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The effect of green bond issuance on ESG scores

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Abstract

In this study, corporate green bonds, whose proceeds are intended to finance green projects, are analysed. The green bond market has grown exponentially over the last years, leading to calls for public regulation. To test whether public regulation is necessary, the evolution of the Environmental component of ESG scores of industrial firms after a green bond issue was analysed. Using a matched sample of 42 green bond issuers and 42 control firms with similar characteristics, no evidence could be found that supports the signalling argument as the rationale behind a green bond issue. Furthermore, results show that verification status of a bond did not matter, as no significant relationship was found between verified green bond issuance and Environment scores. Overall, this could indicate that greenwashing is an issue in the current green bond market, as greenwashing firms do not aim to improve environmentally after a green bond issue. As a result, public regulation might be a necessary step to legitimize the green bond market.

Keywords: Sustainable Finance; Green Bonds; European Green Bond Standard; Greenwashing

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1 Introduction

Over the last years many initiatives were started to promote sustainability in an attempt to fasten the transition towards a green future. While Corporations mainly valued shareholders' wealth in the past, they have now started incorporating the environment into their long-term objectives (Ensign, 2022). As sustainability becomes more important, investors seem to value sustainable companies more highly than their polluting counterparts. This brings potential financial benefits with it, making the step towards sustainability more attractive for corporations. One of these initiatives, the green bond market, has seen considerable growth over the last decade and a half. Green bonds, which are bonds whose proceeds are committed to finance environmental and climate-friendly projects (ICMA, 2021), are an invention from 2008. Since then, issuance of green bonds has increased from less than 5 billion dollars in 2013 to 487.2 billion in 2022 (Climatebonds, 2023).

Since the market is relatively young, studies into the efficacy of green bonds and the consequences of issuing these bonds are limited. As the market matured over the last years, regulations were added to ensure that the green bond market is used as a legitimate tool by corporations to finance green projects. One of these tools is the verification of green bonds, which involves a third-party assessment to determine whether the projects funded through green bonds meet the criteria to be considered green and if the funds are actually used towards environmental improvements. However, the green bond market currently remains fragmentized, as all green bond verifiers are still private companies that do not adhere to a single taxonomy and verification is not yet mandatory (ICMA, 2021). Greenwashing, which is the deceptive practice where corporations pretend to be environmentally responsible, could therefore still be present in the current green bond market (Talbot, 2017; Badenhoop, 2022; Pyka, 2023).

The European Green Bond Standard (EUGBS), which will be introduced to the market in December 2024, aims to change this by making verification mandatory (European Union, 2023). As for now, the EUGBS is a voluntary standard, but due to the standard being officially released by the European Union (EU) and its alignment with the EU taxonomy, it might become valuable for green bond issuers to follow this new standard. Investors already seem to have a preference for verified green bonds, bringing with it some advantages, such as higher bond premiums and stock market returns (Flammer, 2021; Tang, 2020).

However, there have been counterarguments to the introduction of another green bond standard. According to Brückbauer (2023), another standard will only fragmentize the market further and current standards will converge towards the EU taxonomy anyway as regulation continues to evolve. Additionally, Flammer (2021) finds evidence for the argument that the green bond market is used as a signalling tool rather than a greenwashing tool when testing to see if Environment, Social and Governance (ESG) scores improve after a green bond issue. This supports the argument that current private market standards are fulfilling the regulatory role appropriately. However, the study done by Flammer (2021) only contains data until 2018, while a significant amount of green bond issues have happened since that year. The study also includes all corporate green bond issues globally, while greenwashing might be more prevalent in specific markets.

To find out whether a new standard is truly necessary or will only fragmentize the market further, this study will test if companies do in fact improve environmentally after the issuance of green bonds. If this is the case, the signalling argument Flammer (2021) proposes as the rationale behind a green bond issue would be supported. Otherwise, greenwashing might be present, which would support the argument that the EUGBS is a necessary step to legitimize the green bond market. To test whether verification alters this effect and if mandatory verification in the future would be an advisable option for the EU, this study will test whether European corporations put in more effort to improve environmentally if their green bonds are verified. Thus, this study aims to answer the following research question:

> *How does the first-time issuance and verification of corporate green bonds impact the scores of the environmental component of ESG scores for corporations in the European Union?*

To answer this question, green bond issuers were first matched with a similar corporation based on several characteristics that determine the likelihood of a green bond issue in a given year. 42 green bond issuers were identified that fulfilled all criteria, which were matched to 42 control firms that have similar characteristics in the pre-issue year of green bond issuers using the nearest-neighbour matching approach and propensity scoring. Using this method, a green bond issuer is matched with a control firm based on having the smallest distance across all used covariates. Doing this ensures that green bond issuers and control firms are as similar as possible, so that the effect of a green bond issue on the Environment score can be isolated.

Following the matching process, a Difference-in-Differences regression was run to find out the effect of a first-time green bond issue on the Environment score of corporations. A significant increase in environment score after an issue would support the signalling argument, as firms that intend to credibly signal a commitment to the environment are expected to improve their environmental awareness, which would be reflected in their Environment score. Subsequently, a second Difference-in-Differences regression was performed to find out whether a firm that issued verified green bonds saw a greater increase in Environment score, by adding an extra dummy variable for verification status. Verified bonds are costlier and firms that issue them undergo more scrutiny, improving the strength of the signal as it further reduces information asymmetry between managers and investors. As a result, a greater increase in environment score is expected for verified green bonds due to the increased credibility of the signal. A significant effect that is stronger for verified green bonds would therefore support the signalling theory further. Additionally, due to the subjectivity of ESG scores (Berg et al., 2020; Chatterji, et al., 2016), regressions were also run with CO_2 emissions as the dependent variable to increase the robustness of the study.

No significant relationship was found when testing whether green bond issuance had an effect on either the Environment score or CO_2 emissions of corporations. The lack of a significant relationship is not consistent with the theory that corporations signal their intentions of environmental awareness towards investors when issuing green bonds. The effect remained insignificant when the verification status of a green bond was included in the regression model, indicating that firms issuing verified green bonds also saw no significant improvement in environment score. A possible explanation for the lack of environmental improvement after a green bond issue could be that firms use the green bond market as a greenwashing tool. In this case, a corporation does not intend to improve environmentally, but tries to seem environmentally friendly to appease investors. Alternatively, it could be explained by the fact that most of the analysed green bonds were issued only recently. Environment score improvements might take time, especially for industrial firms, but since the green bond market is still quite young, the long-term effects could not yet be analysed properly.

The findings of this paper provide practical implications for the regulation of the green bond market in the EU and investors. Firstly, a lack of improvement in the environment score of green bond issuers might indicate that greenwashing is present in the European green bond market. In this case the introduction of the EUGBS and further regulations would be a necessary step to legitimize the green bond market. Secondly, it helps investors gain insight on whether firms actually commit to the environment after raising funds for green projects. The lack of significant results might indicate that a green bond issue is not enough to determine whether a firm is committed to the environment. Finally, the study adds to the existing literature by helping to understand the rationale behind the issuance of green bonds. A better understanding of the rationale of firms when using new green financial tools could help prevent the misuse of these tools through the development of the appropriate public regulation.

The rest of the paper is organized as follows: the next chapter will go into depth about the theoretical background of this research. Then, the methodology of the study will be discussed. Subsequently, the results will be presented and analysed, after which the study will be concluded in the final chapter.

2 Literature review

2.1 Green bond market

As mentioned in the introduction, a green bond is a bond of which the proceeds are committed to finance environmental and climate-friendly projects. The green bond market has existed for less than 16 years at the time of the study and has just recently gained traction as a legitimate tool for sustainable financing. It was not until 2017 that the number of yearly corporate industrial green bond issuances exceeded 100, while in 2023 the amount of yearly issuances had risen to around 500 (ICMA, 2024).

Initially, no legal definition of what pertains to a green bond existed, causing many academics to argue that the green bond market was heavily underregulated (Berensmann, 2017; Lehner et al., 2023). As a response, the Climate Bonds Initiative (CBI) and the International Capital Market Association (ICMA), two private entities, created frameworks to provide these definitions. Both the Climate Bond Standards (CBS) introduced by CBI in 2011 and Green Bond Principles (GBP) introduced by ICMA in 2014 provided rules to follow for corporations issuing green bonds.

Although this move increased investor confidence in the legitimacy of green bonds, academics still doubt the true efficacy of the green bond label. The lack of legal enforcement and a uniform taxonomy to follow, allows corporations to still attach a green label to their bonds without having to face any repercussions if the bond is not actually green (Talbot, 2017; Badenhoop, 2022; Pyka, 2023). This phenomenon, called greenwashing, allows companies to deceptively pretend to practice environmental friendliness, while not actually following through on promises of sustainability. The potential of greenwashing decreases investor trust in the green bond market, making the potential benefits of issuing a legitimate green bond, such as an improved public image for example, less impactful and thus decreases the appeal of the financial tool to begin with. As a result, corporations that wish to signal the legitimacy of a green bond have to incur additional transactions costs to prove to investors that funds are actually committed towards green projects. This creates an additional barrier of entry for financing green projects with green bonds (Deschryver & de Mariz, 2020; Flammer, 2021). Also, due to green bond issuers having to rely on private entities to verify green bonds, the market has become fragmentized, as no true standard exists for green bond issuers to follow. Several scholars therefore propose that public entities such as the European Union (EU) should take a leading role in regulating the green bond market (Berensmann, 2017; Torvanger et al., 2021).

