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Abstract: In recent years, the green bond market has seen significant growth as a means of financing environmentally-friendly projects. However, while much research has focused on pricing, little attention has been given to the investors who hold these bonds. This paper uses a preferred habitat framework to analyze the preferences of European investors for green bonds. By analyzing a confidential dataset of portfolio holdings from 2016-Q4 to 2022-Q4, the study finds that European investors, particularly mutual funds and pension funds, show a high demand for green bonds. In contrast, insurance corporations and households tend to avoid green bonds. The research also suggests that the demand for green bonds among mutual funds and pension funds is price inelastic, while banks and insurance corporations display an elastic demand. The findings highlight the presence of a preferred habitat for green bonds among European mutual funds and pension funds. These findings are robust for potential endogeneity concerns when we apply matching techniques, are stronger for domestic green bonds, and also apply to sustainability-linked bonds.

Key words: green bonds, preferred habitat, institutional investors, securities holdings statistics, greenium, climate change, environmental impact, sustainability-linked bonds, portfolio holdings.

JEL codes: G11, G15, G23, Q54, Q56.

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1. Introduction

Climate change has become a major concern for investors globally, leading to a growing body of research in sustainable finance focusing on green bonds. Green bonds are essential in financing long-term projects to combat climate change, and the market has expanded rapidly reaching EUR 2 trillion by the end of 2022 (Climate Bonds Initiative, 2023). While numerous studies highlight the advantages of green bonds (e.g. Maltais & Nykvist, 2020; Flammer, 2021), the impact on issuing firms (e.g. Tang & Zhang, 2020; Flammer, 2021; Nguyen, Alpert, & Faff, 2021), and, analyze lower financing costs compared to other bonds, cq. greenium (e.g. Bachelet, Becchetti & Manfredonia, 2019; Gianfrate & Peri, 2019; Zerbib, 2019; MacAskill et al., 2021; Hyun, Park & Tian, 2021; Lau et al., 2022; Teti et al., 2022), little empirical work has examined the investor clientele of green bonds specifically. While recently a growing body of literature studies green bond investors (e.g. Fatica & Panzica, 2021; Baker et al., 2022; Boutabba & Rannou, 2022), a comprehensive framework to understand a greenium and why investors hold green bonds is currently lacking.

This studies analyzes green bond investments in the euro area. Although green bonds make up only 1.5 percent of the total outstanding bonds, our data shows they constitute around 3.7 percent of the euro area bond portfolios by the end of 2022. This raises the question as to why European investors hold a significantly higher proportion of green bonds than other investors worldwide.

We investigate the driving factors behind the demand for green bonds. In this study, we apply a preferred habitat perspective to analyze the demand for green bonds among euro area investors using a detailed dataset on bond-level holdings from the European Central Bank (ECB), which includes 2,884 green bonds and 315,190 other bonds yielding across investor-country and investor-sector in total 12,474,824 observations for the sample period 2016-Q4 to 2022-Q4. Vayanos and Vila (2021) have demonstrated that bond markets are segmented between arbitrageurs, who are highly responsive to price changes and quickly adjust their portfolios accordingly, and preferred habitat investors, who are relatively insensitive to price changes and drive a wedge in the market. Preferred habitat investors exhibit lower price sensitivity in a particular market segment; in Vayanos and Vila's model, this segmentation occurs in long-term maturities. Similarly, a preference for investing in green bonds implies

that certain investors are disproportionately attracted to these instruments because they align with their environmental preferences, creating a preferred habitat for green bond investment.[1]

To examine whether the motives for holding green bonds are distinct from those for other bonds, we utilize comprehensive data on bond portfolios held by various types of investors across the euro area. Specifically, we estimate the demand for green bonds by different investor segments in the region. We seek to determine whether European investors, in general, are more sensitive to climate change concerns and display stronger environmental preferences than other investors, as evidenced by their preference for green bonds. Furthermore, we investigate whether the demand for green bonds among certain European investors is consistent with a preferred habitat framework.

Our paper explores the concept of preferred habitat in the green bond market, building on previous literature that has investigated green bond investors' portfolio allocations and environmental investment motives. Our preferred habitat model is supported by recent empirical evidence on green bond investors, such as the observation that institutional investors are less likely to sell green bonds during periods of volatility (Fatica & Panzica, 2021). Prior studies on the greenium do not identity who is holding green bonds nor do they explain whether the price wedge is attributable to environmental motives or other non-financial factors. We also draw on studies that suggest green bond investors derive nonpecuniary utility from holding these bonds and are willing to adopt buy-and-hold strategies to compensate for liquidity risks (e.g. Baker et al., 2022; Boutabba & Rannou, 2022).[2]

Our study aims to understand the motives behind green bond investments and the potential emergence of a greenium in the market, driven by a large group of investors with non-financial preferences for holding green bonds. Using data from bond portfolios held by various types of investors in the euro area, we investigate whether European investors have stronger environmental preferences and whether their demand for green bonds aligns with a preferred habitat framework. Our study contributes to the literature on green bonds and sheds

[1] There are other theoretical models in the corporate finance literature that is built on the assumption that *some* investors have a preference for green assets to which our work is complementary, e.g. Pástor et al. (2021), Pedersen et al. (2021), De Angelis et al. (2023) and Oehmke and Opp (2023).
[2] Sangiorgi and Schopohl (2021) survey 48 European asset managers and show that they have excess demand for green bonds, especially for non-financial corporate bonds issued by manufacturing firms.

light on the behavior of green bond investors and their impact on the market including the greenium.

