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Financing Transition: Assessing Potential and Environmental Impact of Climate Transition Bonds and Green Bonds

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ABSTRACT

The study examines the market for sustainable finance and transition finance, critically evaluating the environmental impact of climate transition bonds and green bonds. Climate transition bonds gained popularity in recent years as alternatives to green bonds for issuers in hard-to-abate industries. Similar to previous research, this study employs a Difference-in-Difference regression with underlying propensity score matching to isolate the impact of transition bond issuances on corporate environmental and ESG performance. Doing so, it aims to test the greenwashing hypothesis. Findings suggest that transition bond issuers do not exhibit significant ESG improvements (i.e., emissions reduction and ESG rating increases) post-issuance as compared to conventional issuers. In an extension, the study further analyses the effect of green bonds on issuers' environmental performance and compares the impact of transition instruments to 'common' green instruments. Contrary, green bond issuers exhibit significant emissions reduction, confirming prior research results. This may either indicate greenwashing and a lack of governance regimes in the transition finance market, or hint towards the very long time horizon needed to achieve meaningful transition that is not captured in this study. The study contributes to the growing, much needed literature on climate transition bonds and links the lack of environmental impact to flaws in the current design of the instruments, as well as a lack of governance regimes and harmonisation in the market for transition finance. It points out improvements based on literature review on green bond structuring and shows the potential to integrate just transition elements into climate transition bonds.

Keywords: Transition Finance, Sustainable Finance, Climate Transition Bonds, Carbon Emissions, Governance

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List of Abbreviations

ATE ..... Average Treatment Effect

ATT ..... Average Treatment Effect in the Treated

BICS ..... Bloomberg's Industry Classification Standard

CCS ..... Carbon Capture & Storage

CSE ..... Clustered Standard Errors

DID ..... Difference-in-Difference Method

DNSH ..... Do No Significant Harm

EIB ..... European Investment Bank

ESG ..... Environmental, Social, and Governance

ETS ..... Emissions Trade Systems

EU ..... European Union

GFANZ ..... Glasgow Financial Alliance for Net Zero

GICS ..... Global Industry Classification Standard

ICMA ..... International Capital Market Association

IEA ..... International Energy Agency

IFRS ..... International Financial Reporting Standards

KPI ..... Key Performance Indicator

NDC ..... Nationally Determined Contribution

NGO ..... Non-Governmental Organization

PSM ..... Propensity Score Matching

SAF ..... Sustainable Aviation Fuel

SPO ..... Second-Party Opinion

tCO_2e ..... Tonnes of CO2 equivalent

TPT ..... Transition Plan Taskforce

UN ..... United Nations

UN SDGs..... United Nations Sustainable Development Goals

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1 Introduction

Limiting global warming is one of the biggest challenges of current and future generations. Reaching the publicly proclaimed 2050 net zero goal will require a drastic transition of economic behaviour. Close to 200 parties have signed to the Paris Agreement, "a legally binding international treaty on climate change […] to limit the temperature increase to 1.5°C above pre-industrial levels" (UNFCCC, 2018). The Paris Agreement, among other things, recommends the implementation of a "long-term low greenhouse gas emission development strategies" (UNFCCC, 2018). Furthermore, a significant number of sovereign and private entities, Non-Governmental Organizations (NGOs), charities, and other stakeholders have committed to its proclaimed goal. The transition towards a low-carbon future requires not only a change in consumer behaviour and regulatory interventions – the International Energy Agency (IEA) estimates that by 2030 approximately USD 4.0 trillion is required each year for climate-friendly projects to achieve net zero emissions by 2050 (IEA, 2021b). This raises the question of how this capital is to be mobilised and whether industries not yet considered "green" can and should be given the opportunity to participate in such a transition.

In recent years, answers to these challenges emerged in the form of sustainable finance debt instruments – bonds that come with a commitment to invest the use of proceeds in sustainable projects (Maltais & Nykvist, 2021). Specifically, green bonds gained popularity in recent years as a tool to channel capital into environmental-friendly investments. While these instruments are relatively established in the capital markets by now, they are exclusive to companies meeting the 'green' standards. They therefore ignore the potential of firms in hard-to-abate sectors, companies in emerging countries with a lack of governance and those with a lack of access to ecological technology. A new instrument could bridge this gap: Climate transition bonds can provide capital to businesses not yet climate-friendly and green bond aligned, but with clear transition plans to become sustainable in the future. This relatively new type of sustainable bond has become increasingly popular especially in 2024, with strong issuance activity particularly in Japan and China. However, the credibility of many transition bonds has been questioned, and concerns arise about the sustainability ambitions of issuers. For example, some have funded coal-to-fossil gas conversions (Robins et al., 2023). Afterall, transition bonds should not intend to provide brown companies the possibility to participate in the sustainable finance market without engaging in true transition efforts. Thus, reliable research is needed on transition bonds' observable environmental impact on a corporate level. Particularly, it is important to understand

the potential use-cases leading to a positive impact and to examine and prevent possible greenwashing attempts within the sustainable finance market. Afterall, those players who contribute the most to the global economic income and have the biggest environmental levers are often the ones who are not yet sustainable.

The purpose of this study is to critically evaluate the current market for transition and sustainable finance, outlining issues and current developments. A particular focus is on the assessment of climate transition bonds as an alternative to 'normal' green bonds. It aims to answer the following research questions:

1. Is the issuance of transition debt instruments associated with a decrease in carbon emissions post-issuance?
2. Can sustainable debt instruments substantially drive decarbonization and allow investors to contribute towards the transition to a low carbon economy?
3. What characteristics ensure effectiveness of sustainable finance (transition) instruments and how can concerns of greenwashing be mitigated by companies, investors and regulatory bodies alike?

In order to answer these questions, the study will first provide an in-depth literature review on the state and current developments of green bonds and climate transition bonds. This section will give an overview over existing scientific literature, regulatory frameworks and the governance regime of green and transition bonds, and sets into context this study within the wider research on sustainable finance. In the data and methodology chapters, the research design will be outlined, focussing on key characteristics of transition bond issuers and conventional issuers alike. The study will employ a Difference-in-Difference (DID) regression analysis to evaluate environmental performance post-issuance, after conducting a propensity matching score algorithm to account for internal and external factors not associated with the bond issuance itself. The analysis chapter will then present regression tables and explain its key findings. Finally, the discussion will reflect results from the empirical part of this study in the context of the existing literature and come up with implications for effectively structuring debt instruments to incentivize transition and harmonise the sustainable finance market. It concludes with a summary of its academic contributions.

This study makes several contributions to the literature. First, it applies established research methodology on green bonds to climate transition bonds, allowing to quantify the environmen-

tal impact of these instruments. This quantification attempt is the first of its kind, and is therefore important to assess their potential and mitigate potential misuse as greenwashing instruments. Building on that, the study contributes recommendations on design and implementation into corporate governance structure of the issuer, based on key findings from research on green finance instruments. Lastly, the study also provides recommendation for market guidelines and regulatory frameworks to promote the efficient use of climate transition bond and transition plans within broader corporate transition ambitions.

2 Literature Review

This chapter discusses the academic literature on sustainable finance more generally, and on climate transition finance specifically. It first outlines the functioning for sustainable debt instruments and describes financial advantages and environmental impact of green and sustainability bonds from an issuer perspective and from the investors' standpoint. This section also addresses concerns and issues with the concepts such as greenwashing and additionality from an impact perspective. The second part introduces the concept of transition finance as a new way of promoting emissions reduction, especially among companies in the high-emitting sector. The third part covers current regulatory frameworks and market standards as of today, and gives an outlook for future developments, drawing on position papers and guidance from national governing bodies and international standard setters. The literature review concludes by pointing out the need for further research on sustainable finance instruments to further understand their potential for financing the transition towards a low-carbon economy.

2.1 Sustainable Finance and Debt Instruments

In 2007, the European Investment Bank (EIB) issued the first bond that can be described as a 'green bond', i.e., an instrument with a green use of proceed, European Union's Energy Action Plan (EIB, 2022). Ever since, the need for a more sustainable investment behaviour in firms and an allocation of bond proceeds in alignment with sustainability goals became more and more apparent. At the same time, investors became increasingly aware of their investments' ecological impact as well as the economic risks associated with an unchanged investment approach. This combination of demand for sustainable investment opportunities and the desire to label corporate fundraising as 'sustainable' led to the emergence of these instruments in the form of green bonds. For several years the number of sustainable finance instruments and the corresponding volumes remained relatively low. However, issuances increased in the middle of last decade (Flammer, 2021), reaching a cumulative volume of USD 4.4tn by the end of 2023 and a market share in Europe of 7.1% of total corporate bond issuance volume (CBI, 2024; EEA, 2024).

The term green bond usually refers to debt instruments issued in alignment with some kind of market standard, for example from the International Capital Markets Association (ICMA) or the EU Taxonomy. Green bonds aim to finance projects that are considered environmentally

sustainable, i.e., ‘green’, or minimize negative environmental impact at least (Bhutta et al., 2022). To achieve that, the proceeds of a green bond will be allocated to finance or refinance new or existing projects in line with green eligibility criteria previously outlined in a green finance framework (ICMA, 2021). The most common use of proceeds are allocated to renewable energy, sustainable buildings and clean transportation (CBI, 2024). Usually, green bonds also assure a certain degree of post-issuance allocation and impact reporting on the financed projects and commit to Do No Significant Harm (DNSH) criteria. Issuers vary in type and size, and can include supranational institutions, sovereign agencies, local, regional, and national governments, corporates, and financial institutions (EEA, 2024). Data from the CBI (2024) show that green bonds are mostly issued in developed countries, with a large share by European entities. Furthermore, it can be noted that the average green bond is rather large, with more than 75% of all issuances being benchmark deals (i.e., above USD 500m).

In contrast, climate transition bonds are a relatively new instrument in the sustainable finance market, and refer to bonds intended to finance transition activities in the scope of a net-zero transition plan. These activities could potentially be ineligible under conventional green bond standards, but still be directed towards interim activity phasing out within mentioned transition plan (CBI, 2020). Although the market is still comparably small with USD 12.5bn issued by the end of 2022 (Robins et al., 2023), it picked up significant momentum in 2024, particularly through the extensive transition issuance program by the Japanese government.

2.2 Ecological Impact and Governance

To assess the effects of transition bonds, it is necessary to look at historic environmental performance of established sustainable debt instruments. If successful, instruments should lead to an improvement of the carbon profile and potentially also the broader ESG profile of the company. On the other hand, if only used as a greenwashing tool, firms would only issue green bonds to build up a more sustainable image without taking real actions, thus not significantly decreasing emissions in the long run (Makpotche et al., 2024). The potential of sustainable finance translating to real, tangible reductions in emissions and other dimensions of sustainability can be demonstrated using research on the green bonds market, as it is the most mature market for sustainable debt. Effects show on an aggregate country level, as well as on an individual company level.

2.2.1 Aggregate Country Level

The environmental effect of green bonds is widely researched as they provide a compelling tool to shift capital towards low-carbon or carbon free industries. They thus promote a reduction in aggregated emissions levels. However, reliable and quantifiable literature at country level is still scarce. Tolliver et al. (2020) estimates an annual carbon emissions reduction by projects financed through green bonds[1] of >108 million tCO_2e, mainly through increases in renewable energy capacity. Dill (2024) finds that the issuance of Green Bonds on a country level is associated with a reduction of 14% in carbon levels in subsequent years, suggesting that Green Bonds might contribute to the transition to a low-carbon economy. Meo and Abd Karim (2022) examine the relationship between carbon emissions in advanced economies which use extensive green finance and can show that it is associated with a strong reduction in carbon emissions.
Beyond the negative correlation with carbon emissions levels, green finance shows to have positive environmental impact. Notably, a strand of literature deals with the broader scope of environmental quality. Chang et al. (2022) use a Quantile-on-Quantile method to confirm that the use of green finance instruments is associated with an increase in environmental quality, measured by the ecological footprint instead of carbon only as defined by Wackernagel and Rees (1998). Shah et al. (2024) show that Green Bonds not only have a positive effect on a country's environmental quality but also improve its clean energy investments and promote the clean energy investment efficiency. This effect is particularly strong in high- and middle-income countries. On a theoretical base, Sartzetakis (2021) examines the role of green bonds through spread the cost of the transition in a just and efficient way across generations to finance large, long-term investments. Tolliver et al. (2019) map the use of green finance to the achievements of UN Sustainable Development Goals (UN SDGs) and Nationally Determined Contribution-related (NDC) environmental outcomes. This analysis shows that while a large portion of the analysed use of proceeds was allocated to clean energy investments and "other projects that address high-priority GHG emissions reduction targets", allocation also took place for example to SDG 6: Clean Water and Sanitation, SDG 11: Sustainable Cities and Communities, or SDG 15: Life on Land.

These findings generally underline the suitability of Green Bonds as a tool to promote overall sustainability, the reduction of carbon emissions and the usage of clean energies, and to encourage investments in this sector. This has practical implications for policies: Meo and Abd Karim

[1] From allocation of green bonds proceeds issued until 2017.

(2022) argue for fiscal policies, green financial development policies and an improved green financial system to advance their efforts in reducing carbon emissions. It is furthermore important to reduce the risks of greenwashing and increase trust and credibility of the sustainable finance market. (Makpotche et al., 2024). Of course, the driving forces of the market in the first place are macroeconomic factors and the geopolitical environment. As such, Tolliver et al. (2020) argue in favour of strengthened economic fundamentals also promoting conventional capital markets. Of course, an active and developed sustainable finance market can only be part of the solution. As governments and regulators have a number of tools to incentivize emissions reduction, the use green bonds will be complementary to measures such as Emissions Trade Systems (ETS) or carbon taxes. Heine et al. (2019) propose a time-spanning model, in which carbon pricing and green financing markets complement each other and balance mitigation costs between current generations and future ones. Dill (2024) shows that both approaches can drastically reduce carbon emissions and thus allow countries to support their NDCs (Tolliver et al., 2020).

2.2.2 Company Level

Observations on a company level generally mirror similar results, emphasizing the benefits of green bonds on corporate environmental performance. Although environmental performance can be measured by a number of Key Performance Indicators (KPIs), most studies focus either on a carbon emissions level directly, or on an aggregated ESG Score metric related to the environment. The 'E-Score' of a company includes all kinds of different environmental dimensions such as the firm's carbon profile, resource use, or waste management (ISS, 2025). Studies measuring the carbon emissions levels mostly focus on Scope 1 emissions[2] and Scope 2 emissions[3], as these are under the direct influence of the company.

Looking at carbon emissions levels and emissions intensity, reduction effects become significant only in the long-term. Flammer (2021) was among the first to document a significant decrease in greenhouse gas emissions for corporate issuers following a green bonds issuance. Using the nearest neighbour Difference-in-Difference (DID) based on firm-level data prior to the issuance, it shows that while short-term reduction of emissions is not significant, the carbon

[2] Scope 1 emissions include direct greenhouse gas emissions that occur from sources that are controlled or owned by an organization
[3] Scope 2 emissions are indirect greenhouse gas emissions associated with the purchase of electricity, steam, heat, or cooling

emissions levels decrease by 12% over the course of two and more years. These findings are validated by Fatica and Panzica (2021) who look at Scope 1 emissions intensity and find similar results, as well as a later study from Makpotche et al. (2024) who confirm the decrease in carbon emissions levels for corporate green bond issuers in the long-term. All three approaches align with the methodological framework used in this study, thereby supporting its applicability and validity.

Beyond improvements on a one-dimensional emissions scale, the issuance of green bonds also seems to improve overall corporate ESG performance in the medium- to long-term.. Zhou and Cui (2019) discover a post-issuance increase in the companies' Corporate Social Responsibility (CSR) score and corresponding activity, and Flammer (2021) provides evidence for a significant increase in Thomson Reuter's ASSET4 environmental score, which includes for example product innovation and resource use and can be used as a proxy for ESG performance. In line with these results, Makpotche et al. (2024) can also note an overall improved resource use efficiency (increased resource use score by c. 8% three years after issuance) and environmental performance in the long term.

Looking at more nuanced driving forces of environmental impact of green bonds, Yeow and Ng (2021), Fatica and Panzica (2021), as well as Flammer (2021) emphasize the importance of certification of green bonds in relation to the subsequent reduction in carbon emissions. This certification is related to the SPO processes by an independent agency such as S&P, Moodys, or ISS ESG, nowadays prevalent in most sustainable debt instruments, and which gives a bond more credibility. Fatica and Panzica (2021) also show that the negative correlation between green bonds and emissions levels seems particularly significant and long-lasting when only looking at bonds intended to newly finance sustainable projects (i.e., not intended for pure refinancing purposes). This makes sense as this would be associated with an increase in the volume of new climate-friendly activities instead of already existing projects. Furthermore, evidence suggests that more recent green bonds are more effective in achieving such sustainability goals, particularly after the Paris Agreement in 2015. According to Fatica and Panzica (2021), stronger reductions in companies' emissions were observed in connection with green bond issuances after 2015.

2.2.3 Governance

Research on green bonds also extends to various effects beyond environmental impact, such as financial aspects, green bond pricing, and corporate governance. While the literature on the economic impact of green bond issuances and their pricing (concept of 'greenium') is extensive, it should be noted that a thorough review thereof is beyond the scope of this study which predominantly focusses on the environmental aspects of sustainable debt instruments. Instead, to further examine the issue of greenwashing, this section aims to explain these governance aspects, particularly looking at green bonds as a transparency tool for investor communication and signalling. Interestingly, governance and sustainable finance issuances seem to have a two-way relationship: On one side, it seems that the issuance itself has positive effects on the governance structure, i.e., reporting, transparency, stakeholder management, of the issuing entity. On the other side, good governance is a prerequisite for a successful bond issuance. Both effects are examined in the following.

