formerly ASSET4). The environmental pillar score (or "E score") is expected to provide a holistic evaluation of a firm's environmental performance since it encompasses themes including emissions, waste generation, green product innovation, water and energy usage, and sustainable supply chains. The scores are percentile rank scores scaled to a range between 0 and 100 and are based on relative sectoral performance (Refinitiv, 2021). Importantly, the issuance of green bonds itself does not affect Refinitiv's assessment in determining the environmental pillar score. Thus, we avoid any distorting effects that could arise from a mechanical connection between green bond issuances and improved environmental scores.

ESG ratings have been the subject of much criticism in recent years, whether for their lack of standardization, opaque methodologies, or potential conflicts of interest faced by rating agencies (Windolph, 2011; Berg et al., 2021). In contrast to financial ratings, there is no regulation or market consensus on how to measure firms' ESG performance. Studies on the major ESG rating agencies have revealed divergent definitions, methodologies, and data sources, which lead to contradicting scores even for the same companies (Dorfleitner et al., 2015; Billio et al., 2021). Nevertheless, research has shown that the same conclusions on the relationship between ESG and financial performance can be found even when comparing results from two different rating providers (e.g., Desclée et al., 2016). Furthermore, for the environmental pillars, the main rating agencies have been found to rate companies largely on the same issues, such as emissions, water and waste (Dorfleitner et al., 2015). Refinitiv is one the largest ESG rating agencies (having acquired ASSET4 as part of Thomson Reuters in 2018) and studies have attributed ASSET4 scores a higher coverage and lower yearly score fluctuation than other rating databases, which explains their use in multiple studies on ESG and financial performance (Dorfleitner et al., 2015; Ortas et al., 2015; Halbritter and Dorfleitner, 2015; Fatica and Panzica, 2020; Flammer, 2021). The ASSET4 ratings have also been found to be significantly positively correlated with other ESG scores, and especially the environmental scores, of major providers such as Bloomberg and KLD (Dorfleitner et al., 2015).

As a second measure of environmental performance, we include the carbon intensity of assets, which is calculated as the ratio of total CO_2 equivalent emissions divided by the firm's total assets. An advantage of this ratio is its more objective measurement compared to ESG ratings. It also allows for a more direct interpretation as the environmental score comprises several areas of a firm's environmental efforts. The measure includes direct (Scope 1) and indirect (Scope 2) CO_2 emissions, as well as equivalent emissions of other GHGs, such as methane (CH_4) and nitrous oxide (N_2O) (Refinitiv, 2021).

Financial performance. We measure firms' financial performance based on the return on assets (ROA), asset turnover (AT), and Tobin's Q. ROA has been widely used in previous green bond research (e.g., Flammer, 2018; Yeow and Ng, 2021) and captures the relative efficiency in the utilization of a firm's assets. It is calculated as the ratio of pre-tax income divided by a firm's total assets. Using the pre-tax ROA rather than the after-tax ROA

allows for more precise comparisons across firms having different financing structures. The total AT measures how efficiently a firm utilizes its corporate assets to produce revenue and is calculated as net revenue divided by average total assets. Tobin's Q is a measure of firm value and is calculated as the ratio between a company's market value and the replacement value of its assets (Tobin and Brainard, 1976).

5.2.1.2 Difference-in-differences regression model

To investigate how green bond issuance affects firms' environmental and financial performance, we analyze the described performance variables subsequent to the bonds' issuance. A key empirical challenge in studying green bond effectiveness is that confounding factors may cause a spurious relationship between green bond issuance and firm performance (Fatica and Panzica, 2020; Flammer, 2021). Ideally, this endogeneity issue would be addressed by conducting a randomized experiment. However, it is not viable to perform a randomized experiment that investigates what would have happened if the green bonds were conventional bonds instead. Therefore, we implement a difference-in-differences (DiD) specification with a matched control group. Using this methodology, we aim to solve the sample selection bias by pairing each green bond issuer ("treated" firms) with a conventional bond issuer ("control" firm) that is as similar as possible to the green bond issuer prior to the green bond issuance, thereby establishing a plausible counterfactual. The DiD model is based on all firm-year observations of treated and control firms from 2013 to 2021, and is set up as follows:

$$Y_{it} = \alpha_i + \alpha_{ct} + \alpha_{st} + \beta_1 \times \text{Green}_i + \beta_2 \times \text{Post}_t + \beta_3 \left(\text{Green}_i \times \text{Post}_t\right) + x_{it} + \varepsilon_{it} \quad (1)$$

where

1) Y_{it} = performance variable (e.g., environmental pillar score or ROA)

2) α_i = firm-fixed effects

3) α_{ct} = country-year fixed effects

4) α_{st} = sector-year fixed effects

5) $Green_i$ = treatment dummy variable (1 = treatment group, 0 = control group)

6) $Post_t$ = time dummy variable (1 = post-issuance, 0 = pre-issuance)

7) x_{it} = vector of control variables

8) ε_{it} = error term

The coefficient of interest is β_3, which represents the DiD estimator. In line with Yeow and Ng's (2021) methodology, we use two observations of the dependent variable at different times: pre-treatment and post-treatment. The pre-treatment observation is identified as one year prior to the bond issuance, and the post-treatment observation is identified as one year after the issuance.

To investigate the effect of green exchange listing and certification on corporate performance, we include two interaction variables in our model:

$$\begin{aligned} Y_{it} = \alpha_i + \alpha_{ct} + \alpha_{st} + \beta_1 \times \text{Green}_i + \beta_2 \times \text{Post}_t + \beta_3 \left(\text{Green}_i \times \text{Post}_t\right) + \beta_4 \times \text{GreenEx}_i \\ + \beta_5 \left(\text{Post}_t \times \text{GreenEx}_i\right) + \beta_6 \times \text{Cert}_i + \beta_7 \left(\text{Post}_t \times \text{Cert}_i\right) \\ + \beta_8 \left(\text{GreenEx}_i \times \text{Cert}_i\right) + \beta_9 \left(\text{Post}_t \times \text{GreenEx}_i \times \text{Cert}_i\right) + x_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

where

1) $GreenEx_i$ = green exchange dummy variable (1 = listed on a green bond exchange, 0 = not listed on a green bond exchange)

2) $Cert_i$ = certification dummy variable (1 = certification present, 0 = certification absent)

The coefficients of interest are β_5, β_7, and β_9, which represent the DiD estimators for the relevant interaction terms.