Our results shows that European investors in aggregate exhibit a strong preference for bonds issued for green investment projects, with a residual demand unexplained by other factors. A significant portion of green bond demand comes from institutional investors, specifically mutual funds and pension funds, supporting the idea of a green bond preferred habitat. Interestingly, insurance corporations exhibit different behavior than other institutional investors, as they like households tend to shun green bonds. Our findings emphasize the importance of the preferred habitat framework in understanding the demand for green bonds among European investors.

More specifically, we test two premises of green bond preferred habitat. First, a certain group of investors holds significantly more green bonds. Our findings reveal that European investors in aggregate have a 20 percent higher propensity to hold green bonds than other bonds after accounting for various factors that could affect their preference. We observe that mutual funds and pension funds invest between 9 percent to 26 percent more in green bonds. By contrast, insurance corporations tend to avoid green bonds as they hold 10 percent to 35 percent less of bonds that are green. Similarly, for households the estimated effects range between null to minus 30 percent for green bonds. The results are stronger for domestically issued green bonds and also carry over to sustainability-linked bonds. These results are even stronger when applying propensity score matching: the extra demand for green bonds results in an additional investment of 104 percent by mutual funds and 35 percent for pension funds, while insurance corporations hold 31 percent less in green bonds. These findings demonstrate the existence of a green bond preferred habitat among certain investors in the euro area.

A second premises of green bond preferred habitat entails that certain investors who hold more green bonds should display lower price sensitivities. Our time-series panel regressions confirm that mutual funds and pension funds are the least responsive to price changes and higher price volatility, while banks tend to decrease their green bond holdings when prices increase. This also tends to hold for insurance corporations, although statistically these results are weaker and not robust. Overall, these findings are supportive of the existence of a green bond preferred habitat for specifically mutual funds and pension funds, but not for other investors. Hence, our study provides important insights into the behavior of investors in the green bond market, highlighting the role of preferred habitat and price sensitivity.

Our paper contributes to various research streams in sustainable finance literature. Firstly, we provide a framework to comprehend the investor clientele for green bonds, which adds to green bond literature. We build upon recent studies on green bond investors, (Chiesa & Barua, 2019; Fatica & Panzica, 2021; Flammer, 2021; Baker et al., 2022; Boutabba & Rannou, 2022; Hacıömeroğlu et al., 2022), by proposing that the demand for green bonds is driven by a preferred habitat to seek investments that address climate change and environmental preferences. Pástor et al. (2021) suggest argue the greenium arises because certain investors have nonpecuniary preference for sustainability, but also because especially investors with long investment horizons hedge against climate risk (see also Baker et al. 2022). Fernando et al. (2017) and Dyck et al. (2018) show that firms with better environmental performance are associated with higher institutional ownership. Hence, if this preferred habitat is strong enough among a significant group of (institutional) investors, it may explain the existence of a greenium, where preferred habitat investors create a price wedge due to their high demand for green bonds, (Baker et al., 2018; Fatica et al., 2020; Gianfrate & Peri, 2019; MacAskill et al., 2021; Pietsch & Salakhova, 2022; Teti et al., 2022).[3] Our results on green bond demand arising from mutual funds and pension funds supports these studies. However, our findings highlight insurance corporations as contrary institutional investors, which are associated with lower investment in green bonds and higher price sensitivity. This result is difficult to place in this broader literature on institutional investors and responsible investment, especially given potentially large exposures to climate risk among insurance corporations (ref).

Second, our work builds on the sustainable finance literature on climate risk and investor portfolio allocations. While some investors may view green assets as a long-term bet on mispricing of climate risk (e.g. Andersson et al., 2016; Bolton & Kacperczyk, 2021), this interpretation cannot fully explain the demand for green bonds. The average maturity of a green bond is relatively short, and surveys of large investors suggest that traditional financial risks are considered more important than climate and environmental risks (Krueger et al., 2020). However, financial markets are starting to price carbon risk, and firms that improve their environmental policies can lower their cost of capital and increase their value (El Ghoul et al., 2018; Seltzer et al., 2019). Studies also suggest that institutional investors value climate

[3] Evidence on the greenium is mixed (see Bachelet, Becchetti, & Manfredonia, 2019; Zerbib, 2019; Liaw, 2020; Lau et al., 2022).

risk disclosures and believe that climate risks have financial implications for their portfolios (Krueger et al., 2020).

The study begins by introducing a preferred habitat approach for green bond investors in Section 2. Section 3 details the sources and data on portfolio holdings, while Section 4 outlines the methodology to calculate investor demand functions and presents cross-sectional results. Section 6 presents the main results. Section 7 expands our estimation specification in various ways. Finally, in Section 8, we draw conclusions.