Governance for sustainable finance instruments is largely decentralised and controlled by market participants and stakeholders. It is characterised by private regimes consisting of third-party certification, market standards (in contrast to market regulation), and voluntary guidelines (Park, 2018). This additional governance aspect from engaging in sustainable finance improves overall corporate governance. For one, the issuing green bonds leads to a dialogue between the issuers and investors on sustainability expectations that would not have occurred without green bonds (Maltais & Nykvist, 2021). This assures investors of the corporate ESG strategy and signals commitment to a low-carbon transition. Furthermore, according to Mohammed et al. (2024) this dialogue can mitigate climate risk for the issuers significantly by reducing transition risk and increasing overall risk management. Similarly, Wang et al. (2022) argue that the issuance of sustainable finance instruments induces more engagement with climate risks firm-internal, implying better risk management and overall increased governance. On the investor side, a sustainable bond issuance leads to the ownership structure exhibiting a larger share of long-term and sustainability-focussed investors (Flammer, 2021; Tang & Zhang, 2020). At the same time, the share of institutional ownership increases, especially from domestic institutions (Tang & Zhang, 2020). These kinds of investors likely appreciate the additional governance and are willing to invest more into these companies. Hussain and Dill (2022) argue that green issuers can benefit from an improved access to institutional investors and thus diversify their investor base. Lastly, Tang and Zhang (2020) also document an increase in media exposure following the issuance, increasing visibility and arguably also improving external governance.

Looking from the other side, the environmental as well as the financial success (i.e., placement of the bond) of a sustainable finance issuance is largely determined by the underlying corporate governance structure pre-issuance. Due to the lack of public governance, the issuer must provide strong governance structures and adhere to common private regimes (e.g., market standards) to give trust to potential investors. Consequently, empirical research shows that green bond issuers exhibit a significantly higher governance rating (Flammer, 2021; Makpotche et al., 2024). Cicchiello et al. (2022) provide evidence that several characteristics associated with good corporate governance are also an indicator for the issuance of a sustainable finance instrument. For example, a more significant percentage of independent board directors, a high share of female board directors, and a longer-term debt structure all increase the propensity of issuing a green bond. Since green bonds are used to finance sustainable investment projects, this is in line with a strand of literature that finds a positive correlation between good governance characteristics and environmentally responsible corporate behaviour (Atif et al., 2020; Liao et al., 2015). Investors also seem to acknowledge the need for good corporate governance pre-issuance, and appreciate a strong framework. Sangiorgi and Schopohl (2021) show that investors tend buy green bonds with sufficient green credibility and high disclosure transparency pre-issuance, as well as good impact reporting post-issuance. On the other side, investors do not buy green bonds with unclear use of proceeds and tend to sell if the post-issuance reporting is poor. These findings naturally translate into the pricing mechanism of green bonds. Frecautan and Ivashkovskaya (2024) find significant impact of governance characteristics on a green bond's yield, such as board size. These findings on investor scrutiny are important since investors act as regulators in the sustainable finance market of private and voluntary regimes (Park, 2018). In this market, investor scrutiny serves as a self-regulatory mechanism and ensures that green bonds only finance eligible projects with a clear sustainability improvement (Sangiorgi & Schopohl, 2021).

2.3 Greenwashing Hypothesis and Challenges

While the effect of green bonds on corporate emissions reduction as a whole is relatively unquestioned, challenges remain. One major concern is greenwashing, i.e., the issuance of sustainable instruments simply for purposes of improving the eco-friendly image of the company. Because the 'green' label is not a regulated definition, the term can be used regardless of the actual use, leaving it to issuers and investors to agree on the actual outcome (Yeow & Ng,

2021). And despite market principles and existing guidelines by standard setters, there is no authority with the competence to reinforce penalties against a misuse of the green label (Talbot, 2017). This leaves the extent of greenwashing versus true impact to be related largely to the good governance and transparency of the issuing entity itself. Tolliver et al. (2019) remark untransparent or insufficient post-issuance reporting with early Green Bonds, with no clear identification of the additionality of many instruments. This can make it difficult to derive the associated impact and the connections environmental outcomes and green bond finance vehicles. On the topic of transparency, Sartzetakis (2021) calls for providing clear green eligibility criteria and bridging the information gap between issuers and investors to dispel concerns about greenwashing.

One way to increase transparency and avoid greenwashing risks is the implementation of second-party opinions to certify the green use of proceeds framework. Choi (2020) identifies robust external certification as a key element for environmental effectiveness. It reduces information asymmetry reassures about the 'greenness' of the issuance (Rose, 2019). Several empirical studies indeed confirm that certified green bonds are less likely to be used for greenwashing purposes only. Fatica and Panzica (2021) show that certified green bonds are associated with a more pronounced reduction in carbon emissions, as well as a stronger improvement of ESG Score. This resonates with research from Yeow and Ng (2021) that show that green bonds are particularly effective and have a positive environmental impact when they are certified by a Second-Party Opinion (SPO) provider. The fact that the certification process is costly makes its issuance a credible signal to the market. Also, the actual process of verifying use of proceeds to tangible projects with impactful environmental benefits counteract the possibility of greenwashing misuse. Besides a pre-issuance certification, rigorous post-issuance reporting is another method to protect against greenwashing allegation. It is one of the most important channel of effective environmental investor communication, and can thus significantly add transparency (Zhang, 2020). Tuhkanen and Vulturius (2022) identify several shortcomings related to post-issuance reporting such as a lack of standardization. Especially impact reporting (as opposed to simple allocation reporting) is a tool that allows investors and stakeholders to assess 'greenness', but lack in the majority of green bonds. Hunt (2024) finds that around 10% of green bonds have no proper post-issuance reporting and calls for a better quality of reporting in terms of reporting certification as well as project-level reporting. Interestingly, Wang (2023) also highlights a connection between a pre-issuance certification and a corresponding higher post-issuance transparency.

Besides the risk of greenwashing, another challenge is the question of additionality in green use of proceeds. Maltais and Nykvist (2021) find that green bonds finance projects that would have happened anyway and thus may give the false impression that they are more impactful than they actually are. The challenge to identify true 'additionality' remains, as the use of proceeds for typical sovereign and corporate green bonds resembles that of conventional investment grade issuances. Especially for bonds that merely re-finance existing green projects, no additional capacity for green projects is generated (Fatica & Panzica, 2021). Maltais and Nykvist (2021) thus argue that green bonds do not appear to lead to significant changes in how capital is allocated.

Despite these challenges, the majority of green bonds proves to lead to an improves environmental performance and reduction in carbon emissions, and the findings in chapter 2.2.1 and 2.2.2 are largely inconsistent with the greenwashing hypothesis. As Flammer (2021) argues, this is also because issuing green bonds is costly for firms, which would then rather choose to pursue other greenwashing strategies. Companies thus credibly signal their commitment toward to green economic activity. Makpotche et al. (2024) show that this is anticipated by investors, who reward non-greenwashing issuances by a premium on the pricing ('greenium'). Translating the greenwashing findings from green bonds to transition bonds, it becomes apparent that for the instrument to be successful, they i) need to be *certified by a second-party opinion* provider, ii) should be accompanied by *regular and transparent post-issuance reporting*, and iii) should be integrated in a *broader transition plan* within the issuing firm.

2.4 Transition Bonds

Another major challenge for the current sustainable finance market in combating global warming is its size. The Green Bond market is too small to mobilize the needed capital as it leaves out important players from participating in the sustainable finance market. Tolliver et al. (2019) show, that the current amount and the trend of green finance allocation can only provide a minor contribution to what would be needed to reach the required 'clean' capital calculated by the IEA (2014) to be USD 53tn by 2035. Especially companies in the hard-to-abate sector play a pivotal role in transitioning the economy as they account for a large portion of emissions and simultaneously have a high capital need to transform. They thus need to be incentivized by other sustainable finance instruments. This gap can potentially be filled by transition bonds.

2.4.1 Functioning and Market

In most recent years, climate transition bonds (or simply transition bonds) gained popularity as a potential instrument to allow these companies to participate in the sustainable finance market. They are similar in their general setup in that they intend to provide clear use of proceeds framework, defining eligible projects categories for allocation of the bond's net proceeds. However, while green bonds require an allocation towards a clear green project under market standards of an authority such as the EU Taxonomy ('EU Green Bonds'), transition bonds focus on financing projects which allow the issuer to progress on an outlined transition path. This could, mean that a transition bond finances a project not eligible for a standard green allocation, yet substantially contributing to the net-zero plan of the issuer. Such projects could refer to retrofitting of existing fossil fuel electricity generation or the development of Sustainable Aviation Fuel (SAF). Zhao et al. (2024) show that transition bonds are most common in the utilities sector and energies, as well as industries related to transportation, particularly aviation and shipping. Especially in Japan, this transition bonds are increasingly popular and is seen as an instrument to reach the government's net-zero targets by 2050. Both for Japan's heavy industry as well as for the government and government-related agencies, a transition to sustainable alternatives in a timely manner has priority because of the country's increased use of natural gas and fossil fuel following the nuclear accident in Fukushima (IEA, 2021a).

In the case of transition bonds, the greenwashing hypothesis outlined in the above chapter is all the more relevant: Corporates interested in issuing such a bond simply for marketing purposes and to showcase participation in the sustainable finance market will not be interested in an emissions reduction. In the longer term, transition bonds will only be successful if greenwashing concerns can be mitigated and if there are international standards that harmonize issuances within a in a global framework (Zhao et al., 2024). However, in contrast to the green finance market, the market for transition finance does not have private governance regimes yet, as it is not as developed. As outlined above, these governance regimes are crucial for the functioning of sustainable debt instruments due to the lack of enforcement mechanisms through public governance (Sangiorgi & Schopohl, 2021). It is the task of standard setters to establish an environment such that investors and other private stakeholders can assess transition finance instruments.

2.4.2 Corporate Governance and Transition Plans

To issue an environmentally successful transition bond leading to a reduction in carbon emissions, good corporate governance is crucial. As part of that, the issuer will usually need to employ an efficient transition plan, as the transition bond can only be effective when embedded within a broader net-zero strategy. Several stakeholder, standard setters and governmental bodies are trying to establish transition frameworks and propose guidelines for corporates to follow, such as the UK Transition Plan Taskforce (TPT) and the Glasgow Financial Alliance for Net Zero (GFANZ). The idea is to define key components that make a credible net-zero transition plan. While there is no universal definition of what defines a 'good' transition plan, the International Financial Reporting Standards (IFRS) sets out good practice for robust disclosures. According to the IFRS (2023), the five disclosure elements to be included in a transition plan are i) the foundation (i.e., the business model, assumptions, etc.), ii) the implementation strategy, iii) the engagement strategy, iv) metrics and targets, and v) the governance structure. This is not only important for regulators and lawmakers; for transition bonds, a widely accepted definition of a good transition plan is needed to assess the ambitiousness of a transition finance framework, and in final instance also to assess the impact that the instrument will likely generate. The ICMA (2023) thus recommends for a transition finance framework to include a detailed description of the company's climate transition strategy, as well as science-based net-zero targets. Similarly, rating agencies and SPO provider already start to assess the quality of transition plans based on guidelines from the IFRS, the GFANZ, and the UK TPT, mirroring the assessment of greenness for green bond issuers (Moody's, 2025).

Furthermore, a successful implementation of climate transition bonds relies not only on the existence of a transition plan, but in general an effective governance structure (Zhao et al., 2024). Because of the unique nature of use of proceeds, these bonds require even stronger monitoring and impact assessment. Zhao et al. (2024) call for a collaborative governance model to coordinate stakeholders in the decision-making process and to ensure that investments are directed towards meaningful transition projects. Drawing on findings from green bond research on governance, it shows that issuing such instruments can help with that: Maltais and Nykvist (2021) argue that the participation in the sustainable finance market leads to an improved dialogue between issuers and external stakeholders post-issuance. In such a setting, investors are able to monitor and control the issuing company, while expressing what they value as being sustainable. According to Sangiorgi and Schopohl (2021), this investor scrutiny serves as a self-regulatory mechanism and ensures that green bonds only finance eligible projects with a clear

sustainability improvement. Likewise, the issuer learns what the market wants in terms of sustainability efforts and can act accordingly.

2.4.3 Use of Proceeds

The use of proceeds section of a transition finance framework identifies and describes intended investment projects to be financed with the proceeds, and is arguable the most important component of the transition bond (Sartzetakis, 2021). Thus, the quality of a transition bond and its environmental impact is largely determined by the question of what qualifies as an eligible project. To ensure these bonds achieve meaningful impact and to prevent greenwashing, it is essential to implement strict eligibility criteria and detailed reporting within a regulatory framework, mirroring what the ICMA (2021) established in its Green Bond Principles. While the Climate Transition Finance Handbook provides ideas for best practice regarding disclosure and actions for transition bonds, it lacks a robust definition of eligible use of proceeds (ICMA, 2023). However, it is commonly agreed by market participant to be projects where significant carbon-intensive activities still occur, yet there is a clear pathway to decarbonization. For example, projects may involve retrofitting of existing fossil-fuel infrastructure or investments into emerging low-carbon technologies. Given the differences of industries that issue transition bonds, eligibility criteria should also be tailored to specific sectors: Projects in electricity generation, aviation or heavy industry might require distinct performance metrics to facilitate both initial evaluation and ongoing monitoring. Lastly, having a clear outline of high-quality eligibility criteria is also important for a potential certification of issuances by an SPO provider (Robins et al., 2023). This will not only establish trust among investors and prevent greenwashing concerns, but also give guidance to issuers of what is expected when investments are labelled ‘transition’.

2.5 Research Gaps

Since the concept climate transition finance is relatively new with issuers, investors and regulators focus on it only in recent years, transition use of proceed bonds as financial instruments are not widely used yet. As such, robust and reliable research on the effectiveness, the financial performance and the structuring of these instruments is scarce. Particularly, research is needed

on the observable environmental impact on a corporate level to help understand the use-cases and the potential of these instruments. This will also help to examine possible greenwashing within the sustainable finance market, and ways to prevent it. Furthermore, research is urgently needed to help establish effective transition finance guidelines and a harmonised framework to coordinate global sustainable finance efforts in the high-emitting sector. This study aims to address this lack of empirical evidence by comparing transition and green use of proceeds instruments, and examine post-issuance environmental performance of issuers.

3 Data

In order to analyse the effect of a transition bond issuance on the environmental performance of the company, various financial and ESG data points are required. This chapter describes the process of gathering the data and provides an overview of descriptive statistics for the used data sets.

3.1 Data Sources

This study uses a comprehensive data set for transition bond issuers and conventional bond issuers, respectively. As Bloomberg offers a unique feature to filter bonds based on their sustainable finance label, it allows to identify all existing transition bonds. The resulting lists comprises all active climate transition bonds and conventional bonds as of January 2025, starting from January 2019.[4] The number of climate transition bonds amounts to a total of 94 active instruments. Due the sheer number of existing conventional bonds issued since January 2019, the study limits the data set for conventional bonds to corporate bonds, with further limitations for the issuance amount[5] and the country of issuance[6]. This leaves the number of corporate conventional bonds at a total of 17,484 active instruments. These filters exclude a significant issuance volume and a large number of issuers – however, the matching methodology applied for the DID analysis later in the study would result in their omission anyway. On the positive side, the chosen approach now allows for a better data collection. For transition bonds, financial service providers and issuers associated with government agencies are filtered out when conducting the DID analysis and regressions, because the identification and the evaluation of these issuers' carbon emissions and their ecological footprint is not possible. Furthermore, even if carbon emissions were identifiable for those issuers, a large part of it is usually beyond their business influence and a sensible connection to the issuance of a sustainable finance instrument cannot be made. However, the mentioned issuer types are kept in the descriptive statistics in order to provide a wholistic view on the instrument.

[4] Bloomberg data was accessed on 03.02.2025 for climate transition bonds and on 11.02.2025 for conventional Bonds
[5] Amount issued larger than the equivalent of EUR 100m
[6] Countries included in the data set are countries of the European Union, Great Britain, Japan, China, Hong Kong

In line with studies similar in data and methodology (Flammer, 2021; Makpotche et al., 2024), firm-level financial and accounting data are obtained from Standard & Poor's Compustat (Compustat Global for all public companies not in North America). The main variables used in this study are the book value of total assets as well as the revenue, both as a proxy for company size. For these metrics, it should be noted that several companies operate on a fiscal calendar that differs from the standard calendar year. To ensure consistency, the study standardizes reporting by reassigning filing dates to the appropriate period. Furthermore, Compustat provides MSCI's Global Industry Classification Standard (GICS) to classify companies into GIC Groups (4-digit code) and GIC Industries (6-digit code). The data is restricted to as early as 2016, which is the year three years before the first transition bonds issuance. As such, all previous years will not be relevant to the DID analysis.

Firm-level ESG data is drawn from Thomson Reuters' Refinitiv. Carbon emissions data focus on direct emissions from company operations (Scope 1) and indirect emissions from purchased electricity or energy (Scope 2). The total emissions is the sum of Scope 1 and Scope 2 carbon emissions in any given year. Emissions intensity is then calculated as the absolute sum of emissions divided by the book value of total assets and by revenue, respectively, as tCO2e per EUR million. While emissions per unit of revenue is considered the typical metric to refer to carbon intensity, several similar studies (Flammer, 2021; Makpotche et al., 2024; Yeow & Ng, 2021) calculate carbon intensity as total emissions per unit of assets (book value). Thus, this study uses both metrics to give a comprehensive picture. Refinitiv also provides ESG Scores, Environmental Scores and resource use Scores for each bond issuer. These scores are usually expressed as an alphabetical value from A+ (best) to D- (worst) but were assigned a numerical value from 1.0 (best) to 0.0 (worst) to facilitate the analysis. Subsequently, numerical scores can be recalculated into alphabetical scores for better readability according to Refinitiv's public methodology (LSEG, 2024).

Several conventional bonds could not be mapped to Compustat or Refinitiv, for example due to the issuer being a separate legal entity for debt issuance. Challenges in identifying these entities across the data bases from Bloomberg, Compustat and Refinitiv thus did not allow to obtain the required data. These unique issuers were dropped from the DID analysis. In order to not drop transition bond issuers and further decrease the comparably small number of companies, the data for transition bonds were supplemented by manual evaluation of sustainability reports, annual reports, and company filings.

