DNB Working Paper
No 797/ January 2024

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DeNederlandscheBank

EUROSYSTEEM

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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

Working Paper No. 797

January 2024

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Pricing of Climate Transition Risk in the Corporate Bond Market[*]

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January 11, 2024

Abstract

We study whether climate transition risk is priced in corporate bond markets. We assess whether corporate bond investors value companies' efforts to mitigate climate change by innovating in the green space. By combining global firm-level data on greenhouse emissions and green patents with bond-level holdings data, we provide evidence of a positive transition risk premium, which is significantly lower for emission intensive companies that engage in green innovation. The joint effect of emission intensity and green innovation on bond yield spreads is driven by European investors, specifically institutional investors. Overall, our results indicate that investors care about whether companies are 'fit' for the green transition.

Keywords — Climate Change, Climate Transition Risk, Carbon Premium, Greenium, Green Innovation, Green Patents, Institutional Investors, Institutional Ownership.

JEL codes — G12, G15, G23, Q51, Q54.

[*]The views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank nor the Eurosystem. Data have been cleared by the Eurosystem for non-disclosure of confidential data. Details are available at www.ecb.europa.eu/stats/financial_markets_and_interest_rates/securities_holdings/html/index.en.html. For helpful comments and suggestions we thank Eline Jacobs.

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I. Introduction

To reach the temperature target of the Paris Accord (2015), the global productive system must decarbonize to reach net-zero emissions by 2050 (IPCC (2014)). The green transition requires the share of "green" (i.e. low carbon) activities to expand and the share of "brown" (i.e. high carbon) activities to decline (Campiglio and der Ploeg (2021)). The most effective policy measures to reach net-zero, such as a carbon tax, face considerable political backlash, however. This brings forward a key role for financial investors who can promote the green transition by redirecting capital towards green activities rather than brown ones. But do financial investors take companies' exposure to climate transition risk into consideration when making their investment decisions?

A recent literature studies whether financial investors price climate transition risk in stock markets (see e.g. Bolton and Kacperczyk (2023b); Bolton and Kacperczyk (2021); Pástor et al. (2021); Hsu et al. (2023); Bauer et al. (2022); Aswani et al. (2023); Loyson et al. (2023)) and whether this risk is accounted for in bank lending decisions (see e.g. Kacperczyk and Peydró (2022); Altavilla et al. (2023)). While more polluting sectors rely to a larger extent on bond financing (Papoutsi et al. (2022)), limited research has been conducted on the pricing of climate transition risk in the corporate bond market. Seltzer et al. (2022) provide evidence that climate regulatory risks causally affects bond yield spreads. Broeders et al. (2024) also find evidence of a carbon premium that investors demand for bonds issued by high carbon-emitting firms in the euro area. These papers use companies' absolute or relative greenhouse gas emissions - which are backward looking - as proxy of their exposure to climate transition risk. the green transition requires the majority of companies to change their business models to ensure their compatibility with climate goals going forward. While some papers consider firms' commitments to net-zero goals (Bolton and Kacperczyk (2023a); Altavilla et al. (2023)) in relationship to pricing, little research has been conducted on the question whether financial investors take into consideration firm's actual efforts to become green by innovating in the green space.

This paper studies whether corporate bond investors value companies' efforts to mitigate climate change by innovating in the green space. We take a forward-looking approach and consider companies' green innovation activities - as measured by the amount of green patents relative to the overall amount of patents - alongside their carbon emissions. We then assess (i) whether corporate bond investors demand a positive transition risk premium from companies with higher carbon emissions and, (ii) whether the risk premium is smaller for carbon intensive companies that engage in green innovation.

To answer these questions we combine global firm-level data on greenhouse emissions from Trucost Environmental with confidential bond-level holdings data. Data on bond holdings are from the ECB Securities Holdings Statistics by Sector database. Our baseline sample, which considers the period from 2016-Q1 to 2021-Q4, consists of 9,313 unique bonds, issued by 1,496 unique companies from 57 countries and has a total amount of observations of 99,941. In our regression analysis we find evidence of a positive transition risk premium that increases with the emission intensity of a company. In particular, a one standard deviation increase in emission intensity raises the bond yield spread with 48.3 basis points - an economically sizable effect. We demonstrate that the effect of emission intensity on yield spreads is of similar magnitude when analyzing a sub-sample of companies (i.e. bond issuers) based in the United States. Additionally, we test the robustness of our results by controlling for bonds' credit ratings, a measure which strongly drives bond yields.

To assess the second question, i.e. whether the transition transition risk premium is lower for carbon intensive companies engaging in green innovation, we augment our dataset with firm-level data on (green) patents from Orbis Intellectual Property. We obtain information on the total amount of patents of each company as well as the amount of 'green' patents they own. We consider all patents that are classified as patents in the Climate Change Mitigation and Adaptation class under the Cooperative Patent Classification (CPC) as green patents (Haščič and Migotto (2015)). To account for differences in the extent to which companies engage in patenting activities, we consider the amount of patents related to green technologies relative to the total amount of patents of a given company (Bolton et al. (2023)). Focusing on the subset of firms that have at least one green patent for this analysis, we find that the interaction between emission intensity and the green patent ratio significantly affects bond yield spreads. In particular, a one standard deviation increase in the green patent ratio reduces the yield spread of a bond issued by a company with a mean emission intensity by 11.7 basis points. This indicates that investors reward carbon emission intensive companies that make efforts to become more green, as measured by their relative engagement in green innovation. Moreover, we highlight that this reward is higher when these companies are currently more emission intensive. This result becomes stronger when we adopt a stricter classification for green patents. The result is also robust against considering absolute Scope 1+2 emissions as explanatory variable, rather than emission intensity. Additionally, we show that the joint effect of emission intensity and green patenting on yield spreads is stronger for companies based in the United States. Overall, our results indicate that investors care about whether companies are 'fit' for the green transition.

To better understand the implications of our main findings we analyze whether green innovation improves corporate environmental performance. Specifically, we assess whether the yield discount offered by investors to companies with high emissions that innovate in the green space is justified. Following Bolton et al. (2023), we assess whether green patenting is associated with a decline in future emissions. We find that an increase in the green patent ratio reduces emission intensity at the three-year horizon. Specifically, a standard deviation increase in the green patent ratio reduces emission intensity by 0.94 tons of CO_2 emissions per million dollars of revenue. However, this result is not robust against using the number of green patents as explanatory variable, nor to using absolute emissions instead of emission intensity as dependent variable. Moreover, the effect is heterogeneous across industries. Overall, it thus remains unclear from our results whether green innovation improves environmental performance, suggesting that investors should exercise caution when accommodating emission intensive companies in the form of smaller bond yield spreads once they innovate in the green space.

In the final part of our analysis, we assess whether European investors behave differently in the corporate bond market than other investors. To this end, we test whether European investors are more inclined to price the exposure climate transition risk. We consider European holders and domestic holders separately and interact the holder-share with the emission intensity and green patent ratio associated with the issuer of the bond. We find that a standard deviation increase in the share of EU-holders reduces the yield spread of company with a mean emission intensity and mean green patent ratio by 5.6 basis points, indicating that European investors are more likely to price the exposure of a company to climate transition risk. As the portfolio of EU-investors is largely tilted towards European firms, we re-estimate this relationship for a sub-sample of European firms and find a comparable effect when we only consider bonds issued by European companies. Finally, we explore whether the pricing of climate transition risk is driven by institutional investors. We find that a standard deviation increase in the share of holdings of institutional investors reduces the yield spread of company with a mean emission intensity and mean green patent ratio by approximately 5.4 basis points. The effect is comparable for insurance companies and pension funds, but is not present for banks, suggesting that the joint effect of emission intensity and green patenting on yields is predominantly driven by European institutional investors.

The remainder of this paper is structured as follows. In Section II, we discuss the related literature and the contribution of this paper. Section III introduces the data and Section IV describes the methodology. The results are presented in Section V. Section VI concludes.

II. Related Literature

This paper relates to two broad strands of literature. First, our paper contributes to the literature on the pricing of climate transition risk in financial markets. Bolton and Kacperczyk (2021) find evidence of a positive carbon premium in the cross-section of U.S. stock returns and Bolton and Kacperczyk (2023b) show that this premium is observed in global stock markets. Hsu et al. (2023) consider the asset pricing implications of industrial pollutants, rather than just CO2-related emissions, and show that environmental policy uncertainty helps price the cross-section of stocks returns. On the contrary, Loyson et al. (2023) do not find evidence that carbon risk is being priced in the European equity market. Aswani et al. (2023) suggest that the association between corporate emissions and stock returns disappears when using emission intensity rather than unscaled emission levels. Boermans and Galema (2023) affirm this result for European stock, but find a carbon premium for non-European stocks using emission intensity. Pástor et al. (2022) and Ardia et al. (2023) empirically test whether green firms outperform brown firms when concerns about climate change increase unexpectedly (Pástor et al. (2021)). Bauer et al. (2022) find more generally and for a range of methodologies that green stocks provide higher returns than brown stocks for much of the past decade. Using syndicated loan data, D'Arcangelo et al. (2023) find that firms with lower carbon emission intensities enjoy lower cost of debt, especially in countries where climate-change mitigation policies become more stringent (see also Ali et al. (2023) and, more generally, Heinkel et al. (2001)). Altavilla et al. (2023) provide evidence that banks charge higher interest rates to firms with higher carbon emissions. Moreover, the authors show that a tightening in monetary policy induces banks to increase carbon emission premia. Conversely, the authors show that banks charge lower rates to firms committing to lower emissions. Less research has been conducted on the pricing of climate transition risk in the corporate bond market, which is the focus of our study. While more polluting sectors rely to a larger extent on bond financing (Papoutsi et al. (2022)), limited research has been conducted on the pricing of climate transition risk in the corporate bond market. Seltzer et al. (2022) provide evidence that climate regulatory risks causally affects bond yield spreads. Broeders et al. (2024) also find evidence of a carbon premium that investors demand for bonds issued by high carbon-emitting firms in the euro area. We contribute to the literature by taking a forward-looking approach, showing that the 'carbon' risk premium charged to carbon intensive companies is lower when an emission intensive company engages in green innovation. This indicates that investors care about whether companies are 'fit' for the green transition.[1]

Second, this paper also relates to a growing literature on green innovation. Cohen et al. (2023) find that firms with lower ESG-scores are key innovators in the United States' green patent landscape. On the contrary, Bolton et al. (2023) find that there is path-dependency in innovation, as green innovation is predominantly undertaken by firms that are already green, while brown firms tend to innovate in brown technologies. This latter pattern is confirmed by Dugoua and Gerarden (2023). Closely related to our paper is Leippold and Yu (2023). Leippold and Yu (2023) show that stocks of firms with higher green innovation measures have lower expected returns. While this paper focuses on the association between green innovation and stock returns, our focus is on whether emission intensity and green innovation jointly determine bond yield spreads. In particular, we assess whether the transition risk premium is lower for emission intensive companies that engage in green innovation. Our contribution is to show that markets reward companies that engage in green innovation - the more so when these companies are currently emission intensive. Leippold and Yu (2023) further show that firms that engage in green innovation reduce carbon emissions over time. ElBannan and Löffler (2024) also document a significantly negative relationship between the volume of issued green bonds and future carbon intensity. This effect is concentrated among financially constrained firms, highlighting that the

[1] While we focus on the corporate bond market as a whole and do not focus on corporate green bonds exclusively, our paper also relates to studies in this literature (e.g. Flammer (2021); Pietsch and Salakhova (2022); Zerbib (2019); ElBannan and Löffler (2024)) as we find evidence of a substantive 'greenium'.

issuance of green bonds relaxes financial constrains, which enhances green innovations by issuing firms. Accetturo et al. (2022) show for Italian SMEs that there is a large positive elasticity of green investments to credit supply. By contrast, Hartzmark and Shue (2023) demonstrate that brown firms face very weak incentives to become more green, indicating sustainable investing that directs capital away from brown firms and toward green firms may be counterproductive. This is confirmed by Bolton et al. (2023), who do not find that green innovation reduces carbon emissions. Rather the authors find that green innovation is associated with an increase in indirect emissions.

III. Data

We construct a comprehensive dataset by compiling data from various sources. Our main database covers the period 2016-Q1 up until 2021-Q4. Data is reported at quarterly frequency at the security-by-security level for bonds issued worldwide. Data on security-level portfolio holdings is obtained from the ECB Security Holdings Statistics Sectoral (SHS-S, hereafter referred to as SHS) and is complemented with data from the ECB Centralized Securities Database (CSDB), which provides various issuer- and bond characteristics at the security level.[2] Data on corporate carbon emissions is obtained from Trucost Environmental and we collect (green) patent information from Orbis Intellectual Property (IP). Corporate fundamentals are obtained from Refinitiv. The databases are matched using international security identifiers (ISIN). The sample for the baseline regressions consists of 9,313 unique bonds (i), issued by 1,496 unique companies (f) from 57 countries worldwide. The total amount of observations (N) equals 99,941. Table 1 provides summary statistics.

A. Security-level portfolio holdings

The SHS database provides detailed information on aggregate security-level portfolio holdings by financial and non-financial holders from all 20 euro area countries (denoted by c) as well as six other European Union countries not part of the euro area. Data is reported at the quarterly frequency at the security-by-security level for bonds issued worldwide.[3] The magnitude of

[2]Both SHS and CSDB are collected and operated by the European System of Central Banks (ESCB).
[3]Data is reported at market value. Nominal values are also available, which are given the aggregated nominal amount of the security, excluding accrued interest.

holdings (as measured by total bond value) within our sample encompasses 0.996 trillion euro in 2016-Q1 and rises to 1.46 trillion euro (in 2021-Q4), which covers approximately 58% of all security holdings reported for euro area investors.[4] The most limiting factor in our coverage is the availability of carbon emissions data. Holders are classified into 8 distinct investor sectors (denoted by s), i.e. insurance companies, pension funds, mutual funds, banks, other financial institutions (including securitizations vehicles), non-financial corporations, governments and households (including non-profit institutions serving households). Holdings of securities issued by companies located in the euro area as well as securities issued by companies located outside of the euro area are reported. The CSDB complements the European holdings data with various issuer - and bond characteristics at the security level, such as issuer name and country, yield to maturity, outstanding amount, coupon rate, and currency.

Figure 1 shows the evolution over time of mean and median bond yields. Both graphs displays a downward trend in bond yields between 2016 and 2021, coinciding with the global decline of interest rates over the sample period. Since bonds are frequently observed for multiple periods, there potentially is autocorrelation in bond yields. In Appendix A we assess the time series properties of bond yields by estimating an autoregressive model. The estimation results suggest that bond yields are stationary.