To examine the hypothesized moderating effect of EPI scores on the relationship between green exchange listing and firms' corporate performance, we modify the previous equation as follows:

$$\begin{aligned} Y_{it} = \alpha_i + \alpha_{ct} + \alpha_{st} + \beta_1 \times \text{Green}_i + \beta_2 \times \text{Post}_t + \beta_3 \left(\text{Green}_i \times \text{Post}_t\right) + \beta_4 \times \text{GreenEx}_i \\ + \beta_5 \left(\text{Post}_t \times \text{GreenEx}_i\right) + \beta_6 \times \text{EPI}_i + \beta_7 \left(\text{Post}_t \times \text{EPI}_i\right) \\ + \beta_8 \left(\text{GreenEx}_i \times \text{EPI}_i\right) + \beta_9 \left(\text{Post}_t \times \text{GreenEx}_i \times \text{EPI}_i\right) + x_{it} + \varepsilon_{it} \end{aligned} \tag{3}$$

where

1) EPI_i = EPI score of firm i's home country

The coefficients of interest are β_7 and β_9, which represent the DiD estimators for the interaction with EPI scores.

5.2.1.3 Controls

We incorporate a vector of control variables, x_{it}, that may affect our measures of corporate performance. In our regressions on environmental performance, we control for the total assets (natural logarithm) as a measure of firm size. According to Elsayed and Paton (2005), firm size is particularly relevant because of the profound economies of scale in environmentally-focused investments. In line with Yeow and Ng (2021), we also include the equity multiplier (EM) and operating margin (OM) as controls. EM is a risk indicator that measures the share of a firm's assets that is financed by stockholder's equity rather than by debt. OM is a profitability ratio that indicates how much of the generated revenue is left after all expenses are paid off. Further, as described in section 4.3, we include AT and Tobin's Q as controls.

For the analysis of firms' financial performance, we again include total assets to control for firm size. Moreover, we include the debt-to-sales (DS) ratio as a measure of debt capacity. Thereby, we account for a possible concern that treated firms may benefit from better access to capital markets (Flammer, 2021).

5.2.1.4 Matching

In this study, we use the nearest-neighbor method to build a matched control group. As a first step for finding a set of control firms, we limit our selection of public companies to those that are issuers of conventional bonds, but not green bonds. Moreover, control firms must be domiciled in the same country and operate in the same sector (same two-digit GICS code) as the treated firms. Thereby, we ensure that treated and control firms operate in similar business environments and, accordingly, face similar macroeconomic conditions.

As part of the next step, within the filtered group of conventional bond issuers, we determine the nearest neighbor to the treated firm based on various firm-level characteristics.

Specifically, we match treatment and control firms based on their environmental pillar score and multiple financial characteristics. Matching based on the environmental score ensures that the treatment and control group adopt similar levels of environmental efforts pre-issuance. Hence, we mitigate the possible concern that green bond issuers structurally pursue stronger environmental strategies than conventional issuers (Fatica and Panzica, 2020). By including ROA as a measure of financial performance, we take into consideration that green bond issuers could be more profitable and benefit from better investment opportunities ex ante (Flammer, 2021). Lastly, by including firm size and leverage as matching characteristics, we rule out that green bond issuers firms have better access to capital markets compared to conventional borrowers.

For each of these four characteristics, we use the value in the year prior to the green bond issuance (t - 1). The nearest-neighbor control firm is identified as the conventional bond issuer with the lowest Mahalanobis distance to the green bond issuer across the four matching characteristics.[6] In Table 12, we present an overview of the pre-issuance covariate imbalances for the green bond issuers and the matched control group, both before and after conducting the matching.

Table 12: Covariate imbalance, before and after nearest-neighbor matching

This table reports covariate imbalances before and after nearest-neighbor matching. Specifically, differences in the mean value of environmental score, return on assets (ROA), total assets (natural logarithm), and leverage (total debt to total assets) are reported.

	Mean (Treat)	Mean (Control)	$\Delta Mean$
Panel A: Matched data			
Environmental score	74.479	64.755	9.724
ROA	0.043	0.037	0.006
Assets	24.721	23.893	0.828
Leverage	1.344	1.196	0.148
Panel B: Unmatched data			
Environmental score	74.690	56.367	18.323
ROA	0.042	0.037	0.005
Assets	24.759	23.492	1.267
Leverage	1.407	1.052	0.355

As shown, matching successfully reduces the covariate imbalance, especially for pre-issuance

[6]The Mahalanobis distance between treated firm i and a matched control firm j is computed as follows: $\|X_i - X_j\| = \left((X_i - X_j)' W_X^{-1} (X_i - X_j)\right)^{1/2}$, where X denotes a vector comprising our matching variables and W_X^{-1} denotes the inverse of the covariance matrix of the variables (Frésard and Valta, 2016).

environmental scores, firm size, and leverage ratios. For instance, through matching the difference in average environmental scores between treatment and control firms is almost halved, dropping from 18.3 to 9.7.

Our DiD regression model is based on the assumption that, in the absence of treatment (i.e., green bond issuance), the difference in the outcome variable between the treatment and matched control group is constant over time. It is not possible to formally test this parallel trends assumption since we cannot observe the entire outcome path for the treatment group absent the treatment. However, we can visually investigate whether the trends of both groups move in parallel before the treatment occurs. In Figure 6, we perform such a visual check, testing the parallel pre-trends in the CO_2 intensity of green bond issuers and conventional bond issuers.