When calculating financial accounting data or metrics which use them (e.g., carbon intensity), they are converted into Euro to facilitate comparison. To account for fluctuations in currency exchange rates, a yearly average exchange rate from the reporting currency to Euro is calculated based on Compustat Global's exchange rate matrix (Compustat, 2025).

3.2 Descriptive Statistics

The data sets for transition and conventional bonds have unique characteristics. A first look at the descriptive statistics can provide an indication of commonalities and differences of transition issuers. This chapter will thus look at the volume and tenure, financial characteristics of the issuer as well as environmental KPIs such as carbon profile and several ESG-related score metrics.

3.2.1 Transition Bonds

The study identifies a total of 94 transition bonds, issued until end of 2024. The total issuance amount of outstanding transition instruments amounts to a Euro-equivalent of c. EUR 36.4bn.

Figure 1. Total Transition Bond Issuance Volumes by Year

This figure reports the global issuance volume for transition bonds (in billion EUR) from 2019 to 2024.

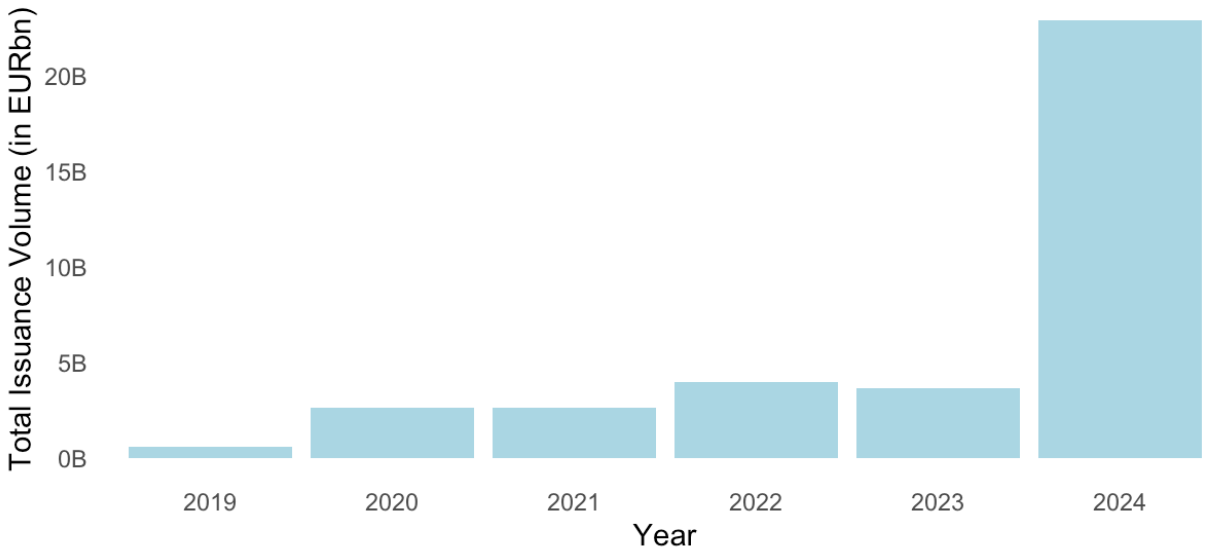


Figure 1 shows the significant growth of issuances in recent years, and most recently in 2024 specifically. Although the first bonds were introduced to the market in 2019, volumes stayed relatively insignificant, being in line with general sustainable financing (green) activity. However, volumes increased drastically in 2024, reaching c. EUR 22.9bn (29 transition bonds) compared to EUR 2.6bn (6 transition bonds) in 2020. This is to a large part also attributable to Japanese government bonds and several other large-volume issuers turning towards transition bonds.

Table 1 gives an overview of the industries that transition bond issuers operate in, as labelled by Bloomberg's Industry Classification Standard (BICS). As expected, the majority can be attributed to companies in the hard-to-abate, carbon-intensive sectors. Notably, many issuers operate in the utilities and energy sector, for example as operator of gas plants. Furthermore, governments and related agencies account for more than 50% of total outstanding volumes, which is mainly due to the Japanese Transition Financing program from 2024. Table 2 provides a country breakdown. It highlights Japan as the dominant issuing country, accounting for over 70% of the total number of transition bonds.

For further analysis, government-related bonds and bonds from financial service providers and banks are excluded for reasons mentioned above. From the total 94 transition bonds, nine issuances are removed based on these criteria. Further, four issuers are removed since no public information on neither financial data nor emissions data could be found (companies are located in the People's Republic of China). Finally, several entities have to be excluded as no environmental data is available. While carbon intensity is available for 74 unique bonds, only 67 companies have received a Refinitiv scores for ESG, Environment, and resource use. Table 3 reports descriptive statistics with the available data.

Table 1. Transition Bond Issuance by Industry

This table reports the issuance volume (in billion EUR) as well as the number of issuances for global for transition bonds since 2019, ordered by issuers' industry.

Issuer Industry for Transition Bonds

Industry	N	N (in %)	Volume (in EURm)	Volume (in %)
Industrial	33	35.11	8,543	23.47
Utility (Electricity)	25	26.60	3,707	10.18
Utility (Gas)	15	15.96	2,725	7.49
Transportation (Aviation)	9	9.57	1,375	3.78
National Government	4	4.26	19,151	52.61
Banks	3	3.19	500	1.37
Special Purpose	3	3.19	111	0.30
Financial	1	1.06	204	0.56
Government Agency	1	1.06	83	0.23

Table 2. Transition Bond Issuance by Country of Risk

This table reports the issuance volume (in billion EUR) as well as the number of issuances for global for transition bonds since 2019, ordered by country of risk.

Issuer Country for Transition Bonds

Country	N	N (in %)	Volume (in EURm)	Volume (in %)
Japan	70	74.47	28,342	77.87
Italy	8	8.51	4,300	11.81
China	7	7.45	847	2.33
Hong Kong	4	4.26	789	2.17
France	2	2.13	200	0.55
Great Britain	2	2.13	1,377	3.78
UAE	1	1.06	543	1.49

Table 3. Transition Bond Descriptive Statistics

This table reports descriptive statistics for the transition bonds dataset from 2019 to 2024. Financial figures are shown in million EUR, while carbon intensity figures are calculated as tCO2eq per million EUR. ESG scores are displayed as a numeric figure between 1 (best) and 0 (worst), which can be translated back to alphabetical scores from A+ (best) to D- (worst).

Statistic	N	Mean	Median	St. Dev.	Min	Max
Issue Volumes (in EURm)	94	329.92	98.94	815.14	30.16	5,275.42
Tenure (years)	94	8.83	7.00	8.46	2.00	60.00
Size (Revenue, in EURm)	81	16,962.64	13,214.16	15,757.07	1,658.31	84,133.48
Size (Assets, in EURm)	81	27,530.99	25,010.23	16,008.28	3,047.91	74,323.03
Carbon Intensity (per EURm Revenue)	74	1,849.18	670.30	4,267.09	18.21	26,432.51
Carbon Intensity (per EURm Assets)	74	870.71	383.86	1,883.00	14.03	11,186.32
ESG Score	67	0.63	0.64	0.17	0.27	0.95
E Score	67	0.73	0.74	0.13	0.38	0.96
ResourceUse Score	67	0.72	0.68	0.15	0.48	1.00

As Table 3 shows, transition bonds are large in volume with an average of EUR 330m, and also have a rather long maturity with a mean of 8.8 years. This could potentially hint towards the capital-intensive and long-term investments projects that these bonds are intended to finance. Furthermore, it can be noted that issuers have a comparably high carbon intensity, especially comparing it to conventional bonds (compare Table 4). This confirms expectations that the majority of transition bond issuers are among the high-emitting players in the corporate sector.

3.2.2 Conventional Bonds

The study identified 17,848 active corporate conventional bonds issued by between 2019 and 2024 in the defined regions and industries. Due to the sheer number of existing conventional bonds, a first filter was already applied in acquiring the data to reduce the amount of data (see chapter 3.1 Data Sources). These bonds were issued by a total of 3,501 unique issuers, thereof 726 with Compustat data. Further, 587 issuers had Refinitiv data available. Table 4 provides descriptive statistics.

Table 4. Descriptive Statistics of Corporate Conventional Bond Data[7]

This table reports descriptive statistics for the corporate conventional bonds dataset from 2019 to 2024. Financial figures are shown in million EUR, while carbon intensity figures are calculated as tCO2eq per million EUR. ESG scores are displayed as a numeric figure between 1 (best) and 0 (worst), which can be translated back to alphabetical scores from A+ (best) to D- (worst).

Statistic	N	Mean	Median	St. Dev.	Min	Max
Issue Volumes (in EURm)	16,031	266.54	157.77	284.12	100.01	8,470.00
Tenure (years)	14,381	6.07	5.00	5.83	0.20	63.30
Size (Revenue, in EURm)	3,307	25,462.52	11,961.16	39,912.42	3.38	411,310.40
Size (Assets, in EURm)	3,325	49,358.67	22,629.60	76,163.61	20.57	594,387.40
Carbon Intensity (per EURm Revenue)	2,295	601.75	49.62	2,136.99	0.06	29,796.74
Carbon Intensity (per EURm Assets)	2,295	300.62	27.79	1,059.38	0.03	17,338.93
ESG Score	2,657	0.62	0.66	0.20	0.03	0.96
E Score	2,632	0.65	0.69	0.22	0.002	0.99
ResourceUse Score	2,602	0.70	0.78	0.25	0.01	1.00

At first sight, issuers of conventional bonds tend to be a bit larger based on revenue and book value of assets. Also, the tenure is short than for transition bonds, with a mean maturity of 6.07 years. Interestingly, looking at environmental metrics, carbon intensity seems indeed to be lower for conventional issuers already pre-issuance: The mean for intensity per revenue (per book value of assets) is 601.75 (300.62), while the median is as low as 49.62 (27.79). This also shows that there is a significant number of issuers with very low emissions (due to the very low median). Furthermore, Refinitiv scores for aggregated ESG performance, environmental performance and for resource usedo not diverge significantly from the average scores for transition bond issuers at first sight, being averages of 0.62, 0.65, and 0.70 for ESG score, E score, and RU score, respectively.

[7] Several bonds do not have issuance volumes provided by Bloomberg, for example because issuances are under a debt issuance program with aggregated volumes or a private placement with undisclosed volume. Tenure is missing for perpetual instruments or callable instruments without a fixed maturity.

4 Methodology

The main analysis of this study applies a Difference-in-Difference (DID) regression to examine differences in issuer groups of transition bonds and conventional bonds. Thus, a differentiation between the issuance of a transition bond as treatment, and no issuance as a control (i.e., issuance of conventional bonds) is needed. To ensure consistency across all bonds, the timelines of both treated groups (transition bond issuers) and control groups (conventional issuers) are normalized into a relative timeline around the issuance date. T_0 marks the year of issuance, while T_{-1} and T_{+1}, T_{+2}, etc. represent the reporting periods before and after the issuance, respectively. The DID analysis focusses on comparing environmental KPIs from the treatment group with KPIs from the control groups. Before that, a matching algorithm is employed in order to increase the comparability and reduce influence of exogenous variables besides the bond issuance. This section describes how the regressions are constructed and how the matching is performed.

4.1 Control Group Selection

In general, the decision to issue a transition bond is not exogenous, but an internal decision made by the management. This poses a challenge to the DID analysis, as the decision to issue such an instrument could potentially be influenced by unobservable variables which simultaneously influence the dependent variable of interest (i.e., carbon emissions). Thus, a control group must be selected that is similar to the treated firms (i.e., the transition bond issuer). To construct such a control group a Propensity Score Matching (PSM) method is applied to find for each treatment issuer their closest neighbour based on certain company KPIs. Additionally, several exact criteria are defined, which have to be met to be eligible for the control group. Caliendo and Kopeinig (2008) describe how the usage of PSM method helps to avoid selection bias and helps to observe the effect of issuance as the causal treatment effect in more isolation. It generally also maximizes comparability. Specifically, this study uses a single nearest neighbour matching (pair matching) with no replacement. According to Austin (2014), this is among the most commonly used implementation and allows to accurately estimate the Average Treatment Effect in the Treated (ATT). The variables used to choose the control firms are similar to that of Flammer (2021). The exact criteria require that treated and control firms operate in the same country and in the same four-digit GIC industry. Furthermore, control groups are also matched based on the year of bond issuance. This accounts for time-fixed effects and captures external

macroeconomic trends. For example, an issuer that issued a transition bond in 2022 is only matched with a conventional issuer from 2022 exhibiting the same country of risk and the same industry. Besides the exact matching criteria, control firms are selected based on their financial characteristics in two continuous variables, namely revenue and book value of assets, both as a baseline average of the three years preceding the issuance.[8] This approach mirrors the approach of Fatica and Panzica (2021) and aims to capture internal factors affecting the issuance decision. Each treatment group then gets matched with a control group with the highest propensity score. This ensures that treated and control firms face the same business conditions and requirements potentially influencing the decision of issuing a debt instruments.

4.1.1 Matching Characteristics

The DID regression requires matched data set of treated and control issuers. This is done according to the algorithm described in chapter 4.1. The following tables illustrate descriptive statistics for matching characteristics and other, non-matching characteristics, showing the similarity between both. Following previous studies such as Makpotche et al. (2024), baselines always refer to the average of the three years preceding the bond issuance. For each characteristic, mean, median and standard deviation is reported. In the last two columns, p-values for difference-in-means and for difference-in-medians between treated and control firms are reported. To test difference-in-means, a t-test is conducted. Testing difference-in-medians requires the use of a nonparametric test. Two options are the Mann-Whitney U Test and the Mood's Median Test. In this case, the Mann-Whitney U Test (or Wilconox test) is used, assuming that all the data samples are independent and similar in distribution shape. Ideally, treated and control firms should be very similar, and thus p-values high enough to not reject the hypothesis that means are equal. Table 5 reports matching characteristics for the regression:

[8] The Robustness section employs PSM matching based on other characteristics, including environmental KPIs such as ESG score

Table 5. Matching Characteristics: Transition (Treatment) vs. Conventional (Control)

This table presents descriptive statistics to compare corporate transition bonds with corporate conventional bonds from 2019 to 2024. Baselines are measured as an average of the respective metric three years preceding the issuance. Financial figures are shown in million EUR, while carbon intensity figures are calculated as tCO2eq per million EUR. ESG scores are displayed as a numeric figure between 1 (best) and 0 (worst), which can be translated back to alphabetical scores from A+ (best) to D- (worst). The last two columns report the p-values for difference-in-means and difference-in-medians tests.

Matching Characteristics Transition (Treatment) vs. Conventional (Control)

Characteristic	Group	Obs.	Mean	Median	Std. dev.	p_mean	p_median
Revenue Baseline	Treatment	73	14121.01	12482.37	9793.99	0.06	0.17
Revenue Baseline	Control	73	11296.78	9848.39	7753.36	0.06	0.17
Asset Baseline	Treatment	73	25553.94	22813.67	13766.72	0.95	0.44
Asset Baseline	Control	73	25394.08	19596.96	16346.95	0.95	0.44
CO2 Intensity (Revenue) Baseline	Treatment	66	1443.28	745.92	2603.01	0.37	0.96
CO2 Intensity (Revenue) Baseline	Control	68	1130.49	996.84	1087.83	0.37	0.96
CO2 Intensity (Assets) Baseline	Treatment	66	695.92	396.24	1211.54	0.16	0.64
CO2 Intensity (Assets) Baseline	Control	68	471.02	437.11	441.15	0.16	0.64
ESG Score Baseline	Treatment	61	0.62	0.62	0.17	0	0
ESG Score Baseline	Control	70	0.51	0.46	0.19	0	0
E Score Baseline	Treatment	61	0.73	0.75	0.12	0	0
E Score Baseline	Control	70	0.61	0.65	0.19	0	0
ResourceUse Score Baseline	Treatment	61	0.73	0.71	0.13	0.02	0.05
ResourceUse Score Baseline	Control	70	0.65	0.65	0.21	0.02	0.05

While in general, the matching works well, treated and control groups are significantly different in some characteristics. P-values for difference-in-means range from 0 to 0.95 across characteristics. P-values for difference-in-medians range from 0 to 0.96. In particular, the unsignificant differences in carbon intensity baseline (per assets and per revenue) are desirable since this is the main variable of interest (p-values in means of 0.37 and 0.16, p-values for medians 0.96 and 0.64). While a better similarity would be desirable, this is thus the most important characteristic.

Also, including more parameters in the PSM matching does not change these results either, given that the exact criteria that must be fulfilled in the first place.[9] This is mainly due to the limited number of observations in the transition bonds group. As can be seen, not all issuers could be matched. This reduces the number of observations quite drastically which in turn reduces significance. Also, the number of observations varies depending on data availability, since fewer issuers have information available on environmental and ESG performance) than on financial performance.

Overall, descriptive statistics confirm that for the most part the control group is reasonably similar to the treatment group. In particular, the treated and control firms have similar emissions intensity levels, despite not being matched according to that. This helps to provide an approximated counterfactual to show how treated firms would behave without the issuance of a transition bond. It also helps to mitigate concerns that firms that have emission problems issue transition or green bonds for reputational purposes only (Flammer, 2021). Furthermore, it should be noted that emissions intensity figures have relatively high volatility across datasets. This will likely impact further analysis and decrease significance.

4.2 Dependent Variable

After the process of matching treated and control firms, the Average Treatment Effect (ATE) on several ESG performance metrics following the bond issuance is analysed. The DID focusses on carbon intensity as the main variable of interest, but also analyses ESG rating scores, environmental rating scores, as well as resource use scores to assess the potential effect on wider ESG firm performance. Makpotche et al. (2024) use to assess resource efficiency and waste management as a distinct measure within the environmental score in a similar DID setting for green bonds. For carbon intensity, full-year emissions of the issuer before and after the issuance are compared. The analysis focusses on direct emissions from company operations (Scope 1) and indirect emissions from purchased electricity or energy (Scope 2). The total emissions of the sum of Scope 1 and Scope 2 carbon emissions in any given year. Scope 3 emissions are excluded for theoretical and practical reasons: As Scope 1 and 2 are under direct influence of the issuing firm, it typically has better ability to reduce those in contrast to Scope 3. Therefore, transition plans usually focus on Scope 1 and 2 mainly and consequently transition bonds are used to primarily finance projects focussing on Scope 1 and 2 emissions. It can thus be

[9] Matching with other characteristics is performed for robustness checks

expected that the biggest emissions reduction will be seen in Scope 1 and 2 emissions. For practical reasons, many companies do not report Scope 3 emissions properly and calculation methods are rather untransparent, leading to worse data availability. The study follows the approach of Flammer (2021) in defining a short-term effect looking at changes in the variable of interest one year after issuance, and a long-term effect two and more years after issuance. This helps to account for the long-term nature of carbon reduction projects and investments.