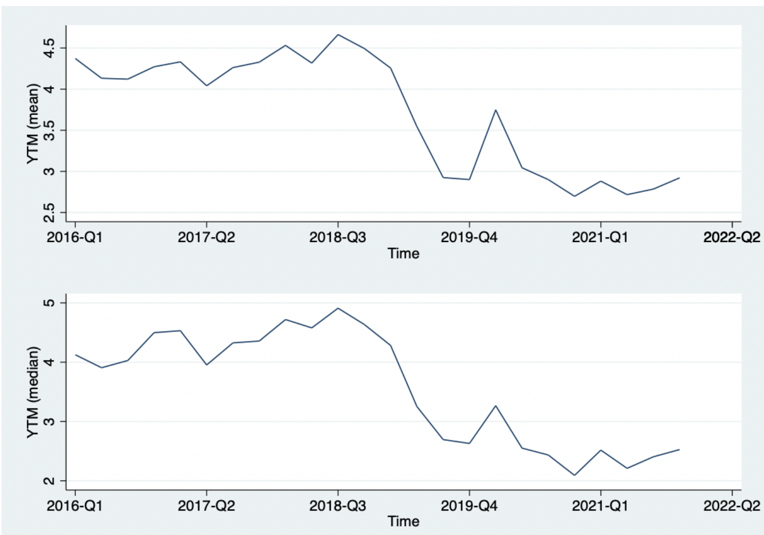

FIGURE 1: THE EVOLUTION OF THE MEAN (UPPER GRAPH) AND MEDIAN (LOWER GRAPH) YIELD TO MATURITY OVER THE SAMPLE PERIOD.

[4]Short-positions, non-active securities, and investments in tax havens are excluded and small positions, highly implausible prices, and debt types as warrants and equity like debt are dropped. Furthermore, reporting is harmonized across euro area countries.

Table 1: Summary statistics

	Mean	SD	Min	Max
Environmental Variables				
Log(Scope 1)	12.553	2.939	-0.120	19.839
Log(Scope 2)	12.321	2.070	-0.009	18.838
(Scope 1 + Scope 2) Emission Intensity	2.540	4.653	0.013	19.940
Bond Characteristics				
Yield to Maturity (%)	2.639	2.785	-1.5	23.625
Amount Outstanding (in m EUR)	554.053	499.031	0.013	8,110.970
Fixed Coupon	0.909	0.287	0	1
EUR	0.333	0.471	0	1
USD	0.485	0.500	0	1
Bond Rating	8.103	2.585	1	22
Green bond	0.0193	0.138	0	1
Corporate Fundamentals				
Total Assets (in bn EUR)	469.205	686.819	45.800	1,932.012
Revenue (in bn EUR)	48.104	11.037	29.532	65.574
Total Equity (in bn EUR)	17.990	5.275	7.751	29.839
Total LT-Debt (in bn EUR)	417.891	672.531	11.376	1,846.886
Leverage	1.893	0.631	1.100	3.086
Profitability	5.141	2.593	1.005	10.044
Cash-Ratio	0.146	0.039	0.087	0.236
Investment-ratio	0.965	0.517	0.308	2.071

Note: Based on 99,941 observations, reported at quarterly frequency at the security-by-security level. Absolute emissions levels are measured in CO2e and are reported in natural logarithms. Emission intensities, measured in CO2e/USDm, are scaled by a factor 1/100. Companies have on average 17.3 bonds outstanding in a given time period, and the highest amount of bonds outstanding for a given company in a given period is equal to 103. Fixed coupon is a dummy which is equal to 1 if a bond has a fixed coupon, and EUR respectively USD are dummy which are equal to 1 if a bond is denominated in euros respectively dollars. Green bond is a dummy which is equal to 1 if a bond has a green bond label. Leverage is defined as total debt divided by earnings before interest, taxation, depreciation and amortization. Profitability is defined as net income dividend by total assets (ROA) The cash- and investment ratio are defined as cash respectively investments divided by total assets, respectively.

Since we are interested in estimating risk premia, we determine the Option-Adjusted Spread (OAS). To this end we subtract from the yield to maturity of a bond the risk-free rate. For bonds with a residual maturity shorter than 731 days, we use the 1-year Eurozone Central Government Bond Par Yield Curve Spot Rate (1-year Treasury Rate for bonds denominated in US dollars). We use the 5-year Eurozone Central Government Bond Par Yield Curve Spot Rate (5-year Treasury Rate for bonds denominated in US dollars) for bonds with a residual maturity between 730 and 2738 days and the 10-Year Eurozone Central Government Bond Par Yield Curve Spot Rate (10-year Treasury Rate for bonds denominated in US dollars) for bonds with a residual maturity longer than 2738 days.[5] Finally, a portion of our corporate bonds has a green bond label. In our sample, we have 276 green bonds (3% of all bonds), issued by 119 distinct companies (8% of all companies).

B. Corporate environmental performance

We obtain information on corporate carbon emissions from Trucost Environmental. Trucost provides firm-level data on carbon - and other greenhouse gas emissions. Data is reported annually and the coverage of Trucost is global. The coverage of Trucost increases vastly after 2016 (Bolton and Kacperczyk (2021)), coinciding with the Paris Agreement, which lead to increased awareness on climate change and increased the salience for the measuring and reporting of environmental data. Data is reported with a publication lag of approximately 12 months. Hence, as of today, data is only available for a limited amount of firms for 2022. Therefore, we focus on a sample period from 2016-Q1 to 2021-Q4. Moreover, while the majority of companies for which Trucost reports carbon emissions are private, we focus on the subset of companies for which we have bond data available, which are public.

Trucost reports absolute carbon emissions (in tons of CO2e) as well as emission intensities, which are given by as a company's emissions in a given year relative to the company's size, as measured by its revenue, in the same year in tons of CO2 emissions per million dollars of revenue (CO2e/USDm). A distinction is made between three sources of emissions. Scope 1 emissions cover emissions from the use of fossil fuels in the companies' production (direct emissions). Scope 2 emissions cover indirect emissions, which stem from the purchase and consumption of

[5]The percentage of bonds within our sample which are denominated in euros is 33.29%. Since a large amount of bonds within our sample is denominated in US dollars (48.52%), we use Treasury Rates when determining the spread for these bonds. Bonds denominated in other currencies are benchmarked against the euro area rates.

heat, steam and electricity by a company. Finally, Scope 3 emissions cover all emissions that are related to a companies operations and products, but which occur along other parts of the value chain (both upstream and downstream). Because Scope 3 emissions are more difficult to measure, they are less often reported and are frequently estimated by data providers. As there is a lack of methodological clarity on how providers estimate these emissions, data on Scope 3 emissions are noisy and more frequently inconsistent than data for Scope 1 and 2 emissions Klaaßen and Stoll (2021)). We therefore exclude Scope 3 emissions from our analysis.

We construct a measure of a company's environmental performance which considers Scope 1 and Scope 2 emissions jointly. To account for company size, we consider a total emissions relative to the companies' revenue in the same year similar to Andersson et al. (2016); Boermans and Galema (2023); Aswani et al. (2023). Thus, the emission intensity measure is given by:

$$\text{Emissison Intensity}_{f,t} = \frac{\text{Scope } 1_{f,t} + \text{Scope } 2_{f,t}}{Revenue_{f,t}}$$

where emission intensity is reported in tons of CO2e/USDm. We scale our measure of environmental performance by a factor 1/100 and winsorize it at the 2.5% level. Table 2 reports correlations across the different measures, which reveals that our measure of emission intensity is strongly correlated with Scope 1 intensities.

Table 2: Correlation between emission measures

	Scope 1	Scope 2	Scope 1 Intensity	Scope 2 Intensity	Emission Intensity
Scope 1	1				
Scope 2	0.597	1			
Scope 1 Intensity	0.621	0.069	1		
Scope 2 Intensity	0.186	0.369	0.278	1	
Emission Intensity	0.607	0.106	0.985	0.400	1

Note: Based on 99,941 observations. Absolute emissions levels are measured in CO2e and are reported in natural logarithms. Emission intensities, measured in CO2e/USDm, are scaled by a factor 1/100 and winsorized at the 2.5%.

We plot the evolution of emission intensity at the firm-level in Figure 2. The left panel shows the evolution of mean emission intensity, and the right panel depicts the evolution of median emission intensity. Both panels reveal a downwards trend in both mean and median emission intensity, which declined by approximately 5 percent annually over our sample period. We also assess the time series properties of our emission intensity variable (see Appendix A). Controlling for time- and firm specific effects our estimates show considerably persistence, but no evidence of a unit root.

FIGURE 2: THE EVOLUTION OF THE MEAN (LEFT) AND MEDIAN (RIGHT) EMISSION INTENSITY, REPORTED AT QUARTERLY FREQUENCY AT THE FIRM-LEVEL, OVER THE SAMPLE PERIOD.

C. Corporate Fundamentals

Information on corporate fundamentals is obtained via Refinitiv, which is also available at the quarterly frequency. We use information on companies' (current) assets, profitability (ROA), revenue, equity, long-term debt, leverage, liabilities, investment ratio, cash ratio and sector classification (based on the Global Industry Classification Standard, or GICS). We exclude all financial corporations from our analysis. Table 3 summarizes the distribution of observations across different industries. This Table exploits relative aggregated industry classifications from TRBC, but a more detailed classification based on GICS can be found in Appendix B.

There is large variation in emission intensity across industries. The largest industries covered by our sample are technology, industrials and consumer cyclicals. Emission intensity is on average highest in the utilities sector, basic materials and the energy sector. Health care and technology have the lowest emission intensity on average. Table B1 in Appendix B reports the mean emission intensity in each industry in each time period. This Table confirm the results of Figure 2, as mean emission intensity has declined for most industries over time.

TABLE 3: DISTRIBUTION OF OBSERVATIONS ACROSS INDUSTRIES

Industry	Observations	Mean Emission Intensity	Median Emission Intensity
Basic Materials	2,418	6.977	4.665
Consumer Cyclicals	2,975	0.742	0.347
Consumer Non-Cyclicals	1,837	1.426	0.548
Energy	1,496	5.086	3.930
Healthcare	1,418	0.371	0.311
Industrials	3,872	1.920	0.405
Real Estate	2,314	0.782	0.681
Technology	2,974	0.482	0.189
Utilities	1,580	10.416	9.614

Note: Observations reported at the firm-period level.

D. (Green) patent information

We obtain information on (green) patents from Orbis IP, which provides global data of patent of public and private companies filed at the European Patent Office (EUPO), the US Patent Office (USPO) and the Japanese Patent Office (JPO). We match the security identifiers in our primary sample with their corresponding identifiers in Orbis (BVD-ID numbers). This allows us to identify all patents registered by a given company within our sample, resulting in a total of 19,406,540 patents associated with 1,236 unique companies. We obtain information on the overall number of patent publications, as well as the number of publications in a given year, and use this to determine the total amount of active patents in a specific year.

Since we are interested in green innovation, we utilize the Cooperative Patent Classification (CPC) to identify companies' green patents. We follow Haščič and Migotto (2015) and consider the entire class on Climate Change Mitigation and Adaptation (Y02).[6][7] We obtain information

[6]The Y02 consists of 8 subclasses, i.e. technologies for adaptation to climate change (Y02A); climate change mitigation technologies related to buildings (Y02B); capture, storage, sequestration or disposal of greenhouse gases (Y02C); climate change mitigation technologies in ICT (Y02D); reduction of greenhouse gasses related to energy generation, transmission or distribution (Y02E); climate change mitigation technologies in the production or processing of goods (Y02P); climate change mitigation technologies related to transportation (Y02T); climate change mitigation technologies related to wastewater treatment or waste management (Y02W).

[7]Bolton et al. (2023) argue that this classification does not always distinguish between patents on renewable energy technologies ("green") and brown efficiency improvement patents. Therefore, the authors classify patents into 3 categories: i) "green" patents for environmental technologies; ii) "general efficiency improvement" patents that deal with technologies that improve process efficiency and therefore could reduce emission intensity; iii) "brown" patents that deal with technological innovation for fossil fuel-based technologies. This classification relies on four technology classification sources on patents relating to the environmental impact of technologies, in particular:

on the publication number, the current owners, the description of the patent, the priority - and application date, as well as the classification of each green patent according to its CPC-code. We assign green patents to a given company in a given year using the application date and the identifier of current owners. This results in 222,091 green patents, which are held by 384 unique companies, indicating that only 31.1% of the companies in our sample that engage in patenting also have green patents. While green patents only represent 1.1% of the total amount of patents within our dataset, the companies that engage in green innovation own 89.7% of all patents (17,403,740 patents from the total of 19,406,540). This suggests that there is high correlation between a companies engagement in green patenting and patenting in general.

Table 4: Number of Patents and Green Patents Filed over the Sample Period

Variable	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Patents	641,460	650,508	649,229	627,537	565,244	476,352
Patents (GP-sub-sample)	556,604	566,941	565,046	547,096	491,537	413,746
Green Patents	7,001	6,827	7,205	7,435	5,652	7,323

To account for this, we construct a relative measure of green innovation, the green patent ratio. This measure considers the amount of patents related to green technologies relative to the total amount of patents of a given company (Bolton et al. (2023)):

$$\text{Green Patent Ratio}_{f,t} = \frac{\#\text{Green Patents}_{f,t}}{\#\text{Patents}_{f,t}}$$

The mean green patent ratio is equal to 0.006 (with a standard deviation of 0.0185), and the highest green patent ratio in our sample is 0.368. We provide summary statistics for the sample of companies which have at least one green patent in Appendix C.[8] There is large variation in the green patent ratio across industries and countries. Table 5 summarizes the mean emission intensity, mean green patent ratio and mean amount of green patents across sectors (we provide the summary statistics using the median in Appendix C). The green patent ratio is highest in the utilities sector, which is also the sector that has the highest emission intensity on average.

the International Patent Classification (IPC) Green Inventory (for green patents), the efficiency-improving fossil fuel-technology categories of Lanzi et al. (2011), as well as a self-identified classification based on patents from the Corporate Knights Clean 200. The OECD classification is used for robustness (Bolton et al. (2023)).

[8]The summary statistics for the sample of companies which have at least one green patent are comparable to those for the sample of all companies on which we obtain patent data. Additionally, we verify the robustness of our results using the sample of all companies on which we obtain patent data.

The green patent ratio is lowest in the health care sector, which is associated with the lowest emission intensity on average. Table 5 further underscores the importance of considering the engagement in green patenting relative to patenting in general. Specifically, while the utilities industry has the highest green patent ratio, it has one of the lowest amounts of green patents on average.

Table 5: Distribution of observations across industries

Industry	Observations	Emission Intensity	Green Patent Ratio	Green Patents
Basic Materials	879	7.195	0.011	39.465
Consumer Cyclicals	615	0.669	0.01	2097.729
Consumer Non-Cyclicals	411	1.625	0.009	337.314
Energy	444	4.684	0.025	39.937
Healthcare	494	0.324	0.002	81.257
Industrials	1,083	1.024	0.011	186.36
Real Estate	45	1.039	0.01	3.178
Technology	924	0.478	0.004	858.086
Utilities	542	10.219	0.033	170.995

Note: Observations reported at the quarterly frequency and firm-level.

IV. Empirical Methodology

We observe each bond i, issued by a company f (located in industry g) in period t, which is measured at the quarterly frequency. Additionally, we observe the bonds' holder j (located in country c and sector s).