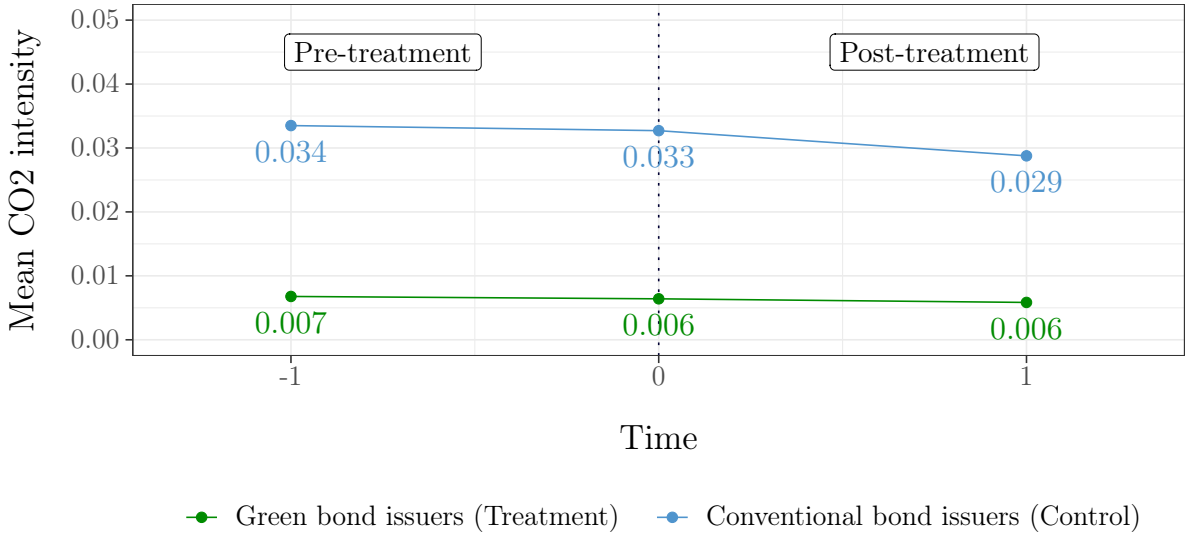

Figure 6: Visual assessment of the parallel trends assumption

As shown, parallel pre-trends can be observed: the CO_2 intensities of the treatment and control group both decrease by approximately 0.001 from the pre-treatment (t = -1) to the treatment year (t = 0). Based on this observation, it appears that the parallel trends assumption holds.[7]

[7]Appendix Figure A.1 presents a visual investigation of parallel trends for firms' environmental scores. Again, we observe parallel movement of environmental scores pre-treatment, further supporting the parallel trends assumption in our analysis.

5.2.2 Results

In this section, we present the results of the DiD regression model, which aims to analyze firms' corporate performance subsequent to the issuance of green bonds. Firstly, we look at the post-issuance environmental performance to investigate the capacity of green bonds to credibly signal firms' environmental commitment. Next, we examine whether firms exhibit substantial improvements in financial performance following green bond issuances.

5.2.2.1 Environmental performance

As shown in Table 13, we find that firms do not exhibit any significant environmental improvements following the issuance of green bonds.

Table 13: Environmental performance following green bond issuances

This table shows results for the difference-in-differences regression model in Eq. (1). *Green* is a dummy variable equal to one if the firm is a green bond issuer. *Post* is a dummy variable equal to one in the post-issuance year. *Environmental score* refers to the environmental pillar score, which is obtained from the Refinitiv ESG database. *CO_2 intensity* is the ratio of CO_2-equivalent emissions (in tons) divided by total assets in US dollars. The sample comprises all firm-year observations of the treated and control firms from 2013 to 2020. Results are computed using heteroskedasticity-robust standard errors.

	Environmental score	CO_2 intensity
	(1)	(2)
Green * Post	-0.769	0.00003
	(t = -0.308)	(t = 0.832)
Firm-level controls	Yes	Yes
Sector-year fixed effects	Yes	Yes
Country-year fixed effects	Yes	Yes
Observations	215	215
R^2	0.293	0.106
Adjusted R^2	0.266	0.071

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

The DiD estimate *Green * Post* shows that one year after issuance, green bond issuers exhibit environmental ratings that are 0.8% lower compared to non-green bond issuers. However, the DiD estimate is statistically insignificant. Further, green bond issuers show CO_2 emissions intensities that are 0.3% higher compared to conventional bond issuers. Again, the estimate does not show significance. This indicates that green bond issuers on average do not exhibit superior improvements in environmental performance compared to

conventional bond issuers. Overall, there is insufficient evidence to conclude that European companies achieve significant environmental improvements subsequent to issuing green bonds.

Thus, our finding is inconsistent with the signaling argument, as it indicates that European green bonds do not signal substantial post-issuance improvements in environmental performance. This is consistent with Yeow and Ng (2021), who find that firms do not significantly reduce their GHG emissions one year after issuance of a green bond. However, our findings do not agree with other studies like Fatica and Panzica (2020) and Flammer (2021) who find that green bond issuers exhibit significant post-issuance reductions in carbon footprints and improvements in environmental ratings. Overall, based on our findings, we cannot rule out a greenwashing motive of green bond issuers, which would suggest that (some) firms issue green bonds without a genuine commitment to improving their environmental efforts.

To investigate the role of green exchange listings and third-party certification in the distinction between credible and greenwashing issuers, we extend our analysis. Specifically, in Table 14, we interact the time dummy variable *Post* with two dummy variables that indicate whether or not the green bond is listed on a dedicated green bond segment or certified by a third party.

As is shown, we do not find evidence that green exchange listing or third-party certification have any significant impact on green bond issuers' environmental performance. When regressing on the *Environmental score*, the interaction coefficients for green exchange listing and certification are both negative, yet statistically insignificant. For green bonds that are listed on a green exchange and at the same time certified, the coefficient is positive but insignificant. Focusing on the results for CO_2 *intensity*, the interaction coefficients for green exchange listing and certification are both negative, yet statistically insignificant. Green bonds that are both listed on a green exchange and certified by a third party exhibit a positive but insignificant increase in carbon intensities.