2. Green bond investors and preferred habitat

Green bonds are designed to promote environmentally-friendly investment projects by allocating the obtained capital exclusively to green projects. In comparison to other bonds, green bonds are more expensive as the proceeds must be monitored and may even require certification by third-party entities to demonstrate their impact, resulting in higher administrative and compliance costs. From a financial standpoint, compared to green bonds issuing other bonds would be simpler and less expensive, because such funding still enables financing of environmental-friendly projects that are deemed financially viable. One reason why green bonds are still attractive is due to information asymmetries between issuers and investors. For example, Flammer (2021) argues that green bond issuance serves as a signal of a commitment to environmental goals that align with society's interests. This suggests that firms and governments issue green bonds to cater certain investors willing to sacrifice returns.[4]

If investors in green bonds have motives beyond financial returns, their inherent preferences towards addressing environmental concerns may cause them to allocate their portfolios differently from other bond positions. We use the term "green bond preferred habitat" to describe a situation where changes in the risk-return profile of a particular green bond do not automatically lead to shifts in portfolio allocations towards or away from green bonds for a segmented group of investors, whereas such shifts would be expected for other bonds. A green bond preferred habitat implies a lower price elasticity and a more persistent holding pattern for green bonds, even when market conditions favor the classical risk-return tradeoff. An important testable implication of a green bond preferred habitat for a particular group of

[4] Classical finance theory predicts a risk-return trade-off. The willingness to sacrifice returns is central where certain investors pursue investment goals beyond financial returns. Nonetheless, green bonds could still be qualifies as more risky as green investment projects may involve high risks.

investors is that they hold a disproportionately high amount of green bonds relative to the amount outstanding and their other portfolio positions.

Vayanos and Vila (2021) introduced the concept of preferred habitat, which describes how certain investors tend to hold bonds with specific maturity profiles, and are unlikely to shift their portfolio allocations in response to changes in short or long-term rates. Instead, arbitrageurs tend to be the ones to rebalance portfolios when yield curves move. The existence of a preferred habitat among investors has implications for the green bond market, as highlighted by Boutabba and Rannou (2022) who show that the potential investor base in the green bond market affects liquidity. Green bond investors have a preference for holding bonds until maturity, as they are compensated for higher liquidity risks with higher maturity. This implies that demand for green bonds by investors is relatively inelastic compared to other similar bonds, in line with the preferred habitat model proposed by Vayanos and Vila (2021).

Another perspective on the green preferred habitat is that investors are less inclined to sell their green bonds in response to market shocks, as it is the arbitrageurs who drive price movements and cause any sell-offs, to which the green preferred habitat investors are less likely to respond. Fatica and Panzica (2021) found evidence of this during the COVID-19 crisis in 2020, with net sales of green bonds proving resilient to institutional investor sell-offs. However, this inelastic response was only observed for this investor segment during the crisis period. Hacıömeroğlu et al. (2022) also found that corporate green bonds provided a safe haven during the pandemic.

The search for environmentally-friendly investment strategies with long-term benefits by green bond preferred habitat investors translates into an investor-clientele effect that is important. Flammer (2021) provides evidence that firms issuing green bonds attract more institutional investors, particularly those who are members of the Ceres Investor Network on Climate Risk and Sustainability, indicating that the association is driven by non-financial motives related to the environment. These findings are consistent with a preferred habitat framework for green bonds, as investors with a general preference for environmental goals seek firms with green bonds. However, Flammer (2021) does not find a greenium, indicating that green investors do not necessarily sacrifice returns. In related work, Baker et al. (2022) demonstrate that US green bonds have non-pecuniary benefits for institutional investors, which aligns with the proposed framework of green preferred habitat. Levels et al. (2023)

find that home bias is also applicable in the green bond market. Using data on European investors they find that increased supply of domestic green bonds induces more home investors to hold domestic green bonds. Hence, European investors may display a tendency to hold more green bonds if domestic issuers are more active on the home market.[5]

European investors have the potential to be significant green preferred habitat investors. Chiesa and Barua (2019) have observed that green bonds from emerging markets may be targeted towards European investors as these bonds are often issued in internationally-orientated economies and denominated in the euro currency. This suggests that if there is a green bond investor clientele this may instigate more green bond issuances and possibly more green investment projects. This phenomenon could create a price differential in the discount rates of green projects and other activities if the proportion of investors with a preference for holding green bonds is sufficiently large, as De Angelis et al. (2022) suggest. This market segmentation could also impact the capital structure of firms and governments that issue green bonds, as noted by Nguyen et al. (2021).[6]

3. Data

We use two main data sources. First, the Securities Holdings Statistics database at sectoral level from the European System of Central Banks (ESCB) provides us with detailed information on bond-level portfolio holdings of each investor sector by euro area country (see ECB 2015). Second, the ECB Centralised Securities Database (CSDB) includes a green bond flag. The reference database also covers multiple issuer and bond characteristics. We analyze cross-sectional data on portfolio holdings for the period 2022-Q4.

After merging with the portfolio holdings we have 2,693 unique green bonds with a total amount outstanding of EUR 1,150 billion by end-2022. This covers 1,095 different issuers from 63 countries. Most bonds outstanding are issued in Germany (178), Sweden (88), United States (80), France (70) and Norway (64), while the largest amounts outstanding are

[5] Tolliver et al. (2020) show that green bond issuances also depend on issuer country specific effects, in particular Nationally Determined Contributions to the Paris Agreement and other macroeconomic and institutional quality. In our empirical work such factors will be included and saturated by including multilateral resistance terms as fixed effects.