As a result, the EU started working towards creating a framework for green bonds that presents principles-based guidance on what economic activities are eligible for a green bond by referring to the EU taxonomy. This framework, called the EU Green Bond Standard (EUGBS), was approved by the European Commission in 2023 and will be introduced in 2024 (European Commission, 2023). With the EUGBS, the EU attempts to increase the standardization in the green bond market by claiming to be the most comprehensive standard compared to widely-used private standards, such as the CBS and GBP. The European Commission asserts that the EUGBS' introduction will enhance the legitimacy of the green bond market due to the new standards set for rating, external review and reporting. Initially, The EUGBS will be a voluntary standard that can be followed by any green bond issuer. As it is the most comprehensive standard, it does require issuers to be verified by a third-party to ensure that funds are appropriately allocated (European Union, 2023).

Several academics argue that the introduction of the EUGBS is no adequate response to the fragmentation of standards in the green bond market. Brückbauer et al. (2023) mentions that the voluntary nature of the EUGBS provides little incentive for corporations to switch from the currently established private standards. The European Central Bank also mentions this as an objection to the introduction of the EUGBS, proposing that the EUGBS be set as the mandatory standard in the EU after a transition period (European Central Bank, 2021). Furthermore, Pyka (2023) argues that in addition to fragmenting the market further, the lack of additional enforcement mechanisms that can be used by green bond holders in case of a so-called 'green default' is also a problematic deficiency. A green default happens when a company uses the raised funds towards projects that are not green in nature. This raises the concern that greenwashing is not appropriately dealt with in this new public standard and is still allowed to exist in the market.

2.2 Rationale for issuing green bonds

To help settle the debate on the necessity of the EUGBS, it is important to first examine the rationales of corporations for issuing green bonds. Green bonds are an interesting financial instrument, as corporations voluntarily restrict the use of raised funds to green projects. Alternatively, a corporation could raise funds for green projects using the conventional bond market, which does not impose such restrictions. Additionally, to officially certify a green bond, a corporation has to undergo third-party verification, which brings additional compliance and administrative costs with it. Thus, it seems to make more intuitive sense to fund green projects using the conventional bond market. Nonetheless, corporations still opt to fund their green projects using the green bond market.

Flammer (2021) theorized that there could be three reasons for use of the green bond market: signalling a commitment to the environment, greenwashing or the reduced cost of capital.

Looking at the worldwide issuance of corporate green bonds up until 2018, Flammer (2021) only found evidence supporting the signalling argument by looking at the ESG scores before and after issuance. According to this study, a rise in ESG score after the issuance of a green bond would show that a corporation intended to send a credible signal to investors of a future focus on the environment.

The rationale behind the signalling argument is rooted in the motivation to reduce information asymmetry between the corporation's management and its investors. As managers have more private information that is not accessible to investors, they have an advantage in understanding the true financial health and future prospects of the corporation. This may create situations where managers make decisions within the corporation to pursue personal benefits rather than act in the best interests of the investors. This dynamic underlines one of the key points in agency theory, which states that there is a misalignment between the interests of these two parties, as management (agent) and investors (principals) often have different motivations (Jensen & Meckling, 1976; Ross, 1973). Issuing a green bond is an attempt at reducing the information asymmetry between the two parties by sending a clear signal that the interest of both parties are aligned. By showing that the corporation is willing to voluntarily reserve the raised funds for sustainable projects, it shows a credible commitment towards the environment, thus building trust with investors.

Since the information asymmetry between management and investors is reduced after the first issue of a green bond, additional issues of green bonds are not expected to have a substantial impact on investor perception. The commitment towards the environment was already signalled during the first green bond issue, resulting in a weak signal for additional green bond issues. Flammer (2021) supports this, as their study found no significant increase in ESG scores with additional green bond issues after the initial issuance.

Investors often lack the information to evaluate whether a corporation is truly committed to the environment (Lyon & Maxwell, 2011; Lyon & Montgomery, 2015), making a credible signal necessary to identify them. A signal is often deemed more credible if comes at a higher cost to mimic for corporations with less desirable characteristics (Riley, 1979; Spence, 1973). Thus, third-party verification of a bond can improve the credibility of a signal substantially. Bachelet et al.

(2019) agrees with this sentiment and mentions that verification is a critical aspect for investors as it reduces the information asymmetry considerably. For example, if a corporation wishes to be verified according to the CBS, there are two phases in which the corporation must undergo verification:

1. Pre-issuance: The projects funded by the bond proceeds must be eligible under the CBS and specified as being green. Additionally, a corporation must have established internal processes and controls to keep track of the use of bond proceeds.
2. Post-issuance: A certifier must verify whether the proceeds of the green bond have been appropriately allocated to green projects in accordance with the CBS. (Climate Bond Standard, 2024)

This process brings significant expenses and scrutiny with it and reveals a lot of information to investors, improving the strength of the signal. Therefore, If a corporations willingly verifies their green bond, it is likely that their commitment to the environment is strong.

Sending a credible signal can provide tangible financial benefits for a corporation, leading to the argument that firms might use the green bond market due to the reduced cost of capital (Flammer, 2021). According to several event studies, a companies' engagement toward the environment results in positive abnormal returns in the stock market (Flammer, 2013; Klassen & McLaughlin, 1996; Krueger, 2015). Academics investigating this aspect in the green bond market by looking at the cumulative abnormal returns after the announcement of a green bond issue have found the same positive returns (Flammer, 2021; Laborda, 2021; Tang et al., 2020; Wang et al., 2020). Flammer (2021) further proves that verification of a green bond results in larger abnormal returns, supporting the notion that investors reward stronger credible signals more significantly.

Another benefit mentioned in several studies is the green bond premium on the bond market itself (Nanayakkara et al., 2019; Wang et al., 2020). Such a premium, also called the greenium, would mean that green bonds have lower yields compared to conventional bonds. This would result in a lower cost of capital for issuers, attracting corporations towards the green bond market for cheaper capital. Whether the greenium truly exists is heavily debated, as other studies find no evidence of its existence (Flammer, 2021; Larcker and Watts, 2019; Lau et al., 2022). According to these studies, the greenium does not exist due to investors fearing greenwashing. Field research also supports the notion that the greenium does not exist, as interviews and surveys with investors revealed that they would not be willing to invest in green bonds if the returns were not competitive (Flammer, 2021).

2.3 Greenwashing

The aforementioned benefits of the issuance of a green bond could be attractive enough to corporations to feign environmental consciousness and enter the green bond market without the intent for improvement. Thus, greenwashing becomes a more probable threat. According to Flammer (2021), greenwashing in the green bond market can be identified by looking at ESG scores. ESG scores are calculated yearly and published with a decent delay due to the comprehensiveness of the included information in these scores. ESG scores can also pose as a signal towards the investor, as higher ESG scores or specifically a high score on the Environment pillar signals an increased environmental awareness (Huang, 2021; Wong & Zhang, 2022). Since ESG scores are calculated by a third party and not the companies themselves, they are harder to manipulate and thus present a fairer image to investors. Therefore, it is expected that firms that actually intent to improve environmentally will improve their ESG score, while firms that greenwash will not. Thus, if green bond issuers signal their values relating to environmental consciousness with a green bond issue, this should be reflected in the environmental pillar of their ESG score in the years after an issue. In contrast, a corporation that issues green bonds purely for the financial benefits would not commit to improve environmentally, thus no improvement in ESG scores would be expected in this case.

2.4 Hypotheses

If the signalling argument is supported and firms wish to signal investors their commitment to the environment by issuing a green bond, then ESG scores are expected to improve after a first-time issue of a green bond. Thus, the following hypothesis was constructed:

H1: The environmental component of the ESG scores of corporations in the EU increases after the first-time issuance of green bonds.

If this hypothesis is rejected and no significant improvement is found in the environmental component of ESG scores after a green bond issue, then greenwashing may be a possible explanation. In this case, the introduction of the EUGBS could help legitimize the green bond market by providing public regulation that prevents firms from using the market as a greenwashing tool.

Additionally, it is important to look at the role of verification, as mandatory verification is one of the main points of the EUGBS. Corporations that issue verified green bonds signal more credibly that they are committed towards the environment, due to the increased cost and scrutiny associated with the verification process. As a result, a greater increase is expected after the issue of a verified green bond compared to a non-verified green bond. Therefore, the following hypothesis was constructed:

H2: Corporations that issue green bonds verified by a third party see a greater increase in the environmental component of ESG scores than corporations that issue non-verified green bonds

Determining whether verification is an important aspect of the credibility of a signal could help indicate whether future regulations surrounding mandatory verification of green bonds are necessary.