Overall, the results in this section indicate that neither green exchange listing nor third-party certification help to predict marked improvements in environmental performance of European green bond issuers. In contrast, previous studies using global samples have found that issuers of certified green bonds exhibit significantly greater improvements in

Table 14: Impact of green exchange listing and certification on environmental performance

This table shows results for variants of the regressions in Table 13 and includes interactions with dummy variables for green bonds listed on dedicated green bond segments (*GreenEx*) and green bonds that are certified by independent third parties (*Cert*). The sample comprises all firm-year observations of the treated and control firms from 2013 to 2020. Results are computed using heteroskedasticity-robust standard errors.

	Environmental score	CO_2 intensity
	(1)	(2)
Post * GreenEx	-3.922	-0.0001
	(t = -0.245)	(t = -0.888)
Post * Cert	-14.958	-0.00005
	(t = -1.095)	(t = -1.062)
Post * GreenEx * Cert	3.046	0.0001
	(t = 0.187)	(t = 0.904)
Firm-level controls	Yes	Yes
Sector-year fixed effects	Yes	Yes
Country-year fixed effects	Yes	Yes
Observations	215	215
R^2	0.319	0.112
Adjusted R^2	0.271	0.049

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

environmental performance than issuers of non-certified green bonds (Fatica and Panzica, 2020; Flammer, 2021; Yeow and Ng, 2021). However, our results are in line with Fossum and Teigland (2020), who do not find significant differences in post-issuance ESG ratings between issuers of certified and non-certified green bonds. In sum, our findings for the European market are not consistent with the signaling argument, as neither green exchange listings nor certification appear to function as effective "seals of approval" that can distinguish credible green bond issuers from issuers with a high risk of greenwashing.

Next, we investigate whether the level of environmental improvements following the issuance of a green-exchange-listed bond differs depending on the level of public environmental attention in the issuer's home country. In Table 15, we therefore include the dummy variable *EPI*, which refers to the EPI score of the issuer's country of domicile.

As shown, the interaction coefficients for *Post * EPI* are small and insignificant, indicating that the environmental performance of green bond issuers in general is not moderated by the EPI score. Similarly, the coefficients for the interaction *Post * GreenEx * EPI* are

Table 15: The moderating effect of EPI scores on green bond issuers' environmental performance

This table shows results for variants of the regressions in Table 13 and includes interactions with the Environmental Performance Index (EPI) score of the issuer's home country (*EPI*) and a dummy variable for green bonds listed on dedicated green bond segments (*GreenEx*). The sample comprises all firm-year observations of the treated and control firms from 2013 to 2020. Results are computed using heteroskedasticity-robust standard errors.

	Environmental score	CO_2 intensity
	(1)	(2)
Post * EPI	-0.023	0.000001
	(t = -0.079)	(t = 0.568)
Post * GreenEx * EPI	0.632	-0.000001
	(t = 0.580)	(t = -0.416)
Firm-level controls	Yes	Yes
Sector-year fixed effects	Yes	Yes
Country-year fixed effects	Yes	Yes
Observations	215	215
R^2	0.351	0.365
Adjusted R^2	0.299	0.313

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

small and statistically insignificant, both for the *Environmental score* and *CO_2 intensity*. Hence, we do not find sufficient evidence that the environmental performance of issuers of green-exchange-listed bonds is moderated by its home country's EPI score. The findings thus contradict our hypothesis as they indicate that the effect of issuing a green bond on issuers' environmental performance is not substantially greater in countries with lower levels of public environmental pressure.

There are several possible explanations for this non-finding. Firstly, issuance of green bonds (and green-exchange listed bonds) generally may not have any substantial impact on issuers' environmental performance. Following this reasoning, it would also be logical to see no significant effect of any country differences. Secondly, the EPI score may not be a suitable proxy for relevant country differences that may moderate the relationship between green bond issuance and issuers' environmental performance. Considering that our previous analysis does not find any significant environmental improvements for green bond issuers, and neither for issuers of green-exchange-listed bonds, the first explanation appears to be most plausible.

5.2.2.2 Financial performance

As can be seen in Table 16, we find that firms do not exhibit any significant financial improvements following the issuance of green bonds.

Table 16: Financial performance following green bond issuances

This table shows results for the difference-in-differences regression model in Eq. (1). *Green* is a dummy variable equal to one if the firm is a green bond issuer. *Post* is a dummy variable equal to one in the post-issuance year. *ROA* is the ratio of income before taxes divided by total assets. *Asset turnover* is calculated as net revenue divided by average total assets. *Tobin's Q*, as a measure of firm value, is the ratio between a company's market value and the replacement value of its assets. The sample comprises all firm-year observations of the treated and control firms from 2013 to 2020. Results are computed using heteroskedasticity-robust standard errors.

	ROA	Asset turnover	Tobin's Q
	(1)	(2)	(3)
Green * Post	0.003	0.020	0.109
	(t = 0.499)	(t = 0.646)	(t = 0.760)
Firm-level controls	Yes	Yes	Yes
Sector-year fixed effects	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes
Observations	215	215	215
R^2	0.210	0.068	0.006
Adjusted R^2	0.191	0.046	-0.018

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

For all three outcome variables considered, the DiD covariate is found to be small and insignificant. This indicates that green bond issuers on average do not show greater increases in financial performance than conventional bond issuers. Overall, there is insufficient evidence to conclude that green bond issuance has a positive effect on firms' ROA, AT, or Tobin's Q.

Next, we revisit Table 16 to examine the role of green exchange listing and third-party certification. Specifically, in Table 17 we interact the time dummy variable *Post* with two dummy variables that indicate whether or not the green bond is listed on a dedicated green bond segment or certified by a third party.