4.3 Regression Specification

Assessing the Average Treatment Effect in the Treated (ATT) on a firm-level requires to estimate the Difference-in-Difference regressions for treatment and control firms before and after the issuance of a transition bond. The study follows previous research from Yeow and Ng (2021), Flammer (2021), and Makpotche et al. (2024), and estimates the regression according to the following formula:

$$y_{it} = \alpha_i + \alpha_S + \beta \times (Treatment_i * Time_t) + \varepsilon_{it},$$

where *i* and *t* are indexes for firms and for years and *y* denotes the variable of interest (namely carbon intensity per book value of asset, carbon intensity per revenue, ESG score, environmental score, and resource use score). α_i denotes firm-fixed effects, and α_S denotes subclass fixed effects that refer to fixed effects for industry, year and country all three simultaneously. Subclass fixed effects are taken from the exact matching algorithm in the PSM. The *Treatment* variable is a dummy equal to one if the firm has issued a transition bond and zero otherwise, and ε denotes an error term. *Time* represents a dummy variable equal to one post-issuance, and zero pre-issuance. Other control variables are not included in the regression anymore, because the pre-regression matching already accounts for external and internal factors not causal by the issuance. Including control variables for robustness checks do not change results significantly.

The coefficient β represents the Difference-in-Difference estimator and is the main coefficient of interest. It tells whether the expected average change in outcome from before and after the issuance is significantly different in treatment and control group. The regression table also provides a coefficient for the estimated difference in the dependent variable between treatment and control group before the bond issuance. This coefficient is expected to be insignificant as the matching based on baselines preceding the issuance should be effective. Furthermore, a coefficient is shown that reflects the expected mean change in the outcome variable absent of the

transition bond issuance, i.e., the effect of the time difference. For β to be interpretable as a causal coefficient the common trend assumption is necessary, i.e., that both treatment and control firms would have reduced emissions in a similar way without the issuance of a transition bond. This assumption is fulfilled as good as possible by the propensity score matching (Ryan et al., 2019). It furthermore requires that the SUTVA assumption is fulfilled, i.e., that the issuance of bonds by other firms does not impact the ESG performance of treated firms. This assumption should be fulfilled by nature for the issuance of transition bonds.

Different regression specifications are made to assess short-term and for long-term effects on the variable of interest separately. Callaway and Sant'Anna (2021) describe the process of establishing multiple time periods in one regression. In order to do so, the basic regression formula is extended to include two separate time dummies, $Time_t^{ST}$ and $Time_t^{LT}$ which are equal to one one year after the issuance (short-term) and two or more years after the issuance (long-term), and zero otherwise. The interpretation of coefficients remains the same. In the following, these regressions are performed.

5 Findings

The following section presents the analysis and results from the DID regression estimates for carbon intensity, as well as several other ESG metrics.

5.1 Regression Results

Table 6 presents findings for the DID regression with transition issuers in as treatment firms and conventional issuers in the control group. First, note that the treatment coefficient is insignificant across all regressions, indicating that the matching process provides a good-enough control group. Furthermore, it is interesting to observe a significant decrease in carbon intensity post-issuance in the short term of -333.140 tCO2e per EURm in revenue, and of -100.894 tCO2e per EURm in book value of assets, which indicates that companies on average reduce emissions regardless of the type of issuance. Looking at the DID estimator of interest, it can be seen there is no significant effect on carbon emissions following a transition bond issuance. Although the average change is negative in the long-term, it is not significant at the 1%, 5%, or 10% confidence level. Columns (1) – (4) show that this observation is consistent across intensity per revenue and intensity per assets, but more importantly also across the observation period in the long-term. While this can certainly be attributed to the high volatility in carbon emissions and the comparably low number of observations in the treatment group, these results already indicate that firms do not substantially improve environmental performance following a transition bond issuance. This can potentially be connected to the greenwashing hypothesis.

Looking at other Refinitiv score metrics as performance indicators, Appendix A provides further information. Columns (5) – (10) find that while the ESG score does not change significantly in comparison to conventional issuers, the average score for E (environmental) and for resource use *decreases significantly* post-issuance, by -5.1 points and -7.5 points in the short term and by -5.9 points and -8.5 points in the long term, respectively. The change is statistically significant at the 5% level. On the contrary, the overall time variable is significantly positive across metrics, indicating that conventional issuers in fact increase their rating over time. This behaviour is equally consistent with the greenwashing hypothesis and might raise concerns about companies without the intention of emissions reduction misusing transition bonds.

Table 6. DID Regression Results: Carbon Intensity

*This table reports estimated Difference-in-Difference regressions as outlined in chapter 4.3. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively.The data set includes all firm-year observations of transition bond issuers and matched conventional issuers from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:			
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)	
	(1)	(2)	(3)	(4)
Treatment	-13.451	-0.900	-0.329	-3.026
	(81.742)	(84.031)	(34.020)	(35.204)
Time (Short-Term)	-333.140***		-100.894**	
	(119.904)		(49.903)	
Time (Long-Term)		-194.491		-105.225
		(205.719)		(86.183)
DiD Estimator (ST)	154.894		-15.199	
	(165.685)		(68.956)	
DiD Estimator (LT)		-68.301		-68.103
		(276.191)		(115.707)
Constant	102.537	102.537	79.122	79.122
	(295.901)	(299.253)	(123.150)	(125.368)
Subclass Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	885	850	885	850
R^2	0.933	0.929	0.939	0.936
Adjusted R^2	0.924	0.919	0.931	0.927
Residual Std. Error	591.802 (df = 778)	598.505 (df = 745)	246.300 (df = 778)	250.736 (df = 745)
F Statistic	101.795*** (df = 106; 778)	93.094*** (df = 104; 745)	113.187*** (df = 106; 778)	104.095*** (df = 104; 745)
Note:				*p<0.1; **p<0.05; ***p<0.01

It is also interesting to note, that the constant in columns (5) – (10), i.e., the score metrics for the matched control firms, are exceptionally low and significant. This is likely due to the nature of the industry that transition bond issuers operate in.

5.2 Robustness

Several robustness checks are conducted to validate findings and address different specifications. Describing them, the following chapter will focus mostly on the DID estimator (both short- and long-term) as the main coefficient of interest.

Clustered Standard Errors (CSE): To adjust for correlation within issuers, clustered standard errors are used to estimate regression. Since intra-cluster correlation is likely, the normal standard errors are underestimated, leading to overconfidence in the statistical significance. Using clusters by each issuance, giving the benefit of clustering by issuer and by year, effectively giving me a two-way cluster with a simple step. When using two-way CSE, findings lose significance. This shows the expected existence of within-correlation and dependent observations. Therefore, non-clustered standard errors were underestimated. However, the economic interpretation of prior results does not change: The carbon intensity change of transition bonds issuer remains insignificant. Appendix B provides the DID regression table with CSE for carbon intensity per revenue and per book value of assets, ESG score, environmental score, and resource use, as dependent variable.

Change of matching baseline: Instead of using the average of three years prior to the respective issuance, matching was conducted only based on KPIs from last year before the issuance. While results become slightly less significant, no other change can be observed.

K-nearest neighbour matching: To assess the sensitivity of the estimated treatment effects to the matching process, different number of neighbours were used. The PSM method changes from single nearest neighbour to k = 2 or k = 5 matched control firms to one treatment firm. This increases the number of control observations, leading to reduced variance and more stable estimates of the DID treatment estimator. On the other hand, with more neighbours the risk of including less similar neighbours increases. To mitigate this, a weighting scheme is used in the subsequent DID regression which limits the influence of not-so-similar control firms. Overall, including more control firms does not change findings in an economical sense. Statistically, several effects can be observed: Firstly, the time effect is more pronounced and significant for all dependent variables, i.e., regardless of the treatment, companies tend to reduce emissions intensity and increase in ESG rating. Secondly, using five control neighbours, transition bonds issuers actually exhibit a slight increase in emissions intensity compared to conventional bonds, significant on a 10% level. At the same time, the decrease in ESG score metrics is very pro-

nounced. This is not surprising and mirrors the results obtained prior, further confirming potential greenwashing. Regression tables for control groups with k-nearest neighbour matching can be found in Appendix B.

Matching variables: Using different matching variables in the PSM algorithm beyond the exact criteria does not lead to a change in findings. Similarly, increasing the number of matching variables does not lead to large deviations in results either. Matching was conducted, for example, based on revenue, book value of assets, carbon intensity, ESG score, environmental score, and resource use score.

5.3 Limitations

The study has several limitations mainly related to the DID regression and the matching. A major challenge concerns the endogeneity of companies' decision to issue transition bonds: The issuance event is affected by a variety of different internal and external factors, which at the same time also affect the environmental performance post-issuance. For example, Wang and Wang (2022) find an increased propensity for issuing a green bond for companies with a good ESG performance. Makpotche et al. (2024) argue that improved green innovation is a characteristic of green bond issuers rather than a post-issuance effect. Similarly, the decision to issue a transition bond could be made by companies already seeing a decrease in carbon intensity, instead of the decrease in carbon intensity as a causal effect from the transition bond issuance. Since it is impossible to identify all factors, this endogeneity complicates the identification of a clear relationship between transition bond issuance and subsequent firm performance. To mitigate this issue and to isolate the effect of issuance, the study employs a first stage of matching based on industry, year of issuance, and country. This exact matching tries to capture the external factors like regulation and industry behaviour. Furthermore, the PSM employed based on certain firm-internal KPIs aims to account for internal factors affecting the bond issuance. This two-fold matching method helps to address the endogeneity problem and ensures that treated and control firms share similar characteristics and operate in comparable environments. However, this only captures observable characteristics; the study further assumes that events not included in the model will affect treated and control firms similarly, therefore leading to a good DID estimator.

Another major limitation is the small number of transition bonds, as well as the short available observation period after the issuance of the majority of existing instruments. For one, transition

bonds only emerged recently, and with only around 100 instruments, statistical effects are difficult to observe. Given the low significance it is also difficult to interpret results in an economically meaningful way. Secondly, for the issuers that have transition use of proceeds instruments in the market, often times there is only a short time window post-issuance with data available. The setup of the DID regression allows only to assess a short-term effect if there is a data point one year following the issuance, and long-term effects for issuers with data points two and more years following the issuance. This means that despite the surge in transition instruments in 2024, these are automatically excluded from the DID regression, further reducing the number of issuer data. Only instruments issued until 2023 are included in short-term DID estimators, and only instruments issued until 2022 are included in the estimation of long-term effects. Since 2024 saw a high number in new transition bonds and 2025 is set to see many more, it would be sensible to revisit the analysis performed in this study in the future. Conducting a similar study in two or more years will provide an even better picture of the potential of transition bond, shed more light on the environmental impact, while also having a more developed transition debt market to put into perspective the importance of the instrument.

Finally, the study is limited by its data accessibility to map bond issuances to the issuing parent company and the respective financial profile and ESG profile data. As outlined in the Data section of the study, issuance data, financial data and ESG data were derived from different sources and platforms. Furthermore, mapping issuing entities to the ultimate parent proved difficult in some cases. Lastly, many entities that could be identified did not provide ESG data over the required time horizon to be considered in the regression analysis. While these factors lead to a relatively large number of exclusions in the final data set for conventional bonds, it is still considered comprehensive and representative for the whole market for corporate bond issuance. As the number for transition bonds in the market is small by nature and exclusions would have made it near to impossible to conduct this analysis, data was added manually for all transition issuers without data available. This allows for a wholistic perspective on the transition bond market, while the data set conventional bonds is representative in the industries and geographies relevant for this analysis.

6 Discussion

The findings of this study provide evidence against a significant environmental improvement following the issuance of climate transition bonds. The DID analysis is not able to confirm that companies that issue a transition bond reduce carbon emissions to a significantly larger extent post-issuance than comparable companies with a similar economic and ecological profile, but without such an issuance. Given the relative short observation window limitation, these findings could however be attributable to the sector-specific pace of transition in the industries which are active in the transition bond market, and which is slower and more capital-intensive than for industries that are already green (Zhao et al., 2024). Furthermore, it seems that the ESG rating of issuers decreases in the short and long term following a transition bond issuance. This could serve as an indicator for potential greenwashing concerns related to this new sustainable finance instrument. The reasons are likely numerous, but one main central issue that comes up in academic research on the sustainable finance market it the lack of governance: Park (2018) describes the challenges that arise in the green bond market due to the lack of public governance regimes, and Flammer (2021) outlines potential misuse of green finance as result of the absence of enforcement mechanisms in private governance compared to public regimes. Given that the transition market is still new and not very regulated, one could interpret the findings in this study to be related to this lack of market development in terms of governance. Additionally, transition plans and general transition ambitions of companies are inherently more difficult to assess and thus harder to regulate.

While overall, these findings suggest that climate transition bonds may not currently live up to their full potential, other papers on these instruments come to other conclusions. In contrast to looking on an individual firm level, Zhao et al. (2024) argue that they can contribute to emissions reduction and renewable energy expansion on a country level, for example in Japan, which is a pioneer in sustainable finance and is able to fund its tremendous transition ambitions at least partly using transition instruments. Although it seems counterintuitive this does not necessarily contradict the presented findings, because even if changing corporate behaviour only marginally, they may still contribute towards an aggregate transition. This may be especially true in a more long-term view on the instrument not reflected in this study. For that to assess, further research beyond corporate bonds could be done on government bonds.

6.1 Practical Implications

The literature review shows that a developed sustainable finance market can indeed incentivize meaningful emissions reduction and incentivize eco-friendly behaviour. The green bond market allows proper academic research which can be used to draw conclusion on factors necessary to foster such a properly working sustainable finance market. As mentioned, the main challenge in combating greenwashing concerns is the lack of public governance regimes in the sustainable finance market. If transition bonds aim to reach a similar impact, it will be crucial for regulators and practitioners to provide market standards, issuance guidelines as well as a proper framework of what is expected from transition issuers in terms of sustainability behaviour. Such guidelines should cover several factors: For one, it will be necessary to mandate a strong governance around the issuance, including a net-zero transition plan, a certified framework detailing the intended investment of use of proceeds, as well as a rigorous post-issuance reporting (Bhutta et al., 2022; Lin & Hong, 2022). In this special case, a particular emphasis must be on the integration of the transition bond within the issuer's transition strategy, which in turn should be aligned with some form of transition plan 'gold standards' such as the IFRS (2023) disclosure framework. The concept of a transition debt instrument can only work if investors and stakeholders see a clear pathway outlining the intended emissions reduction that needs financing via the bond. To document the progress made along this pathway, it furthermore requires regular post-issuance reporting focussing not only on allocation of proceeds, but more importantly documenting the impact of the financed projects. This is important for investors and issuer alike, as it guarantees transparency (Tuhkanen & Vulturius, 2022). Finally, the existence of market standards and issuance guidelines will allow credible certification of transition bonds by second-party opinion provider, facilitating investors' assessment of impact and sustainability contribution. The possibility to obtain certification in alignment to some form of market standard will also promote a more widespread use of transition bonds. It also reduces the risk of greenwashing (Flammer, 2021). A well-functioning transition bond market can thus provide tools to investors looking to invest in companies with the potential to further reduce emissions instead of already green ones. It can furthermore provide an opportunity to invest into a sustainable product with ESG characteristics for people who still want exposure to traditional hard-to-abate sectors for financial or diversification reasons. In contrast, if the regulatory framework and the overall market control is not strong enough, transition bonds may be misused as a greenwashing instrument by high-emitting companies. As the market is now, transition bonds do not deliver on the promised potential.

6.2 Harmonising Transition Finance and Just Transition

Besides the small ecological impact, separating transition bonds as unique sustainable finance instruments from the rest of the market may complicate the governance of such bonds. Practitioners warn that transition finance may simply water down and relabel common green finance, arguing that transition bonds are shifting capital “from brown to lighter brown [instead of green]” (Michaelsen, 2019). The idea behind a green finance is already transitional in nature and even if the instrument itself does not allow for ‘transition’ use of proceeds the market as a whole already encompasses many of the characteristics attributed to transition bonds. It thus questions the necessity for a separate instrument. The current green bond guidelines do not imply a static state of sustainability; they rather already inherently have a built-in "transition" feature. Green bonds recognize that issuers engage in transition by investing into green projects rather than transition projects. Of course, this may exclude several important companies operating in hard-to-abate sectors, but instead of focussing on transition finance, a more coherent strategy could be to expand existing green bond guidelines in order to encompass the gradual transition of all companies.

Nevertheless, climate transition bonds as a concept are in no way obsolete: Promoting high-quality transition plans in relation to sustainable debt issuances will help to credibly communicate issuers’ sustainability profile, while giving investors a tool to hold them accountable to measurable targets. Furthermore, they can contribute to achieving a just transition. One major challenge with transition finance lies in the fact that rapid and drastic shifts from the current status quo negatively impacts people, workforce and communities traditionally dependent on fossil fuels (Zhao et al., 2024). Related to that is the principle of climate justice, which encompasses the trade-off in environmental expenses for current and future generations (Newell & Mulvaney, 2013). Transition thus requires carefully planned phase-out of fossil fuels at a pace that allows for a social adaption of new technologies. At the same time, it requires additional funds beyond the ones needed to finance the actual environmental transition, for example to finance retraining and redeployment of workers to prevent job losses (ILO, 2022). What makes transition bonds so attractive as a tool for financing a just transition is that a variety of stakeholders that are important to a just transition can issue these bonds (Robins et al., 2023). For instance, educational, housing, or health authorities, governments, or non-profit organisations can participate in the debt market, while raising capital from equity markets is not possible. The concept of (just) transition bonds should therefore be defined more broadly. Naturally, the con-

cept is all the more important for stakeholders active in high-emitting industries, whereas companies active in low-carbon sectors are not affected by the need for a just transition. A transition company such as a utility or gas provider likely exhibits a slower transition due to social and technological constraints, while a renewable energy provider can reduce its carbon profile more easily. The findings from this study can be connected to this argument: For transition bond issuers active in such industries, the short-term and long-term[10] reduction DID effect was not significant, which could just be related to the slow pace of a just transition.