3 Methodology

The effect of green bond issuance on ESG scores and CO2 emissions will be analysed by first matching the sample of green bond issuers through propensity scoring and nearest neighbour matching with regular bond issuers. Then, the matched data will be used to estimate the effect of green bond issuance on ESG scores and CO2 emissions through a fixed effects Difference-in-Differences regression.

3.1 Data collection

The data for this study was collected using the LSEG database. First, data was collected on corporate green bond issuances in Europe. This was done by filtering the data on green bond issuances, filtering the country of issue on just countries within the European Union (EU) and excluding bonds issued by government entities. Eurobonds that were issued by corporations that operate within the EU were also included in the filter with all issue amounts being converted to the United States Dollar, as this is the standard currency used by the LSEG database. All recorded issuances of green bonds were included in this data, with the first recorded corporate issue happening in 2013 and the last issues happening in 2024. Between 2013 and 2024 3.078 green bonds were issued by a total of 558 corporations.

Table 1 shows the summary statistics of all green bonds issued in the EU. The rapid growth of the green bond market is clearly visible, although growth does seem to stagnate over the last few years. The stagnation of the total issue amount in 2020 could possibly be explained by the fact that investors were practicing increased risk aversion during the COVID-19 pandemic, causing a dip in the demand for bonds. Additionally, the interest rate hikes starting in July 2022 in the EU (European Central Bank, 2024) might explain the decrease in the number of corporate green bonds issued starting in 2022. Interest rate hikes cause bond yields to increase, making it more expensive for corporations to borrow money. This makes it less attractive to enter the green bond market to fund new green projects.

TABLE 1. CORPORATE GREEN BONDS WITHIN THE EU OVER TIME

This table reports the number of corporate green bonds issued per year, the percentage of these bonds that were verified green bonds, the average amount these bonds were worth in millions of USD per year and the total issuance amount in millions of dollars. For this data, all corporate green bonds issued in the European Union from 2013-2024 were analysed.

Year	Number of bonds	Verified %	Average issue amount Millions USD	Total issue amount Millions USD
2013	14	43%	154.56	2,163.86
2014	56	34%	135.95	7,613.43
2015	45	33%	249.00	11,205.00
2016	69	32%	271.19	18,712.43
2017	116	41%	301.84	35,013.56
2018	123	43%	242.17	29,786.41
2019	251	56%	304.62	76,156.07
2020	426	42%	188.16	80,156.59
2021	680	52%	222.69	151,430.17
2022	597	77%	294.32	175,709.33
2023	492	83%	312.08	153,230.81
2024*	209	85%	334.68	68,944.15
Total	**3078**	**61%**	**263.63**	**810,121.81**

*Data from 2024 only contains the bond issuances until the first of May.

Another interesting statistic is the percentage of green bonds verified by a third-party. A green bond is noted as being verified if it has received a Second Party Opinion (SPO) according to the data retrieved from the LSEG database. In 2022 the amount of verified green bonds notably jumps from 52% to 77%. This can possibly be explained by the release of the legislative proposal for the EUGBS in July of 2021, in which mandatory verification is mentioned as one of its core components (European Commission, 2023). Corporations might be preparing for the entry of the EUGBS onto the market and expect the importance of verification to increase.

3.2 Data filtering and panel data

To ensure that the necessary data is available and only corporations with useful ESG data remain, two additional types of firms were filtered out. Firstly, Corporations operating in a financial sector according to the first two digits of their SIC (Standard Industrial Classification) were excluded from the dataset. Financial institutions have a different regulatory environment and its operations are often indirectly responsible for environmental damages through investments and financial services. ESG scores, in particular the environmental pillar, of these corporations are therefore often dependent on investments and thus often more reflective of their portfolios rather than production or direct environmental impact (Crespi & Migliavacca, 2020). Eliminating financial corporations from the data results in the removal of 385 corporations from the dataset. Secondly, private corporations were removed by excluding every corporation that did not have an active public International Securities Identification Number (ISIN). Private firms are rarely scored on ESG performance and do not offer enough information regarding their financials to accurately analyse the effects of a green bond issue. An additional 101 corporations were either not publicly traded or had no information on ESG scores and were therefore removed, leaving just 72 corporations that fulfil all criteria. After filtering out the private and financial firms, only public industrial corporations remain

To assess the effects of green bond issuance, panel data on several variables were retrieved from the LSEG database for the 72 corporations that fulfilled the previous requirements. First, the total LSEG ESG scores and individual pillar scores (Environment, Governance and Social) of these corporations were retrieved for the years 2011 - 2024. A caveat of using ESG scores calculated by a single company is the subjective nature of ESG ratings (Berg et al., 2020; Chatterji, et al., 2016). Scores might also increase directly as a result of issuance of green bonds, since this might qualify as showing environmental awareness. Therefore, an additional test was executed to increase robustness. Similarly to Flammer (2021), the ratio of CO_2 emissions (in tonnes) divided by the book value of assets in millions of US dollars was also tested as a dependent variable in the model as an alternative to using ESG scores. CO_2 emissions are calculated by the same third-party that calculates the ESG scores, in this case LSEG. The amount of CO_2 emissions is one of the main parameters to determine sustainability and is used widely as a benchmark for assessing a company's environmental performance (Alvarez, 2012; Matsumura et al., 2014; Smale et al., 2006). It is an objective measure that should show improvement if corporations improve their environmental performance. Therefore, it is expected that any increase in ESG score should be accompanied by a decrease in CO_2 emissions. Data on the total CO_2 emissions is also collected from the LSEG database and includes both scope 1 (direct) and 2 (indirect through energy use) emissions. Dividing this data by the value of assets is necessary to control for the direct influence of the size of a firm on CO_2 emissions.

Finally, corporations that did not have an ESG score prior or after the year of first green bond issuance were excluded from the dataset, since these corporations could not be matched and analysed to see the effects of the issuance. Since ESG scores calculations are relatively elaborate and therefore require some time to calculate, most corporations only have updated ESG scores until 2022. Thus, all corporations that issued green bonds in or after 2022 did not have sufficient data on ESG scores and were eliminated from the dataset. After eliminating the 19 corporations that issued green bonds in or after 2022 and 11 other corporations that did not have ESG data in their pre-issue year, 42 corporations that issued 120 bonds in total of which 86 were verified remain in the final dataset that can be analysed.

3.3 Matching

Studying the effects of green bond issuance on corporate ESG performance is difficult due to the inherent endogeneity present in the link between the two. Companies in industries with stricter environmental regulations are more likely to find ways to improve their ESG scores through green bonds for example (Lu & Cheng, 2023; Naeem & Cankaya, 2022). Certain industries are therefore more represented when looking at green bond issuance, such as the energy industry or the transportation industry (Flammer, 2021). Besides, companies with higher ESG scores might also be more environment-focused and as a result be more likely to issue green bonds and further improve their ESG scores. In summary, the issuance of green bonds is not random. It is difficult to find an instrumental variable that can be introduced to the model to get rid of this endogeneity due to the high variety of factors influencing the likeliness of a company to issue green bonds. As an alternative approach, nearest neighbour matching is used to attempt to get rid of the endogeneity. Green bond issuers are matched with corporations that did not issue green bonds based on several variables that have been shown to influence the tendency of corporations to issue green bonds or debt in general using the nearest neighbour matching approach. This way, an artificial sample is created of corporations with similar statistics, where a green bond issue can be considered random, as matched firms have a similar likelihood of issuing a green bond. If the matching is successful, it allows for an unbiased comparison in which the effect of a green bond issue on the Environment score can be isolated.

The nearest neighbour matching approach was chosen over alternative matching approaches due to its effective matching (Austin, 2014). Due to the small sample size of 42 green bond issuers, it is important that no or very few issuers are emitted from the data as a result of the matching process. Nearest neighbour matching ensures that each green bond issuer is matched to the closest control unit based on similar characteristics. Using this matching method, all green bond issuers will be matched, even if the distance between two firms is large for some of the used matching variables. A caveat of this method is that it requires a Welch two-sample t-test to see whether the matching was a success. If the distances for the matching variables are too large, some endogeneity could still persist, as the effect of a green bond issue would not be completely isolated.

The matching of the green bond issuers or “treated” firms with similar corporations, “control firms”, is based on data from several variables one year pre-issuance. Control firms are required to be public firms that have issued a regular corporate bond in the past within the EU. This ensures that control firms have access to the bond market and have used it as a tool to raise capital. To compensate for the effect of the industry on green bond issuance, the control firms must also operate within the same industries as the treated firms. This is based on the first two digits of the SIC. Any control firms that operate in industries that are not represented in the green bond dataset are excluded.