[6] A concern for such green bond investors is that green bonds often lack of reporting transparency on the use of green bond proceeds (Febi, Schäfer, Stephan, & Sun, 2018; Boutabba & Rannou, 2022), a topic not analyzed in this paper. Green bond label shows inconsistent definitions and standards which introduces unwanted heterogeneity among green bonds (Hyun, Park & Tian, 2021).

from France (EUR 93 bln), Germany (EUR 77 bln), Great Britain (EUR 49 bln), the Netherlands (EUR 44 bln) and the United States (EUR 37 bln).

For extensions, we add "averaged" issuer ratings information from Moody's, Fitch and S&P for a subsample of 657 green bonds, covering 443 billion of amount outstanding (38 percent of the total). Finally, geographical distance indicators from CEPII are included.

The total holdings of green bonds are EUR 446 billion by end-2022, showing that we analyze more than a third of all green bond investments within our holdings dataset. The rest of the holdings data covers 97,436 other unique bonds from 23,645 issuers, worth EUR 75.1 trillion. Thus, green bonds comprise about 1.5 percent of the observed bond market by end-2022. The portfolio holdings by holder-country and investor type consist of 648,485 observations representing a market value of EUR 11,8 trillion in non-green bonds and EUR 446 billion in green bonds, or about 3.7 percent of the total portfolio.

Table 1 provides further details on the sample for 2022-Q4, showing that mutual funds and banks are the largest investors in general, with holdings of EUR 4.0 trillion and EUR 3.9 trillion respectively, while for green bonds mutual funds and insurance corporations are the largest investors with green bond investments of EUR 212 billion and EUR 97 billion each. In relative terms, pension funds and mutual funds have the largest share of their bond holdings allocated towards green bonds, 6.9 percent and 5.5 percent respectively.

Table 2 presents several key summary statistics for 2022-Q4, indicating that the average holdings in green bonds are smaller than for other bonds. In terms of size, both green and other bonds are on average about EUR 500 million in amounts outstanding (nominal value). Green bonds held are a bit closer to the home market than other bonds (560 km vs 883 km), but an equal share between 11-12 percent is held from domestic issuers. The majority of green bonds are denominated in EUR, compared to a minority in USD. Interestingly, the bond yields on green bonds tend to be higher (4.67 percent) than other bonds (3.83 percent), but their residual maturity is also higher (4.83 years) compared to other bonds (4.28 years). Green bonds held are also more often eligible for collateral at the ECB (47 percent) with a credit rating of on average A- (similar to other bonds).

In addition, we run a multidimensional panel time-series for the period 2016Q4-2022Q4. We chose this period because before 2017 the number of green bonds outstanding is very limited.

4. General demand for green bonds regressions

We analyze the preferences to hold green bonds in a simplified gravity model with bond-level data similar to Boermans and Vermeulen (2020). They use the log of the holding amount per bond at market value, *ln HOLD*, so as to obtain the demand function to estimate the cross-sectional determinants of bond holdings.

We start with a country-level regression specifications:

$$(1)\ \ln HOLD_{i,j,g} = \alpha + \beta\ GREEN_{i,j,g} + \gamma'_k GRAVITY_{j,g} + \beta' X_{i,j,g} + \ \varepsilon_{i,j,g}$$

where each bond *i* is held by investors from country *j* and issued by destination country *g*, with the vector *GRAVITY* capturing bilateral country gravity between the investor country *j* and issuer country *g* based on country size and distance indicators, and, the vector *X* containing a set of control variables at the bond- or issuer-level.[7,8]

Table 3 shows that European investors display a significant preference to hold green bonds based on Equation (1). The bivariate regression in Column (1) suggest that without considering other variables, investors have a tendency to invest 29 percent more in green bonds than other bonds. However, when we apply a simple gravity model in Column (2) we show this propensity to hold green bonds is smaller, with a coefficient of 17 percent, but still strongly significant. Column (3) further controls for a wide range of investment determinants at the bond- and issuer-level and takes country-specific preferences into account by including country-level fixed effects. Doing so shows only a weakly significant association between green bonds and investment, suggesting for European investors 13 percent higher investment in green bonds than other bonds after controlling for an extensive set of controls. Finally, in a subsample consisting of rated bonds, Column (4) shows that the preference to invest more in green bonds is strongly significant and relatively stable with a tendency to hold 20 percent more in green bonds than other bonds.

[7] Note that bond level variation *i* already captures issuer level characteristics *g*. We only display *g* for illustrational purposes related to the gravity model.

[8] When analyzing investment patterns towards a certain destination countries without employing any additional modeling techniques, it is necessary to incorporate issuer country fixed effects to account for the fixed preferences of the specific euro area investor towards the destination country. However, destination country controls may not be sufficient since the issuers belong to different sectors. By including issuer sector fixed effects, we can capture unobserved issuer sector characteristics. These fixed effects, namely issuer country and issuer sector, are often referred to as multilateral resistance terms in gravity models since they account for country-specific frictions and preferences related to particular issuers. These fixed effects are included in the investor country-level regression Equation (1). This is important because issuance of green bonds is very dependent on country-level factors (see Tolliver et al., 2020).