Main Specifications To determine whether the bond yield spread is larger for bonds issued by companies with higher carbon emissions, we estimate the following regression for the bond yield spread at the bond-period level:

$$\text{Spread}_{i,t} = \beta_1 \text{ Emission Intensity}_{f,t-1} + \beta_2' X_{f,t-1} + \beta_3' Z_{i,t} + \alpha_t + \alpha_f + \alpha_i + \varepsilon_{i,t} \qquad (1)$$

where emission intensity is measured at the firm level in tons of CO2 emissions per million dollars of revenue (CO2e/USDm). We include the lagged value of emission intensity to prevent relating bond returns to current emissions. The vector of one-period lagged corporate (f) fundamentals

($X_{f,t-1}$) includes profitability, leverage, cash-ratio, and investment-ratio. We also include a vector of contemporaneous bond (i) characteristics, $Z_{i,t}$, which includes the outstanding amount (which is a proxy for liquidity, see Friewald et al. (2012), in natural logarithms), a dummy which indicates if the bond has a fixed coupon, a dummy which indicates whether the bond is denominated in euro and a dummy which indicates whether the bond has a green bond label. The terms α_j with $j \in \{f, i, t\}$ are firm, bond and time fixed effects and $\varepsilon_{i,t}$ is the idiosyncratic error term. We estimate the equation using (i) time fixed effects, and (ii) time fixed effects and firm fixed effects. Additionally, to assess whether there is a relationship between emission intensity and bond yield spreads at the within bond-level we estimate this equation using (iii) time fixed effects and bond fixed effects (note that the firm dimension, f, is nested in the bond dimension, i). Regarding the idiosyncratic error term, standard errors are clustered at the more detailed (GICS) industry level, resulting in 73 clusters (see Table B2, in Appendix B).[9] Additionally, we include analytical weights based on the total amount of bonds outstanding of each firm in each period.

To test whether the bond yield spreads becomes smaller when a company engages in green innovation, we proceed as follows. We interact emission intensity with our relative measure of green innovation, and estimate the following regression at the bond-period level:

$$\text{Spread}_{i,t} = \beta_1 \text{Emission Intensity}_{f,t-1} + \beta_2 \text{Green Patent Ratio}_{f,t-1} + \beta_3 \text{Emission Intensity}_{f,t-1} \cdot \text{Green Patent Ratio}_{f,t-1} + \beta_4 X'_{f,t-1} + \beta_5 Z'_{i,t} + \alpha_t + \alpha_f + \alpha_i + \varepsilon_{i,t} \quad (2)$$

where we take the lagged value of emission intensity, the green patent ratio and the interaction between the two. Compared with Equation (1) we include the same vector of corporate fundamentals, $X_{f,t-1}$, bond characteristics, $Z_{i,t}$ and combinations of fixed effects as controls. Standard errors are again clustered at the (GICS) industry level, resulting in 53 clusters (see Table B3, in Appendix B).

Changes in Corporate Environmental Performance To better understand the implications of our main findings we analyze whether green innovation improves corporate environmental performance. Specifically, we assess whether the yield discount offered by investors to companies

[9] For related approaches in the literature that analyze determinants of corporate bond spreads, see Helwege et al. (2014); Huang and Petkevich (2016); Bauer et al. (2021).

with high emissions that innovate in the green space is justified. Following Bolton et al. (2023), we estimate the impact of green innovation on corporate environmental performance by linking a companies' future emission intensity to its contemporaneous green innovation activity. That is, we estimate the following regressions at the firm-level:

$$\text{Environ. Performance}_{f,t+h} = \beta_1 \text{Green Patent}_{f,t} + \beta_2' X_{f,t} + \alpha_t + \alpha_g + \upsilon_{f,t} \tag{3}$$

where we use the emission intensity as our measure of a firm's environmental performance. We verify the robustness of the results against using the absolute Scope 1 + 2 emissions (in log) as measure of environmental performance. We use either the green patent ratio as main explanatory variable in Equation (3) or the amount of green patents associated to a company (in log). We estimate the model for $h \in \{4, 8, 12\}$, i.e. for 1, 2 and 3 years ahead. We include the same vector of corporate fundamentals, $X_{f,t}$. For the regressions with absolute Scope 1+2 emissions as dependent variable, we additionally include revenue (in billions) as control variable. We estimate the relation using Ordinary Least Squares (OLS) with time- and industry (g)-fixed effects, and verify the robustness of the results using the Arellano and Bond (1991) two-step GMM estimator. Standard errors are clustered at the firm-level.

Holdership Dynamics We test whether European investors are more inclined to price the exposure to climate transition risk. We interact the green patent ratio with the share of bonds held by European investors and estimate the following regression at the bond-period level:

$$\begin{aligned} \text{Spread}_{i,t} = \; & \beta_1 \text{Emission Intensity}_{f,t-1} + \beta_2 \text{Green Patent Ratio}_{f,t-1} + \beta_3 \text{Holder Share}_{j,t-1} \\ & + \beta_4 \text{Green Patent Ratio}_{f,t-1} \cdot \text{Emission Intensity}_{f,t-1} \cdot \text{Holder Share}_{j,t-1} \\ & + \beta_5' X_{f,t-1} + \beta_6' Z_{i,t} + \alpha_t + \nu_{i,t} \end{aligned} \tag{4}$$

where we take the lagged value of emission intensity, the green patent ratio, the holder share, as well as the interaction between these three variables. We measure the different holder shares at the bond level as the total holdings of specific European investors (denoted by j) in a given period relative to the total amount outstanding (at market values). The parameter of interest is β_4. We expect a negative coefficient, i.e. European investors ask a lower risk premium conditional on emission intensity and green patent activity of the firm. We distinguish between EU-holders, EA-holders, and 'home'-holders (i.e. holders located in the same country as the issuer of the bond, see Boermans and Galema (2023)). Additionally, we distinguish between European institutional investors, a sub-set of institutional investors and banks to assess whether investors in a certain sector are more inclined to price the exposure to climate transition risk. We include the same vector of corporate fundamentals, $X_{f,t-1}$, bond characteristics, $Z_{i,t}$ as control variables, as well as time fixed effects.

V. Results

A. Baseline Regressions

We start with testing whether bond yield spreads are larger for bonds issued by companies with higher carbon emissions. We estimate Equation (1) by OLS for three different sets of fixed effects, i.e. time, firm- and time, and bond- and time fixed effects. Table 6 provides the results for our baseline regressions. For each of the three specifications, the first column reports the results when only the control variables are incorporated in the regression. The second column then reports the results including our main explanatory variable of interest, i.e. the emission intensity.

Generally, we find evidence of a climate transition risk premium, as corporate bonds of companies with higher carbon emissions face a larger bond yield spread. Regarding the specification with time fixed effects (column 2), the effect of emission intensity on the bond spreads is positive and statistically significant at the 5 percent significance level. An increase in emission intensity by one standard deviation raises the yield spread with 48.6 basis points. This effect is economically sizable. To disentangle the carbon premium (i.e. the positive risk premium for exposure to carbon risk) from the 'greenium' (i.e. the yield discount associated with green bonds), we additionally control for whether a bond has a green bond label in the third column. The results in column 3 indicate that bonds that qualify as green bond are associated with a large and highly significant yield discount, of 52.2 basis points. Importantly, controlling for whether a bond has a green bond label does not change the effect of emission intensity on yield spreads. The effect stays in roughly equal in size and remains statistically significant at the 5 percent significance level.

We also estimate the relationship with firm fixed effects, which enlarges the explanatory power of the regression. The effect of emission intensity on bond spreads remains significant at the 10 percent significance level with firm fixed effects (column 5-6) and is comparable in magnitude. Finally, we estimate Equation (1) using bond fixed effects, see column 7-8 (note that the green bond status is subsumed in the bond fixed effects). This is an additional test to assess whether the positive relationship between emission intensity and bond yield spreads is also observed within the individual bond's time series. Note that Seltzer et al. (2022) do not include bond fixed effects in their main specification. We no longer find evidence that higher carbon emissions increase bond yield spreads. Hence, the results indicate that the effect we find is largely identified by the cross-sectional variation in the data.

We conduct several tests to assess the robustness of our results. The results are reported in Table 7. In column 1 we verify the robustness of our results against the inclusion of a dummy indicating whether the bond is denominated in US dollars, as a large amount of bonds in our sample are denominated in this currency. The effect of emission intensity on the bond spreads remains positive and statistically significant at the 5 percent significance level. We also verify the robustness of our results when focusing on a sub-sample of US companies. The results, which are reported in column 2, provide weak evidence that the effect of emission intensity on the bond spreads is positive for companies located in the US. The coefficient is of similar magnitude as we find for the sample with global bond issuers. We also assess the robustness of our results against the inclusion of bond credit ratings, since the credit risk associated with the bond issuer constitutes an important determinant of the yield spread. For this exercise, we augment or dataset with information on bond credit ratings data. Rating data is obtained via the CSDB and is directly reported by ratings agencies Fitch, Moody's, S&P and DBRS to the ECB. Ratings data is only available for 38,000 observations, hence this robustness test is conducted for a subset (38%) of our sample.[10] The results for the sub-sample with credit rating are reported in column 3. As expected, bond credit ratings have high explanatory power for

[10]The summary statistics indicate that this sub-sample consists of companies which are slightly larger in size. In particular, the emission intensity of companies within this sub-sample are slightly higher than in our baseline sample. When it comes to bond characteristics, the amount outstanding is slightly higher as well and more bonds within this sample are denominated in US dollars. Corporate fundamentals as well as the distribution of companies across sectors are roughly comparable to those in the baseline sample. Additionally, the average credit rating over this sample is 8.103 (with a standard deviation of 2.585), which corresponds to a lower medium-grade ($BBB+$) bond. The highest bond rating within this sample is equal to 1 (highest quality, AAA), and the lowest is 22 (near-default, CC).

the variation in bond yield spreads. The effect of bond credit ratings on the bond spreads is positive and statistically significant at the 1 percent significance level in line with the literature (e.g. Friewald et al., 2012; Helwege et al., 2014; ElBannan and Löffler, 2024). A one standard deviation increase in bond credit ratings raises the yield spread with 95.3 basis points - an economically large effect. Once we control for credit ratings, the effect of emission intensity on the bond spreads remains statistically significant, although it becomes smaller in size. A one standard deviation increase in emission intensity raises the yield spread with 24.1 basis points, compared to the baseline result of 48.3 basis points. Finally, in column 4 of Table 7 it is shown that our baseline results are robust against the exclusion of sampling weights.

Table 6: The Effect of Emission Intensity on Yield Spreads

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.Emission Intensity		0.104**	0.104**		0.109*	0.107*		0.086
		(0.042)	(0.041)		(0.058)	(0.059)		(0.069)
Green Bond			-0.522***			-0.240**		
			(0.152)			(0.106)		
L.Profitability	0.201**	0.132	0.126	0.203***	0.148***	0.146***	0.349***	0.304***
	(0.080)	(0.081)	(0.081)	(0.034)	(0.045)	(0.044)	(0.030)	(0.044)
L.Leverage	1.657**	1.023	0.963	1.663***	1.162***	1.148***	3.014***	2.606***
	(0.723)	(0.740)	(0.741)	(0.305)	(0.414)	(0.410)	(0.263)	(0.407)
L.Cash-Ratio	-5.414*	-3.028	-2.807	-5.306***	-3.431**	-3.379**	-10.479***	-8.955***
	(2.783)	(2.771)	(2.775)	(1.174)	(1.503)	(1.487)	(1.026)	(1.468)
L.Investment-Ratio	-0.679*	-0.362	-0.331	-0.681***	-0.439**	-0.431**	-1.386***	-1.188***
	(0.387)	(0.390)	(0.391)	(0.157)	(0.216)	(0.214)	(0.134)	(0.213)
L.Amount Outstanding	-0.279***	-0.239***	-0.238***	-0.101***	-0.099***	-0.098***		
	(0.065)	(0.057)	(0.056)	(0.024)	(0.023)	(0.023)		
Fixed Coupon	0.493**	0.579***	0.580***	0.306*	0.308*	0.312*		
	(0.220)	(0.191)	(0.189)	(0.183)	(0.180)	(0.180)		
EUR	-0.490***	-0.540***	-0.526***	-0.323***	-0.321***	-0.318***		
	(0.158)	(0.142)	(0.140)	(0.064)	(0.066)	(0.066)		
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	Yes	Yes	Yes	No	No
Bond-FEs	No	No	No	No	No	No	Yes	Yes
Observations	99,941	99,941	99,941	99,941	99,941	99,941	99,941	99,941
R-squared	0.068	0.115	0.116	0.542	0.544	0.544	0.796	0.797

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Baseline results for Equation (1), estimated with OLS with three different sets of fixed effects, i.e. time fixed effects, firm fixed effects and time fixed effect, and bond fixed effects and time fixed effects. For each estimation method, the first column reports the results when only the control variables are incorporated in the regression. The second column reports the results including our main explanatory variable of interest, emission intensity. The third column additionally controls for whether a bond has a green bond label. Standard errors are clustered at the (GICS) industry-level.

Table 7: Robustness Tests: The Effect of Emission Intensity on Yield Spreads

	USD	US	Ratings	No weights
	(1)	(2)	(3)	4
L.Emission Intensity	0.107**	0.106*	0.052**	0.075**
	(0.043)	(0.063)	(0.023)	(0.033)
Green Bond	-0.586***	-0.494***	-0.466***	-0.496*
	(0.174)	(0.069)	(0.106)	(0.274)
L.Profitability	0.121	0.059	0.053	0.191***
	(0.081)	(0.038)	(0.046)	(0.045)
L.Leverage	0.920	0.465	0.317	1.569***
	(0.740)	(0.315)	(0.388)	(0.410)
L.Cash-ratio	-2.597	-0.102	-0.288	-5.366***
	(2.766)	(1.187)	(1.650)	(1.501)
L.Investment-Ratio	-0.305	-0.092	0.013	-0.640***
	(0.389)	(0.163)	(0.204)	(0.213)
L.Amount Outstanding	-0.167***	-0.164***	-0.053	-0.413***
	(0.047)	(0.044)	(0.045)	(0.057)
Fixed Coupon	0.599***	0.986***	0.120	0.897***
	(0.196)	(0.115)	(0.312)	(0.178)
EUR	-1.173***	-0.281***	-0.685***	-0.634***
	(0.227)	(0.073)	(0.122)	(0.143)
USD	-0.839***			
	(0.207)			
Bond Rating			0.369***	
			(0.070)	
Time-FEs	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	No
Bond-FEs	No	No	No	No
Observations	99,941	37,190	38,000	99,941
R-squared	0.137	0.170	0.307	0.098

Robust standard errors in parentheses

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

Note: Robustness tests for Equation (1), estimated with pooled OLS with time fixed effects. Standard errors are clustered at the industry level.

B. *Green Innovation*

In this section we test whether corporate bond investors reward emission intensive companies that make efforts to become more green, as measured by their relative engagement in green innovation. We extend the baseline analysis by incorporating information on companies' relative engagement in green innovation, as proxied by the green patent ratio. We estimate Equation (2) by OLS, using the same three different specifications for the fixed effects. For each specification, the first column reports the results when only the control variables are incorporated in the regression. The second column reports the results when emission intensity is included as explanatory variable, whereas the third column reports the results when the green patent ratio is included as explanatory variable. Column 4 shows the results when we include both variables and column 5 adds the interaction between the green patent ratio and emission intensity, which is our main explanatory variable of interest. Finally, in column 6 we add the green bond indicator as well. Only a subset of companies in our sample have green patents and we focus on these firms for the subsequent results, which gives us a sample of 38,379 observations.