After filtering the data, the firms have been matched based on five variables one year pre-issuance: The environment pillar of the ESG score, size, Tobin's Q, Return on Assets (ROA) and Leverage (Debt-To-Capital). Matching based on Environment score pre-issuance ensures that corporations that have a tendency to issue green bonds due to their focus on environmental performance are matched with a firm that also focuses on environmental performance. The other four variables have been used in previous studies to match companies, since this ensures financial similarity (Almeida, et al., 2012; Frésard & Valta, 2016). By matching based on measures of profitability, such as ROA and Tobin's Q, the concern that treated firms are more profitable or have better growth opportunities is ruled out. Tobin's Q indicates how a firm is valued by investors, by adding market capitalization to the value of assets, subtracting the book value of common stock and dividing the result by the value of assets. Matching based on the other two variables, size (assets) and debt capacity (leverage), further ensures that corporations in the treatment group do not have better access to capital markets. Data on the asset value of firms will be logarithmized to improve the readability of the dataset. Additionally, to prevent outliers from impacting the regression, all ratios will be Winsorized at the 1st and 99th percentiles of their distribution.

In addition to using the nearest neighbour matching approach, a propensity score was calculated to estimate if the sample can be matched and how well the matching was executed. Propensity scores were calculated by using the following logistic regression:

$$(1)\ \ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 Size + \beta_2 TobinsQ + \beta_3 ROA + \beta_4 Leverage + \beta_5 EnvironmentScore + \beta_6 Industry$$

The propensity score (P) indicates how likely a firm is to issue a green bond in the year of observation based on the independent variables listed in the equation. An summarized overview of these variables can be found in Appendix I. In an ideal scenario, matched firms have similar propensity scores in the same year after using the nearest neighbour matching approach. After the matching was completed, all unmatched firms were excluded from the dataset, so that only the dataset with matched firms remained.

To test whether the matching was successful, a Welch two-sample t-test was performed to assess whether there are significant differences between the treated and control firms for all matching variables. If no significant differences are found between the two groups, the matching process can be considered a success. This would mean that every green bond issuer is matched with an appropriate counterfactual that behaves similarly to how the green bond issuer would behave if they had not issued a green bond.

3.4 Difference-in-Differences

The matched dataset was then used to perform a Difference-in-Differences (DiD) regression to identify the influence of green bond issuance on either Environment score or CO_2 emissions. Having a perfectly matched dataset of treated and control companies would eliminate the need for any control variables in the DiD regression. In a perfectly matched dataset the only difference between the treatment and control firms would be the issuance of a green bond. However, no two corporation are the exact same in all areas, thus fully perfect matches can never be produced. As a result, some individual differences that could influence the regression will always remain. These individual effects were controlled for by using a fixed effects regression, controlling for both individual specific and time fixed effects.

Additionally, Firm size has been shown to have an influence on ESG scores due to the enhanced organizational legitimacy of larger corporations (Drempetic et al., 2020). Any change in firm size over time can therefore have an impact on the difference between ESG scores of matched firms. This effect is corrected for by adding a control variable for firm size according to the value of assets when the Environment Score is analysed.

In a DiD regression, several dummy variables are used to indicate whether a firm belongs to the treatment group and if treatment has taken place. All treated firms are identified by a 1 for the variable *GreenBond*, while control firms are indicated with a 0. The dummy variable *Post* indicates whether a green bond has been issued and remains 1 for all years after the issuance. This dummy variable also turns to 1 for the matched control firm associated with the treated firm in the same year, so there is a distinguished pre- and post-treatment period for all matched pairs. Finally, the interaction term *Greenbond * Post* is introduced to estimate the effects of the treatment, which in this case would be the first-time issuance of a green bond. Taking these things into account, the following fixed effects regression equation was formulated:

$$(2)\ Y_{it} = \beta_1 Y_{i(t-1)} + \beta_2 GreenBond_i + \beta_3 Post_t + \beta_4 (GreenBond_i * Post_t) + \beta_5 Size_{it} + \alpha_{it} + \varepsilon_{it}$$

. *Y* is used to denote the dependent variable, which is either *EnvironmentScore* or *CO2divAssets*, which is the amount of CO_2 emissions divided by the value of assets. The values of the dependent variables are, in part, explained by the values of the dependent variables in the previous period due to the continuity of Environment Scores and CO_2 emissions. To prevent autocorrelation from being an issue, the dependent variable lagged with one period was added to the regression model as an independent variable. Subscript *i* and *t*, indicate the individual (firm) and time respectively. The fixed effects of both individuals and time are captured with α_{it}, while the error term is captured with ε_{it}. The coefficient of the interaction term indicates the strength of the effect of an issuance, as it denotes the difference between the treatment and control group after the issuance of a green bond. A summarized overview of the used covariates can be found in Appendix I

To test whether verification alters the effect of a green bond issue, the dummy variable *Verification* was added. This dummy variable will be 1 for every firm that has issued a verified green bond. The dummy variable will be included in an additional interaction term multiplying *Verification* with *Post* so that it will turn to 1 following the issue of a verified green bond. The coefficient of this interaction term indicates the impact of a verified green bond issue on the Environment Score. Adding this new dummy and interaction term will make the regression equation to test the impact of green bond verification on Environment Score as follows:

$$(3)\ Y_{it} = \beta_1 Y_{i(t-1)} + \beta_2 GreenBond_i + \beta_3 Post_t + \beta_4 (GreenBond_i * Post_t) + \beta_5 Verification_i + \beta_6 (Verification_i * Post_t) + \beta_7 Size_{it} + \alpha_{it} + \varepsilon_{it}$$

4 Results

First, the results of the matching process will be presented. Then, the results of the DiD regression regarding the influence of green bond issuance on both Environment score and CO_2 emissions will be presented and interpreted. Finally, the effect of verification on the strength of the effect will be analysed.

4.1 Matching results

First a propensity score (p-score) was calculated for all years and firms in the dataset that were going to be matched. This propensity score indicates how likely a firm was to issue a green bond in a given year. This likelihood is calculated by using a logistic regression that includes variables that influence the likelihood of a green bond issue, which can be found in equation (1). Preferably, firms with similar p-scores and thus a similar chance of issuing a green bond that year are matched. This helps create comparable groups based on the used covariates, so that the influence of a green bond can be isolated.

To estimate whether matching is a feasible approach, a histogram was made to visualize the p-scores of the treated and control firms. Ideally, there is a lot of overlap, as this means that green bond issuers can be matched with a control firm that has a similar likelihood of issuing a green bond. As can be seen in Figure 1, the p-scores of treated and control firms overlap for most scores, which indicates that matching is a feasible approach. Since there are only 42 treated firms that can be matched and analysed, it is essential that no or very little green bond issuers are discarded during the matching process. The overlap of p-scores shows that no treated firms will have to be discarded in this case.

Additionally, before matching, a Welch two-sample t-test was run on the unmatched dataset to test the assumption that the dataset is not random and that a green bond issuer can be identified by the matching criteria. The results of the Welch test can be found in Table 2. The p-value for all matching variables except for the Return On Assets is highly significant, indicating that the difference in means is unlikely to have occurred as a result of random sampling variability.