The bond demand functions, as it signifies the drivers of the bond holdings, in Table 3 appear in line with prior research. Virtually all control variables have the expected signs (see e.g. Boermans, 2022). In line with size and distance effects in gravity models, we show that larger bonds attract higher investment, while bonds from issuer countries at greater geographical distance obtain lower investment, even though this effect is not statistically robust. The distance effect is most pronounced for domestically issued bonds, which by nature of a home bias attract more than double the investment. Turning to bond characteristics we find that EUR-denominated bonds are preferred to other currencies, while we only find a weak relationship for USD-denominated bonds in Table 3 Column (5). In general, European investors dislike more risky bonds with higher yields and prefer bonds with floating coupon rates or those that are eligible for collateral. We find no association between holdings and maturity or credit ratings. With bonds issued by banks as benchmark, non-financial bonds and bonds from other financial institutions are associated with lower investment. Finally, in Table 3 Column (4) 19.3 percent of the variation in holdings at the bond level is explained in the regression model, which is relatively high for such a granular analysis at cross-sectional holder country-level.

5. Market segmented investor type demand for green bond

5.1 Investor heterogeneity – baseline

For a green bond preferred habitat general preferences to hold green bonds by European investors seems too general for such a framework. Therefore to deepen our understanding of the green bond preferences among European investors, we analyze how different investor types hold green bonds. We expect that only a certain group of European investors tend to overinvest in green bonds. We build on the gravity demand functions in Section 4 Equation (1) and the results of Table 3 to by allowing for market segmentation across certain groups of investors within Europe. By using interaction terms for different investor sectors we allow β to vary; that is, for example banks may have a different disposition to hold green bonds than, say, pension funds. If so, the estimated preferences to hold green bonds shows an average effect which may hide investor sector heterogeneity. To fully absorb this, other covariates must also allow for variance at the investor sector level. Therefore, for γ'_k and β' we also include investor type interaction terms to allow these other factors to vary in way they impact portfolio allocations across different investors.

(2) $\ln HOLD_{i,s,j,g} = \alpha + \beta_{s-1} GREEN_{i,j,g} * HS_s + \gamma'_{k,s-1} GRAVITY_{j,g} * HS_s + \beta'_{s-1} X_{i,j,g} * HS_s + \varepsilon_{i,s,j,g}$

where HS_s includes seven dummies for each investor sector from a set of eight different sectors s. We include investor country and investor sector fixed effects.

For our regressions of Equation (2) we follow the same estimation strategy as in Table 3 while disregarding credit ratings due to limited availability.

Results in Table 4 Column (1) show that the European preference to invest more in green bonds can be fully attributed to a particular group of institutional investors: mutual funds. Mutual funds invest 16 percent more in green bonds compared to other bonds controlling for a wide range of other factors that are associated with portfolio choice. By contrast, we find that households and insurance corporations avoid green bonds keeping other factors constant. We find that insurance corporations have 28 percent lower green bond holdings than anticipated after controlling for a broad range of investment determinants. For households this negative association between green bonds and holdings translates into 20 percent lower investments. Finally, we find no association between green bonds and pension fund investment, nor for banks and governments. To conclude, these findings show strong divergence in green bond preferences, suggesting only mutual funds show excess green bond demand.

5.2 Only issuers of both green bonds and other bonds

One popular approach in the green bond literature is to focus only on other bonds with very comparable characteristics or similar issuers (e.g. Bachelet et al., 2019; Gianfrate & Peri, 2019; Simeth, 2022; Pietsch & Salakhova, 2022). Hence, we analyze a subsample of issuers that have issued at least one green bond in addition to having issued at least one other bond. This approach helps to mitigate the issue of portfolio allocations being driven by other bond issuers differing on some unobserved characteristics not captured in the regressions. By limiting the sample issuers of green- and other bonds leaves us with 1,068 issuers with 25,872 different bonds, of which 2,591 green bonds.

The results from Table 4 Column (2) indicate that the preference to hold green bond is fully associated with a certain group of institutional investor demand: again mutual funds. Additionally, the results show a significant green bond demand by pension funds. The relationship between green bonds and the holdings of insurance corporations is absent. In this

more narrow sample, the negative relationship between green bonds and household holdings is also present, and weakly significant for the government. In general, this specification appears relatively robust compared to Column (1) showing strong demand by mutual funds and negative demand by households, while the green bond demand by insurance corporations and pension funds depends on the subsample. Overall the findings in Table 4 Column (2) indicate that European mutual funds and pension funds may act as preferred habitat investors in the global green bond market.

5.3 Are non-financials different across investors?

Much of the empirical literature on green bonds focuses on non-financial bond issuers (e.g. Flammer, 2021). In this section we test if the green bond preferred habitat is also associated with higher holdings of green bonds issued by non-financials. While our prior regressions control for investor-sector specific demand for certain issuer sectors, here we perform an analysis only on non-financials. This yields us 5,002 different issuing firms with 18,971 bonds, of which 1,065 green bonds. Table 4 Column (3) presents the results, showing a very robust association between green bonds and mutual fund holdings. In addition, pension funds also prefer to hold green bonds, however, for non-financials this relationship is reversed for insurance corporations, albeit only weakly significant. The negative relationship for households is again robust and again absent for government.

In summary, our main take-away from Table 4 is that the green bond demand by European investors is highly segmented and fully associated with investments by mutual funds and pension funds. European mutual funds invest 16 to 24 percent more in green bonds compared to other bonds. The results for pension funds are similar, yet less robust. Pension funds are associated with null to 15 percent higher holdings of green bonds. By contrast, households display a tendency to dislike green bonds and the findings also point to a negative demand from insurance corporation, although this relationship is less robust.