Ideally designed climate transition bonds and supplementary transition frameworks will recognize this, but outline a path to still arrive at measurable carbon reduction measures, while paying attention to the transition being just (IFRS, 2023). As such, transition bonds offer a useful tool as 'just transition bonds' which should incorporate just transition elements into design and implementation. Hall et al. (2018) identify – among others –good governance, due process, and intra-generational equity to be part of a total of 6 key principles of a just transition. They should thus also be reflected in corporate transition frameworks. By doing so, issuers can address potential adverse social impacts, while at the same time enhancing the credibility and markets participants' acceptance of transition instruments.

[10] Even though long-term effects are observed, these are only two or more years per definition. To observe effects accounting for the pace of a just transition, study designs spanning several years or even decades are needed.

7 Conclusion

This study examined the environmental impact of climate transition bonds, comparing them to conventional bonds and assessing their potential to contribute towards the transition ambitions (i.e., carbon reduction) of issuing companies. The literature review section gives an overview of the current research on sustainable finance instruments, the degree of development in the green bond market and the instruments' impact on an environmental level. It also outlines the greenwashing risks and necessary governance aspects of the sustainable finance market to ensure effectiveness, and sets the analysis on transition bonds into context. The quantitative section of the study then employs a Difference-in-Difference regression with a propensity score matching method to isolate the environmental effect of transition bond issuances. It cannot find significant decrease in carbon intensity or other substantial ESG improvements for climate transition bond issuers. This suggests that firms participating in the sustainable finance market by issuing transition instruments without improving on an environmental dimension may engage in greenwashing, or require a longer-than usual time horizon to transition.

Lastly, the discussion also points out the opportunity to integrate just transition elements into climate transition bonds, which could offer a tool to entities having the strong need to consider climate justice in its investment behaviour, i.e., companies, communities, or governments heavily dependent on fossil fuels or active in high-emitting sectors. In doing so, these stakeholders can credibly signal transition ambitions while addressing social adverse impacts.

The findings do not make transition bonds obsolete – it rather calls for more guidance based on established mechanisms from the green bond market found in the existing literature to improve the usage of transition bonds, as well as to harmonise sustainable finance labelled bonds. They also emphasize the importance of corporate governance and a coherent transition strategy in relation to transition bond issuance. To prevent greenwashing and achieve material environmental improvements, the study calls for a stronger governance regime in form of a regulatory framework or a private regime, allowing stakeholder to evaluate each instrument's impact. For that, it is necessary to provide market guidelines that focus not necessarily on the greenness of companies only, but beyond that on their transition ability and willingness. Three key points identified are i) the *embedment of the issuance within a well-aligned, science-based transition plan*, ii) *certification of the transition finance framework by independent SPO provider*, and iii) *regular, transparent and quantifiable impact reporting post-issuance*.

The study contributes to the growing literature of research on sustainable finance in general, and to the environmental impact of corporate issuances specifically. It furthermore contributes to much needed research on transition debt instruments, which gained popularity only recently. Research on it is scarce, but necessary to assess their potential and the inherent risk of greenwashing in the sustainable finance industry. The study is a novelty in its quantitative approach to isolate the effect of a climate transition bond issuance based on a Difference-in-Difference regression and the underlying matching to account for internal and external factors. It follows prior research methodology from Fatica and Panzica (2021) and Flammer (2021) on the environmental performance of green bond issuers.

In conclusion, climate transition bonds as they are can not deliver the impact they promise. This might be due to the fact that issuers in the targeted industries take a long time to transition and to show significant emissions reduction. It could however also indicate greenwashing in sustainable finance markets. Nevertheless, when structured properly, they can be a tool to mobilise urgently needed capital to finance large-scale transition in the hard-to-abate sector, while considering just transition elements.

8 Extension

To enhance the understanding of the role of climate transition bonds within the sustainable debt instrument market, the following section aims to assess the environmental performance of green bond issuers in several dimensions, and to compare the performance of transition bond issuers with those of green bond issuers.

8.1 Purpose

The extension allows to create a more wholistic picture of transition bonds as an alternative debt instrument for firms in the hard-to-abate sector who want to participate in the sustainable finance market. This helps to better understand what is driving the emissions reductions, why transition bonds do not seem to improve the issuer's ESG performance and if this is really a signal of greenwashing. It also explains the difference to green bond issuers' significant emissions reduction as outlines in the literature review. Furthermore, contrasting the environmental performance of transition bonds post-issuance against green bond data will underline the findings on the greenwashing hypothesis found in previous chapters. Lastly, since the study connects the findings on transition bonds to the research on green bonds, the extension helps to draw conclusions for effective structuring of the instrument and support the implications for necessary market guidelines on this type of transition instrument.

In order to do so, the extension aims to answer the following research question:

1. Is the issuance of green debt instruments associated with a decrease in carbon emissions post-issuance?
2. How does the empirical effect compare to the post-issuance performance of transition bond issuers, specifically in industries particularly affected by transition needs?

While the assessment of green bonds' environmental impact on issuer environmental performance is a central aspect of research on green bonds, comparing them to other sustainable finance instruments (specifically climate transition bonds) is a novelty and unique in its approach. Comparing the two after the initial matching will lead to insights about the characteristics of both types of issuers.

8.2 Research Design

Drawing on the research approach outlined in the previous chapters, the extension of this study introduces a third data set in addition to transition and conventional bond issuances. Using data on green bond issuances in the same time frame as the one for transition and conventional issuers, the extension can conduct two additional Difference-in-Difference analysis, for one a DID regression on the environmental performance (i.e., carbon emissions reduction, ESG score, etc.) of green bond issuers vs. conventional bond issuers, and – more importantly – also a DID regression on the environmental performance of transition bond issuers vs. green bond issuers. This allows to match issuers in the transition industry with peers already active in the green bond market.

8.2.1 Data

Similar to the DID analysis in the main body of this study, its extension uses a data set comprising various financial and ESG data points required for the matching process and the subsequent regression. To identify all active green bonds, a unique Bloomberg function is used to filter bonds based on their sustainable finance label. Doing so results in a comprehensive list of all green bonds as of January 2025, starting from January 2019. Due to the relatively high number of existing instruments, green bonds issued by financial institutions and banks, governments, government agencies, supra-national institutions and financial SPVs were excluded, resulting in a "clean" data set of corporate green bonds. Financial service providers and issuers associated with government agencies are filtered out because a sensible interpretation of these issuers' carbon emissions and their ecological footprint is not possible. Especially for financial service providers, even if carbon emissions were identifiable most of it is usually beyond their business influence and a sensible connection to the issuance of a sustainable finance instrument cannot be made. The number of corporate green bonds amounts to a total of 2,675 active instruments. The green bond issuance data completes the data set of climate transition bonds and conventional bonds used in the prior study. The number of climate transition bonds amounts to a total of 94 active instruments, while the filtered[11] number of corporate conventional bonds is a total of 17,484 active instruments.

[11] Filtered based on amount issued (larger than the equivalent of EUR 100m), countries (countries of the European Union, Great Britain, Japan, China, Hong Kong), and issuer type (corporate issuances excl. financial institutions and banks, governments, government agencies, supra-national institutions and financial SPVs)

In line with the previously conducted analysis and following studies similar in design (Flammer, 2021; Makpotche et al., 2024), firm-level financial and accounting data are obtained from Standard & Poor's Compustat. The main variables of interest are the book value of total assets as well as revenue figures, both are used in the PSM method as a proxy for company size. Furthermore, Compustat provides MSCI's Global Industry Classification Standard (GICS) to classify companies into GIC Groups (4-digit code) and GIC Industries (6-digit code), which is also used in the exact matching approach.

Firm-level ESG data is sourced from Thomson Reuters' Refinitiv. Carbon emissions data includes direct emissions from a company's operations (Scope 1) and indirect emissions resulting from purchased electricity or energy (Scope 2). Emissions intensity is then calculated by dividing the absolute sum of total Scope 1 plus Scope 2 emissions by the book value of total assets and by revenue, respectively, yielding values in tCO_2e per EUR million. While emissions per unit of revenue is commonly used to represent carbon intensity in practice, several related academic studies (Flammer, 2021; Makpotche et al., 2024; Yeow & Ng, 2021) also measure carbon intensity as emissions per unit of assets (book value). To provide a comprehensive analysis, this study incorporates both metrics. Furthermore, Refenitiv data also encompasses figures for ESG scores, environmental scores, and resource use scores. For analytical purposes, the scores in discrete alphabetical ratings (from A+, highest to D-, lowest) are converted into numerical values ranging from 1.0 (best) to 0.0 (worst). These numerical scores can then be retranslated into alphabetical ratings using Refinitiv's publicly available methodology (LSEG, 2024) for better readability.

Similar to conventional bonds, several green bonds could not be matched to its parent entities and the corresponding data in Compustat or Refinitiv.[12] Due to difficulties in identifying and cross-connecting these entities across the Bloomberg, Compustat, and Refinitiv databases, these unmatched issuers are excluded from the matching process and the DID analysis. Lastly, all financial accounting data are converted into Euro to ensure comparability. Environmental metrics depending on financial figures (e.g., carbon intensity) is the calculated based on Euro to capture improvements in carbon emissions reduction instead of changes in exchange rate. To adjust for currency fluctuations, annual average exchange rates were applied using the exchange rate matrix already used in the previous analysis.[13]

[12] E.g., because the issuer is a SPV legal entity created for debt issuance
[13] Compustat Global's exchange rate matrix

8.2.2 Descriptive Statistics

The study identified 2,675 active corporate green bonds issued by corporates[14] between 2019 and 2024. 927 unique green bonds issuers were identified, of which 297 could be mapped according to Compustat data. 245 unique issuers had Refinitiv data on carbon emissions, ESG score, environmental score, and resource use available. Although green bonds are a more established instrument than transition bonds, the green bond market especially gained traction post-covid, and has been very active since (CBI, 2024). Table 7 reports descriptive statistics for all active green bonds since 2019.

Table 7. Descriptive Statistics of Corporate Green Bond Data [15]

This table reports descriptive statistics for the corporate green bonds dataset from 2019 to 2024. Financial figures are shown in million EUR, while carbon intensity figures are calculated as tCO2eq per million EUR. ESG scores are displayed as a numeric figure between 1 (best) and 0 (worst), which can be translated back to alphabetical scores from A+ (best) to D- (worst).

Statistic	N	Mean	Median	St. Dev.	Min	Max
Issue Volumes (in EURm)	2,519	238.01	115.81	277.19	0.003	2,180.00
Tenure (years)	2,417	11.54	6.10	53.85	0.30	1,000.00
Size (Revenue, in EURm)	831	15,209.42	5,532.00	30,203.32	5.45	384,027.80
Size (Assets, in EURm)	831	33,806.94	14,494.43	55,132.88	20.35	359,757.30
Carbon Intensity (per EURm Revenue)	561	1,068.20	235.07	3,288.19	0.05	53,321.18
Carbon Intensity (per EURm Assets)	561	494.68	79.54	1,982.11	0.03	31,405.60
ESG Score	604	0.63	0.68	0.18	0.04	0.95
E Score	603	0.65	0.69	0.20	0.01	0.98
ResourceUse Score	594	0.69	0.76	0.26	0.01	1.00

Similarly to transition bonds, the average green bonds is rather large in volume and has a very long tenure with a mean of over 11 years.[16] As mentioned, it also shows that carbon intensity figures are significantly lower than for transition bond issuers, with averages at 1,068.20

[14] This excludes issuers by government, sovereign agencies, supra-national issuers, financial institutions, or special purpose vehicles

[15] Several bonds do not have issuance volumes provided by Bloomberg, for example because issuances are under a debt issuance program with aggregated volumes or a private placement with undisclosed volume. Tenure is missing for perpetual instruments or callable instruments without a fixed maturity.

[16] It should be noted that the data does not account for very short-term bonds since it only includes active instruments (i.e., not expired already). This artificially increases the mean tenure; it does however not have a significant effect on the analysis.

tCO2eq per million Euro in revenue and 498.68 tCO2eq per million Euro in book value of assets, respectively. This confirms the hypothesis that transition bond issuers mainly operate in high-emitting sectors or in sectors commonly referred to as 'brown', and thus in urgent need of transition. At the same time, green bond issuers are already quite environmentally sustainable and emit less carbon.

8.2.3 Methodology

While the previous section employed a DID regression based on two data sets as treatment group (transition bonds) and control group (conventional bonds), the green bond data set allows to conduct two further regressions: Green vs. Conventional and Transition vs. Green. Mirroring the approach used before, both regressions focus on comparing environmental KPIs from the treatment groups with KPIs from the control groups. Before that, a Propensity Score Matching algorithm is employed (refer to section 4.1 for further explanation on the PSM). The timeline of bond issuances is normalized into a relative timeline around the issuance date. T_0 marks the year of issuance, while T_{-1} and T_{+1}, T_{+2}, etc. represent the reporting periods pre-issuance and post-issuance, respectively.

8.2.4 Matching Characteristics

The study now comprises a total of three different DID regressions: Transition vs. conventional, green vs. conventional, and transition vs. green. Each regression requires a data set of treated issuers (transition bonds or green bonds) and control issuers. This is done in line with the algorithm outlined in section 4.1. Doing so results in matched data sets with the following baseline characteristics.[17] For each characteristic, the mean, median and standard deviation is reported. In the last two columns, p-values for difference-in-means and for difference-in-medians between treated and control firms are reported. To test difference-in-means, a t-test is conducted. Testing difference-in-medians requires the use of a nonparametric test. Two options are the Mann-Whitney U Test (or Wilconox test) and the Mood's Median Test. In this case, the Mann-

[17] Following previous studies such as Makpotche, M., Bouslah, K., & M'Zali, B. (2024). Long-run performance following corporate green bond issuance. *Managerial Finance*, *50*(1), 140-178. https://doi.org/10.1108/Mf-12-2022-0588 , baselines always refer to the average of the three years preceding the bond issuance

Whitney U Test is used, assuming that all the data samples are independent and similar in distribution shape. Table 8 and Table 9 report the descriptive matching characteristics for the two additional regressions of Green vs. Conventional and Transition vs. Green.

Both matched data sets now complete the matched data sets of transition vs. conventional bonds as established in the main body of this study (chapter 4.1.1).

Table 8. Matching Characteristics: Green (Treatment) vs. Conventional (Control)

This table presents descriptive statistics to compare corporate green bonds with corporate conventional bonds from 2019 to 2024. Baselines are measured as an average of the respective metric three years preceding the issuance. Financial figures are shown in million EUR, while carbon intensity figures are calculated as tCO2eq per million EUR. ESG scores are displayed as a numeric figure between 1 (best) and 0 (worst), which can be translated back to alphabetical scores from A+ (best) to D- (worst). The last two columns report the p-values for difference-in-means and difference-in-medians tests.

Matching Characteristics Green (Treatment) vs. Conventional (Control)

Characteristic	Group	Obs.	Mean	Median	Std. dev.	p_mean	p_median
Revenue Baseline	Treatment	331	16121.11	5998.89	35774.95	0.22	0.01
Revenue Baseline	Control	331	19600	8399	37224.41	0.22	0.01
Asset Baseline	Treatment	331	31598.69	18451.86	44906.52	0.2	0.09
Asset Baseline	Control	331	36780	20340.13	57447.29	0.2	0.09
CO2 Intensity (Revenue) Baseline	Treatment	238	1192.16	186.87	3153.39	0.88	0.51
CO2 Intensity (Revenue) Baseline	Control	248	1150.6	148.97	3132.44	0.88	0.51
CO2 Intensity (Assets) Baseline	Treatment	238	429.02	60.94	1121.86	0.91	0.5
CO2 Intensity (Assets) Baseline	Control	248	417.83	52.82	1082.63	0.91	0.5
ESG Score Baseline	Treatment	251	0.59	0.63	0.2	0.23	0.41
ESG Score Baseline	Control	289	0.56	0.61	0.22	0.23	0.41
E Score Baseline	Treatment	251	0.63	0.69	0.21	0.14	0.13
E Score Baseline	Control	286	0.6	0.64	0.23	0.14	0.13
ResourceUse Score Baseline	Treatment	248	0.64	0.71	0.26	0.39	0.71
ResourceUse Score Baseline	Control	286	0.62	0.64	0.29	0.39	0.71

Table 9. Matching Characteristics: Transition (Treatment) vs. Green (Control)

This table presents descriptive statistics to compare corporate transition bonds with corporate green bonds from 2019 to 2024. Baselines are measured as an average of the respective metric three years preceding the issuance. Financial figures are shown in million EUR, while carbon intensity figures are calculated as tCO2eq per million EUR. ESG scores are displayed as a numeric figure between 1 (best) and 0 (worst), which can be translated back to alphabetical scores from A+ (best) to D- (worst). The last two columns report the p-values for difference-in-means and difference-in-medians tests.