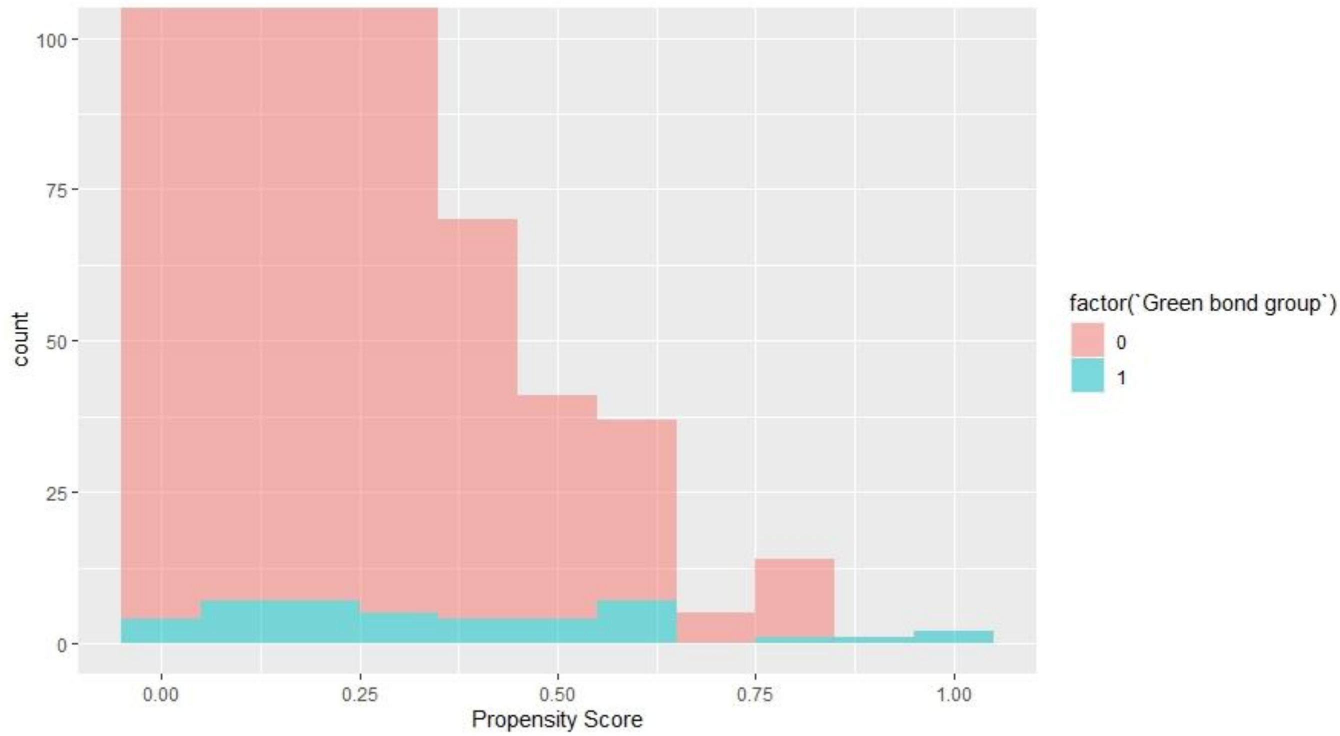

FIGURE 1. ZOOMED IN HISTOGRAM OF PROPENSITY SCORES OF TREATED AND CONTROL FIRMS

TABLE 2. RESULTS WELCH TWO-SAMPLE T-TEST PRE-MATCHING INCLUDING ALL FIRM-YEARS

This table shows the mean and standard deviation of each variable for corporations that issued a green bond and for corporations that did not. The significant p-values indicate that the difference between the two groups is significant enough to identify in which group the firm belongs.

	Green bond Issuers (1)	Control firms (0)	p-value (diff. in means)
Log(Assets)	10.203337	9.843537	< 2.2e-16***
	(0.664)	(0.653)	
Tobin's Q	1.593233	1.866161	< 2.2e-16***
	(0.461)	(0.907)	
Return On Assets	4.353418	4.175359	0.5173
	(5.01)	(6.73)	
Debt%	48.35125	44.74247	0.0007423***
	(19.9)	(23.6)	
Environment score	73.30520	60.51558	< 2.2e-16***
	(17.5)	(23.1)	
Observations	433	2588	

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

Matching was performed by using the nearest neighbour matching approach to match one green bond issuer with one control firm in the same year pre-issue. No treated firms were discarded as a result of the matching process. As such, the matched dataset consists of 42 treated and 42 control firms. After matching, another Welch two-sample t-test was run on the matching variables to test whether the dataset can be considered random. The results, shown in Table 3, indicate that the matching process was successful. All p-values of the matching variables are non-significant and means have converged. Additionally, the average p-score of both groups were checked on similarity. In the optimal scenario, the p-scores of both groups are similar, as individual matches should have p-scores that match. The average p-score of the control group does still show a significant difference in means. The most probable reason for this is the limited amount of control firms that are available for matching. To account for the difference in p-scores, an alternatively matched dataset will also be analysed. Both datasets will then be further regressed and checked for differences.

TABLE 3. RESULTS WELCH TWO-SAMPLE T-TEST POST-MATCHING

This table shows the mean and standard deviation of each variable for corporations that issued a green bond and for corporations that did not after matching the sample. The p-values are insignificant, indicating that a firm cannot be identified as belonging to one of either groups based on the variables.

	Green bond Issuers (1)	Control firms (0)	p-value (diff. in means)
Log(Assets)	10.05344	10.14946	0.5186
	(0.722)	(0.632)	
Tobin's Q	1.617601	1.676873	0.7132
	(0.693)	(0.777)	
Return On Assets	4.275238	4.526429	0.8088
	(2.96)	(6.01)	
Debt%	47.03952	41.48905	0.2034
	(20.9)	(18.7)	
Environment score	71.84667	71.65286	0.9614
	(17.7)	(18.9)	
Propensity score	0.3644597	0.2567147	0.03629**
	(0.267)	(0.190)	
Observations	42	42	

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

After matching the datasets the Environment score and CO_2 emissions were plotted to see how the dependent variables change over time. These plots can be found in Appendix II. The results of the Welch two-sample t-test and plots for the alternatively matched dataset can be found in Appendix III.

4.2 Effects of green bond issuance

The matched dataset was used to perform a Difference-in-Differences regressions to identify the effects of green bond issuance on Environment score and CO_2 emissions. The results of these regressions can be found in Table 4.

TABLE 4. RESULTS OF THE DIFFERENCE-IN-DIFFERENCES REGRESSIONS REGARDING THE EFFECTS OF GREEN BOND ISSUANCE ON ENVIRONMENT SCORE AND CO_2 EMISSIONS

*This table reports estimates for the Difference-in-Differences specification. Environment score refers to the Environment pillar of ESG scores. The variable CO2 / Assets is calculated by dividing the total amount of direct and indirect CO2 emissions in tonnes by the book value of assets in millions of US dollars. L1 indicates that the variable is lagged with one period, which was included for both dependent variables. Green bond * Post indicates the effect of green bond issuance on ESG scores. Green Bond group is a dummy variable that is 1 for all green bond issuers and Post green bond is 1 for the period after the first-time issuance of a green bond. Finally, the variable Assets denotes how much the logarithmized asset value of a firm affects the environment score. The data for these regressions includes all matched data from two different datasets of treated and control firms from 2011-2023. Both matched datasets were created by using nearest-neighbour matching. In dataset (2) some green bond issuers were matched with alternative control firms to test if the effect remains consistent. The diagnostic checks for these models can be found in Appendix II for dataset (1) and Appendix III for dataset (2).*

	Matched dataset (1)		Matched dataset (2)	
	Dep. variable: Environment score	Dep. variable: CO_2 / Assets	Dep. variable: Environment score	Dep. variable: CO_2 / Assets
L1.Environment Score	0.766***		0.752***	
	(0.048)		(0.048)	
L1.CO_2 / Assets		0.885***		0.824***
		(0.033)		(0.033)
Green bond group	-0.439	-18.629	-0.825	-0.562
	(1.173)	(12.320)	(1.006)	(12.035)
Post green bond	0.572	-29.390**	-0.401	-18.172
	(0.819)	(12.125)	(0.732)	(8.987)
Green bond * Post	-0.160	20.479	1.424	-6.997
	(1.041)	(16.275)	(1.148)	(12.980)
Assets	1.138***		0.934***	
	(0.436)		(0.458)	
Observations	621	621	609	609
R-squared	0.732	0.846	0.717	0.794
Adj. R-squared	0.681	0.817	0.662	0.754
F statistic	285.115***	717.855***	257.727***	490.745***
Fixed effects	YES	YES	YES	YES

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

For the first model with dependent variable Environment score, 621 and 609 observations of several years between 2011 and 2023 of 84 firms were analysed. Fixed effects were added to the regression to account for individual firm differences and fixed time effects. It was found that green bond issuance has no significant effect on the Environment score of a firm, as evidenced by the insignificant coefficients of the interaction term (Green bond * Post) for both datasets. This contradicts the signalling argument, as firms issuing green bonds were expected to have increased Environment scores after a green bond issue. This insignificant result may be explained by greenwashing, as greenwashing firms do not seek to improve their Environment score after a green bond issue. Alternatively, most green bonds were issued relatively recently, leaving little time for firms to improve their Environment score after issuance. Since only industrial firms were included in the sample, these types of firms might need more time to alter processes to decrease their environmental impact and increase their Environment score. To test whether this assumption may be right, an additional regression was run that replaces the post green bond variable with a dummy variable that changes to 1 two years after issuance instead of one. The results of these regressions can be found in Appendix IV. The results remain insignificant, but the amount of data is limited as only 27 firms have data available for 2+ years after a green bond issue.

For the second model with dependent variable CO_2 emissions divided by Assets the same matched datasets with 621 and 609 observations were used. In these regressions, fixed effects were also controlled for. Based on the results for the effect of green bond issuance on the Environment score, insignificant results were expected for the effect between CO_2 emissions and green bond issuance which is in line with the results found in both datasets. Results reflect that firms do not significantly decrease their CO_2 emissions after a green bond issue, further contradicting the signalling argument.

4.3 Verification

Additional DiD regressions were done to estimate the effects of verification on Environment score and CO_2 emissions. The results of these regressions are shown in Table 5. No significant results were found in both datasets, which further contradicts the signalling argument. A stronger and more significant signal was expected as a result of verification, but the findings do not support this expectation. Once again, this may be caused by the limited time that firms had to alter processes to increase ESG scores after the issuance of a green bond. This assumption was also tested for verified green bonds, by replacing the post green bond dummy variable with a dummy variable that turns to 1 two years after an issuance instead of one. The results of this regression can be found in Appendix IV. The results remain insignificant, indicating that the Environment score of firms does not significantly increase two years after a green bond issue. However, it is important to note that there may be too few firms with information on Environment scores for 2+ years after a verified green bond issue to draw any final conclusions.