Concluding, the results suggest a green bond preferred habitat among European mutual funds and pension funds as they display excess demand for green bonds that cannot be explain by other factors than the mere fact that the bond is green. These findings are also important for other theoretical models that assume that certain investors opt for green assets (see Pástor et al., 2021; Pedersen et al., 2021; De Angelis et al., 2023; Oehmke & Opp, 2023). One particular result stands in sharp contrast to other papers on the role of certain institutional investors and the demand for green assets, specifically the contrarian demand by insurance corporations. For example, Seltzer et al.

(2023) find that insurance corporations drive divestment of bonds of firms with weak environmental profiles, while mutual funds take these up. However, our results only apply to green bond positions.

6. Sensitivity analysis

6.1 Are domestic green bond holdings different across investors?

Portfolio allocations tend to be strongly biased towards domestic assets. Our control variable "*HOME*" in various specifications confirmed the presence of a home bias in the euro area bond market (similar to Boermans & Vermeulen, 2020). However, the preference to hold green bonds may differ between domestically and foreign issued bonds. Hence, home bias may also be relevant for green bonds, where investors disproportionally seek to buy green bonds issued by the home market. Taking this explicitly into the analysis is important because wide differences in market sizes of green bonds within the euro area exist.

According to official statistics from the ECB (2023), the total amount outstanding of green debt, a broader indicator than green bonds, was EUR 170 billion in France, EUR 150 billion in Germany and EUR 118 billion in the Netherlands, while other euro area countries had much less than half such amounts outstanding, e.g. Spain and Italy stood at EUR 50 billion by 2022Q4. By contrast, the largest investors in the bond market by country are France (EUR 98 billion) and Germany (EUR 90 billion), followed by the Netherlands, (EUR 46 bln), Italy (EUR 37 billion), and Spain (EUR 20 billion). Note that the positions by Luxembourg are EUR 91 billion. This suggest a potential mismatch in the availability of domestic green bond assets for euro area investors. In addition, Levels et al. (2023) show that mismatches between domestic supply and domestic demand for green bonds explain green bond portfolio allocations. Specifically, they find that issuance of green bonds in the home market is concurrently associated with more green bond holdings in the domestic market. To analyze if domestic green bond holdings are different from foreign green bond holdings we include an interaction term between *GREEN* and *HOME*.

The results in Table 5 suggest that for the preferred habitat investors in the green bonds market, namely mutual funds and pension funds, this demand is even stronger for domestic green bonds. However, the general tendency to hold green bonds issued outside the home market also persists for these investors. First, we find that there is a positive relationship between domestic green bonds and investments, where pension funds tend to hold between 20 to 57 percent more green bonds when issued domestically. Mutual funds display a

preference for green bonds that is between null and 28 percent higher when the green bond is domestic. For green bonds issued abroad, pension funds hold null to 37 percent more, and mutual funds between null and 48 percent more. Hence, this confirms the strong demand for green bonds by mutual funds and pension funds, in particular for domestic green bonds. By contrast, banks tend to shun domestically issued green bonds, while for other investor sectors the results are not robust. These findings fit well into a green bonds preferred habitat framework.

6.2 The stability of green bond demand: pre-pandemic period (2019-Q4)

One concern with the prior analysis is that a cross-sectional analysis cannot establish the stability of the estimated effect sizes over time. We verify if the preference to hold green bonds was similar before the global COVID-19 pandemic outbreak in early 2020. We repeat the analysis from Table 4 and show in Table 6 that insurance corporations and mutual funds have the strongest tendency to hold green bonds. The association between green bonds and pension fund investment is insignificant, while households tend to dislike green bonds. These findings are consistent with the results for the period 2022-Q4. The only notable difference is that the green bond demand by governments is significant in the pre-pandemic, yet absent in 2022-Q4, while the reverse holds for banks.

6.3 Are green bond preferences similar to sustainability-linked bond preferences?

While green bonds have gained tremendous traction over the past years, more recently a related green debt climate type bond is also growing rapidly since the first issuance in September 2019: sustainability-linked bonds (SLB). In this section we study if the preferred habitat for green bond holdings can be extended to sustainability bonds. According to the International Capital Market Association (ICMA) definition these bonds have financial and/or structural characteristics that can vary depending on whether the issuer achieves pre-defined sustainability or ESG goals (ICMA, 2020). In our sample, the total amount outstanding of SLB was EUR 55 billion by end-2022.

Vulturius et al. (2022) explain that while issuers of green bond commit to using the proceeds exclusively to finance environmental-friendly projects, the proceeds of SLBs are used for general purposes in support of the issuer's objectives for any type of future improvement in sustainable outcomes, so no earmarking is necessary. Kölbel and Lambillon (2022) explain that the financial and/or structural characteristics could be higher coupon rates to be paid when sustainable objectives are not reached as a penalty. Pohl et al. (2023) show that SLBs

tend to be associated with lower yields, similar to a greenium found for green bonds. Kölbel and Lambillon (2022) confirm this, however, they question the relevance of the penalties on issuers when goals are not met. They argue that for issuers of SLBs there is "a free lunch" as penalties are too low when targets are not met compared to the size of the issue discount, thus leaving room for potential green washing.