Table 8 reports the results from the specification with time fixed effects. The interaction between the green patent ratio and emission intensity (labeled 'Interaction') significantly affects bond yield spreads at the one percent level. The results in column 5 show that the effect of the interaction term is negative. In particular, a one-standard deviation increase in the green patent ratio reduces bond yield spreads by 11.7 basis points for a company with a mean emission intensity. This indicates that investors reward emission intensive companies that make efforts to become more green, as measured by their relative engagement in green innovation. Compared with the results from the baseline sample (Table 6), emission intensity has a slightly stronger effect on bond yield spreads, which is statistically significant at the 1 percent significance level. As a result, the climate transition risk premium becomes somewhat larger with a one standard deviation increase in emission intensity raising yield spreads by 56.7 basis points. Columns 3 and 4 show that the green patent ratio itself does not have a statistically significant effect on bond yield spreads.

Table 8: Joint Effect of Emission Intensity and Green Patenting on Yield Spreads

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L.Emission Intensity		0.116***		0.120***	0.144***	0.144***
		(0.034)		(0.031)	(0.033)	(0.033)
L.Green Patent Ratio			2.923	-8.039	8.067	8.259
			(7.520)	(10.519)	(8.344)	(8.427)
L.Interaction					-2.253***	-2.260***
					(0.814)	(0.818)
Green Bond						-0.501***
						(0.095)
L.Profitability	0.229**	0.144*	0.230**	0.138*	0.120	0.116
	(0.102)	(0.086)	(0.102)	(0.080)	(0.075)	(0.074)
L.Leverage	1.975**	1.188	1.984**	1.129	0.955	0.923
	(0.881)	(0.747)	(0.877)	(0.700)	(0.655)	(0.649)
L.Cash-ratio	-6.680*	-3.729	-6.713*	-3.518	-2.836	-2.715
	(3.371)	(2.800)	(3.363)	(2.634)	(2.464)	(2.444)
L.Investment-Ratio	-0.840*	-0.459	-0.845*	-0.429	-0.339	-0.322
	(0.455)	(0.375)	(0.453)	(0.352)	(0.330)	(0.327)
L.Amount Outstanding	-0.247***	-0.177***	-0.245***	-0.180***	-0.167***	-0.164***
	(0.059)	(0.040)	(0.058)	(0.041)	(0.039)	(0.039)
Fixed Coupon	0.436	0.629***	0.433	0.647***	0.666***	0.669***
	(0.279)	(0.220)	(0.274)	(0.202)	(0.189)	(0.189)
EUR	-0.252	-0.305**	-0.248	-0.317***	-0.344***	-0.339***
	(0.159)	(0.117)	(0.159)	(0.118)	(0.117)	(0.116)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	No	No	No
Bond-FEs	No	No	No	No	No	No
Observations	38,379	38,379	38,379	38,379	38,379	38,379
R-squared	0.082	0.168	0.082	0.170	0.185	0.186

Robust standard errors in parentheses

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

Note: Estimation results for Equation (2), estimated with time fixed effects. Standard errors are clustered at the (GICS) industry-level.

Table 9: Joint Effect of Emission Intensity and Green Patenting on Yield Spreads

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L.Emission Intensity		0.129**		0.129**	0.143**	0.143**
		(0.057)		(0.057)	(0.054)	(0.054)
L.Green Patent Ratio			12.957	12.686	49.953***	49.771***
			(11.354)	(12.067)	(15.323)	(15.517)
L.Interaction					-2.433***	-2.417***
					(0.780)	(0.782)
Green Bond						-0.493**
						(0.203)
L.Profitability	0.216***	0.136**	0.219***	0.138***	0.134***	0.131***
	(0.054)	(0.051)	(0.053)	(0.050)	(0.047)	(0.046)
L.Leverage	1.793***	1.062**	1.816***	1.085**	1.047**	1.017**
	(0.480)	(0.434)	(0.472)	(0.429)	(0.399)	(0.389)
L.Cash-ratio	-5.852***	-3.137**	-5.936***	-3.222**	-3.066**	-2.948**
	(1.755)	(1.506)	(1.729)	(1.489)	(1.379)	(1.348)
L.Investment-Ratio	-0.741***	-0.392*	-0.752***	-0.403*	-0.383**	-0.367*
	(0.235)	(0.204)	(0.232)	(0.202)	(0.187)	(0.183)
L.Amount Outstanding	-0.123***	-0.120***	-0.122***	-0.120***	-0.120***	-0.118***
	(0.035)	(0.034)	(0.035)	(0.034)	(0.034)	(0.034)
Fixed Coupon	0.531***	0.530***	0.531***	0.529***	0.525***	0.529***
	(0.147)	(0.148)	(0.146)	(0.147)	(0.148)	(0.149)
EUR	-0.267***	-0.271***	-0.267***	-0.271***	-0.272***	-0.268***
	(0.081)	(0.081)	(0.080)	(0.081)	(0.081)	(0.081)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Bond-FEs	No	No	No	No	No	No
Observations	38,379	38,379	38,379	38,379	38,379	38,379
R-squared	0.437	0.442	0.437	0.442	0.443	0.444

Robust standard errors in parentheses

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

Note: Estimation results for Equation (2), estimated with time fixed effects and firm fixed effects. Standard errors are clustered at the (GICS) industry-level.

Table 9 reports the estimation results for the specification with firm- and time fixed effects. Again we observe a significant interaction effect of emission intensity with the green patent ratio. This suggests that the yield discount which emission intensive companies enjoy as they engage in green innovation is not explained by firm-specific characteristics. For green innovation, in columns 3 and 4 there is no significant effect of patents on yield spreads. The positive effect of patents on spreads in columns 5-6 is the result of the interaction effect and thus cannot be interpreted on its own. This indicates that that green innovation for more carbon intensive firms is associated with lower spreads, but obviously not infinitely as high green innovation levels may be viewed as risky, even for high carbon intensive firms, thus leading to higher yield spreads. We provide the results of the estimation of Equation (2) with time and bond fixed effects in Appendix D. In this case, we find weak evidence that the green patent ratio and emission intensity on bond yield spreads. For a company with a mean emission intensity, a one standard deviation increase in the green patent ratio raises bond yield spreads by 7.7 basis points. Therefore, the magnitude of the effect becomes relatively smaller in comparison to the estimation results with time- and firm and time fixed effectss.

Our estimation results indicate that investors reward emission intensive companies that make efforts to become more green, as measured by their relative engagement in green innovation. We test whether this empirical result continues to hold in various directions. First, we test whether our results continue to hold when we include all companies for which patent information is available but do not have any green patents (that is, we include all companies with a green patent ratio of 0 in our sample). This expands our sample to 1,236 unique firms and 90,886 observations, which represents more than 90 percent of our baseline sample. The results are reported in column 1 of Table 10 and show that the joint effect of emission intensity and green patenting remains significant in this sample and the overall results remain comparable. Second, we verify the robustness of our results against the use of an alternative classification of green patents . We follow Acemoglu et al. (2023) who only consider a subset of innovations in the technological subclass Y02 of the CPC as green innovations. In particular, the authors only consider patents which are in the Y02E10 (renewable electricity), Y02E30 (nuclear energy) or Y02E50 (biofuels and fuel from waste) subclass as green patents. This classification reduces the amount of green patents on which we obtain information to 32,174, held by 178 unique companies. The results are reported in column 2 of Table 10. The results show that the joint effect of emission intensity and green patenting becomes larger in size, and is significant at the 5% significance level. This suggests that more focused green innovations by carbon intensive firms are effective in lowering their corporate bond spreads. Third, in column 3 of Table 10 we verify the robustness of our results against the inclusion of bond credit ratings. Within the green patent sub-sample, the average credit rating is 7.35 (with a standard deviation of 2.539), which corresponds to an upper medium-grade (A-) bond. Moreover, the highest bond rating within this sample is equal to 1 (highest quality, AAA), and the lowest is 22 (near-default, CC). The results show, as expected, that the effect of bond credit ratings on the bond yield spread is positive and statistically significant. Importantly, the interaction effect between carbon emission intensity and green patenting remains statistically significant once we control for credit risk, although it becomes slightly smaller in size. Fourth, we check the robustness of our results when focusing on a sub-sample of US companies. The results are reported in column 4 of Table 10 and indicate that joint effect of emission intensity and green patenting on bond spreads is stronger for companies located in the US. Fifth, we assess the robustness of our results against the exclusion of sampling weights. The results, which are reported in column 5, highlight the importance of controlling for the amount of bonds outstanding for each company in a given period.[11] We also test the robustness of our results against using absolute emissions, rather than, emission intensity. The results, which are reported in Appendix D, show that the joint effect of environmental performance and green patenting becomes larger in magnitude once we consider absolute Scope 1+2 emissions. Finally, we test for non-linearity of the effect of the interaction term on yield spreads. To this end, we divide our sample. Specifically, we estimate Equation (2) for (i) observations with an emission intensity below the sample mean and a green patent ratio below the sample mean, (ii) observations with an emission intensity below the sample mean and a green patent ratio above the sample mean, (iii) observations with an emission intensity above the sample mean and a green patent ratio below the sample mean and (iv) observations with an emission intensity and a green patent ratio above the sample mean. The results, which are reported in Appendix E, indicate that the joint effect of emission intensity and green patenting on yield spreads is entirely driven by companies which have the worst environmental performance, but, at the same time, innovate most in the green space.

[11] To rule out that the results are driven by issuers of bonds with low values, we re-estimate Equation (2) for a sample which only includes bonds with an outstanding amount larger than 200 million euro. This reduces our sample by 15%, to 32,781 observations. In this specification, the interaction term remains significant at the one percent level, with a coefficient of -1.359.

Table 10: Robustness Tests: Joint Effect of Emission Intensity and Green Patenting on Yield Spreads

	Full Sample	Classification	Ratings	US	No weights
	(1)	(2)	(3)	(4)	(5)
L.Emission Intensity	0.120***	0.034	0.063*	0.270***	0.078***
	(0.043)	(0.032)	(0.037)	(0.027)	(0.022)
L.Green Patent Ratio	-1.551	20.769*	8.995	64.764***	12.444**
	(8.168)	(10.674)	(5.677)	(19.929)	(6.169)
L.Interaction	-1.660*	-3.197**	-1.845**	-6.837***	-1.166
	(0.894)	(1.488)	(0.702)	(1.131)	(0.937)
Green Bond	-0.612***	-0.684***	-0.657***	-0.363***	-0.603***
	(0.140)	(0.151)	(0.132)	(0.067)	(0.112)
L.Profitability	0.108	0.185	0.125	0.027	0.187***
	(0.080)	(0.163)	(0.081)	(0.081)	(0.056)
L.Leverage	0.804	1.391	0.952	0.184	1.594***
	(0.742)	(1.280)	(0.685)	(0.681)	(0.490)
L.Cash-ratio	-2.158	-4.042	-2.372	0.477	-5.236***
	(2.765)	(4.587)	(2.677)	(2.434)	(1.838)
L.Investment-Ratio	-0.249	-0.460	-0.328	0.027	-0.688***
	(0.391)	(0.622)	(0.350)	(0.324)	(0.249)
L.Amount Outstanding	-0.235***	0.019	0.011	-0.164**	-0.278***
	(0.058)	(0.062)	(0.044)	(0.071)	(0.055)
Fixed Coupon	0.536***	0.479***	0.552***	0.995***	0.676***
	(0.190)	(0.134)	(0.099)	(0.083)	(0.195)
EUR	-0.565***	-0.637***	-0.673***	-0.189***	-0.285**
	(0.146)	(0.178)	(0.136)	(0.062)	(0.141)
Bond Ratings			0.327***		
			(0.089)		
Time-FEs	Yes	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	No	No
Bond-FEs	No	No	No	No	No
Observations	90,886	8,762	16,889	15,224	38,379
R-squared	0.125	0.362	0.348	0.348	0.106

Robust standard errors in parentheses

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

Note: Robustness tests for Equation (2), estimated with time fixed effects. Standard errors are clustered at the industry level.

C. Corporate Environmental Performance

In the previous section, we showed that investors reward emission intensive companies in the form of a lower yield spread when this company engages in green innovation. In this Section, we study whether this yield discount is justified. Specifically, we assess whether an increase in a companies' green patent ratio, or in the number of green patents the company holds, are associated with a better environmental performance the following years. In other words, we investigate whether investors actually are 'funding the fittest'. We use emission intensity as our main measure of environmental performance. We estimate the effect over a horizon of one-, two- and three-years. The results are reported in Table 11. Column 1-3 report the results when considering the green patent ratio as explanatory variable, and Column 4-6 report the results when using the (log) number of green patents as explanatory variable.

The estimates in column 1-3 indicate that the green patent ratio is negatively associated with a company's future emission intensity. However, we only find that the relationship is statistically significant at the three-year horizon. In this case, a one standard deviation increase in the green patent ratio reduces emission intensity by 0.94 tons of CO2 emissions per million dollars of revenue. While we find that an increase in the number of green patents is associated with a reduction in emission intensity at the one-, two-, and three-year horizon, we fail to find evidence that an increase in the amount of green patents leads to lower emission intensity.

We assess the robustness of the results when using absolute Scope 1+2 emission levels in Appendix F. We find evidence that the green patent ratio is negatively associated with absolute Scope 1+2 emissions at the one-, two-, and three-year horizon. By contrast, we find that the number of green patents is positively associated with absolute Scope 1+2 emissions. A one standard deviation increase in the green patent ratio reduces emission intensity by 0.88 tons of CO2 emissions per million dollars of revenue after three year, while an additional green patent increases emission intensity by 0.05 tons of CO2 emissions per million dollars of revenue after three years. We estimate the relationship using the Arellano and Bond (1991) two-step GMM estimator, but this does not provide conclusive evidence either (see Appendix F). To further explore the heterogeneity in the effect of green innovation on environmental performance, we estimate the relationship between green innovation and environmental performance at the industry level, focusing on a two-year horizon. The results, which are reported in Appendix F, reveal mixed findings regarding the impact of green innovation on environmental performance. For example, in the real estate sector, an increase in both the green patent ratio and the number of green patents is associated with a decrease in emission intensity and the absolute level of Scope 1 and 2 emissions. Similarly, in the energy sector, an increase in the green patent ratio leads to a reduction in emission intensity and the absolute level of emissions. However, the results are ambiguous for the healthcare sector, as increase in the green patent ratio reduces emission intensity while an increase in the number of green patents increases absolute emissions.

Overall, the results do not provide a clear answer to whether green innovation improves environmental performance, but suggest that investors should exercise caution when accommodating emission intensive companies with a smaller bond yield spread once they innovate in the green space. Our results are qualitatively in line with Bolton et al. (2023) who also find that green innovation does not materialize into future emission reductions.