TABLE 5. RESULTS OF THE DIFFERENCE-IN-DIFFERENCES REGRESSIONS REGARDING THE EFFECTS OF VERIFIED GREEN BOND ISSUANCE ON ENVIRONMENT SCORE AND CO_2 EMISSIONS

*This table reports estimates for the Difference-in-Differences specification regarding verified green bonds. Verified is the dummy that is 1 for firms that have issued verified green bonds. The additional effect of the verification status of a green bond on the dependent variable is captured with interaction term Verified * Post, which turns 1 after a firm has issued a verified green bond. The dependent and other independent variables are described in Table 4. The data for these regressions includes all matched data from two different datasets of treated and control firms from 2011-2023. Both matched datasets were created by using nearest-neighbour matching. In dataset (2) some green bond issuers were matched with alternative control firms to test if the effect remains consistent. The diagnostic checks for these models can be found in Appendix II for dataset (1) and Appendix III for dataset (2).*

	Matched dataset (1)		Matched dataset (2)	
	Dep. variable: Environment score	Dep. variable: CO_2 / Assets	Dep. variable: Environment score	Dep. variable: CO_2 / Assets
L1. Environment Score	0.765***		0.751***	
	(0.049)		(0.048)	
L1.CO_2 / Assets		0.885***		0.822***
		(0.033)		(0.034)
Green bond group	0.984	-6.919	0.590	-15.703
	(1.550)	(9.986)	(1.909)	(11.115)
Post green bond	0.553	-29.490**	-0.376	-18.479
	(0.815)	(12.178)	(0.728)	(9.105)
Green bond * Post	-0.637	12.097	0.281	7.254
	(1.201)	(16.240)	(1.476)	(28.238)
Verified	-1.743	-14.488	-1.652	18.076
	(1.681)	(12.418)	(1.929)	(16.078)
Verified * Post	0.730	12.212	1.489	-18.930
	(1.359)	(16.541)	(1.424)	(33.220)
Assets	1.156***		0.966***	
	(0.433)		(0.470)	
Observations	621	621	609	609
R-squared	0.733	0.846	0.717	0.794
Adj. R-squared	0.681	0.817	0.661	0.754
F statistic	203.366***	477.144***	183.890***	326.511***
Fixed effects	YES	YES	YES	YES

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

5 Discussion and Conclusion

This paper sheds light on the corporate green bond market, a relatively new fast-growing financial instrument in sustainable finance. Data shows that green bonds have become more popular over time, especially within the European Union. Additionally, there seems to be a growing preference for verified green bonds as corporations begin to adapt in preparation for the introduction of the EUGBS.

This study finds that the Environment pillar of ESG scores of corporations does not significantly increase after a green bond issuance. This finding is inconsistent with the signalling argument proposed by Flammer (2021), as environmental improvement is expected after a green bond issue in this case. In contrast, the results possibly indicate the presence of greenwashing, suggesting that corporations may be using the market to appear more sustainable to their stakeholders than they actually are.

Moreover, a more pronounced and significant increase in the Environment pillar of ESG scores was expected for verified green bonds, which were expected to send a more credible signal. No evidence was found that verified green bonds result in an increased Environment score after a green bond issuance, which further contradicts the signalling argument.

These results carry practical implications for both regulators and investors. If greenwashing is indeed the main rationale behind the issue of a green bond in the EU, further regulation is necessary to legitimize the green bond market. The introduction of the EUGBS can provide the basic framework, but additional regulations and market oversight are advised if greenwashing is indeed present. Furthermore, the study provides information to investor by showing that a green bond issue is not directly indicative of a future rise in ESG scores. Thus, an issue of a green bond is not enough to determine whether a firm is truly committed to the environment. As a result, the positive reaction from investors after a green bond issue, which results in abnormal returns on the equity market and possibly the debated greenium, may be unjust. Finally, this study adds to the existing literature by helping to understand the rationale behind the issuance of green bonds. A better understanding of the rationale of firms when using new green financial tools could help prevent the misuse of these tools through the development of the appropriate public regulation.

This study is limited by several factors. As the green bond market is relatively new, the amount of observations is limited. Only 42 green bond issuers could be matched and analysed, partially due to the exclusion of financial firms. Additionally, the long-term effects could not be studied effectively, as most industrial green bond issuers analysed in this study only recently issued green bonds. It is possible that the effects of a green bond issue are only visible after a longer period of time, which could not be tested effectively in this study. Therefore, future studies could provide additional long-term and larger-scale evidence for the rationale behind a green bond issue. Furthermore, the matching was not completely accurate due to the limited availability of public control firms with access to the conventional bond market in the European Union. Thus, an alternative way to get rid of the endogeneity in the link between green bond issuance and ESG scores could provide additional and clearer insights into the effects of a green bond issue.

Future research could also help increase the understanding of the green bond market as a new green financial tool. Research after the introduction of the EUGBS can help better understand the role of public regulation in sustainable finance. Additionally, studies focussing on other regions or the effect of a green bond issuance for financial firms could help determine if the conclusions of this study are region- or sector-specific.

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7 Appendix

7.1 Appendix I: Description of variables

Variable	Explanation	Type
	Logistic regression propensity scoring	
Size	Logarithmized firm size according to asset value in USD	Continuous
TobinsQ	Ratio of market value to company asset replacement cost. Calculated by adding market capitalization to the value of assets, subtracting the book value of common stock and dividing the result by the value of assets	Continuous
ROA	Return on Assets percentage	Continuous
Leverage (Debt%)	Percentage of debt compared to total capital	Continuous
EnvironmentScore	Score of the environmental pillar of ESG scores as calculated by LSEG	Continuous
Industry	Industry according to first two digits of SIC	Categorical
	Difference-in-Differences regressions	
EnvironmentScore	Score of the environmental pillar of ESG scores as calculated by LSEG	Continuous
CO2divAssets	Total amount of direct and indirect CO2 emissions in tonnes divided by the book value of assets in millions of US dollars	Continuous
GreenBond	Indicator for green bond issuer/control firm	Dummy
Post	Indicator for pre- or post-treatment	Dummy
Verification	Indicator whether firm belongs to verified green bond issuers or not	Dummy
Size	Firm size according to asset value in USD	Continuous

7.2 Appendix II: Matched data overview first matched dataset

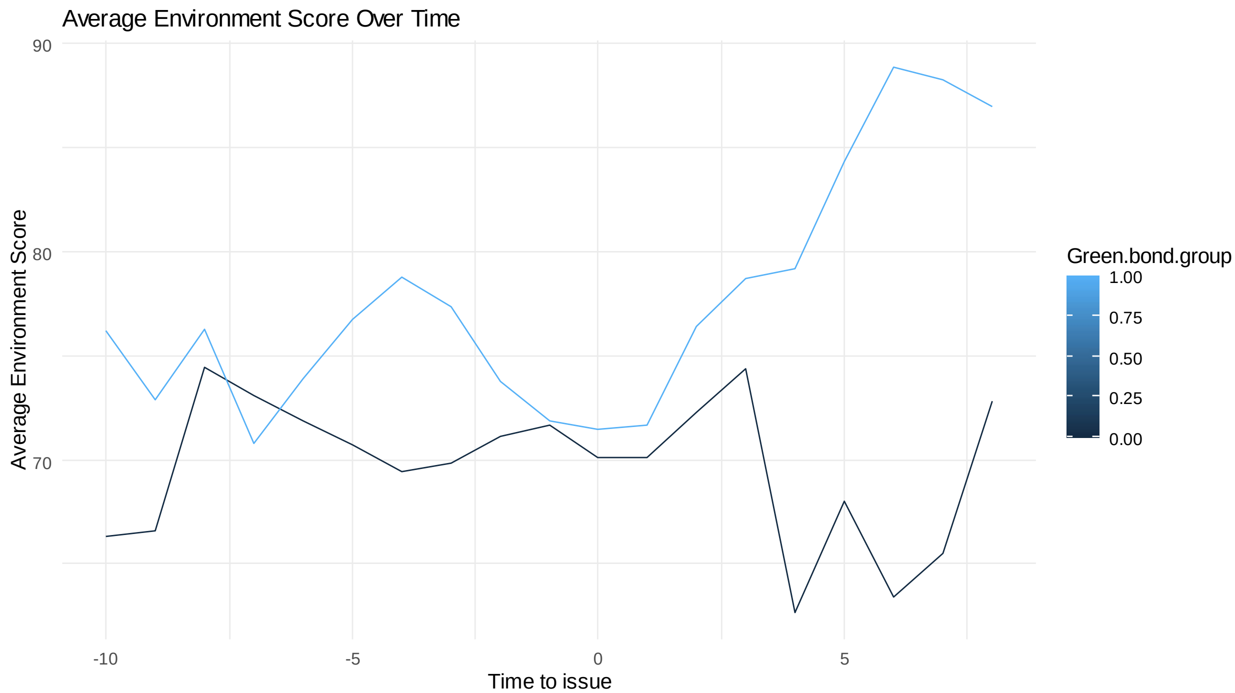

FIGURE 2. DEVELOPMENT OF ENVIRONMENT SCORE OVER TIME BEFORE AND AFTER ISSUE

Figure 2 shows the development of the average Environment score over time for the matched dataset, starting at T-10, meaning ten years before issue for all firms that have this data available. An increase after the issuance of a green bond is visible for the green bond group. However it is important to note that while there are 42 matched pairs, only 27 pairs have data for two years after the issuance, which drops further to 19 and 7 for three and four years after issuance respectively.