As is shown, we find little evidence that green-exchange-listing or third-party certification have any significant impact on green bond issuers' financial performance. The only significant DiD coefficient is found for the effect of certification on *Asset turnover*. The coefficient is significant at the 10% level. This suggests that issuers of certified green bonds

Table 17: Impact of green exchange listing and certification on financial performance

This table shows results for variants of the regressions in Table 16 and includes interactions with dummy variables for green bonds listed on dedicated green bond segments (*GreenEx*) and green bonds that are certified by independent third parties (*Cert*). The sample comprises all firm-year observations of the treated and control firms from 2013 to 2020. Results are computed using heteroskedasticity-robust standard errors.

	ROA	Asset turnover	Tobin's Q
	(1)	(2)	(3)
Post * GreenEx	-0.010	0.188	0.176
	(t = -0.665)	(t = 1.418)	(t = 0.611)
Post * Cert	0.006	0.232*	0.150
	(t = 0.542)	(t = 1.762)	(t = 0.525)
Post * GreenEx * Cert	0.007	-0.169	0.050
	(t = 0.410)	(t = -1.227)	(t = 0.138)
Firm-level controls	Yes	Yes	Yes
Sector-year fixed effects	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes
Observations	215	215	215
R^2	0.225	0.099	0.017
Adjusted R^2	0.183	0.050	-0.036

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

on average generate a greater improvement in asset turnover compared to conventional bond issuers. However, the coefficients for certification are small and statistically insignificant when regressing on *ROA* and *Tobin's Q*. Therefore, the evidence is not sufficiently robust to conclude that green bond certification has a positive effect on issuers' overall financial performance.

All DiD covariates for green-exchange-listed bonds are small and insignificant, regardless of the outcome variable. Similarly, for green bonds that are listed on a green exchange and at the same time certified, all DiD coefficients are small and statistically insignificant.

Overall, our findings show that green bonds are not effective in contributing to better operating performance or efficiency levels, which are indicators of financial performance. Moreover, neither green exchange listing nor third-party certification are found to have a significant impact on green bond issuers' financial performance. The results are congruent with previous studies such as Yeow and Ng (2021) and Sachs et al. (2019), who find that green bonds and conventional bonds are nearly identical in terms of the financial benefits

they provide. Meanwhile, our finding contradicts prior studies such as Flammer (2018) and Zhou and Cui (2019) who find that green bond issuers exhibit superior financial performance. Our results suggest that, at least in the short run, diversifying one's portfolio by including green bonds will not necessarily increase the portfolio's returns. The finding is also consistent with qualitative research conducted by Maltais and Nykvist (2021), whose interviews with Swedish green bond market participants revealed that the primary benefits of green bond issuance are believed to be non-financial (e.g., attracting new customers and staff) rather than financial.

In Table 18, we extend our analysis by investigating a potential moderating effect of EPI scores on issuers' financial performance.

Table 18: The moderating effect of EPI scores on green bond issuers' financial performance

This table shows results for variants of the regressions in Table 16 and includes interactions with the Environmental Performance Index (EPI) score of the issuer's home country (*EPI*) and a dummy variable for green bonds listed on dedicated green bond segments (*GreenEx*). The sample comprises all firm-year observations of the treated and control firms from 2013 to 2020. Results are computed using heteroskedasticity-robust standard errors.

	ROA	Asset turnover	Tobin's Q
	(1)	(2)	(3)
Post * EPI	0.001	-0.003	-0.016
	(t = 0.776)	(t = -1.289)	(t = -0.922)
Post * GreenEx * EPI	-0.002	-0.0003	-0.056
	(t = -1.467)	(t = -0.022)	(t = -0.831)
Firm-level controls	Yes	Yes	Yes
Sector-year fixed effects	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes
Observations	215	215	215
R^2	0.280	0.102	0.035
Adjusted R^2	0.313	0.233	-0.028

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

As is shown, we do not find significant evidence suggesting that the financial performance of firms issuing green bonds in general or issuers of green-exchange-listed bond issuers is moderated by the EPI score of the issuer's home country. The coefficients for the interactions *Post * EPI* and *Post * GreenEx * EPI* are small and insignificant when regressing on *ROA*, *Asset turnover*, and *Tobin's Q*.

Again, this non-finding might be explained either by green bond issuance generally not

having any substantial effect on firms' financial performance, or the EPI score not being a suitable proxy for relevant country differences. As our analysis shows no significant impact on financial improvements for issuers of green bonds (including green-exchange listed bonds), the former explanation appears to be most plausible.

5.3 Stock returns and corporate environmental performance

To further illuminate the role of green bonds as credible signals for firms' environmental commitment, we connect our findings of the event study with the analysis of issuers' environmental performance. Specifically, we create a link between the abnormal returns from green bond issuance and issuers' environmental performance. The aim of this analysis is to explore the capacity of investors to discern green bonds whose issuers indeed achieve substantial environmental improvements post-issuance. For this purpose, we investigate whether the stock market reaction to green bond announcements, as measured by the level of abnormal returns, is correlated with the post-issuance development of firms' environmental performance.

5.3.1 Methodology

Adopting the methodology developed by Sun (1995), we investigate the relationship between abnormal returns and environmental improvements based on the following regression models:

$$CAR_i = \beta_0 + \beta_1 \times \Delta EnvScore_i + x_i + e_i \tag{4}$$

$$CAR_i = \beta_0 + \beta_1 \times \Delta CO2Intensity_i + x_i + e_i \tag{5}$$

where

1) CAR_i = cumulative abnormal return of firm i over the event window
2) $\Delta EnvScore_i$ = change in environmental pillar score of green bond issuer i from pre-issuance year to post-issuance year
3) $\Delta CO2Intensity_i$ = change in CO_2 emissions intensity of green bond issuer i from pre-issuance year to post-issuance year

4) x_i = vector of control variables

5) ε_{it} = error term

The CARs are obtained based on the event study analysis in section 5.1, and were computed using the market-adjusted model for the baseline event window [-5, 5]. For this analysis, we include similar control variables as in our regression on environmental performance (cf. section 5.2.1), namely total assets (natural logarithm), equity multiplier (EM), operating margin (OM), asset turnover (AT), and Tobin's Q. For each of these control variables, we consider the value in the year of the green bond issuance (i.e., at $t = 0$).