Table 11: The Effect of Green Innovation on Environmental Performance

	Emission Intensity					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L4.Green Patent Ratio	-3.114					
	(2.755)					
L8.Green Patent Ratio		-3.483				
		(2.832)				
L12.Green Patent Ratio			-5.107***			
			(1.869)			
L4.Green Patents				-0.052		
				(0.092)		
L8.Green Patents					-0.068	
					(0.097)	
L12.Green Patents						-0.067
						(0.103)
L.Profitability	0.350***	0.256***	0.167***	0.370***	0.245**	0.153***
	(0.104)	(0.093)	(0.040)	(0.115)	(0.099)	(0.037)
L.Leverage	3.080***	2.214***	1.219***	3.257***	2.094**	1.092***
	(0.921)	(0.829)	(0.331)	(1.015)	(0.875)	(0.316)
L.Cash-Ratio	-12.055***	-8.724***	-5.472***	-12.713***	-8.242**	-5.087***
	(3.607)	(3.241)	(1.324)	(3.980)	(3.417)	(1.289)
L.Investment-Ratio	-1.543***	-1.145***	-0.530***	-1.632***	-1.081**	-0.457**
	(0.483)	(0.434)	(0.187)	(0.531)	(0.458)	(0.184)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Industry-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,407	4,051	2,849	4,926	3,662	2,561
R-squared	0.435	0.435	0.429	0.457	0.467	0.456

Robust standard errors in parentheses

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

Note: Estimation results for Equation (3), with time- and industry fixed effects. We estimate the relationship using a 1-year, 2-year and 3-year lag of the green patent ratio, respectively the amount of green patents. Standard errors are clustered at the firm-level.

D. Holdership Dynamics

We test whether European investors are more likely to price the exposure to climate transition risk. In particular, we assess whether European investors are more inclined to reward emission intensive companies that engages in green innovation in the form of smaller bond yield spreads. To this end, we interact the green patent ratio with different holder-area shares. While some papers analyzing corporate bond spreads have used ownership data, these studies look at equity holdings at the bond issuing firm (Huang and Petkevich, 2016; Bauer et al., 2021) but not at the direct investors of the particular bond itself. We are interested in the transmission effects bond investors may have directly on the corporate bond spreads in relationship with companies carbon emissions and green innovation efforts. Do these investors directly affect the pricing of corporate bonds?

We distinguish between EU-holders, EA-holders, and 'home'-holders. For each bond we calculate the observed share of ownership at a given period by taking the sum of the investor sector and investor country holdings divided by the amount outstanding of a bond (at market values). For our worldwide sample of corporate bonds, the average share owned by EU-investors is equal to 34 percent, with a standard deviation of 0.375, signifying the large ownership of European investors in corporate bond markets globally. Euro area investors account for the majority of these holdings, as the share of holdings of euro area investors is equal to 33 percent (standard deviation of 0.373), showing the dominance of euro area investors. Given that our sample constitutes bonds issued from 57 different countries, the average 'home bias' in our sample is relatively low, as the share of bonds held by investors which are located in the same country as the issuing firm is equal to 10 percent (standard deviation of 0.230). In Appendix G, we show the evolution of the various holder-shares over our sample period, which indicate that the share of bonds held by the various types of investors steadily declines over time.

Table 12 reports the results of Equation (4), estimated with pooled OLS and time fixed effects. The first column shows the effect of EU-holdership on bond yield spreads, and includes an interaction between the lagged emission intensity, green patent ratio and the share of EU-holder. The interaction effect is negative and statistically significant at the 1 percent significance level. In particular, a standard deviation increase in the share of EU-holders reduces the yield spread of company with a mean emission intensity and mean green patent ratio by 5.6 basis points.

This indicates that European investors are more likely to price the exposure of a company to climate transition risk, taking into consideration both the emission intensity of a company as well as its green patent ratio. The results are similar when we consider the share of EA-holders, as evident in Table 12 column 2. However, as shown in column 3, we do not find evidence that home-holders are more likely to price the joint effect of emission intensity and green patenting.

The portfolio of European investors is largely tilted towards European firms. Specifically, the share of bonds held by European investors for European firms is nearly twice as large compared to non-European bond ownership (amounting to 64 percent, with a standard deviation of 0.345). Similarly, for bonds issued by European firms the share of bonds held by 'home' investors from Europe becomes 27 percent (standard deviation of 0.314), which is almost three times as large compared to the case in which we consider bonds issued by global companies, showing significant home bias in the corporate bond market.

To rule out that our results are driven by the fact that European investors hold bonds of a specific type of company, we re-estimate Equation (4) for a sub-sample of bonds issued by European firms. Table 12, column 4 -6 report the results. The interaction effect remains statistically significant at the 1 percent significance level, both for EU- and euro area holders. A standard deviation increase in the share of EU (or EA)-holders reduces the yield spread of company with a mean emission intensity and mean green patent ratio by approximately 4.7 basis points. The size of the effect thus remains roughly similar when we only consider bonds issued by European companies. Moreover, column 6 shows weak evidence that home-investors are more likely to reward emission intensive companies that engages in green innovation in the form of smaller bond yield spreads.

Table 12: Holdership Dynamics

	Global Firms			EU Firms		
	EU	EA	Home	EU	EA	Home
	(1)	(2)	(3)	(4)	(5)	(6)
L.Emission Intensity	0.137***	0.137***	0.122***	0.083***	0.082***	0.067***
	(0.036)	(0.036)	(0.036)	(0.022)	(0.022)	(0.015)
L.Green Patent Ratio	-3.368	-3.435	-8.332	18.684	18.166	3.289
	(9.522)	(9.547)	(10.379)	(14.935)	(15.062)	(17.192)
Green Bond	-0.405***	-0.406***	-0.474***	-0.535***	-0.534***	-0.510***
	(0.068)	(0.068)	(0.075)	(0.191)	(0.190)	(0.184)
L.SHS EU-share	-0.147			0.054		
	(0.329)			(0.251)		
L.Interaction EU	-8.656***			-7.827***		
	(2.887)			(2.056)		
L.SHS EA-share		-0.148			0.050	
		(0.341)			(0.255)	
L.Interaction EA		-8.592***			-7.725***	
		(2.899)			(2.025)	
L.SHS Home-share			0.249			0.310
			(0.189)			(0.208)
L.Interaction Home			-10.905			-5.448*
			(6.589)			(2.982)
Corporate Fundamentals	Yes	Yes	Yes	Yes	Yes	Yes
(Other) Bond Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	No	No	No
Bond-FEs	No	No	No	No	No	No
Observations	35,072	35,072	35,072	12,761	12,761	12,761
R-squared	0.181	0.181	0.173	0.163	0.162	0.156

Robust standard errors in parentheses
*** $p < 0.01$, ** $p<0.05$, * $p<0.1$

Note: Estimation of Equation (4), with time fixed effects. The first column reports the effect of EU-holdership (measured as the total value held by EU-investors as a fraction of the amount outstanding) on bond yield spreads, and includes an interaction between the lagged emission intensity, green patent ratio and the share of EU-holders. We estimate Equation (4) as well using the share of EA-holders in column 2, and the share of "home"-holders in column 3. We estimate the relationship for a sub-sample of bonds issued by European firms in column 4-6. The average bond holdings in the sample by investor sector from a given investor country is 170.038 million euros (s.d. 260.264).

We further explore whether institutional investors in Europe are more likely to price the exposure to climate transition risk in Appendix G. In particular, we assess whether institutional investors are more inclined to reward emission intensive companies that engages in green innovation in the form of smaller bond yield spreads. We interact the green patent ratio with different holder-sector shares, and distinguish between institutional investors, insurance companies and pension funds (a subset of institutional investors) and banks. Most of the European investments in corporate bonds stem from institutional investors. The ownership share of European institutional investors in global bonds is on average 29 percent, with a standard deviation of 0.338. Insurance companies and pension funds account for approximately half of these holdings, as the average share of bonds held by these institutional investors is equal to 16 percent (standard deviation of 0.277). European banks hold a relatively small share of corporate bonds within our worldwide sample (0.3 percent on average with standard deviation equal to 0.087). The results across different institutional investors are reported in Table G3. The interaction effect is statistically significant at the one percent significance level for institutional investors. In particular, a standard deviation increase in the share of holdings of institutional investors (insurance companies and pension funds) reduces the yield spread of company with a mean emission intensity and mean green patent ratio by approximately 5.4 (5.1) basis points. In contrast, the interaction effect is not statistically significant for banks. This suggests that the yield discount with large European ownership, which is received by emission intensive companies that engage in green innovation, is predominantly driven by institutional investors and particularly so by insurance companies and pension funds.

VI. Conclusion

The urgency to meet the temperature targets set by the Paris Accord necessitates a shift towards net-zero emissions by 2050. Financial investors can play a pivotal role in the green transition. This paper studied whether financial investors take up this role in the period following the adoption of the Paris Agreement. In particular, we aimed to answer the question whether corporate bond investors value companies' efforts to mitigate climate change, by innovating in the green space. Importantly, our study adopts a forward-looking approach, considering companies' actual efforts to become green. We focus on the amount of green patents relative to the total amount of patents of a given company, and assess whether the interaction between emission intensity and the green patent ratio affects bond yield spreads.

Our empirical results provide evidence that a firm's carbon emission intensity positively affects the bond yield spread. At the same time we find that investors reward those emission-intensive companies engaging in green innovation. These results are robust against controlling for factors such as green bond qualification, bond credit ratings and against using a more stringent classification for when a patent qualifies as a green patent.

To interpret our main findings, we aimed to determine what the effect of green innovation is on corporate environmental performance. In particular, we assess whether green patenting is associated with a decline in future emission intensity. We document substantial heterogeneity in the effect over time and across industries. Hence, it remains unclear from our results whether green innovation improves environmental performance, and whether investors indeed 'fund the fittest'. Rather, our results suggest that investors should exercise caution when accommodating emission intensive companies with a smaller bond yield spreads once they innovate in the green space.

Finally, our results reveal that European investors, and particularly institutional investors, are more inclined to price exposures to climate transition risk. This implies a regional focus on environmental considerations and aligns with the broader efforts within the European Union to promote sustainable finance. As investors increasingly recognize the importance of companies aligning with green goals, our findings contribute valuable insights for policymakers, investors, and businesses.

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Appendix A. Time Series Properties

A1. Bond Yield

We assess the autoregressive properties of bond yields, which we winsorize at the 1% level. We estimate the following second-order autoregressive panel data model:

$$\text{Yield to Maturity}_{i,t} = \beta_1 \text{Yield to Maturity}_{i,t-1} + \beta_2 \text{Yield to Maturity}_{i,t-2} + \gamma_i + \zeta_t + \epsilon_{i,t}$$

where γ_i are bond fixed effects, and ζ_t are time fixed effects. We estimate the model by (i) pooled OLS, (ii) fixed effects OLS and (iii) first-differenced GMM. While pooled OLS only controls for time effects, fixed effects OLS and first-differenced GMM also control for the bond specific effects. Standard errors are clustered at the bond level.

Table A1: Autocorrelation in Bond Yields

	OLS	FE	GMM
L.Yield to Maturity	0.749**	0.530**	0.481**
	(0.014)	(0.004)	(0.047)
L2.Yield to Maturity	0.203**	0.079**	0.124**
	(0.014)	(0.004)	(0.017)

*Note: Standard errors in parentheses, ** p<0.05, * p<0.1.*

Table A1 shows that there is significant autocorrelation in yields, even when including fixed effects as well as when estimating the relationship using GMM. The pooled OLS estimate, which only corrects for aggregate time effects, suggests that bond yields are highly persistent over time. However, the FE OLS and GMM estimates show that there is no reason to assume that bond yields are non-stationary and we therefore continue our estimation in levels, rather than in first-differences.

A2. Emission Intensity

To assess the autoregressive properties of emission intensity, we first collapse our sample to the firm-period level. We again use a second-order autoregressive model:

$$\text{Emission Intensity}_{f,t} = \beta_1 \text{Emission Intensity}_{f,t-1} + \beta_2 \text{Emission Intensity}_{f,t-2} + \delta_f + \zeta_t + \epsilon_{f,t}$$

where δ_f are firm fixed effects and ζ_t are time fixed effects. We estimate the model by the same three methods as before and standard errors are clustered at the firm-level.

Table A2: Autocorrelation in Emission Intensity

	OLS	FE	GMM
L.Emission Intensity/100	0.988**	0.844**	0.606**
	(0.002)	(0.008)	(0.069)
L2.Emission Intensity/100	-0.006**	-0.067**	-0.010*
	(0.001)	(0.008)	(0.006)

*Note: Standard errors in parentheses, ** p<0.05, * p<0.1.*

Table A2 displays the results. The pooled OLS estimate, which only corrects for aggregate time effects, suggests that emission intensity is highly persistent over time. However, the autocorrelation pattern weakens when controlling for firm fixed effects as is apparent from the fixed effects OLS and GMM estimates. There is no sign that the emission intensity variable is non-stationary as the autoregressive estimates are still far from the unit root.

Appendix B. Variation Across Industries

Table B1: Mean Emission Intensity by Industry and Period

	Basic Mat.	Cons. Cyc.	Cons. N-Cyc.	Energy	Healthcare	Industrials	Real Estate	Technology	Utilities
2016-Q2	7.755	0.83	1.46	5.026	0.463	2.299	0.692	0.491	11.657
2016-Q3	7.620	0.976	1.457	4.902	0.454	2.323	0.691	0.495	11.899
2016-Q4	7.404	0.829	1.465	4.967	0.453	2.230	0.701	0.438	12.054
2017-Q1	7.044	0.801	1.478	4.725	0.544	2.070	0.732	0.447	11.817
2017-Q2	7.175	0.793	1.475	5.060	0.440	2.040	0.766	0.402	11.310
2017-Q3	7.028	0.793	1.468	5.081	0.454	1.972	0.768	0.567	11.624
2017-Q4	7.240	0.815	1.391	4.764	0.452	1.919	0.753	0.547	11.421
2018-Q1	6.884	0.754	1.695	4.698	0.392	1.875	0.787	0.546	10.240
2018-Q2	6.580	0.579	1.732	4.806	0.345	1.940	0.881	0.543	10.348
2018-Q3	6.662	0.581	1.669	4.554	0.334	1.843	0.862	0.545	10.258
2018-Q4	6.576	0.562	1.388	4.509	0.337	1.832	0.871	0.531	10.289
2019-Q1	6.882	0.718	1.330	4.692	0.291	1.828	0.883	0.541	10.891
2019-Q2	7.176	0.720	1.584	5.210	0.318	1.865	0.858	0.538	10.855
2019-Q3	7.163	0.734	1.550	5.402	0.296	1.912	0.865	0.545	10.963
2019-Q4	7.153	0.742	1.566	5.637	0.296	1.918	0.861	0.538	10.934
2020-Q1	7.355	0.733	1.574	6.201	0.340	1.863	0.713	0.505	9.743
2020-Q2	7.180	0.722	1.562	5.904	0.355	1.798	0.696	0.508	9.736
2020-Q3	6.615	0.729	1.563	5.922	0.348	1.844	0.693	0.493	9.367
2020-Q4	6.798	0.716	1.455	5.883	0.347	1.799	0.696	0.419	9.300
2021-Q1	6.398	0.778	1.077	4.622	0.295	1.715	0.693	0.401	9.188
2021-Q2	6.407	0.718	1.028	4.669	0.348	1.813	0.749	0.402	8.502
2021-Q3	6.822	0.742	1.063	4.761	0.351	1.843	0.862	0.382	8.827
2021-Q4	6.606	0.727	1.006	4.845	0.339	1.822	0.861	0.342	8.933