Matching Characteristics Transition (Treatment) vs. Green (Control)

Characteristic	Group	Obs.	Mean	Median	Std. dev.	p_mean	p_median
Revenue Baseline	Treatment	43	12928.35	12482.37	9769.08	0.03	0.03
Revenue Baseline	Control	43	8625.86	3992.89	8451.74	0.03	0.03
Asset Baseline	Treatment	43	22720.06	22693.77	8828.06	0.91	0.03
Asset Baseline	Control	43	22292.84	14890.73	21967.93	0.91	0.03
CO2 Intensity (Revenue) Baseline	Treatment	38	626.1	539.84	546.83	0.43	0.63
CO2 Intensity (Revenue) Baseline	Control	38	794.4	377.45	1170.57	0.43	0.63
CO2 Intensity (Assets) Baseline	Treatment	38	364.4	210.61	426.12	0.46	0.46
CO2 Intensity (Assets) Baseline	Control	38	293.01	105.1	405.35	0.46	0.46
ESG Score Baseline	Treatment	38	0.72	0.74	0.13	0	0
ESG Score Baseline	Control	35	0.57	0.6	0.17	0	0
E Score Baseline	Treatment	38	0.79	0.75	0.08	0	0
E Score Baseline	Control	35	0.63	0.68	0.17	0	0
ResourceUse Score Baseline	Treatment	38	0.77	0.73	0.13	0.09	0.63
ResourceUse Score Baseline	Control	35	0.68	0.78	0.26	0.09	0.63

Ideally, treated and control firms should be very similar, as it is the case in the green vs. conventional matching groups. For difference in means, p-values reach from 0.14 to 0.91, and thus the hypothesis that means are equal is not rejected. The same goes for difference in medians, with the exception of the financial characteristics.[18] Looking at the matching for transition vs. green, the picture is somewhat different. Table 9 reports the characteristics for transition issuers vs. green issuers. P-values range from 0 to 0.91. P-values for difference-in-medians range from 0 to 0.96. Especially significant differences in baseline ESG score, environmental score, and resource use score can be observed. However, it should be noted that while a better similarity

[18] An exception is the p-value for difference-in-median for the characteristic revenue; likely, the distribution of revenue is very dispersed and more volatile than that for other financial and environmental characteristics.

would be desirable, the key characteristics and particularly the baseline in carbon intensity during the preceding three years before the issuance are similar.

8.2.5 ESG Issuer Profile

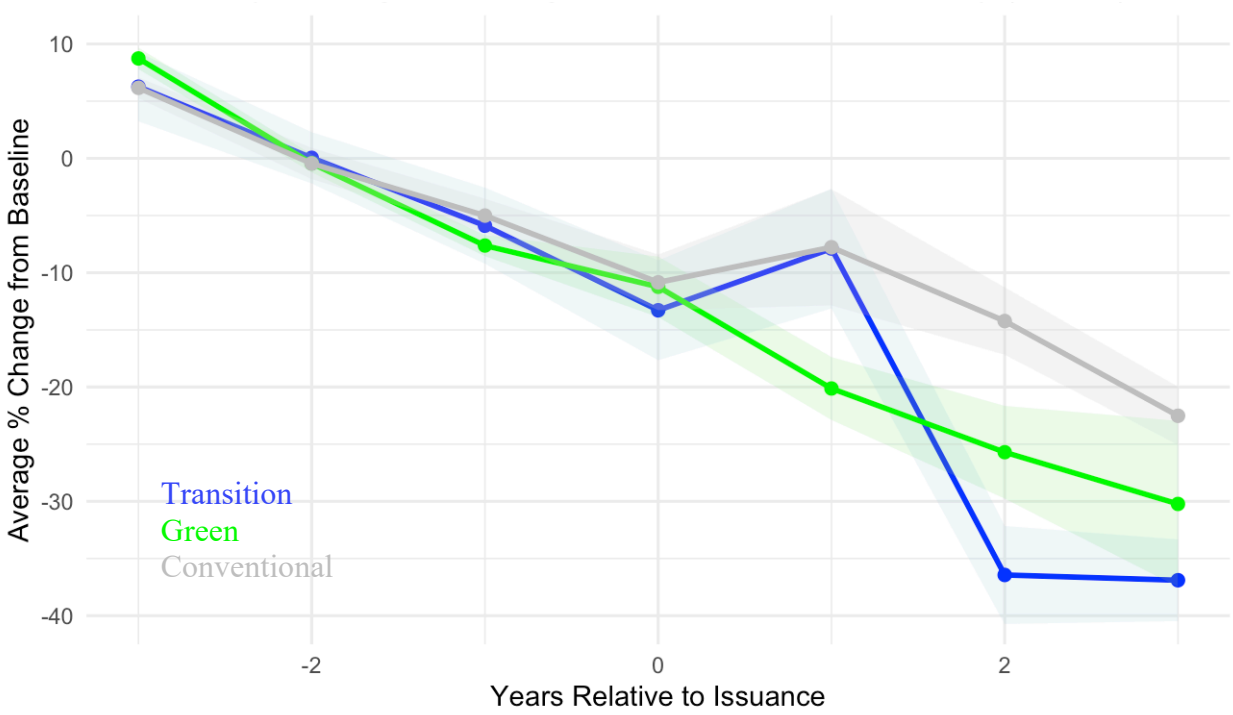
After the process of matching treated and control firms, the Average Treatment Effect (ATE) on several ESG performance metrics following the bond issuance is analysed. The DID focusses on carbon intensity as the main variable of interest, but also analyses ESG rating scores, environmental rating scores, as well as resource use scores to assess the potential effect on wider ESG firm performance. The exact approach is detailed in chapter 4.2 of this study. In addition, and to give an overview of the variable development, Figure 2 now compares the average change in emissions intensity relative to the baseline, before and after the date of issuance T_0. All three issuer types exhibit an average decrease in carbon emissions intensity. Also, emissions intensity per revenue seems to be slightly more volatile due to the unpredictable nature of revenue compared to assets.

Transition bond issuers exhibit a relatively steady decrease in emissions during the three years prior to issuance. Notably however, the change one year following the issuance is positive and carbon emissions increase significantly in the short-term. Although conventional bonds show a similar effect, explaining this with certainty proves difficult. One potential explanation could be the impact of Covid in 2020 and 2021, which led to a decrease in emissions during these years but subsequently higher (relative) emissions. Furthermore, transition bond issuers were particularly impacted by the pandemic (aviation industry, utility, etc.). Assuming that the majority of transition bonds was issued around that time, this could partially explain why emissions were higher in T_1 than what would be expected. In the medium- to long-term, transition bond issuers seem to be able to significantly reduce emissions intensity (particularly in year two following the issuance). This effect is stronger than it is for green bond issuers and could be a first indication of a true, 'additional' effect through transition ambitions. For green bond issuers, carbon profile decreases significantly around the time of issuance (T_0). Both intensity figures show a steady decrease in emissions preceding the green bond, but more importantly continue to decrease emissions after the issuance in a similar pace. This not only supports the thesis that green bonds are issued by companies willing and able to turn more sustainable; on the contrary, it also raises the question of the additionality of the instrument, i.e., whether any change in environmental performance can really be attributed towards the green instrument itself. Lastly,

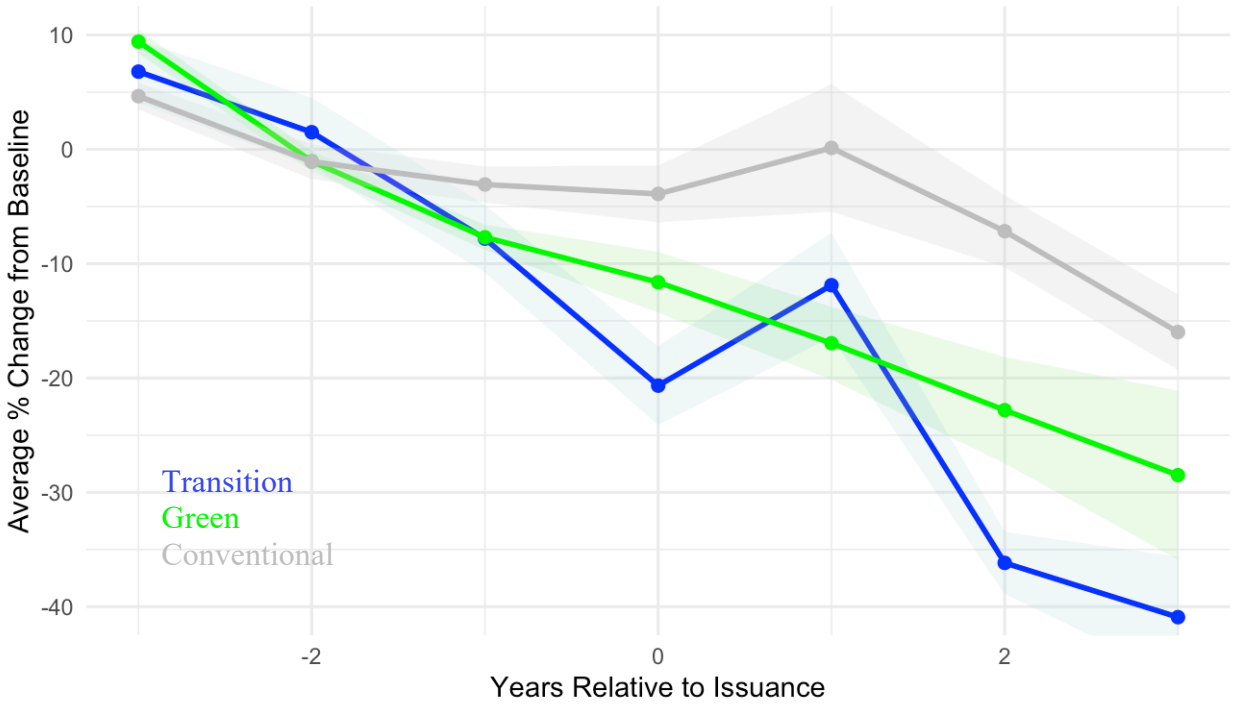
looking at the development of conventional issuers first, the decrease in carbon intensity is not as pronounced as for transition and green bond issuers, but a general trend of emissions reduction is still observable. Conventional issuers exhibit the same increase in emissions in the year following the bond issuance, which could be for similar reasons as for transition and conventional bonds, i.e., the specific time window of the study (increase in emissions following the drop related to Covid-19).

Figure 2. Average Percentage Change in Carbon Emissions Intensity

Panel A. Percentage Change in Carbon Emissions per Book Value of Assets



Panel B. Percentage Change in Carbon Emissions per Revenue



Appendix C provides further figures on the development of several other ESG performance indicators around the date of issuance, which confirm the observations made. Even more, they show that while conventional and green bond issuers tend to increase in several score metrics, transition bond issuers do not exhibit a statistically significant change in either ESG score, environmental score, or resource use score.

8.3 Findings

In the following, the DID regressions are conducted to estimate the Average Treatment Effect in the Treated (ATT). The regression tables can be interpreted the same way as in section 4.1 and section 5 of this study according to the following regression formula:

$$y_{it} = \alpha_i + \alpha_S + \beta \times (Treatment_i * Time_t) + \varepsilon_{it}.$$

This regression is estimated for the two different variations of green vs. conventional, and transition vs. green.

8.3.1 Green vs. Conventional Issuer

Regression results for green bonds are provided in Table 10. Looking at the treatment variable first, there is no significant baseline difference between treatment (green) and control (conventional) issuing firms. Equivalent to Table 6, columns (1) – (4) report a time difference across both groups, indicating that companies overall reduce emissions significantly. The coefficient for revenue intensity is -268.489 at a 1% significance level in the short term and -117.312 at a 5% significance level in the long term. For asset intensity, coefficients are -95.462 at a 1% significance level and -59.996 at a 1% significance level in the short and long term, respectively. Focussing on the DID estimator, green bonds issuers exhibit decrease emissions intensity significantly in the long run. For revenue intensity, the carbon emissions decrease by -208.534 and are significant at the 1% level, while for asset intensity the coefficient is -48.192, significant at the 10% level. Given the sample mean from Table 8, this corresponds to a -17.49% decrease for revenue intensity compared to a baseline mean of 1,192.161, and a -11.23% decrease for asset intensity compared to a baseline mean of 429.019. Effects on emissions intensity in the

short term are negative, but not significant. These results confirm prior findings of similar studies with a DID regression approach. For ESG and E score, no DID estimator coefficient is observable. However, the time effect is significant.

Table 10. Regression Results: Carbon Intensity for Green Bonds vs. Conventional Bonds

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a green bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. The data set includes all firm-year observations of green bond issuers and matched conventional issuers from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:			
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)	
	(1)	(2)	(3)	(4)
Treatment	10.200	23.085	2.458	4.696
	(39.893)	(37.529)	(12.827)	(12.359)
Time (Short-Term)	-268.489***		-95.462***	
	(46.871)		(15.097)	
Time (Long-Term)		-117.312**		-59.996***
		(48.019)		(15.814)
DiD Estimator (ST)	-65.410		-17.146	
	(76.780)		(24.701)	
DiD Estimator (LT)		-208.534***		-48.192*
		(77.995)		(25.685)
Constant	723.920*	711.035**	605.940***	603.702***
	(374.962)	(351.550)	(120.559)	(115.773)
Subclass Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	3,709	3,708	3,708	3,708
R^2	0.947	0.951	0.961	0.962
Adjusted R^2	0.940	0.945	0.956	0.957
Residual Std. Error	645.767 (df = 3255)	605.422 (df = 3257)	207.630 (df = 3254)	199.380 (df = 3257)
F Statistic	129.452*** (df = 453; 3255)	141.979*** (df = 450; 3257)	176.896*** (df = 453; 3254)	184.208*** (df = 450; 3257)
Note:				*p<0.1; **p<0.05; ***p<0.01

Appendix D provides further findings on the ESG score, environmental score, and resource use score. It does not find significant DID estimators across either score metric. However, the overall time effects show that the ESG score increases by 0.056 in the short term and by 0.054 in the long term, while the environmental score increases by 0.064 in the short term and 0.055 in the long term, and resource use increases by 0.055 in the short term and 0.046 in the long term.

All coefficients are significant at a 1% level. It thus seems, that the mean change in these dependent variables is not significantly different in green bond issuers beyond the overall time effect for control firms. Therefore, the study can not confirm the findings of research by Flammer (2021) and Makpotche et al. (2024), who find significant improvements in ESG scores following a green bond issuance. This can potentially be attributed to the limited data set (limited by geography and by issuer type) of conventional bond issuers, as well as the comparably high number of exclusions of green issuers due to data availability.

8.3.2 Transition vs. Green Issuer

To finally compare transition bonds and green bonds in their ecological impact, the last DID regression uses transition bonds as treatment group versus green bond control firms. If one instrument is better in its impact on corporate ESG performance, there should be a difference in issuer performance post-issuance.

However, Table 11 finds no significant DID estimator in either dependent variable at the 1%, 5%, or 10% level. While long-term emissions intensity reduction seems to be higher on average for transition bonds by 192.631 for revenue intensity and by 133.398 for asset intensity, these results are not economically meaningful. Furthermore, columns (1) – (4) also show that the time effect becomes insignificant at least in the long term. This is remarkable insofar, as it means that even the matched green issuing firms do not exhibit a meaningful reduction, contrary to what the average DID estimator from Table 10 would suggest.

The unexpected finding is attributable to the characteristics of the matched firms in the control group, most likely to the same industries that as transition bonds issuers operate in. It means that while the average green bond issuer decreases carbon emissions significantly post-issuance (findings from Table 10), the type of green issuer that can be matched with transition bond issuers (e.g., operating in sectors of utility and electricity generation) does not exhibit the same kind of reduction.

Table 11. Regression Results: Carbon Intensity for Transition Bonds vs. Green Bonds

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. The data set includes all firm-year observations of transition bond issuers and matched green issuers from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:			
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)	
	(1)	(2)	(3)	(4)
Treatment	28.019	52.695	14.271	28.886
	(141.719)	(142.010)	(83.914)	(84.575)
Time (Short-Term)	-142.942*		-100.613**	
	(77.892)		(46.121)	
Time (Long-Term)		-56.509		-38.534
		(105.485)		(62.823)
DiD Estimator (ST)	3.856		9.084	
	(110.112)		(65.199)	
DiD Estimator (LT)		-192.631		-133.398
		(148.757)		(88.594)
Constant	115.438	-71.716	113.890	21.820
	(252.540)	(258.021)	(149.532)	(153.667)
Subclass Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	457	442	457	442
R^2	0.921	0.879	0.888	0.865
Adjusted R^2	0.907	0.857	0.868	0.841
Residual Std. Error	314.775 (df = 388)	313.549 (df = 374)	186.382 (df = 388)	186.737 (df = 374)
F Statistic	66.307*** (df = 68; 388)	40.405*** (df = 67; 374)	45.225*** (df = 68; 388)	35.887*** (df = 67; 374)
Note:				*p<0.1; **p<0.05; ***p<0.01

Appendix D provides further findings on the Refinitiv score metrics. Here, columns (5) – (10) show that the negative effect on ESG ratings that was observable on transition bond issuers versus conventional issuers are still prevalent versus green issuers. The long-term DID estimator is significantly negative across for ESG score (-0.048) and resource use score (-0.086), implying a decrease or at least not as much of an increase as for green bond peers. On the contrary, the overall long-term time effect is significant positive, with 0.071 (significant at 1%) for ESG score, 0.049 (significant at 10%) for environmental score, and 0.061 (significant at 5%) for

resource use score. This implies that the average green bond issuer in the control group is likely to experiencing an increase in ESG score post-issuance, while the average transition bond issuer is not. Consequently, transition bonds issuers are likely still more pronounced to greenwashing than their green bond peers.

8.3.3 Robustness

Several robustness checks are performed the same way as chapter 5.2. This helps to validate findings and address different specifications. In general, changes in the matching algorithm in terms of using different matching variables, increasing control group size by increasing the number of matched neighbours, or changes in the calculation of the baseline matching characteristics do not change presented findings significantly. Interestingly, when adding more matching variables based on firms' ESG score, results for green bonds exhibit a slight but significant *decrease* in ESG score and environmental scores as DID estimator. This indicates that the environmental performance improvement suggested by other research is not only not confirmed as mentioned before, but in fact the opposite when matching is conducted on similarity of ESG score. However, no conclusions should be drawn prematurely, but further research is needed on the current state of green bonds. Similarly, using different regression approaches such as the inclusion of clustered standard errors do not have significant impact on the results. Appendix E provides further regression results for robustness checks.