Certain bond-specific characteristics may also affect the stock reaction to the announcement of green bonds. In particular, as recognized in previous studies (e.g., Glavas, 2018), the coupon rate, maturity, and issue size of a bond can have an effect on the stock market reaction. To increase the robustness of our results, we add these three bond-level controls in a second variant of each regression model. The variables for the coupon rate and maturity have been winsorized at the 1% level. For issue size, we consider the natural logarithm of the issue amount.

5.3.2 Results

In this section, we present the results of the regression models outlined in Equations (4) and (5), which aim to analyze whether changes in the environmental performance of green bond issuers are significantly correlated with the abnormal returns associated with green bond announcements. As shown in Table 19, we do not find any significant relationship between post-issuance environmental performance and firms' CAR during the baseline event window [-5, 5].

As can be seen, the regression coefficients for both the environmental pillar scores and CO_2 emissions intensity are small and insignificant. Results do not change considerably when adding bond-level controls to the model, indicating a high level of robustness. Hence, we do not find sufficient evidence for a significant correlation between firms' post-issuance environmental performance and the CARs associated with green bond announcements. This indicates that the stock market reaction to such announcements does not depend significantly on the change in environmental performance following green bond issuances.

Table 19: Stock returns and issuers' environmental performance

This table shows results for the regression models outlined in Eq. (4) and (5). $\Delta EnvScore$ refers to the change in the Refinitiv environmental pillar score of green bond issuers from the pre-issuance year to the post-issuance year. $\Delta CO2Intensity$ is the change in the CO_2 emissions intensity (in percent) of green bond issuers from the pre-issuance year to the post-issuance year. *CAR* refers to the cumulative abnormal returns of green bond issuers during the baseline event window [-5, 5], which are calculated based on the market-adjusted model. Column (1) and (3) show results for the regression models including only firm-level controls. Column (2) and (4) show results including both firm-level and bond-level controls. The sample comprises 55 firm-year observations, based on European green bond issuances between 2013 and 2020.

	CAR	CAR	CAR	CAR
	(1)	(2)	(3)	(4)
$\Delta EnvScore$	0.003	0.003		
	(t = 1.447)	(t = 1.299)		
$\Delta CO2Intensity$			0.119	0.120
			(t = 1.273)	(t = 1.303)
Firm-level controls	Yes	Yes	Yes	Yes
Bond-level controls	No	Yes	No	Yes
Observations	55	55	55	55
R^2	0.396	0.459	0.391	0.460
Adjusted R^2	0.321	0.351	0.314	0.351

Note: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Figure 7 provides an illustration of these results. Panel (a) of the figure compares the daily AARs to the announcement of green bonds whose issuers achieve an above-average change in post-issuance environmental ratings to those that exhibit below-average changes. Panel (b) illustrates the same comparison based on the change in issuers' CO_2 emissions intensity.

As is shown, during the event window, abnormal returns of issuers exhibiting superior improvements environmental performance (i.e., above-average $\Delta EnvScore$ or below-average $\Delta CO2Intensity$) are not substantially greater when compared to issuers that do not achieve such improvements.

Overall, our results suggest that green bond investors do not have the capacity to effectively identify those firms that achieve tangible environmental improvements subsequent to issuing a green bond. This is in line with the findings of our DiD analysis on issuers' environmental performance. In this section, we found that neither green exchange listing nor certification are effective indicators that can help to distinguish between