To understand the demand for sustainability-linked bonds by European investors we compare the results from Table 4 on green bonds with similar regressions where we replace the variable *GREEN* for an indicator variable *SLB*. We include 804 sustainability-linked bonds which focus on environmental outcomes, representing a total amount outstanding of EUR 466 billion, which is 40 percent of the size of the green bond market. The results in Table 7 show that mutual funds and pension funds invest more in bonds that are classified as a sustainability-linked bonds, consistent with the investment pattern for green bonds. In addition, also in line with the previous results on green bonds, insurance corporations and households tend to shun sustainability-linked bonds, whereas for other investors sectors we do not find a consistent relationship.

6.4 Matching techniques for selection bias

A conceivable concern is that green bonds are distinct from other bonds in such a way that there is too little overlap in bond and issuer characteristics. If so, this endogeneity concern of green bonds characteristics being very different ex ante cannot be well addressed with standard OLS regressions. For example, Chiesa and Barua (2019) have demonstrated notable discrepancies between green bonds and other bonds, particularly in terms of their longer maturities. In Section 3 our summary statistics in Table 2 confirmed this and suggested other dissimiliarities between green bonds and other bonds, such as the currency of denomination and lower yields. Therefore, it is plausible that within a preferred habitat framework the estimated demand may be merely reflecting a selection bias, where investor dispositions for longer maturities, euro-denominated bonds or particular yields are confounded with the greater frequency of other characteristics associated with green bonds.

To address this concern we apply propensity score matching based on forced matching. First, we select issuers that have issued green bonds in addition to issuing other bonds. Next, bonds are matched based on the amount outstanding, currency, yields, residual maturity, coupon type, eligibility for collateral status and issuer sector. These first stage probit regressions explain 12 percent of the total variance in whether a bond is green or not, with all these

explanatory variables being highly significant and strongly associated with green bonds. Finally, we compute the average effect of the treatment on the "treated", here the green bond status, on the outcome variable the log of holdings.

The results in Table 8 confirm that predominantly mutual funds and pension funds invest significantly more in green bonds. This effect is the largest for mutual funds: after matching we find that an average investment position in a green bond is EUR 4.5 million, compared to EUR 2.2 million in a highly comparable non-green bonds. For pension funds we also find great economic magnitudes in terms of green bond demand. Within the matched sample we find that pension funds green bond holdings are on average EUR 1.9 million for green bonds, compared to EUR 1.3 million in a highly comparable non-green bond. For other investor sectors we find no significant or reverse relationship, however, for insurance corporations green bond holdings are on average a green bond EUR 2.6 million which is significantly less compared to EUR 3.8 million in a highly comparable non-green bond. Overall, these matching results confirm the role of European mutual funds and pension funds as green bond preferred habitat investors.

6.5 Lessons from cross-sectional analysis

The results in Section 4 at the country-level (Table 3) and in Section 5 and Section 6 at the investor sector level suggest that only *some* European investors have a preference to hold green bonds. The association between green bonds and portfolio investment is strongest for mutual funds and also highly significant for pension funds. The tendency to hold green bonds is stronger for domestic bonds, however, this demand preference by mutual funds and pension funds is not fully saturated, meaning they also display a preference to hold foreign green bonds. This green bond preferred habitat is persistent as we confirm robustness of the 2022-Q4 findings for the pre-pandemic period of 2019-Q4. The green bond demand by mutual funds and pension funds in Europe is most likely explained by a non-financial motive to seek sustainable investment because we show this excess demand also applies to sustainability-linked bonds *only* for this group of investors. Finally, instead of using OLS cross-sectional regressions we apply matching techniques, which again confirm the preference to hold green bonds only among mutual funds and pension funds. We argue that this is in line with a preferred habitat to hold green bonds and ostensibly a preference to invest in environmental-friendly products to combat climate change.

To our knowledge we are the first study to show that the demand for green bonds in Europe displays a market segmentation as higher green bonds holdings are only associated with particular institutional investors, while in fact insurance corporations have a tendency to shun green bonds in most specifications. This suggest that the demand for green bonds is segmented by investor type, even within institutional investors in Europe.

7. Time-series analysis

7.1. Green bond preference in a time-series

So far we analyzed the recent relationship between green bonds and investments by different European investors for the period 2022-Q4 and showed the persistence of green bond preferences in the pre-pandemic period 2019-Q4. Fortunately, we also have a full multidimensional time-series panel on bond-level holdings that we can use to extend the cross-sectional analysis of Section 4 Equation (1) with investor heterogeneity as in Section 5 Equation (2) as follows:

$$(3)\ \ln HOLD_{i,s,j,g,t} = \alpha + \beta_{s-1} GREEN * HS + \beta_{k,s-1} GRV_{j,g,t} * HS + \beta'_{s-1} X_{i,t} * HS + \varepsilon_{i,s,j,g,t}$$

where we allow for time variance with subscript *t* and we include time fixed effect in the vector *X*, with standard errors additionally clustered at the investor country and investor sector (*HS*). We apply the same specifications as in Table 4.