Table B2: Distribution of observations across GICS industries

GICS Industry Name	Observations	Emission Intensity (mean)	Emission Intensity (median)
Aerospace & Defense	389	0.353	0.234
Air Freight & Logistics	194	1.613	0.855
Automobile Components	320	1.127	0.627
Automobiles	259	0.251	0.239
Beverages	352	0.598	0.493
Biotechnology	271	0.323	0.352
Broadline Retail	255	0.440	0.262
Building Products	162	0.861	0.606
Capital Markets	23	0.046	0.049
Chemicals	842	5.472	4.397
Commercial Services & Supplies	383	1.023	0.435
Communications Equipment	136	0.188	0.162
Construction & Engineering	570	0.945	0.434
Construction Materials	227	15.990	19.940
Consumer Finance	6	0.350	0.352
Consumer Staples Distribution & Retail	455	0.496	0.447
Containers & Packaging	178	1.695	1.228
Distributors	15	0.386	0.379
Diversified Consumer Services	44	0.357	0.341
Diversified REITs	173	0.872	0.729
Diversified Telecommunication Services	639	0.534	0.385
Electric Utilities	752	11.304	11.226
Electrical Equipment	339	0.727	0.376
Electronic Equipment, Instruments & Comp	277	0.654	0.429
Energy Equipment & Services	229	3.386	1.004
Entertainment	209	0.195	0.181
Financial Services	173	0.693	0.088
Food Products	576	1.519	0.740
Gas Utilities	134	2.762	2.122
Ground Transportation	220	1.937	1.511
Health Care Equipment & Supplies	343	0.267	0.198
Health Care Providers & Services	322	0.374	0.366
Health Care REITs	99	0.675	0.700
Health Care Technology	68	0.161	0.097
Hotels, Restaurants & Leisure	512	1.573	0.571

GICS Industry Name	Observations	Emission Intensity (mean)	Emission Intensity (median)
Household Durables	332	0.402	0.322
Household Products	87	1.612	1.235
IT Services	263	1.107	0.143
Independent Power and Renewable Electric	354	12.831	19.940
Industrial Conglomerates	311	4.783	1.797
Industrial REITs	109	0.550	0.701
Insurance	23	0.188	0.248
Interactive Media & Services	71	0.118	0.118
Leisure Products	63	0.544	0.604
Life Sciences Tools & Services	68	0.805	0.372
Machinery	725	0.387	0.366
Marine Transportation	164	11.085	11.756
Media	470	0.171	0.124
Metals & Mining	878	7.383	4.665
Mortgage REITs	81	0.110	0.071
Multi-Utilities	317	8.415	5.694
NULL	47	0.209	0.121
Office REITs	209	0.515	0.516
Oil, Gas & Consumable Fuels	1,027	5.988	4.700
Paper & Forest Products	229	6.584	5.078
Passenger Airlines	345	10.253	10.340
Personal Care Products	47	1.344	0.332
Pharmaceuticals	422	0.451	0.290
Professional Services	239	0.132	0.116
Real Estate Management & Development	1,191	0.829	0.681
Residential REITs	69	1.076	0.701
Retail REITs	246	0.692	0.707
Semiconductors & Semiconductor Equipment	425	1.633	0.740
Software	366	0.126	0.109
Specialized REITs	73	2.098	1.526
Specialty Retail	275	0.469	0.525
Technology Hardware, Storage & Periphera	188	0.264	0.155
Textiles, Apparel & Luxury Goods	215	0.311	0.123
Tobacco	45	0.256	0.148
Trading Companies & Distributors	242	0.514	0.319
Transportation Infrastructure	221	0.855	0.522
Water Utilities	41	4.205	4.672
Wireless Telecommunication Services	260	0.445	0.328

Table B3: Distribution of observations across GICS industries (Orbis, mean)

GICS Industry Name	Observations	Emission Intensity	Green Patent Ratio	Green Patents
Aerospace & Defense	236	0.291	0.001	14.915
Air Freight & Logistics	46	1.466	0.001	3.500
Automobile Components	173	1.126	0.002	147.208
Automobiles	213	0.264	0.019	5885.995
Beverages	66	0.649	0.004	29.788
Biotechnology	132	0.286	0.002	14.924
Broadline Retail	54	0.321	0.009	3.796
Building Products	72	1.029	0.005	59.250
Chemicals	411	5.970	0.004	61.333
Commercial Services & Supplies	36	0.909	0.004	106.139
Communications Equipment	72	0.162	0.000	50.472
Construction & Engineering	114	0.488	0.013	9.535
Construction Materials	29	19.940	0.010	8.586
Consumer Staples Distribution & Retail	105	0.543	0.006	2.314
Containers & Packaging	47	1.687	0.002	4.511
Diversified Telecommunication Services	157	0.425	0.007	316.363
Electric Utilities	347	12.268	0.039	257.176
Electrical Equipment	229	0.789	0.025	206.074
Electronic Equipment, Instruments & Comp	90	0.814	0.005	329.256
Energy Equipment & Services	27	0.773	0.010	1.444
Food Products	96	0.896	0.021	5.104
Gas Utilities	47	2.795	0.024	36.787
Ground Transportation	47	1.427	0.018	127.532
Health Care Equipment & Supplies	70	0.242	0.001	339.443
Health Care Providers & Services	3	0.026	0.000	0.000
Health Care Technology	12	0.415	0.000	20.000
Household Durables	72	0.624	0.011	8777.473
Household Products	21	0.307	0.001	66.429
IT Services	45	0.102	0.026	180.289
Independent Power and Renewable Electric	68	15.557	0.025	22.515
Industrial Conglomerates	76	5.693	0.007	1763.197
Leisure Products	23	0.462	0.010	228.174
Life Sciences Tools & Services	10	0.357	0.000	0.200

GICS Industry Name	Observations	Emission Intensity	Green Patent Ratio	Green Patents
Machinery	278	0.370	0.014	498.309
Marine Transportation	39	11.007	0.003	0.821
Media	46	0.120	0.002	3.000
Metals & Mining	287	9.291	0.027	25.986
Multi-Utilities	87	1.939	0.015	2.000
Oil, Gas & Consumable Fuels	339	5.455	0.011	20.950
Paper & Forest Products	95	3.327	0.003	19.463
Personal Care Products	23	0.342	0.000	8.000
Pharmaceuticals	267	0.362	0.002	53.064
Real Estate Management & Development	20	0.503	0.022	4.850
Semiconductors & Semiconductor Equipment	312	1.934	0.017	52.660
Software	88	0.120	0.001	2.568
Specialized REITs	23	1.565	0.000	2.000
Technology Hardware, Storage & Periphera	99	0.182	0.001	528.182
Textiles, Apparel & Luxury Goods	24	0.906	0.001	15.583
Tobacco	22	0.386	0.003	71.182
Trading Companies & Distributors	73	1.026	0.009	95.260
Transportation Infrastructure	7	4.688	0.007	0.571
Water Utilities	15	0.830	0.008	1.600
Wireless Telecommunication Services	47	0.418	0.007	110.532

Table B4: Distribution of observations across GICS industries (Orbis, median)

GICS Industry Name	Observations	Emission Intensity	Green Patent Ratio	Green Patents
Aerospace & Defense	236	0.220	0.000	3.000
Air Freight & Logistics	46	1.352	0.001	3.500
Automobile Components	173	0.563	0.001	8.000
Automobiles	213	0.243	0.006	210.000
Beverages	66	0.477	0.002	10.000
Biotechnology	132	0.311	0.001	9.000
Broadline Retail	54	0.285	0.002	3.000
Building Products	72	0.777	0.001	54.000
Chemicals	411	4.101	0.001	10.000
Commercial Services & Supplies	36	0.339	0.000	0.000
Communications Equipment	72	0.177	0.000	67.000
Construction & Engineering	114	0.398	0.009	2.000
Construction Materials	29	19.940	0.001	3.000
Consumer Staples Distribution & Retail	105	0.515	0.004	2.000
Containers & Packaging	47	1.670	0.002	5.000
Diversified Telecommunication Services	157	0.422	0.009	6.000
Electric Utilities	347	13.816	0.045	14.000
Electrical Equipment	229	0.466	0.001	11.000
Electronic Equipment, Instruments & Comp	90	0.295	0.003	8.000
Energy Equipment & Services	27	0.205	0.001	1.000
Food Products	96	0.630	0.000	3.000
Gas Utilities	47	3.667	0.002	1.000
Ground Transportation	47	1.350	0.011	99.000
Health Care Equipment & Supplies	70	0.133	0.001	3.000
Health Care Providers & Services	3	0.026	0.000	0.000
Health Care Technology	12	0.385	0.000	20.000
Household Durables	72	0.349	0.011	4422.500
Household Products	21	0.309	0.001	68.000
IT Services	45	0.125	0.001	271.000
Independent Power and Renewable Electric	68	19.940	0.015	11.000
Industrial Conglomerates	76	0.637	0.001	6.000
Leisure Products	23	0.365	0.005	181.000
Life Sciences Tools & Services	10	0.284	0.000	0.000

GICS Industry Name	Observations	Emission Intensity	Green Patent Ratio	Green Patents
Machinery	278	0.390	0.000	10.000
Marine Transportation	39	11.756	0.002	0.000
Media	46	0.130	0.002	3.000
Metals & Mining	287	7.456	0.003	8.000
Multi-Utilities	87	1.399	0.013	1.000
Oil, Gas & Consumable Fuels	339	4.884	0.003	10.000
Paper & Forest Products	95	3.074	0.002	10.000
Personal Care Products	23	0.332	0.000	8.000
Pharmaceuticals	267	0.242	0.000	18.000
Real Estate Management & Development	20	0.500	0.006	5.000
Semiconductors & Semiconductor Equipment	312	0.752	0.000	10.000
Software	88	0.099	0.000	1.500
Specialized REITs	23	1.526	0.000	2.000
Technology Hardware, Storage & Periphera	99	0.110	0.000	3.000
Textiles, Apparel & Luxury Goods	24	0.083	0.001	17.000
Tobacco	22	0.391	0.004	71.000
Trading Companies & Distributors	73	0.735	0.009	112.000
Transportation Infrastructure	7	6.900	0.012	1.000
Water Utilities	15	0.818	0.010	1.000
Wireless Telecommunication Services	47	0.534	0.008	90.000

Appendix C. Summary Statistics for the Green Patent Sample

Table C1: Summary statistics

	Mean	SD	Min	Max
Environmental Variables				
Log(Scope 1)	13.840	2.634	2.905	19.506
Log (Scope 2)	13.203	1.656	3.738	17.014
(Scope1 + Scope2) Emission Intensity	2.804	4.908	0.018	19.940
Green Patent Ratio	0.006	0.018	0	0.368
Bond Characteristics				
Yield to Maturity (%)	2.131	2.256	-1.500	23.625
Amount Outstanding (in m EUR)	663.259	541.087	0.048	5238.095
Fixed Coupon	0.902	0.298	0	1
EUR	0.346	0.476	0	1
USD	0.509	0.500	0	1
Bond Rating	7.350	2.539	1	22
Green bond	0.012	0.111	0	1
Corporate Fundamentals				
Total Assets (in bn EUR)	465.679	682.768	45.799	1932.012
Revenue (in bn EUR)	48.000	11.025	29.533	65.575
Total Equity (in bn EUR)	17.965	5.276	7.751	29.839
Total LT-Debt (in bn EUR)	414.466	668.579	11.376	1846.886
Leverage	1.890	0.631	1.100	3.086
Profitability	5.132	2.572	1.005	10.044
Cash-ratio	0.146	0.039	0.087	0.236
Investment-Ratio	0.968	0.515	0.308	2.072

Note: Based on 38,379 observations. Absolute emissions levels are measured in CO2e and are reported in natural logarithms. Emission intensity, measured in CO2e/USDm, is scaled by a factor 1/100. Fixed coupon is a dummy which is equal to 1 if a bond has a fixed coupon, and EUR respectively USD are dummy which are equal to 1 if a bond is denominated in euros respectively dollars. Finally, green bond is a dummy which is equal to 1 if a bond has a green bond label. Leverage is defined as total debt divided by earnings before interest, taxation, depreciation and amortization. Profitability is defined as net income dividend by total assets (ROA) The cash- and investment ratio are defined as cash respectively investments divided by total assets, respectively.

Table C2: Distribution of observations across industries (median)

Industry	Observations	Emission Intensity	Green Patent Ratio	Green Patents
Basic Materials	879	4.875	0.001	7
Consumer Cyclicals	615	0.356	0.002	11
Consumer Non-Cyclicals	411	0.556	0.002	6
Energy	444	4.188	0.004	10
Healthcare	494	0.248	0.000	10
Industrials	1,083	0.398	0.001	7
Real Estate	45	0.925	0.000	2
Technology	924	0.203	0.001	10
Utilities	542	9.102	0.029	6

Note: Observations reported at the reported at the quarterly frequency and firm-level.

Appendix D. Robustness Tests for Equation (2)

D1. Bond Fixed Effects

Table D1: Joint Effect of Emission Intensity and Green Patenting on Yield Spreads

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L.Emission Intensity		0.102		0.102	0.110	0.110
		(0.078)		(0.078)	(0.079)	(0.079)
L.Green Patent Ratio			2.709	2.864	25.026*	25.026*
			(5.399)	(5.948)	(14.286)	(14.286)
L.Interaction					-1.487*	-1.487*
					(0.830)	(0.830)
L.Profitability	0.347***	0.279***	0.348***	0.280***	0.277***	0.277***
	(0.045)	(0.054)	(0.044)	(0.053)	(0.051)	(0.051)
L.Leverage	3.010***	2.391***	3.014***	2.396***	2.369***	2.369***
	(0.402)	(0.461)	(0.398)	(0.455)	(0.437)	(0.437)
L.Cash-Ratio	-10.415***	-8.120***	-10.430***	-8.136***	-8.030***	-8.030***
	(1.471)	(1.591)	(1.458)	(1.570)	(1.507)	(1.507)
L.Investment-Ratio	-1.383***	-1.086***	-1.385***	-1.088***	-1.074***	-1.074***
	(0.196)	(0.212)	(0.194)	(0.210)	(0.201)	(0.201)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	No	No	No
Bond-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	38,379	38,379	38,379	38,379	38,379	38,379
R-squared	0.716	0.719	0.716	0.719	0.719	0.719

Robust standard errors in parentheses

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

Note: Estimation results for Equation (2), estimated with time fixed effects and bond fixed effects. Standard errors are clustered at the (GICS) industry-level.