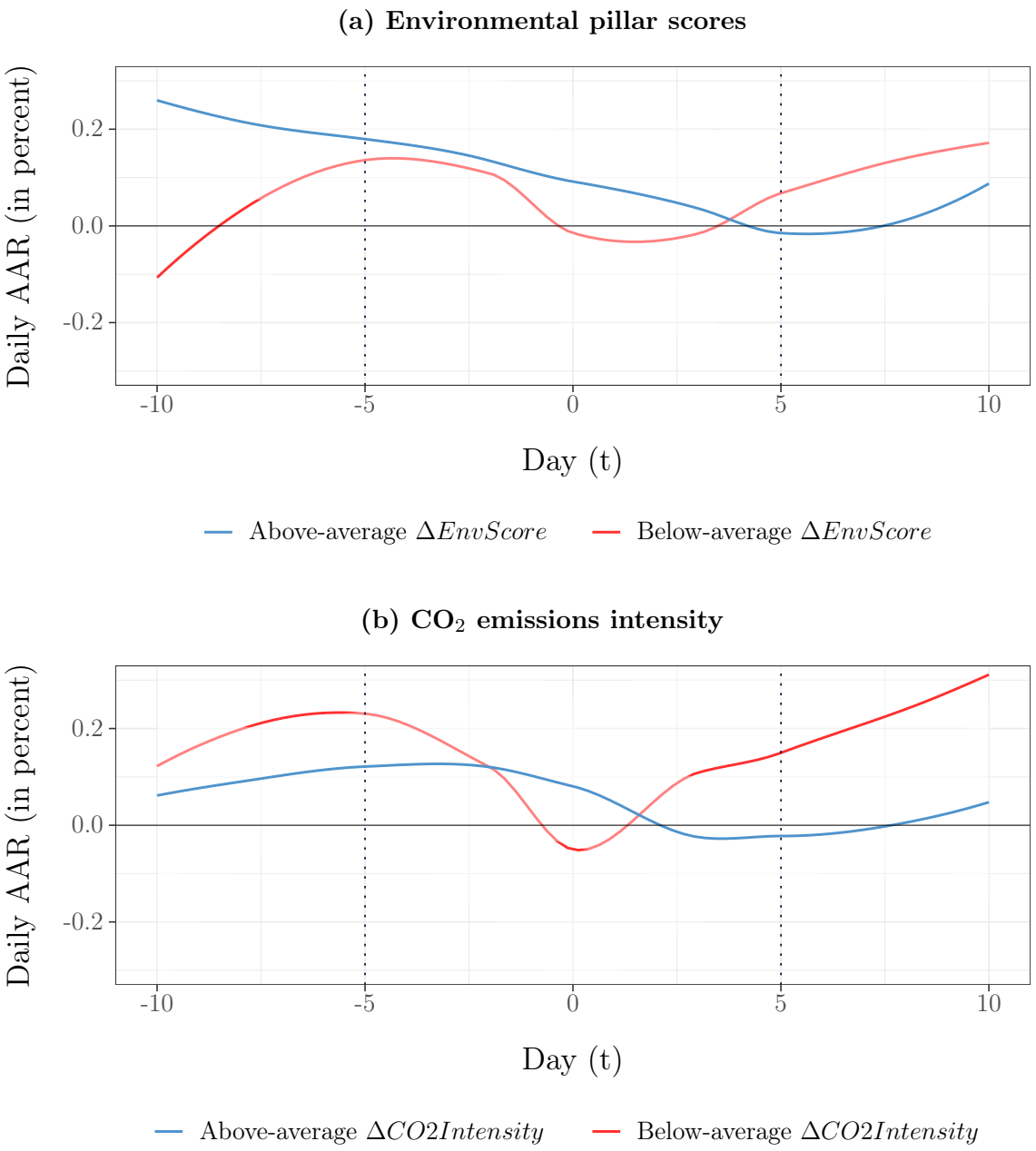

Figure 7: Average abnormal returns (AARs) and issuers' environmental performance

credible green bond issuers from greenwashing firms. The fact that we do not find any significant correlation between the stock market reaction and post-issuance environmental performance further suggests that there currently are no (other) signals that enable investors to make such a distinction. This conclusion is based on the assumption that investors have a preference for green investments that truly have a positive effect on the environment, and/or that investors deem enhanced environmental commitment to yield financial benefits for firms. Since we find a significant stock market reaction for

green-exchange-listed bonds (cf. section 5.1.2.2), it is reasonable to assume that investors do hold such preferences and beliefs.

5.4 Limitations and future research

The limitations of the chosen research methodology are mainly associated with the investigated time horizon. Green bonds are a relatively recent phenomenon, and data availability on environmental performance indicators, such as direct and indirect GHG emissions, is only gradually improving. At present, it is therefore difficult to perform an analysis of green bond issuers' corporate performance with a sufficiently long time horizon. As discussed by Yeow and Ng (2021), green bonds aim to fuel green innovation of firms. However, truly going green often requires vast upfront investments, such as research and development (R&D) on green technologies, practical implementation and (re-)training of employees (Nidumolu et al., 2009). The environmental benefits reaped from these initiatives will typically materialize more profoundly in the long term. Some elements, such as R&D on green product innovation, are incorporated rather quickly into firms' environmental ratings. However, other key indicators of environmental performance, such as GHG emissions, tend to be affected by green initiatives in the longer term. Similarly, green bonds do not affect corporate financial performance directly. Rather, the efficiency gains from green practices likely lead to cost savings predominantly in the long run. Other benefits of turning green, such as increased trust among customers, may also take multiple years to develop and influence firms' financial outcomes (Jørgensen et al., 2022). Hence, we expect that the environmental commitment associated with issuing green bonds only pays off years later, both with regard to environmental and financial benefits.[8] Future research should thus focus on longer time horizons (for instance, 5+ years) in order to accurately measure the impact of green bonds on corporate performance.

Moreover, the chosen DiD methodology has certain shortcomings. While creating a matched control group helps to mitigate the endogeneity concern for green bonds, this does not substitute for an experimental empirical setting in which firms (quasi-)randomly issue green bonds. Future developments in the green bonds markets may provide empirical settings in which endogeneity could be addressed by using an instrumental variable for

[8]For instance, Danish energy company Ørsted has signaled this long-term commitment by issuing multiple green bonds with a 1000-year maturity (Jacobs, 2017).

the issuance of green bonds. For instance, multiple Asian countries, such as Singapore and Japan, have in recent years launched green bond subsidies and grant schemes to help firms cover the costs of external reviews or provide tax deductions for issuance costs (Azhgaliyeva and Kapsalyamova, 2021). If such schemes proliferate, they could potentially facilitate the construction of relevant instrumental variables in future research. Analyzing the long-term implications of green bond issuances in alternative empirical settings could help to advance our understanding of green bonds.

6 Conclusion

Considering the tremendous growth of the green bond market in recent years, establishing the credibility of the signal sent by green bond issuance has become paramount. A credible signal that firms will truly improve their green practices is critical to reducing information asymmetries and agency issues between issuers and investors and thus redirecting capital flows toward green projects that constitute tangible contributions to combatting climate change.

We first examine how the stock market reacts to the issuance of green bonds. We find that the stock market on average does not react positively to issuance announcements. While certification does not appear to affect the investors' response, the stock market reaction is positive and significant for the announcement of green bonds that are listed on green exchanges. Moreover, we find that this reaction is stronger in countries with high levels of asymmetric information regarding firms' environmental efforts. Crucially, our results indicate that firms do not substantially improve their environmental performance following the issuance of green bonds. Similarly, firms' financial performance is not found to be affected significantly by green bond issuances. Neither green exchange listings nor certification are found to have an effect on these firm-level outcomes. In the final part of our analysis, we find that the stock market reaction is not substantially linked to firms' environmental performance post-issuance, indicating that investors are not able to identify "successful" green bond issuers who will achieve tangible environmental improvements.