8.4 Discussion

Results from the additional regressions made in the extension generally support prior research on green bonds and confirm the positive impact on environmental issuer performance (i.e., emissions reduction). However, they also provide evidence for a reduced impact of green bonds in hard-to-abate sectors, similar to the insignificant findings on transition bonds in the main body of this study.

Looking at green bond issuers first, the DID regression could find a significant carbon reduction following an issuance, which confirms prior research results related to the environmental impact of these instruments. The results are consistent with Fatica and Panzica (2021), Flammer (2021), Yeow and Ng (2021), and Makpotche et al. (2024), who all find a positive effect from green bond issuance on carbon reduction. They are also evidence against the greenwashing

hypothesis in the green bond market. Comparing this to the insignificant findings for the transition bond market found in chapter 5, this could probably be due to the more developed private governance regime for green instruments: In general, the existing control and certification mechanisms in form of, for example, ICMA guidelines, SPO process, etc., seem to work in the sense that issuing companies can be held accountable to a certain degree by investors. This seems not to be the case with transition bonds, for which the market and the governance regime only just develops. In contrast to previous research however, the extended DID analysis can not find an effect of green bond issuance on ESG score metrics, and is thus not consistent with findings of Zhou and Cui (2019), Flammer (2021), and Zheng et al. (2023). I attribute this to issues of data set limitations in this study (limited by geography and by issuer type) and a comparably high number of exclusions due to data availability issues.

Lastly, the extension finds that there is no significant difference in post-issuance environmental performance between transition bonds and green bonds when matching them according to their country and industry. It thus seems that while the average green bond issuer seems to improve their carbon profile, issuers in the same industry as transition bond issuers seem to lack the ability to do so. This indicates that the *type of issuers* (e.g., industry or geography) and its company-internal commitment to sustainability determines much more the ecological impact associated with the issuance, rather than the *type of instrument* itself. This for one is rooted in the nature of the business environment itself: The pace of transition is often given through external circumstances such as, clean technologies available in the specific sector, or current legislation in the specific geography the issuer operates in. Of course, it is furthermore rooted in the perceived importance or urgency of sustainable transition which the issuer faces.

Revisiting the results from the discussion in the main body of this study, this does not make transition bonds obsolete but instead calls for harmonisation of bond labels available to all companies pursuing a ‘genuine’ and ambitious transition: The presented results shows that green bond issuers which are similar in characteristic to transition bond issuers (found in the matching process) indeed exhibit similar, below-average post-issuance environmental performance. Sustainable finance market, investors and regulators alike, should therefore much rather look at the issuer characteristics to assess the transition qualities *in addition to* the greenness of a debt instrument, instead of relying on labels like ‘green bond’ or ‘transition bond’. Until now, investors usually look at the degree of greenness of an issuer (Dorfleitner et al., 2022). While the pure greenness is a convenient metric and relatively easy to assess, investors should however be enabled to assess the quality of transition in addition. As described above, this is possible

only through embedding the sustainable finance issuance within a transition plan, a sustainable finance framework and transparent reporting. In turn, clear guidelines and market standards on these topics will also help SPO provider to give their view on the quality of the transition plan, changing from a 'shades of green assessment' to some form of 'shades of transition assessment'. This is already done by rating agencies such as Moody's (2025), and can provide credible certification for transition investors.

8.5 Conclusion

The extended research analysed the impact of green bond issuances on the issuers' environmental performance, in particular the carbon emissions reduction. Connecting to the results from the main body of this study, it furthermore compares the environmental performance of transition bond issuers and green bond issuers, to derive concrete implications for the not yet developed transition finance market. By employing a DID regression analysis with prior propensity score matching, I find significant emissions reduction for green bond issuers post-issuance comparing to conventional issuers, especially in the long-term. This confirms prior research. In contrast, when matching green bond issuers with transition bond issuers, there does not seem to be a significant difference in emissions reduction between both groups. In light of prior findings on the environmental performance of transition bond issuers versus conventional issuers conducted in this study, this implies a limited impact of both instruments. I attribute this to an inherent difficulty to transition certain hard-to-abate sectors regardless of the instrument (or at least in a very long time horizon only), as well as the lack of governance structures in the transition finance market. In light of existing literature on green bonds, functioning private governance regimes are necessary to control issuers, and to give investors a tool to assess and hold accountable issuers to their proclaimed transition plans.

The extension furthermore makes a case for a harmonisation of sustainable finance labels in debt instruments, as well as governance structures that allows stakeholders to assess the quality of transition plans in addition to an issuer's greenness, regardless of the issued instrument. This requires, above all, the embedment of sustainable finance issuances within a transition plan in line with recognized standards, a SPO-certified sustainable finance framework and transparent reporting. This is important to stakeholders who seek to avoid greenwashing, and to enable the sustainable finance market to contribute more significantly towards a net-zero future.

The extended analysis provides the first comparison of transition bonds and green bonds, therefore further contributing to the much-needed literature on climate transition bonds, as well as to the existing literature on green bonds. It is the first quantitative study of its kind, following prior research similar in methodology on green bonds. My findings in the extension help to understand better the issuer profile of transition bond issuers and green bond issuers in the hard-to-abate sector, and provides evidence for the lack of environmental impact in these instruments. It connects to the results from the main part of this study by pointing out the importance of governance regimes to combat greenwashing due to structural weaknesses in the current market transition finance.

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Table A1. Comprehensive DID Regression Results with ESG Score, Environmental Score, and Resource Use Score

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of transition bond issuers and matched conventional issuers from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:									
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score		ResourceUse Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treatment	-13.451	-0.900	-0.329	-3.026	0.002	0.002	0.005	0.003	0.006	0.004
	(81.742)	(84.031)	(34.020)	(35.204)	(0.010)	(0.010)	(0.013)	(0.013)	(0.016)	(0.016)
Time (Short-Term)	-333.140***		-100.894**		0.058***		0.065***		0.053**	
	(119.904)		(49.903)		(0.014)		(0.017)		(0.021)	
Time (Long-Term)		-194.491		-105.225		0.063***		0.080***		0.075***
		(205.719)		(86.183)		(0.015)		(0.018)		(0.022)
DiD Estimator (ST)	154.894		-15.199		-0.017		-0.051**		-0.075**	
	(165.685)		(68.956)		(0.020)		(0.024)		(0.030)	
DiD Estimator (LT)		-68.301		-68.103		-0.032		-0.059**		-0.085**
		(276.191)		(115.707)		(0.021)		(0.026)		(0.033)
Constant	102.537	102.537	79.122	79.122	0.313***	0.313***	0.379***	0.379***	0.534***	0.534***
	(295.901)	(299.253)	(123.150)	(125.368)	(0.039)	(0.039)	(0.047)	(0.047)	(0.059)	(0.059)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	885	850	885	850	944	937	939	932	924	917
R^2	0.933	0.929	0.939	0.936	0.872	0.875	0.808	0.806	0.744	0.746
Adjusted R^2	0.924	0.919	0.931	0.927	0.857	0.859	0.784	0.782	0.711	0.714
Residual Std. Error	591.802 (df = 778)	598.505 (df = 745)	246.300 (df = 778)	250.736 (df = 745)	0.077 (df = 839)	0.077 (df = 833)	0.094 (df = 834)	0.095 (df = 828)	0.118 (df = 819)	0.118 (df = 813)
F Statistic	101.795*** (df = 106; 778)	93.094*** (df = 104; 745)	113.187*** (df = 106; 778)	104.095*** (df = 104; 745)	55.168*** (df = 104; 839)	56.537*** (df = 103; 833)	33.773*** (df = 104; 834)	33.461*** (df = 103; 828)	22.860*** (df = 104; 819)	23.153*** (df = 103; 813)

Note: *p<0.1; **p<0.05; ***p<0.01

Table B1. DID Regression Results with Clustered Standard Errors

*This table reports estimated Difference-in-Difference regressions with two-way clustered standard errors. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of transition bond issuers and matched conventional issuers from 2019 – 2024. Standard errors are two-way clustered based on issuer and based on year (reported in parentheses). *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:									
	Carbon Intensity (Revenue)		Carbon Intensity (Assets)		ESG Score		E Score		RU Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treatment	-7.368	-0.037	-0.792	-3.686	0.006***	0.003*	0.008***	0.006**	0.010***	0.004
	(6.334)	(3.701)	(3.097)	(5.016)	(0.001)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
Post_ST	-318.482***		-114.797***		0.079***		0.073***		0.086***	
	(51.045)		(16.606)		(0.010)		(0.010)		(0.014)	
Post_LT		-277.870***		-134.782***		0.070***		0.075***		0.077***
		(85.711)		(39.897)		(0.010)		(0.015)		(0.015)
Treatment:Post_ST	137.789*		-1.462		-0.037***		-0.058***		-0.106***	
	(77.515)		(38.338)		(0.014)		(0.021)		(0.025)	
Treatment:Post_LT		2.549		-40.811		-0.039**		-0.056*		-0.086***
		(80.932)		(94.540)		(0.018)		(0.030)		(0.031)
Constant	28.054***	28.054***	14.917***	14.917***	0.791***	0.791***	0.858	0.858***	0.834***	0.834***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:								*p<0.1; **p<0.05; ***p<0.01		

Table B2. DID Regression Results with k = 2 nearest neighbour matching

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of transition bond issuers and two matched conventional issuers for each treated observation, from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:							
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	-7.368	-0.037	-0.792	-3.686	0.006	0.003	0.008	0.006
	(68.888)	(71.322)	(29.048)	(30.273)	(0.009)	(0.009)	(0.010)	(0.011)
Time (Short-Term)	-318.482***		-114.797***		0.079***		0.073***	
	(83.168)		(35.070)		(0.010)		(0.012)	
Time (Long-Term)		-277.870*		-134.782**		0.070***		0.075***
		(143.494)		(60.906)		(0.011)		(0.014)
DiD Estimator (ST)	137.789		-1.462		-0.037**		-0.058***	
	(136.294)		(57.472)		(0.016)		(0.020)	
DiD Estimator (LT)		2.549		-40.811		-0.039**		-0.056**
		(229.657)		(97.478)		(0.018)		(0.022)
Constant	28.054	28.054	14.917	14.917	0.791***	0.791***	0.858***	0.858***
	(162.022)	(164.394)	(68.320)	(69.777)	(0.021)	(0.021)	(0.025)	(0.025)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,192	1,137	1,192	1,137	1,310	1,293	1,289	1,272
R^2	0.925	0.919	0.930	0.925	0.896	0.900	0.845	0.845
Adjusted R^2	0.916	0.909	0.922	0.916	0.885	0.890	0.829	0.830
Note:								*p<0.1; **p<0.05; ***p<0.01

Table B3. DID Regression Results with k = 5 nearest neighbour matching

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of transition bond issuers and five matched conventional issuers for each treated observation, from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:							
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	-1.502	6.261	2.251	4.717	0.005	0.005	0.005	0.002
	(58.239)	(58.503)	(24.652)	(25.178)	(0.007)	(0.007)	(0.009)	(0.009)
Time (Short-Term)	-427.598***		-154.027***		0.083***		0.064***	
	(62.879)		(26.616)		(0.007)		(0.009)	
Time (Long-Term)		-303.329***		-122.041**		0.080***		0.073***
		(112.916)		(48.596)		(0.009)		(0.011)
DiD Estimator (ST)	237.623*		36.264		-0.040***		-0.048***	
	(125.158)		(52.979)		(0.015)		(0.018)	
DiD Estimator (LT)		20.202		-50.268		-0.047***		-0.051**
		(209.822)		(90.302)		(0.017)		(0.021)
Constant	28.054	28.054	14.917	14.917	0.791***	0.791***	0.858***	0.858***
	(115.324)	(113.967)	(48.816)	(49.048)	(0.015)	(0.014)	(0.018)	(0.018)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,704	1,623	1,704	1,623	1,859	1,835	1,833	1,809
R^2	0.919	0.918	0.913	0.910	0.887	0.893	0.830	0.832
Adjusted R^2	0.912	0.910	0.905	0.902	0.878	0.885	0.816	0.819
Note:								*p<0.1; **p<0.05; ***p<0.01