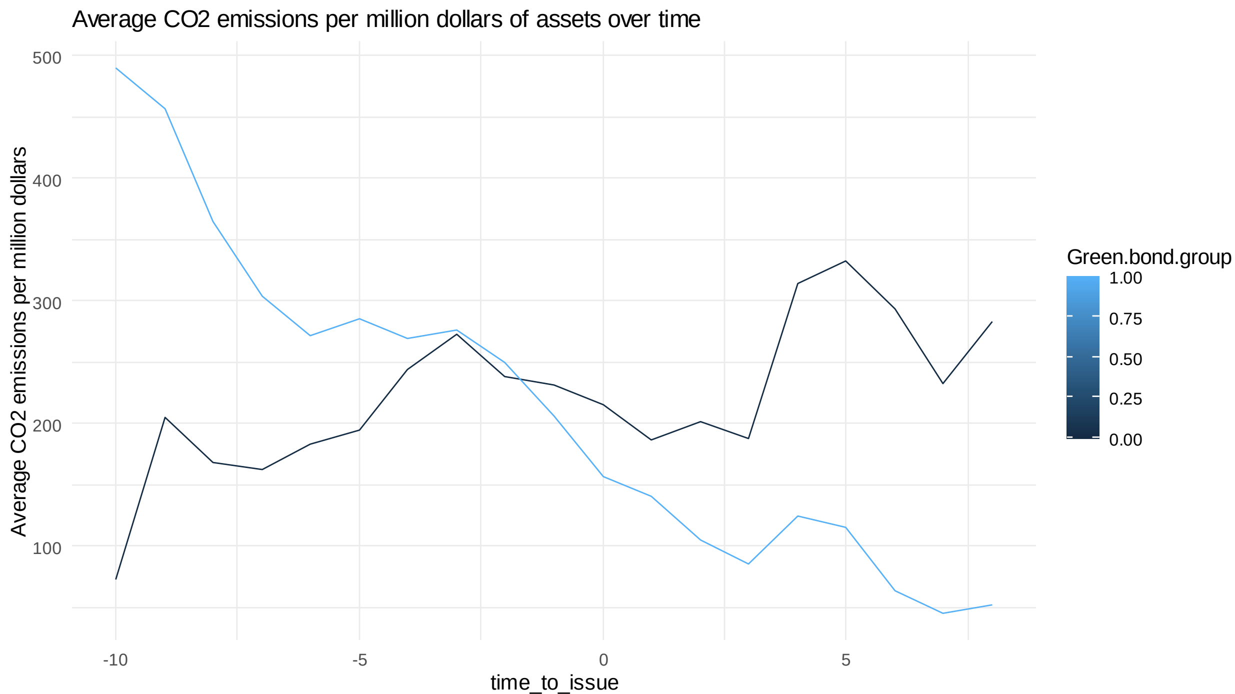

FIGURE 3. DEVELOPMENT OF CO_2 EMISSIONS OVER TIME BEFORE AND AFTER ISSUE

Figure 3 shows the development of CO_2 emissions over time for the matched dataset. The data is most reliable from -2 until 2 years after the issuance of a green bond, as most corporations have data recorded at these times. Similarly to the environment score, fewer corporations have data the further away from the time to issue.

Diagnostic checks dataset (1)

TABLE 6. STATIONARITY TEST DATASET (1)

To test for stationarity the Augmented Dickey-Fuller Test was performed. Both dependent variables EnvironmentScore and CO2divAssets were found to be stationary as the p-value of both was lower than 0.01.

	Test statistic	Lag order	p-value
EnvironmentScore	-6.5377	8	0.01***
CO2divAssets	-7.1899	8	0.01***

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

TABLE 7. MODEL-SPECIFIC DIAGNOSTIC TESTS DATASET (1)

Several tests were done to ensure the validity of the results. The Breusch-Pagan test is used to find heteroskedasticity. All models show significant p-values, indicating that heteroskedasticity is present. The Breusch-Godfrey test is used to find autocorrelation. Significant results (p-value <0.05) were found for both models using the dependent variable CO_2 / Assets, indicating that autocorrelation is present in these models. To help solve the issues of heteroskedasticity and autocorrelation, all models use robust standard errors. Additionally, a Hausmann test was done to test whether using a fixed effects model is the right choice. As can be seen, all p-values are significant, which indicates that fixed effects rather than random effects is the preferred approach.

	Effect green bond		Effect verified green bond	
	Dep. variable: Environment score	Dep. variable: CO_2 / Assets	Dep. variable: Environment score	Dep. variable: CO_2 / Assets
Breusch-Pagan	48.5260***	183.61***	50.5500***	183.66***
Breusch-Godfey	1.6198	67.375***	1.4437	67.436***
Hausmann	24.4350***	17.548***	24.8540***	19.468***

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

7.3 Appendix III: Matched data overview second matched dataset

TABLE 8. RESULTS WELCH TWO-SAMPLE T-TEST POST-MATCHING SECOND MATCHED DATASET

	Green bond Issuers (1)	Control firms (0)	p-value (diff. in means)
Log(Assets)	10.05344	10.09141	0.7897
	(0.722)	(0.569)	
Tobin's Q	1.617601	1.582899	0.7918
	(0.693)	(0.490)	
Return On Assets	4.275238	3.378333	0.3233
	(2.96)	(5.04)	
Debt%	47.03952	43.28881	0.4137
	(20.9)	(20.9)	
Environment score	71.84667	71.86976	0.9955
	(17.7)	(19.5)	
Propensity score	0.3644597	0.2132263	0.003137**
	(0.267)	(0.177)	
Observations	42	42	

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

The above table showcases the results of the Welch two-sample t-test for an alternatively matched dataset also using nearest neighbor matching. The p-values of the variables confirm that the dataset can be considered random.

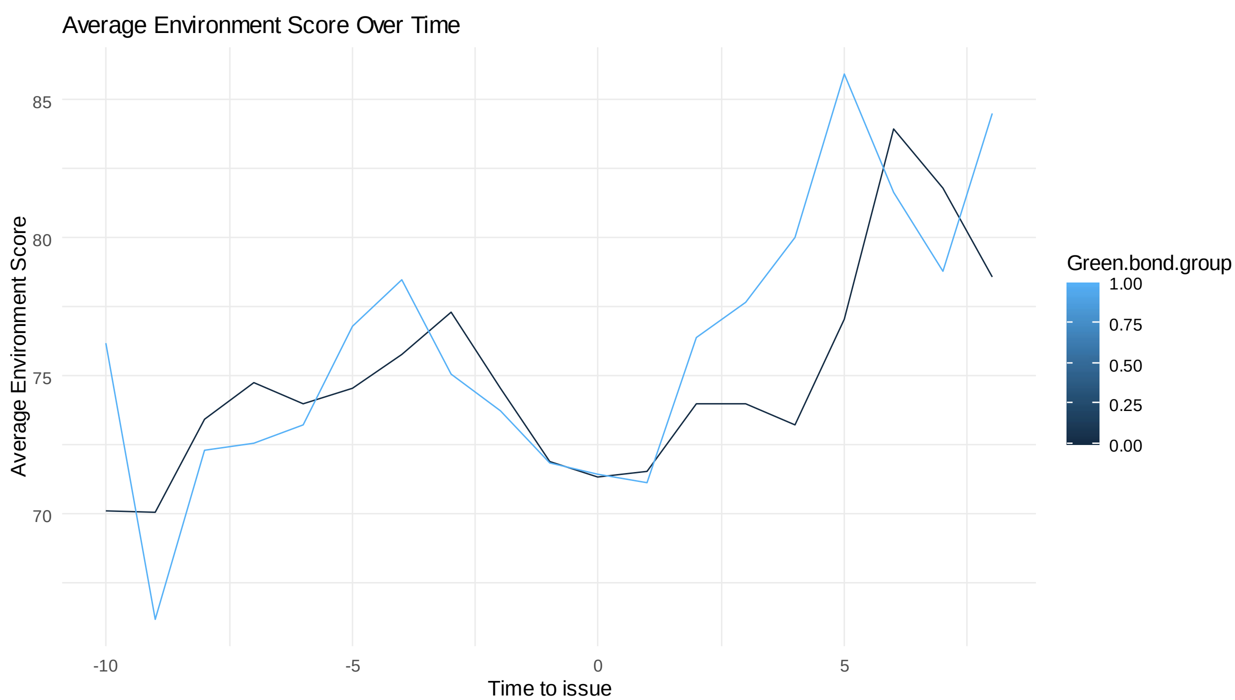

FIGURE 4. DEVELOPMENT OF ENVIRONMENT SCORE OVER TIME BEFORE AND AFTER ISSUE SECOND MATCHED DATASET

The development of the average environment score over time for the second matched dataset shows promise for the dataset being matched accurately, as the trend over time is visible in both the treated and control group. Similarly to the first dataset, data before T-2 and after T+2 is limited.