D2. Absolute Scope 1+2 Emissions

Table D2: Joint Effect of Emissions and Green Patenting on Yield Spreads

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L.Absolute Emissions		0.023		0.023	0.055	0.055
		(0.123)		(0.120)	(0.117)	(0.117)
L.Green Patent Ratio			6.002	6.039	88.082**	88.211**
			(8.547)	(8.599)	(34.496)	(34.638)
L.Interaction					-5.484**	-5.484**
					(2.181)	(2.187)
Green Bond						-0.427***
						(0.116)
L.Profitability	0.254**	0.250**	0.256**	0.252**	0.245**	0.243**
	(0.101)	(0.104)	(0.101)	(0.104)	(0.101)	(0.101)
L.Leverage	2.165**	2.123**	2.188**	2.145**	2.084**	2.057**
	(0.866)	(0.889)	(0.868)	(0.893)	(0.861)	(0.859)
L.Cash-ratio	-7.599**	-7.436**	-7.673**	-7.509**	-7.235**	-7.133**
	(3.367)	(3.501)	(3.380)	(3.522)	(3.385)	(3.378)
L.Investment-Ratio	-0.933**	-0.911*	-0.945**	-0.922*	-0.885*	-0.871*
	(0.446)	(0.458)	(0.447)	(0.461)	(0.443)	(0.442)
L.Amount Outstanding	-0.322***	-0.322***	-0.316***	-0.316***	-0.310***	-0.308***
	(0.096)	(0.096)	(0.092)	(0.092)	(0.090)	(0.090)
Fixed Coupon	0.583*	0.598**	0.575*	0.589**	0.592**	0.594**
	(0.312)	(0.267)	(0.304)	(0.260)	(0.259)	(0.259)
EUR	-0.380*	-0.393**	-0.370*	-0.383**	-0.392**	-0.388**
	(0.203)	(0.169)	(0.198)	(0.168)	(0.163)	(0.163)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	No	No	No
Bond-FEs	No	No	No	No	No	No
Observations	39,456	39,456	39,456	39,456	39,456	39,456
R-squared	0.090	0.091	0.091	0.092	0.100	0.101

Robust standard errors in parentheses

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

Note: Estimation results for Equation (2), estimated with pooled OLS and time fixed effects. For each estimation method, the first column reports the results when only the control variables are incorporated in the regression. The second column reports the results including emission intensity. The third column reports the results including the green patent ratio. The fourth column reports the results including both emission intensity and the green patent ratio. The fifth column also includes the interaction term. The sixth additionally controls for whether a bond has a green bond label. Standard errors are clustered at the (GICS) industry-level.

Table D3: Joint Effect of Emissions and Green Patenting on Yield Spreads

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L.Absolute Emissions		0.015		0.018	0.078	0.081
		(0.141)		(0.140)	(0.170)	(0.170)
L.Green Patent Ratio			18.026	18.077	106.319**	107.385**
			(14.881)	(14.866)	(51.223)	(51.064)
L.Interaction					-5.163*	-5.221*
					(2.925)	(2.922)
Green Bond						-0.612***
						(0.214)
L.Profitability	0.236***	0.235***	0.239***	0.238***	0.237***	0.233***
	(0.055)	(0.053)	(0.054)	(0.053)	(0.051)	(0.049)
L.Leverage	1.979***	1.971***	2.007***	1.997***	1.987***	1.950***
	(0.492)	(0.475)	(0.486)	(0.468)	(0.450)	(0.437)
L.Cash-ratio	-6.621***	-6.587***	-6.723***	-6.683***	-6.616***	-6.469***
	(1.834)	(1.761)	(1.814)	(1.738)	(1.659)	(1.609)
L.Investment-Ratio	-0.837***	-0.832***	-0.850***	-0.845***	-0.834***	-0.814***
	(0.243)	(0.234)	(0.240)	(0.232)	(0.221)	(0.214)
L.Amount Outstanding	-0.132***	-0.132***	-0.132***	-0.132***	-0.132***	-0.130***
	(0.036)	(0.037)	(0.036)	(0.036)	(0.037)	(0.036)
Fixed Coupon	0.569***	0.568***	0.568***	0.568***	0.565***	0.569***
	(0.150)	(0.150)	(0.149)	(0.149)	(0.149)	(0.151)
EUR	-0.265***	-0.265***	-0.265***	-0.265***	-0.266***	-0.262***
	(0.082)	(0.082)	(0.081)	(0.082)	(0.082)	(0.082)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Bond-FEs	No	No	No	No	No	No
Observations	39,456	39,456	39,456	39,456	39,456	39,456
R-squared	0.493	0.493	0.493	0.493	0.494	0.495

Robust standard errors in parentheses

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

Note: Estimation results for Equation (2), estimated with pooled OLS and firm- and time fixed effects. For each estimation method, the first column reports the results when only the control variables are incorporated in the regression. The second column reports the results including emission intensity. The third column reports the results including the green patent ratio. The fourth column reports the results including both emission intensity and the green patent ratio. The fifth column also includes the interaction term. The sixth additionally controls for whether a bond has a green bond label. Standard errors are clustered at the (GICS) industry-level.

Table D4: Joint Effect of Emissions and Green Patenting on Yield Spreads

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L.Absolute Scope 1+2 Emissions		-0.014		-0.014	0.009	0.009
		(0.131)		(0.131)	(0.160)	(0.160)
L.Green Patent Ratio			3.872	3.817	35.027	35.027
			(6.301)	(6.420)	(44.552)	(44.552)
L.Interaction					-1.828	-1.828
					(2.467)	(2.467)
L.Profitability	0.352***	0.353***	0.353***	0.353***	0.353***	0.353***
	(0.044)	(0.045)	(0.043)	(0.044)	(0.043)	(0.043)
L.Leverage	3.054***	3.062***	3.059***	3.067***	3.063***	3.063***
	(0.393)	(0.394)	(0.389)	(0.389)	(0.381)	(0.381)
L.Cash-Ratio	-10.645***	-10.680***	-10.665***	-10.697***	-10.671***	-10.671***
	(1.446)	(1.444)	(1.432)	(1.429)	(1.395)	(1.395)
L.Investment-Ratio	-1.404***	-1.409***	-1.407***	-1.411***	-1.407***	-1.407***
	(0.192)	(0.192)	(0.190)	(0.190)	(0.186)	(0.186)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	No	No	No
Bond-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	39,456	39,456	39,456	39,456	39,456	39,456
R-squared	0.756	0.756	0.756	0.756	0.756	0.756

Standard errors in parentheses

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

Note: Estimation results for Equation (2), estimated with fixed effects. For each estimation method, the first column reports the results when only the control variables are incorporated in the regression. The second column reports the results including emission intensity. The third column reports the results including the green patent ratio. The fourth column reports the results including both emission intensity and the green patent ratio. The fifth column also includes the interaction term. The sixth additionally controls for whether a bond has a green bond label. Standard errors are clustered at the (GICS) industry-level.

Appendix E. Sample Splits for Equation (1) and (2)

Table E1: The Effect of Emission Intensity on Yield Spreads

	Green Patent Ratio = 0			Green Patent Ratio > 0		
	T	T+F	T+B	T	T+F	T+B
	(1)	(2)	(3)	(4)	(5)	(6)
L.Emission Intensity	0.100	0.083	0.068***	0.115***	0.136**	0.105***
	(0.062)	(0.064)	(0.005)	(0.034)	(0.058)	(0.006)
Green Bond	-0.685**	-0.090		-0.342*	-0.385*	
	(0.323)	(0.187)		(0.172)	(0.214)	
L.Profitability	0.137*	0.169***	0.330***	0.138	0.123**	0.276***
	(0.080)	(0.046)	(0.014)	(0.084)	(0.051)	(0.017)
L.Leverage	1.039	1.352***	2.836***	1.126	0.939**	2.351***
	(0.767)	(0.443)	(0.118)	(0.732)	(0.436)	(0.140)
L.Cash-Ratio	-2.898	-3.966**	-9.711***	-3.626	-2.803*	-8.124***
	(2.887)	(1.695)	(0.422)	(2.752)	(1.555)	(0.493)
L.Investment-Ratio	-0.345	-0.528**	-1.298***	-0.431	-0.333	-1.068***
	(0.424)	(0.250)	(0.061)	(0.368)	(0.206)	(0.073)
L.Amount Outstanding	-0.260**	-0.071**		-0.211***	-0.125***	
	(0.098)	(0.031)		(0.047)	(0.035)	
Fixed Coupon	0.295	0.066		0.721***	0.501***	
	(0.414)	(0.359)		(0.204)	(0.138)	
EUR	-0.695***	-0.376***		-0.302**	-0.279***	
	(0.197)	(0.070)		(0.120)	(0.084)	
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-FEs	No	Yes	No	No	Yes	No
Bond-FEs	No	No	Yes	No	No	Yes
Observations	55,352	55,352	55,352	44,589	44,589	44,589
R-squared	0.092	0.584	0.841	0.160	0.484	0.735

Robust standard errors in parentheses

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

Note: Sample split for Equation (1), estimated with pooled OLS with three different sets of fixed effects, i.e. time fixed effects, firm fixed effects and time fixed effect, and bond fixed effects and time fixed effects. Column 1-3 reports the results for observations with a green patent ratio corresponding to zero. Column 4-6 reports the results for observations with a green patent ratio corresponding larger than zero. Standard errors are clustered at the (GICS) industry-level.

Table E2: Joint Effect of Emission Intensity and Green Patenting on Yield Spreads

	Low Emission Intensity		High Emission Intensity	
	Low GPR	High GPR	Low GPR	High GPR
	(1)	(2)	(3)	(4)
L.Emission Intensity	0.161*	-0.201	0.139	0.121
	(0.083)	(0.137)	(0.113)	(0.072)
L.Green Patent Ratio	92.054	-4.431	-43.774	41.005
	(127.864)	(8.760)	(385.666)	(30.452)
L.Interaction	-42.790	5.634	36.045	-3.806**
	(80.499)	(3.718)	(70.551)	(1.745)
Green Bond	-0.511***	-0.206	-0.653**	0.243
	(0.124)	(0.222)	(0.266)	(0.494)
L.Profitability	0.142**	0.381*	0.089	-0.269*
	(0.067)	(0.194)	(0.288)	(0.134)
L.Leverage	1.126*	3.454*	0.923	-2.534**
	(0.632)	(1.721)	(2.362)	(1.081)
L.Cash-ratio	-3.425	-12.788*	-2.205	9.363**
	(2.396)	(6.790)	(7.757)	(4.188)
L.Investment-Ratio	-0.421	-1.692*	-0.300	1.446**
	(0.324)	(0.886)	(1.005)	(0.530)
L.Amount Outstanding	-0.126**	-0.354**	-0.211**	-0.658
	(0.049)	(0.173)	(0.078)	(0.451)
Fixed Coupon	0.833***	-0.334	0.370	0.771
	(0.165)	(0.459)	(0.414)	(0.581)
EUR	-0.201**	-0.025	-0.713***	-2.202***
	(0.098)	(0.327)	(0.142)	(0.740)
Time-FEs	Yes	Yes	Yes	Yes
Firm-FEs	No	No	No	No
Bond-FEs	No	No	No	No
Observations	24,892	3,653	7,596	2,238
R-squared	0.094	0.059	0.227	0.281

Robust standard errors in parentheses

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

Note: Sample split for Equation (2), estimated with pooled OLS with time fixed effects. Column 1 reports the results for observations with an emission intensity and a green patent ratio below the sample mean. Column 1 reports the results for observations with an emission intensity below the sample mean and a green patent ratio above the sample mean. Column 3 reports the results for observations with an emission intensity above the sample mean and a green patent ratio below the sample mean. Column 4 reports the results for observations with an emission intensity and a green patent ratio above the sample mean. Standard errors are clustered at the (GICS) industry-level.

Appendix F. Robustness Tests for Equation (3)

F1. Absolute Scope 1+2 Emissions

Table F1: The Effect of Green Patenting on Environmental Performance

	Absolute Scope 1+2 Emissions					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L4.Green Patent Ratio	-4.405***					
	(1.395)					
L8.Green Patent Ratio		-4.618***				
		(1.584)				
L12.Green Patent Ratio			-4.759***			
			(1.361)			
L4.Green Patents				0.247***		
				(0.043)		
L8.Green Patents					0.258***	
					(0.046)	
L12.Green Patents						0.267***
						(0.049)
L.totrevenue_ipo	0.005	-0.001	-0.004	0.007	-0.003	-0.002
	(0.007)	(0.008)	(0.008)	(0.007)	(0.010)	(0.009)
L.Profitability	-0.100	0.046	0.059*	-0.105	0.062	0.046
	(0.078)	(0.060)	(0.033)	(0.083)	(0.065)	(0.035)
L.Leverage	-0.629	0.300	0.294*	-0.564	0.389	0.305*
	(0.509)	(0.359)	(0.166)	(0.550)	(0.364)	(0.165)
L.Cash-Ratio	3.700	-1.246	-1.734	3.916	-1.942	-1.432
	(2.910)	(2.226)	(1.324)	(3.086)	(2.502)	(1.447)
L.Investment-Ratio	0.208	-0.107	-0.059	0.094	-0.115	-0.133
	(0.231)	(0.240)	(0.256)	(0.258)	(0.276)	(0.271)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Industry-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,534	4,142	2,907	4,998	3,709	2,587
R-squared	0.377	0.386	0.390	0.421	0.442	0.454

Robust standard errors in parentheses

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

Note: Robustness tests for Equation (3), estimated with pooled OLS (with time- and industry-fixed effects). We estimate the relationship using a 1-year, 2-year and 3-year lag of the green patent ratio, respectively the amount of green patents. Standard errors are clustered at the firm-level.

F2. GMM

Table F2: The Effect of Green Patenting on Environmental Performance

	Emission Intensity					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L4.Green Patent Ratio	26.606					
	(16.997)					
L8.Green Patent Ratio		27.291				
		(23.262)				
L12.Green Patent Ratio			7.461			
			(12.753)			
L4.Green Patents				-1.146**		
				(0.454)		
L8.Green Patents					-0.867*	
					(0.526)	
L12.Green Patents						-0.908
						(0.565)
L.Profitability	-1.268***	-1.127***	-1.240***	-0.915***	-1.138***	-1.075***
	(0.237)	(0.262)	(0.247)	(0.305)	(0.242)	(0.286)
L.Leverage	-11.449***	-10.197***	-11.254***	-8.271***	-10.294***	-9.728***
	(2.139)	(2.363)	(2.228)	(2.748)	(2.188)	(2.586)
L.Cash-Ratio	44.881***	39.944***	44.027***	32.423***	40.353***	38.127***
	(8.398)	(9.278)	(8.747)	(10.763)	(8.576)	(10.135)
L.Investment-Ratio	6.012***	5.346***	5.919***	4.340***	5.401***	5.105***
	(1.123)	(1.242)	(1.169)	(1.442)	(1.148)	(1.357)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Hansen p-value	0.772	0.870	0.696	0.611	0.782	0.793
AR(1) p-value	0.348	0.678	0.972	0.986	0.708	0.950
AR(2) p-value	0.740	0.389	0.555	0.713	0.944	0.771
Observations	5,407	4,051	2,849	4,926	3,662	2,561

Robust standard errors in parentheses

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

Note: Robustness tests for Equation (3), estimated with GMM. We estimate the relationship using a 1-year, 2-year and 3-year lag of the green patent ratio, respectively the amount of green patents. Standard errors are clustered at the firm-level.

Table F3: The Effect of Green Patenting on Environmental Performance

	Absolute Scope 1+2 Emissions					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
L4.Green Patent Ratio	3.587					
	(3.580)					
L8.Green Patent Ratio		5.141				
		(5.586)				
L12.Green Patent Ratio			1.909			
			(3.126)			
L4.Green Patents				0.188		
				(0.283)		
L8.Green Patents					0.124	
					(0.318)	
L12.Green Patents						0.169
						(0.255)
L.Profitability	-0.095	-0.063	-0.071	-0.105	-0.116	0.000
	(0.157)	(0.171)	(0.176)	(0.172)	(0.192)	0.000
L.Leverage	-0.822	-0.570	-0.647	-0.945	-1.052	-0.000
	(1.418)	(1.543)	(1.585)	(1.561)	(1.736)	-0.001
L.Cash-Ratio	3.270	2.231	2.540	3.711	4.123	0.000
	(5.561)	(6.053)	(6.215)	(6.119)	(6.804)	0.000
L.Investment-Ratio	0.426	0.300	0.338	0.495	0.552	-0.000
	(0.744)	(0.810)	(0.833)	(0.819)	(0.911)	-0.001
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Hansen p-value	0.933	0.950	0.913	0.581	0.629	0.427
AR(1) p-value	0.674	0.705	0.628	0.521	0.455	0.321
AR(2) p-value	0.768	0.544	0.848	0.347	0.403	0.230
Observations	5,534	4,142	2,907	4,998	3,709	2,587

Robust standard errors in parentheses

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

Note: Robustness tests for Equation (3), estimated with GMM. We estimate the relationship using a 1-year, 2-year and 3-year lag of the green patent ratio, respectively the amount of green patents. Standard errors are clustered at the firm-level.