Overall, our results thus do not support the signaling argument. Due to the combination of stringent listing requirements and greater visibility associated with green exchanges, European investors appear to perceive green exchange listings as a more credible signal of issuers' commitment to green practices than certification. Nevertheless, our results pertaining to issuers' environmental performance suggest that neither green exchange listing nor certification help to identify green bonds whose issuers will achieve tangible improvements in their environmental footprints. Based on our findings, we cannot rule out that issuers are driven by a greenwashing motive, which entails agency issues between investors and issuers. This indicates that the current (mostly privately organized) governance regime for the European green bond market has considerable shortcomings.

To ensure genuine environmental integrity of green bond issuers, alternative governance designs should be explored. For instance, combining private and public governance could increase the efficiency of green bond markets. With the development of the EU Green Bond Standard, the European Commission is taking important first steps towards such a hybrid governance system. Whether this novel system will be successful in establishing a more efficient European green bond market remains to be seen.

Future research on green bonds should aim to build a more profound understanding of the long-term implications of corporate green bond issuance. Since green bonds are a relatively new phenomenon, our analyses are based on a rather small set of observations and a relatively short time horizon. As the market for green bonds matures and firms' environmental disclosures improve, future studies could more precisely investigate the long-term effect of green bond issuance on corporate performance.

While we have focused on the European context in this study due to Europe's leadership role in sustainable finance, further research is needed to understand the specificities of green bond issuance in other regions, such as North America and Asia. As we have seen, the results of our study on Europe have often diverged from the results of similar studies with a global sample, showing that regional specificities can have a strong influence on the credibility, visibility, and informational quality of green bond issuances.

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A Appendix

Table A.1: European stock exchanges with dedicated ESG bond segments

This table lists all European stock exchanges that have launched a dedicated segment for green and/or sustainable bonds.

Name of stock exchange	Type of dedicated segment	Launch year
Oslo Stock Exchange	Green bonds	2015
Stockholm Stock Exchange	Sustainable bonds	2015
London Stock Exchange	Sustainable bonds	2015
Luxembourg Stock Exchange	Luxembourg Green Exchange	2016
Borsa Italiana	Green and Social bonds	2017
Bolsas y Mercados Españoles	Green, Sustainable and Social bonds	2017
Vienna Exchange	Green and Social bonds	2018
Swiss Stock Exchange	Green and Sustainability bonds	2018
Frankfurt Stock Exchange	Green bonds	2018
Euronext	Green, Sustainable and Social bonds	2019

Table A.2: EPI scores of European countries

This table lists the 2020 Environmental Performance Index (EPI) scores of European countries. The data has been retrieved from the Yale Center for Environmental Law & Policy.

Rank	Country	EPI Score
1.	Denmark	82.5
2.	Luxembourg	82.3
3.	Switzerland	81.5
4.	United Kingdom	81.3
5.	France	80.0
6.	Austria	79.6
7.	Finland	78.9
8.	Sweden	78.7
9.	Norway	77.7
10.	Germany	77.2
11.	Netherlands	75.3
12.	Spain	74.3
13.	Belgium	73.3
14.	Ireland	72.8
15.	Iceland	72.3
16.	Slovenia	72.0
17.	Czech Republic	71.0
17.	Italy	71.0
19.	Malta	70.7
20.	Greece	69.1
21.	Slovakia	68.3
22.	Portugal	67.0
23.	Estonia	65.3
24.	Cyprus	64.8
25.	Romania	64.7
26.	Hungary	63.7
27.	Croatia	63.1
28.	Lithuania	62.9
29.	Latvia	61.6
30.	Poland	60.9
31.	Bulgaria	57.0
32.	Serbia	55.2
33.	Belarus	53.0
34.	Armenia	52.3
35.	Ukraine	49.5
36.	Albania	49.0
37.	Azerbaijan	46.5
38.	Montenegro	46.3
39.	Bosnia	45.4
40.	Moldova	44.4
41.	Georgia	41.3

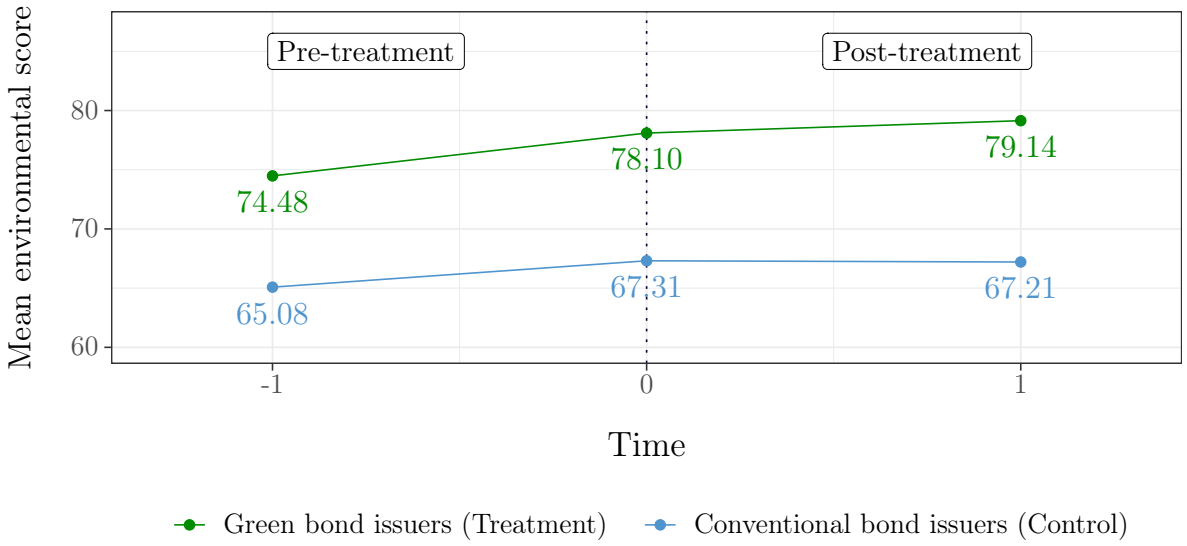

Figure A.1: Visual assessment of the parallel trends assumption for environmental scores