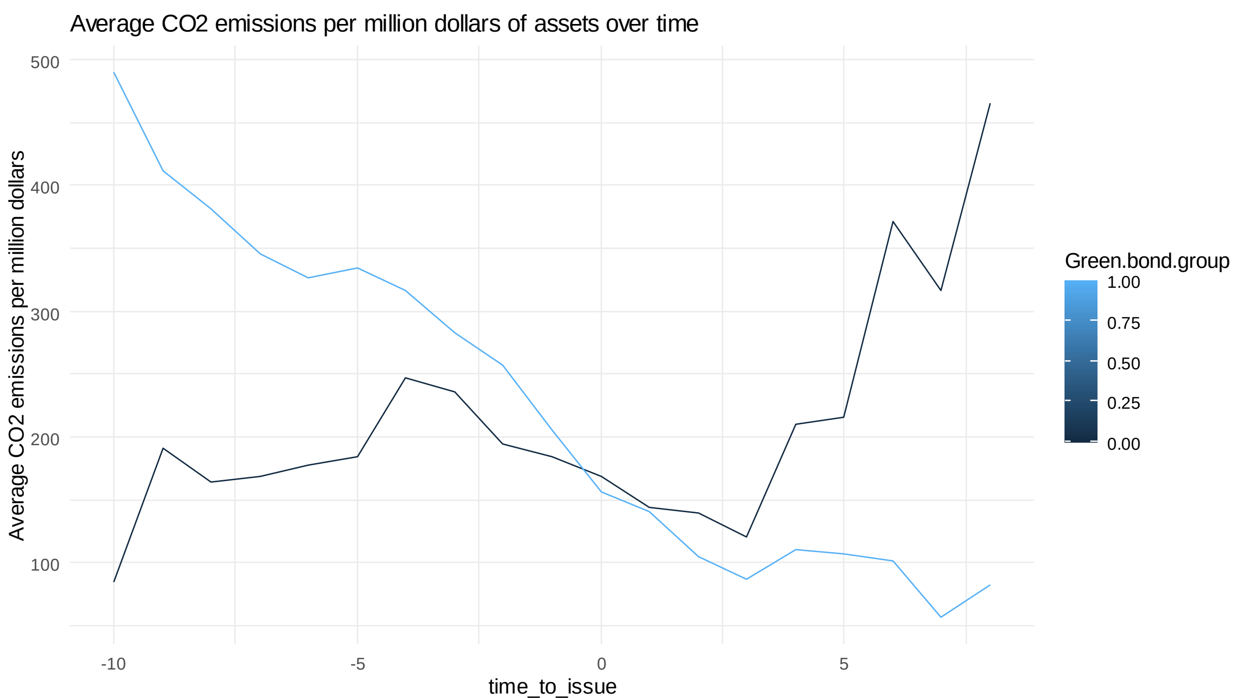

FIGURE 5. DEVELOPMENT OF CO_2 EMISSIONS OVER TIME BEFORE AND AFTER ISSUE SECOND MATCHED DATASET

The beginning of this graph is very similar to the graph of CO_2 emissions over time for the first dataset. However, after T+3 the emissions seem to trend heavily upward for the control group. This is probably caused by the limited amount of matches for T+4 and further, as only 8 matches have data for T+4 and matches become less accurate the further away the data is from the matched pre-issue year.

Diagnostic checks dataset (2)

TABLE 9. STATIONARITY TEST DATASET (2)

To test for stationarity the Augmented Dickey-Fuller Test was performed. Both dependent variables EnvironmentScore and CO2divAssets were found to be stationary as the p-value of both was lower than 0.01.

	Test statistic	Lag order	p-value
EnvironmentScore	-6.7985	8	0.01***
CO2divAssets	-7.0801	8	0.01***

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

TABLE 10. MODEL-SPECIFIC DIAGNOSTIC TESTS DATASET (2)

Several tests were done to ensure the validity of the results. The Breusch-Pagan test is used to find heteroskedasticity. All models show significant p-values, indicating that heteroskedasticity is present. The Breusch-Godfrey test is used to find autocorrelation. Significant results (p-value <0.05) were found for both models using the dependent variable CO_2 / Assets, indicating that autocorrelation is present in these models. To help solve the issues of heteroskedasticity and autocorrelation, all models use robust standard errors. Additionally, a Hausmann test was done to test whether using a fixed effects model is the right choice. As can be seen, all p-values are significant, which indicates that fixed effects rather than random effects is the preferred approach.

	Effect green bond		Effect verified green bond	
	Dep. variable: Environment score	Dep. variable: CO_2 / Assets	Dep. variable: Environment score	Dep. variable: CO_2 / Assets
Breusch-Pagan	56.5820***	135.86***	59.7050***	135.94***
Breusch-Godfey	3.3577*	33.333***	3.5165*	33.925***
Hausmann	17.3740***	43.333***	17.1820**	45.259***

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

7.4 Appendix IV: Long-term regressions

TABLE 11. RESULTS OF THE DIFFERENCE-IN-DIFFERENCES REGRESSIONS REGARDING THE LONG-TERM EFFECTS OF GREEN BOND ISSUANCE ON ENVIRONMENT SCORE AND CO_2 EMISSIONS

This table reports estimates for the Difference-in-Differences specification regarding green bonds. The dependent and independent variables used in this regression are described in Table 4. Alternative to the regression in Table 4, the variable Post has been replaced with variable 2Y Post, which turns to 1 two years after a green bond issue rather than after one year. The data for these regressions includes all matched data from two different datasets of treated and control firms from 2011-2023. Both matched datasets were created by using nearest-neighbour matching. In dataset (2) some green bond issuers were matched with alternative control firms to test if the effect remains consistent

	Matched dataset (1)		Matched dataset (2)	
	Dep. variable: Environment score	Dep. variable: CO_2 / Assets	Dep. variable: Environment score	Dep. variable: CO_2 / Assets
L1.Environment Score	0.766***		0.755***	
	(0.049)		(0.048)	
L1.CO_2 / Assets		0.886***		0.827***
		(0.035)		(0.033)
Green bond group	-0.462	-10.144	-0.618	1.928
	(1.111)	(9.917)	(0.925)	(12.967)
2Y Post green bond	1.386	-3.774**	0.039	-4.894
	(1.005)	(11.628)	(0.855)	(11.617)
Green bond * 2YPost	-0.140	-3.625	1.475	-19.362
	(1.210)	(14.700)	(1.043)	(18.178)
Assets	1.096***		0.903**	
	(0.438)		(0.448)	
Observations	621	621	609	609
R-squared	0.734	0.845	0.720	0.793
Adj. R-squared	0.683	0.816	0.665	0.753
F statistic	287.501***	711.549***	261.915***	488.188***
Fixed effects	YES	YES	YES	YES

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

TABLE 12. RESULTS OF THE DIFFERENCE-IN-DIFFERENCES REGRESSIONS REGARDING THE LONG-TERM EFFECTS OF VERIFIED GREEN BOND ISSUANCE ON ENVIRONMENT SCORE AND CO_2 EMISSIONS

This table reports estimates for the Difference-in-Differences specification regarding green bonds. The dependent and independent variables used in this regression are described in Table 5. Alternative to the regression in Table 5, the variable Post has been replaced with variable 2Y Post, which turns to 1 two years after a green bond issue rather than after one year. The data for these regressions includes all matched data from two different datasets of treated and control firms from 2011-2023. Both matched datasets were created by using nearest-neighbour matching. In dataset (2) some green bond issuers were matched with alternative control firms to test if the effect remains consistent

	Matched dataset (1)		Matched dataset (2)	
	Dep. variable: Environment score	Dep. variable: CO_2 / Assets	Dep. variable: Environment score	Dep. variable: CO_2 / Assets
L1. Environment Score	0.766***		0.754***	
	(0.049)		(0.048)	
L1.CO_2 / Assets		0.886***		0.823***
		(0.035)		(0.034)
Green bond group	0.918	-4.732	0.598	-13.452
	(1.514)	(8.252)	(1.841)	(10.208)
2Y Post green bond	1.377	-3.884	0.066	-5.181
	(1.012)	(11.684)	(0.842)	(11.798)
Green bond * 2YPost	-0.446	6.334	0.148	19.882
	(1.468)	(16.897)	(1.272)	(19.755)
Verified	-1.684	-6.438	-1.406	18.883
	(1.706)	(11.862)	(1.930)	(13.336)
Verified * 2YPost	0.492	-12.669	1.647	-50.312
	(1.288)	(14.342)	(1.261)	(21.327)
Assets	1.109***		0.931***	
	(0.432)		(0.463)	
Observations	621	621	609	609
R-squared	0.734	0.845	0.720	0.794
Adj. R-squared	0.682	0.815	0.665	0.753
F statistic	205.055***	472.827***	186.783***	326.330***
Fixed effects	YES	YES	YES	YES

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