F3. Environmental Performance Across Industries

Table F4: The Effect of Green Patenting on Environmental Performance

	Emission Intensity								
	Basic Materials	Cons. Cyc.	Cons. non-Cyc.	Energy	Healthcare	Industrials	Real Estate	Technology	Utilities
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
L8.Green Patent Ratio	-4.027	-6.787	22.939	-11.615***	6.702	-0.696	-74.144*	-3.574	57.691
	(3.370)	(5.513)	(38.040)	(3.437)	(7.620)	(2.750)	(18.155)	(5.466)	(51.759)
L.Profitability	0.344	0.038	0.110	0.050	0.052***	0.187	0.023	0.075	1.487**
	(0.411)	(0.025)	(0.110)	(0.160)	(0.017)	(0.128)	(0.320)	(0.059)	(0.718)
L.Leverage	2.752	0.353	0.934	0.445	0.423***	1.643	0.210	0.504	13.690**
	(3.724)	(0.213)	(0.978)	(1.467)	(0.137)	(1.151)	(2.894)	(0.476)	(6.389)
L.Cash-Ratio	-10.265	-1.250	-3.850	-1.335	-1.673***	-6.688	-0.822	-2.324	-54.267**
	(14.645)	(0.862)	(3.897)	(5.816)	(0.570)	(4.539)	(11.345)	(2.056)	(24.952)
L.Investment-Ratio	-1.487	-0.194	-0.454	-0.160	-0.209***	-0.843	-0.110	-0.203	-7.201**
	(1.955)	(0.121)	(0.506)	(0.759)	(0.070)	(0.604)	(1.519)	(0.233)	(3.348)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-FEs	No	No	No	No	No	No	No	No	No
Observations	634	478	303	318	411	807	35	706	359
R-squared	0.006	0.033	0.011	0.147	0.025	0.006	0.525	0.007	0.069

Robust standard errors in parentheses

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

Note: Robustness tests for Equation (3) using the green patent ratio as explanatory variable, estimated with pooled OLS (with time fixed effects). We estimate the relationship separate for each distinct industry, using the 2-year lag of the green patent ratio. Standard errors are clustered at the firm-level.

Table F5: The Effect of Green Patenting on Environmental Performance

	Absolute Scope 1+2 Emission								
	Basic Materials	Cons. Cyc.	Cons. non-Cyc.	Energy	Healthcare	Industrials	Real Estate	Technology	Utilities
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
L8.Green Patents	-0.660*	0.012	-0.137	-0.430	0.021	-0.038	-0.772***	0.014	0.500
	(0.343)	(0.033)	(0.269)	(0.301)	(0.024)	(0.087)	(0.014)	(0.030)	(0.549)
L.Profitability	0.110	0.050**	0.181	-0.137	0.052***	0.168	0.252*	0.082	1.804**
	(0.353)	(0.022)	(0.153)	(0.130)	(0.017)	(0.138)	(0.072)	(0.068)	(0.722)
L.Leverage	0.584	0.470**	1.582	-1.315	0.420***	1.459	2.282*	0.547	16.553**
	(3.163)	(0.205)	(1.367)	(1.167)	(0.131)	(1.238)	(0.655)	(0.550)	(6.372)
L.Cash-Ratio	-1.734	-1.703**	-6.348	5.704	-1.648***	-5.995	-8.944*	-2.526	-65.469**
	(12.374)	(0.760)	(5.421)	(4.648)	(0.536)	(4.895)	(2.567)	(2.383)	(24.782)
L.Investment-Ratio	-0.363	-0.257**	-0.793	0.764	-0.206***	-0.740	-1.197*	-0.226	-8.702**
	(1.659)	(0.123)	(0.706)	(0.604)	(0.065)	(0.646)	(0.344)	(0.268)	(3.336)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-FEs	No	No	No	No	No	No	No	No	No
Observations	630	431	269	303	383	687	27	599	333
R-squared	0.054	0.012	0.004	0.126	0.050	0.010	0.964	0.007	0.066

Robust standard errors in parentheses

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

Note: Robustness tests for Equation (3) using the amount of green patents as explanatory variable, estimated with pooled OLS (with time fixed effects). We estimate the relationship separate for each distinct industry, using the 2-year lag of the amount of green patents. Standard errors are clustered at the firm-level.

Table F6: The Effect of Green Patenting on Environmental Performance

	Emission Intensity								
	Basic Materials	Cons. Cyc.	Cons. non-Cyc.	Energy	Healthcare	Industrials	Real Estate	Technology	Utilities
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
L8.Green Patent Ratio	-2.911**	25.689***	-19.259**	-13.692***	-231.887*	1.130	-44.086**	-19.160	6.794
	(1.103)	(7.919)	(9.206)	(4.141)	(117.760)	(2.719)	(8.827)	(29.071)	(15.032)
L.Profitability	0.129	-0.005	0.177	-0.050	0.254	-0.096	-0.166	0.043	0.100
	(0.104)	(0.140)	(0.130)	(0.108)	(0.234)	(0.088)	(0.315)	(0.100)	(0.197)
L.Leverage	1.087	-0.269	1.602	-0.772	2.211	-0.678	-1.505	0.054	0.928
	(0.948)	(1.158)	(1.203)	(0.937)	(2.091)	(0.733)	(2.845)	(0.872)	(1.682)
L.Cash-Ratio	-4.109	1.303	-6.006	4.084	-9.243	2.995	5.900	-0.686	-3.698
	(3.760)	(4.325)	(4.468)	(3.416)	(8.232)	(3.107)	(11.154)	(3.491)	(6.448)
L.Investment-Ratio	-0.574	0.175	-0.759	0.476	-1.207	0.258	0.790	0.141	-0.489
	(0.499)	(0.604)	(0.599)	(0.416)	(1.084)	(0.373)	(1.493)	(0.474)	(0.877)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-FEs	No	No	No	No	No	No	No	No	No
Observations	634	478	303	318	411	807	35	706	359
R-squared	0.020	0.078	0.057	0.257	0.090	0.002	0.466	0.012	0.012

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Robustness tests for Equation (3) using the green patent ratio as explanatory variable, estimated with pooled OLS (with time fixed effects). We estimate the relationship separate for each distinct industry, using the 2-year lag of the green patent ratio. Standard errors are clustered at the firm-level.

Table F7: The Effect of Green Patenting on Environmental Performance

	Absolute Scope 1+2 Emissions								
	Basic Materials	Cons. Cyc.	Cons. non-Cyc.	Energy	Healthcare	Industrials	Real Estate	Technology	Utilities
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
L8.Green Patents	0.201	0.298***	0.060	-0.041	0.377**	0.218**	-0.0501	0.396***	0.166
	(0.131)	(0.067)	(0.246)	(0.327)	(0.176)	(0.097)	(0.035)	(0.089)	(0.164)
L.Profitability	0.091	-0.0695	0.086	-0.154	0.214	-0.068	0.13*	0.087	0.05
	(0.093)	(0.165)	(0.177)	(0.154)	(0.235)	(0.105)	(0.04)	(0.105)	(0.215)
L.Leverage	0.721	-0.836	0.769	-1.708	1.807	-0.385	1.172*	0.597	0.515
	(0.857)	(1.43)	(1.637)	(1.377)	(2.1)	(0.877)	(0.363)	(0.914)	(1.82)
L.Cash-Ratio	-2.603	3.507	-2.739	7.68	-6.991	1.982	-4.594*	-2.588	-2.174
	(3.407)	(5.461)	(6.172)	(5.177)	(8.381)	(3.7)	(1.424)	(3.695)	(6.934)
L.Investment-Ratio	-0.376	0.469	-0.311	0.958	-0.918	0.08	-0.615*	-0.261	-0.275
	(0.452)	(0.747)	(0.837)	(0.663)	(1.103)	(0.445)	(0.191)	(0.47)	(0.948)
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-FEs	No	No	No	No	No	No	No	No	No
Observations	630	431	269	303	383	687	27	599	333
R-squared	0.047	0.221	0.011	0.013	0.133	0.072	0.743	0.274	0.042

Robust standard errors in parentheses

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

Note: Robustness tests for Equation (3) using the amount of green patents as explanatory variable, estimated with pooled OLS (with time fixed effects). We estimate the relationship separate for each distinct industry, using the 2-year lag of the amount of green patents. Standard errors are clustered at the firm-level.

Appendix G. Holder-Sector Dynamics

Table G1: Mean Holder Shares by Holder-Area Over Time

	Global Firms			**EU Firms**		
Period	**EU**	**EA**	**Home**	**EU**	**EA**	**Home**
2016-Q3	0.372	0.371	0.126	0.692	0.690	0.310
2016-Q4	0.366	0.365	0.122	0.687	0.686	0.304
2017-Q1	0.370	0.368	0.123	0.686	0.684	0.306
2017-Q2	0.365	0.364	0.117	0.682	0.680	0.296
2017-Q3	0.361	0.360	0.115	0.673	0.671	0.292
2017-Q4	0.357	0.355	0.112	0.665	0.662	0.287
2018-Q1	0.348	0.346	0.109	0.657	0.654	0.285
2018-Q2	0.336	0.334	0.105	0.640	0.637	0.281
2018-Q3	0.341	0.339	0.104	0.639	0.636	0.268
2018-Q4	0.331	0.329	0.100	0.632	0.629	0.265
2019-Q1	0.335	0.333	0.101	0.634	0.631	0.265
2019-Q2	0.343	0.341	0.102	0.648	0.644	0.268
2019-Q3	0.347	0.344	0.103	0.662	0.655	0.278
2019-Q4	0.346	0.342	0.101	0.650	0.643	0.271
2020-Q1	0.318	0.315	0.092	0.619	0.612	0.256
2020-Q2	0.330	0.327	0.093	0.636	0.628	0.256
2020-Q3	0.324	0.321	0.088	0.634	0.627	0.250
2020-Q4	0.325	0.319	0.088	0.634	0.627	0.258
2021-Q1	0.319	0.314	0.084	0.632	0.626	0.251
2021-Q2	0.311	0.307	0.082	0.624	0.618	0.251
2021-Q3	0.308	0.303	0.082	0.613	0.605	0.251
2021-Q4	0.305	0.300	0.077	0.612	0.603	0.238

Note: Based on a sample of 35,072 bond-level observations for global companies, and 12,761 bond-level observations for EU-companies. We distinguish between EU-holders, EA-holders, and 'home'-holders (i.e. holders located in the same country as the issuer of the bond).

Table G2: Mean Holder Shares by Holder-Sectors Over Time

	Global Firms			**EU Firms**		
Period	**Inst.**	**Ic-Pf**	**Banks**	**Inst.**	**Ic-Pf**	**Banks**
2016-Q3	0.312	0.178	0.034	0.570	0.363	0.062
2016-Q4	0.307	0.177	0.034	0.565	0.360	0.063
2017-Q1	0.312	0.180	0.036	0.567	0.362	0.062
2017-Q2	0.309	0.179	0.035	0.567	0.363	0.061
2017-Q3	0.307	0.178	0.036	0.561	0.360	0.061
2017-Q4	0.306	0.174	0.033	0.561	0.351	0.057
2018-Q1	0.298	0.168	0.033	0.552	0.345	0.057
2018-Q2	0.286	0.159	0.032	0.536	0.326	0.059
2018-Q3	0.293	0.163	0.032	0.539	0.330	0.056
2018-Q4	0.283	0.156	0.033	0.532	0.323	0.057
2019-Q1	0.287	0.158	0.033	0.534	0.324	0.061
2019-Q2	0.294	0.162	0.035	0.545	0.331	0.065
2019-Q3	0.297	0.162	0.035	0.555	0.337	0.068
2019-Q4	0.298	0.163	0.036	0.550	0.335	0.064
2020-Q1	0.274	0.151	0.032	0.525	0.321	0.060
2020-Q2	0.284	0.155	0.033	0.538	0.324	0.060
2020-Q3	0.281	0.154	0.031	0.541	0.330	0.058
2020-Q4	0.283	0.154	0.034	0.541	0.316	0.060
2021-Q1	0.277	0.151	0.033	0.541	0.327	0.061
2021-Q2	0.271	0.147	0.032	0.531	0.324	0.062
2021-Q3	0.267	0.145	0.033	0.519	0.314	0.062
2021-Q4	0.265	0.144	0.032	0.520	0.314	0.062

Note: Based on a sample of 35,072 bond-level observations of global companies, and 12,761 bond-level observations for EU-companies. We distinguish between institutional investors, a subset of institutional holders - insurance companies and pension funds -, and banks.

Table G3: Holder Dynamics

	Global Firms			EU Firms		
	Inst.	Ic-Pf	Banks	Inst.	Ic-Pf	Banks
	(1)	(2)	(3)	(4)	(5)	(6)
L.Emission Intensity	0.135***	0.131***	0.123***	0.079***	0.077***	0.061***
	(0.036)	(0.034)	(0.035)	(0.020)	(0.019)	(0.015)
L.Green Patent Ratio	-3.149	-7.270	-8.137	19.039	13.080	1.008
	(9.478)	(10.673)	(10.327)	(14.245)	(15.937)	(15.898)
Green Bond	-0.407***	-0.464***	-0.459***	-0.510***	-0.534**	-0.484***
	(0.068)	(0.077)	(0.065)	(0.180)	(0.198)	(0.137)
L.SHS Inst.-share	0.108			0.429***		
	(0.244)			(0.143)		
L.Interaction Inst.	-9.153***			-8.250***		
	(3.030)			(1.913)		
L.SHS Ic-Pf-share		-0.288			0.124	
		(0.176)			(0.145)	
L.Interaction Ic-Pf		-10.686***			-8.472***	
		(3.562)			(1.874)	
L.SHS Bank-share			-1.415**			-2.474**
			(0.545)			(1.007)
L.Interaction Banks			-16.375			-0.139
			(9.804)			(5.101)
Corporate Fundamentals	Yes	Yes	Yes	Yes	Yes	Yes
(Other) Bond Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time-FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	35,072	35,072	35,072	12,761	12,761	12,761
R-squared	0.181	0.179	0.179	0.164	0.160	0.175

Robust standard errors in parentheses
*** $p < 0.01$, ** $p<0.05$, * $p<0.1$

Note: Estimation of Equation (4), estimated with pooled OLS with time fixed effects. The first column reports the effect of holdership by institutional investors (measured as the total value held by institutional-investors as a fraction of the amount outstanding) on bond yield spreads, and includes an interaction between the lagged emission intensity, green patent ratio and the share of institutional-holders. We estimate Equation (4) as well for insurance companies and pension funds - a subset of institutional holders - in column 2, and for banks in column 3. We estimate the relationship separately a subsample of bonds issued by European firms in column 4-6.

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