Appendix C

Figure C1. Average Percentage Change in ESG Score

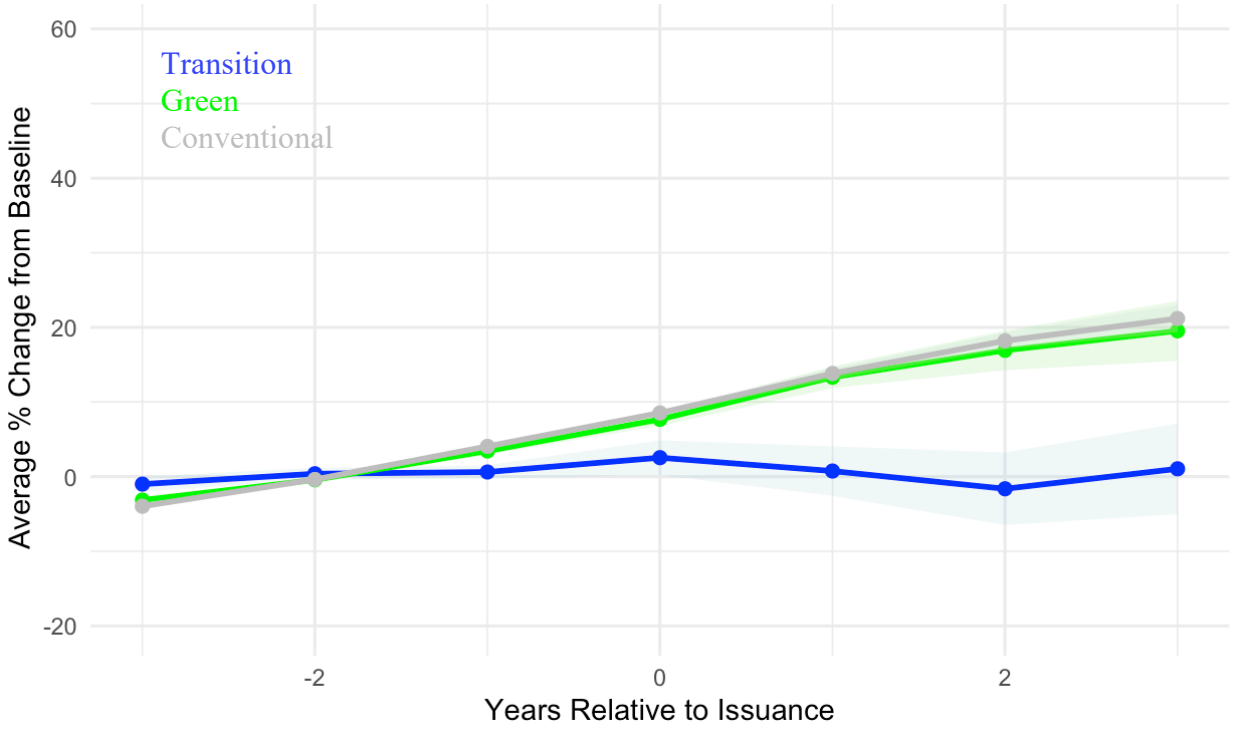


Figure C2. Average Percentage Change in Environmental (E) Score

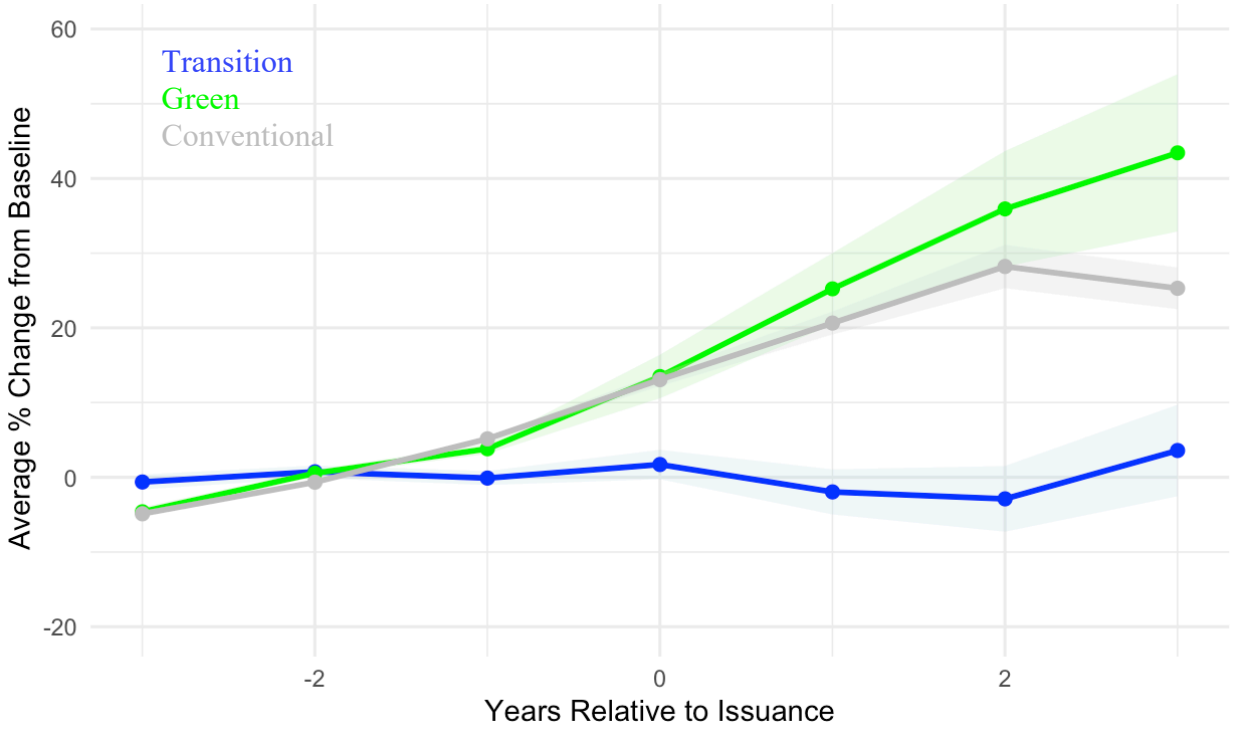


Figure C3. Average Percentage Change in Resource Use Score

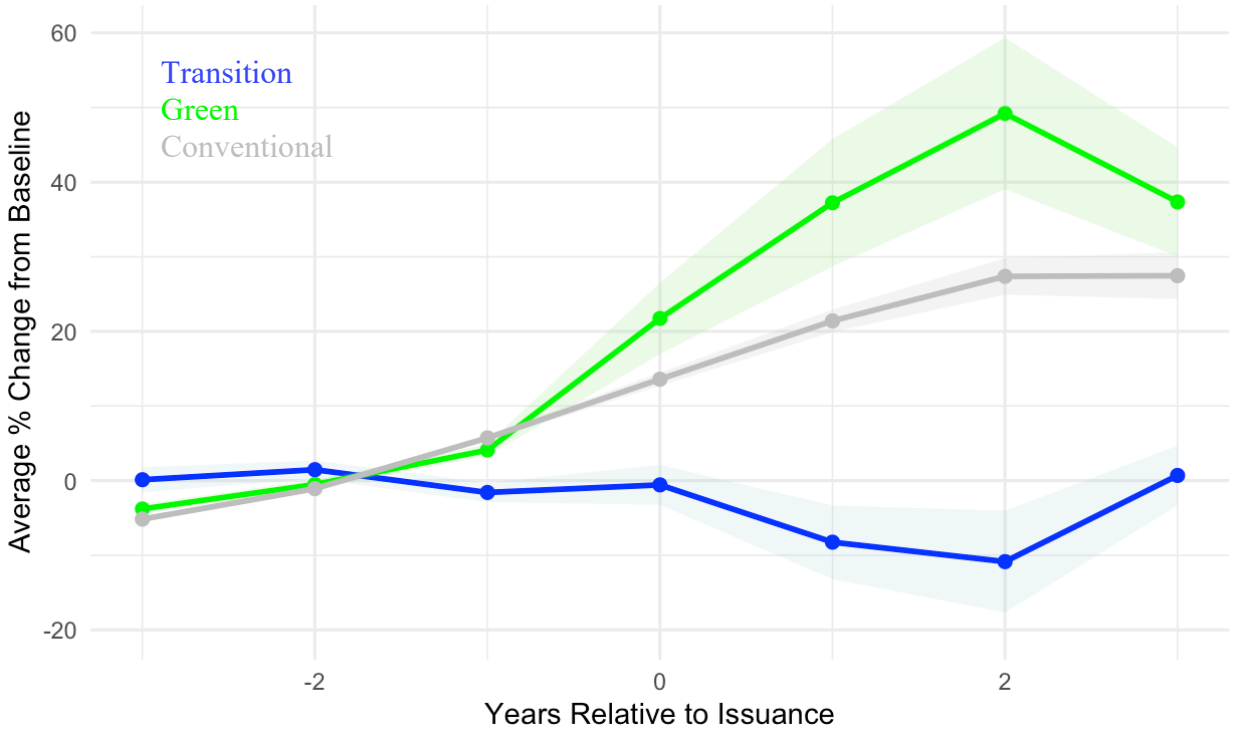


Table D1. Comprehensive DID Regression Results: Green Bonds vs. Conventional Bonds with ESG Score, Environmental Score, and Resource Use Score

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a green bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of green bond issuers and matched conventional issuers from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:									
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score		ResourceUse Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treatment	10.200	23.085	2.458	4.696	-0.002	-0.002	-0.00002	0.0002	0.002	-0.001
	(39.893)	(37.529)	(12.827)	(12.359)	(0.004)	(0.004)	(0.005)	(0.005)	(0.007)	(0.006)
Time (Short-Term)	-268.489***		-95.462***		0.056***		0.064***		0.055***	
	(46.871)		(15.097)		(0.005)		(0.006)		(0.007)	
Time (Long-Term)		-117.312**		-59.996***		0.054***		0.055***		0.046***
		(48.019)		(15.814)		(0.005)		(0.007)		(0.008)
DiD Estimator (ST)	-65.410		-17.146		0.007		-0.008		-0.018	
	(76.780)		(24.701)		(0.008)		(0.011)		(0.013)	
DiD Estimator (LT)		-208.534***		-48.192*		0.010		-0.004		0.006
		(77.995)		(25.685)		(0.008)		(0.011)		(0.013)
Constant	723.920*	711.035**	605.940***	603.702***	0.593***	0.582***	0.774***	0.769***	0.819***	0.813***
	(374.962)	(351.550)	(120.559)	(115.773)	(0.079)	(0.077)	(0.102)	(0.100)	(0.121)	(0.119)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,709	3,708	3,708	3,708	5,140	5,176	4,997	5,034	4,711	4,751
R^2	0.947	0.951	0.961	0.962	0.901	0.905	0.854	0.861	0.855	0.860
Adjusted R^2	0.940	0.945	0.956	0.957	0.891	0.895	0.838	0.846	0.838	0.844
Residual Std. Error	645.767 (df = 3255)	605.422 (df = 3257)	207.630 (df = 3254)	199.380 (df = 3257)	0.077 (df = 4639)	0.076 (df = 4679)	0.100 (df = 4497)	0.097 (df = 4538)	0.118 (df = 4215)	0.116 (df = 4258)
F Statistic	129.452*** (df = 453; 3255)	141.979*** (df = 450; 3257)	176.896*** (df = 453; 3254)	184.208*** (df = 450; 3257)	84.785*** (df = 500; 4639)	90.265*** (df = 496; 4679)	52.909*** (df = 499; 4497)	56.924*** (df = 495; 4538)	50.150*** (df = 495; 4215)	53.122*** (df = 492; 4258)

Note: *p<0.1; **p<0.05; ***p<0.01

Table D2. Comprehensive DID Regression Results: Transition Bonds vs. Green Bonds with ESG Score, Environmental Score, and Resource Use Score

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of transition bond issuers and matched green issuers from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:									
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score		ResourceUse Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treatment	28.019	52.695	14.271	28.886	0.001	0.008	0.001	-0.002	0.0004	-0.003
	(141.719)	(142.010)	(83.914)	(84.575)	(0.035)	(0.035)	(0.042)	(0.042)	(0.046)	(0.046)
Time (Short-Term)	-142.942*		-100.613**		0.068***		0.040*		0.029	
	(77.892)		(46.121)		(0.018)		(0.021)		(0.023)	
Time (Long-Term)		-56.509		-38.534		0.071***		0.049*		0.061**
		(105.485)		(62.823)		(0.021)		(0.025)		(0.027)
DiD Estimator (ST)	3.856		9.084		-0.030		-0.041		-0.065**	
	(110.112)		(65.199)		(0.024)		(0.029)		(0.032)	
DiD Estimator (LT)		-192.631		-133.398		-0.048*		-0.049		-0.086**
		(148.757)		(88.594)		(0.029)		(0.034)		(0.037)
Constant	115.438	-71.716	113.890	21.820	0.698***	0.674***	0.768***	0.763***	0.701***	0.700***
	(252.540)	(258.021)	(149.532)	(153.667)	(0.063)	(0.063)	(0.075)	(0.075)	(0.081)	(0.082)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	457	442	457	442	497	486	497	486	493	482
R^2	0.921	0.879	0.888	0.865	0.825	0.828	0.728	0.722	0.800	0.796
Adjusted R^2	0.907	0.857	0.868	0.841	0.799	0.803	0.688	0.680	0.770	0.765
Residual Std. Error	314.775 (df = 388)	313.549 (df = 374)	186.382 (df = 388)	186.737 (df = 374)	0.079 (df = 432)	0.078 (df = 422)	0.093 (df = 432)	0.094 (df = 422)	0.102 (df = 428)	0.102 (df = 418)
F Statistic	66.307*** (df = 68; 388)	40.405*** (df = 67; 374)	45.225*** (df = 68; 388)	35.887*** (df = 67; 374)	31.780*** (df = 64; 432)	32.296*** (df = 63; 422)	18.103*** (df = 64; 432)	17.354*** (df = 63; 422)	26.676*** (df = 64; 428)	25.867*** (df = 63; 418)

Note: *p<0.1; **p<0.05; ***p<0.01

Table E1. DID Regression Results: Green Bonds vs. Conventional Bonds with Clustered Standard Errors

This table reports estimated Difference-in-Difference regressions with two-way clustered standard errors. Treatment is a dummy equal to one if the firm issued a green bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of green bond issuers and matched conventional issuers from 2019 – 2024. Standard errors are two-way clustered based on issuer and based on year (reported in parentheses).

, **, and * denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:									
	Carbon Intensity (Revenue)		Carbon Intensity (Assets)		ESG Score		E Score		RU Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treatment	14.404	20.291**	3.347	3.966	-0.002	-0.002	-0.0003	0.0004	0.001	-0.002
	(11.132)	(9.475)	(2.966)	(2.795)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Post_ST	-249.678***		-91.411***		0.053***		0.059***		0.049***	
	(47.007)		(13.993)		(0.006)		(0.007)		(0.008)	
Post_LT		-136.895***		-66.586***		0.054***		0.055***		0.045***
		(23.778)		(11.852)		(0.006)		(0.007)		(0.010)
Treatment:Post_ST	-78.751		-19.682		0.010		-0.003		-0.012	
	(97.908)		(26.028)		(0.010)		(0.012)		(0.015)	
Treatment:Post_LT		-187.579**		-41.554*		0.010		-0.003		0.006
		(85.242)		(24.618)		(0.010)		(0.015)		(0.017)
Constant	252.425***	242.525***	238.030***	236.168***	0.597***	0.587***	0.784***	0.780***	0.831***	0.825***
	(11.365)	(2.336)	(5.678)	(4.141)	(0.013)	(0.024)	(0.011)	(0.016)	(0.012)	(0.017)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:									*p<0.1; **p<0.05; ***p<0.01	

Table E2. DID Regression Results: Transition Bonds vs. Green Bonds with Clustered Standard Errors

This table reports estimated Difference-in-Difference regressions with two-way clustered standard errors. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of transition bond issuers and matched green issuers from 2019 – 2024. Standard errors are two-way clustered based on issuer and based on year (reported in parentheses).

, **, and * denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:									
	Carbon Intensity (Revenue)		Carbon Intensity (Assets)		ESG Score		E Score		RU Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treatment	37.863	69.544	20.965	39.742	0.005	0.009	0.002	-0.003	0.002	-0.004
	(23.424)	(44.197)	(12.778)	(24.910)	(0.004)	(0.006)	(0.002)	(0.002)	(0.002)	(0.003)
Post_ST	-214.082**		-115.233***		0.074***		0.040**		0.031	
	(100.160)		(41.728)		(0.017)		(0.020)		(0.027)	
Post_LT		-258.279		-78.950**		0.082***		0.055		0.057
		(181.238)		(37.267)		(0.020)		(0.034)		(0.045)
Treatment:Post_ST	72.454		24.169		-0.036*		-0.041		-0.067*	
	(107.362)		(62.416)		(0.021)		(0.029)		(0.037)	
Treatment:Post_LT		13.120		-87.199		-0.057**		-0.056		-0.084
		(170.824)		(102.234)		(0.028)		(0.048)		(0.056)
Constant	89.306**	-100.493	101.134***	3.813	0.694***	0.672***	0.766***	0.765***	0.699***	0.701***
	(44.602)	(76.118)	(23.780)	(42.289)	(0.006)	(0.010)	(0.004)	(0.007)	(0.005)	(0.009)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:									*p<0.1; **p<0.05; ***p<0.01	

Table E3. DID Regression Results: Green Bonds vs. Conventional Bonds with k = 2 nearest neighbour matching

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a green bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of green bond issuers and two matched conventional issuers for each treated observation, from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:							
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	14.404	20.291	3.347	3.966	-0.002	-0.002	-0.0003	0.0004
	(35.540)	(33.646)	(11.730)	(11.374)	(0.004)	(0.004)	(0.005)	(0.005)
Time (Short-Term)	-249.678***		-91.411***		0.053***		0.059***	
	(39.357)		(13.006)		(0.004)		(0.005)	
Time (Long-Term)		-136.895***		-66.586***		0.054***		0.055***
		(40.441)		(13.671)		(0.004)		(0.006)
DiD Estimator (ST)	-78.751		-19.682		0.010		-0.003	
	(70.908)		(23.411)		(0.008)		(0.010)	
DiD Estimator (LT)		-187.579***		-41.554*		0.010		-0.003
		(72.213)		(24.412)		(0.008)		(0.010)
Constant	252.425	242.525	238.030	236.168	0.597***	0.587***	0.784***	0.780***
	(716.635)	(676.679)	(236.521)	(228.756)	(0.036)	(0.035)	(0.046)	(0.045)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,501	4,513	4,500	4,513	6,168	6,253	6,014	6,101
R^2	0.949	0.952	0.962	0.963	0.900	0.904	0.852	0.860
Adjusted R^2	0.942	0.946	0.957	0.958	0.890	0.895	0.837	0.846
Note:								*p<0.1; **p<0.05; ***p<0.01

Table E4. DID Regression Results: Transition Bonds vs. Green Bonds with k = 2 nearest neighbour matching

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of transition bond issuers and two matched green issuers for each treated observation, from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:							
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	37.863	69.544	20.965	39.742	0.005	0.009	0.002	-0.003
	(153.441)	(153.689)	(85.688)	(86.029)	(0.035)	(0.035)	(0.042)	(0.042)
Time (Short-Term)	-214.082***		-115.233***		0.074***		0.040**	
	(66.561)		(37.171)		(0.014)		(0.017)	
Time (Long-Term)		-258.279***		-78.950		0.082***		0.055***
		(91.151)		(51.023)		(0.016)		(0.020)
DiD Estimator (ST)	72.454		24.169		-0.036*		-0.041	
	(105.538)		(58.937)		(0.021)		(0.025)	
DiD Estimator (LT)		13.120		-87.199		-0.057**		-0.056*
		(143.020)		(80.057)		(0.025)		(0.030)
Constant	89.306	-100.493	101.134	3.813	0.694***	0.672***	0.766***	0.765***
	(257.236)	(262.799)	(143.652)	(147.105)	(0.059)	(0.059)	(0.070)	(0.071)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	569	553	569	553	629	617	629	617
R^2	0.912	0.874	0.877	0.856	0.850	0.856	0.793	0.792
Adjusted R^2	0.898	0.854	0.858	0.833	0.830	0.837	0.766	0.765
Note:								*p<0.1; **p<0.05; ***p<0.01

Table E5. DID Regression Results: Green Bonds vs. Conventional Bonds with k = 5 nearest neighbour matching

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a green bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of green bond issuers and five matched conventional issuers for each treated observation, from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:							
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	10.344	16.809	0.918	2.067	-0.003	-0.002	-0.001	0.0002
	(30.806)	(28.685)	(9.526)	(9.110)	(0.004)	(0.003)	(0.005)	(0.004)
Time (Short-Term)	-270.702***		-99.031***		0.052***		0.058***	
	(31.317)		(9.693)		(0.003)		(0.005)	
Time (Long-Term)		-160.686***		-79.410***		0.052***		0.053***
		(31.498)		(10.003)		(0.004)		(0.005)
DiD Estimator (ST)	-56.261		-11.812		0.010		-0.003	
	(63.899)		(19.763)		(0.007)		(0.009)	
DiD Estimator (LT)		-161.093**		-28.962		0.011		-0.001
		(63.506)		(20.169)		(0.007)		(0.009)
Constant	239.485	242.525	233.722	236.168	0.591***	0.584***	0.778***	0.781***
	(657.024)	(611.010)	(203.168)	(194.050)	(0.034)	(0.033)	(0.044)	(0.043)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,624	5,665	5,623	5,665	7,628	7,783	7,460	7,618
R^2	0.950	0.955	0.964	0.965	0.900	0.905	0.853	0.859
Adjusted R^2	0.945	0.950	0.960	0.962	0.892	0.897	0.840	0.848
Note:								*p<0.1; **p<0.05; ***p<0.01

Table E6. DID Regression Results: Transition Bonds vs. Green Bonds with k = 5 nearest neighbour matching

*This table reports estimated Difference-in-Difference regressions. Treatment is a dummy equal to one if the firm issued a transition bond. Time dummies are equal to one for short term in the year following the bond issuance and for long term two or more years following the bond issuance. CO2 intensity is reported in tCO2eq per million EUR of revenue and of book value of assets, respectively. ESG score metrics are reported as numeric value from 0 to 1, corresponding to alphabetic scores from A+ (best) to D- (worst). The data set includes all firm-year observations of transition bond issuers and five matched green issuers for each treated observation, from 2019 – 2024. Standard errors are reported in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% level.*

	Dependent variable:							
	CO2 Intensity (Revenue)		CO2 Intensity (Assets)		ESG Score		E Score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	53.476	91.451	38.654	61.298	0.005	0.013	0.003	-0.003
	(163.516)	(164.384)	(88.244)	(88.374)	(0.034)	(0.034)	(0.041)	(0.041)
Time (Short-Term)	-283.663***		-124.259***		0.064***		0.026**	
	(58.484)		(31.562)		(0.011)		(0.013)	
Time (Long-Term)		-354.466***		-109.221**		0.080***		0.050***
		(78.880)		(42.407)		(0.013)		(0.015)
DiD Estimator (ST)	137.096		32.850		-0.025		-0.028	
	(104.369)		(56.325)		(0.019)		(0.022)	
DiD Estimator (LT)		105.222		-53.713		-0.053**		-0.049*
		(141.394)		(76.015)		(0.022)		(0.027)
Constant	56.787	-134.827	75.055	-27.935	0.693***	0.667***	0.763***	0.766***
	(262.798)	(269.727)	(141.823)	(145.008)	(0.054)	(0.054)	(0.065)	(0.066)
Subclass Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	723	707	723	707	817	803	817	803
R^2	0.887	0.851	0.865	0.848	0.859	0.864	0.811	0.807
Adjusted R^2	0.872	0.831	0.847	0.827	0.843	0.848	0.790	0.785
Note:								*p<0.1; **p<0.05; ***p<0.01