The results in Table 9 broadly confirms that mutual funds and pension funds display a preference to hold green bonds. However this relationship is insignificant in the full specification in Table 9 Column (1), but strongly significant and economically meaningful in the subsample with only green bond issuers and non-financial firms in Columns (1) and (2). For example, Table 9 Column (2) suggests that mutual funds invest 30 percent more in green bonds compared to other bonds that have similar characteristics based on the observables. Similarly, pension funds display a tendency to hold more of a bond if the bond has a green label: investments by pension funds in green bonds are 29 percent higher compared to other bonds, ceteris paribus. By contrast, insurance corporations and household tend to dislike green bond holdings. These results are very consistent with the cross-sectional analysis, suggesting that a green bond preferred habitat is persistent across mutual funds and pension funds in Europe.

7.2 Preferred habitat and price elasticities in a time-series framework

A second premises of the preferred habitat model is not only that certain investors prefer specific assets, with a persistent tendency to hold such assets, but also to continue to hold assets in volatile times when prices move. In short, preferred habitat investors are less price sensitive. To test this we estimate the following model:

$$(4)\ \Delta \ln HOLD_{i,s,j,g,t} = \alpha + \beta_{s-1} GREEN * HS * \Delta PRICE + \beta_{k,s-1} GRAV_{j,g,t} * HS + \beta'_{s-1} X_{i,t} * HS + \varepsilon_{i,s,j,g,t}$$

We use two proxies for price sensitivities given the quarterly nature of the bond investment data. First, for $\Delta PRICE$ we use the difference between the price at the beginning of the quarter with the price at the end of the quarter, divided by the price at the beginning of the quarter (mean = 0.00; s.d = 0.046). This first proxy captures whether higher price changes are associated with higher shifts in green bond holdings. Second, for $\Delta PRICE$ we use the price volatility in a given quarter measured as the absolute change in average daily prices per month summed over the quarter, divided by the price at the beginning of the quarter (mean = 0.030; s.d. = 0.059). This second proxy captures if bond-level price volatility is associated with changes in green bond portfolios.

Results in Table 10 show that positive price changes are associated with lower green bond holdings by banks and insurance corporations. Banks and insurance corporations are very responsive to price changes: when prices increase by one percent banks reduce their green bond holdings by 1.63 percent based on Table 10 Column (1). Similarly, insurance corporations reduce their green bond holdings by about 1.24 percent when prices increase with one percent. In other words, European banks and insurance corporations are very price sensitivities and act as arbitrageurs in green bond markets In terms of price volatility, only insurance corporations respond by shifting their green bond portfolios.

Most importantly, the finding that European mutual funds and pension funds act as green bond preferred habitat investors is confirmed throughout Table 10. They show a strong preference to hold green bonds where green bond holdings appears not to change when prices move. Rather, mutual funds increase green bond holdings when pricing go up or become more volatile, as shown in Table 10 Columns (3) and (4). These findings are in line with a green bond preferred habitat for mutual funds and pension funds as they are less willing to

change bond holdings when prices move, which confirms the relative price inelasticity of their green bond demand.

8. Conclusion

The market for green bonds, which facilitates long-term environmental-friendly projects, has received great attention among investors in recent years. These green bonds have also become an important part of the portfolio of European investors, comprising 3.7 percent of the total bond holdings. Our work suggests that the high demand for green bonds by European investors displays a strong market segmentation, where our results show that only mutual funds and pension funds seek greater investment in green bonds compared to other European investors and their excess demand for green bonds is also less responsive to price. Mutual funds and pension funds generally have relative long investment horizons and ostensibly care to combat climate change. These findings fit within a preferred habitat framework where only certain investors invest more in green bonds for non-financial motives and display highly inelastic demand.

Using detailed portfolio holdings based on sample of 2,693 green bonds and 12,474,824 observations over the period 2016-Q4 to 2022-Q4 we show first that mutual funds and pension funds tend to hold much more green bonds, with estimates varying from 9 percent to even 104 percent. Second, we find these investors display a low price sensitivity as changes in price or higher price volatility is not associated with shifts in green bonds holdings, while other investors do respond to such price signals. Our study is of general interest to firms and government who plan to issue green bonds as they will be dependent on demand arising from these institutional investors for their investor clientele and potential future demands on the design of green bonds.

One puzzling but very consistent results concerns insurance corporations, a class of investors often regarded as institutional investors along with mutual funds and pension funds. We find that they have a negative tendency to hold green bonds in ways similar to households. In addition, they are very responsive to price changes: when prices increase by one percent insurance corporations reduce their green bond holdings by about 0.8 percent to 1.38 percent. In other words, European insurance corporations are very price sensitivities and act as arbitrageurs in green bond markets in ways similar to banks. In addition, green bond holdings of insurance corporations are vulnerable to increased price volatility. Future research may

provide further explanations as to why these institutional investors appear to act to the contrary.

Our results show no relationship between banks and green bond investments. However, regulatory changes in collateral requirements may lead to increased green demand from the banking industry in the future. Currently, banks tend to avoid investing in green bonds due to the perceived risk and penalties associated with non-government issuers. This is largely due to strict capital requirements imposed on banks. However, the regulatory landscape is rapidly evolving, with the European Central Bank conducting a climate stress test among banks in May 2022 and proposing to incentivize climate-related investments to ensure long-term financial stability. These changes may result in a significant increase in capital directed towards green bond investments by European banks.

Future research would benefit from further elaborations. First, not all green bonds are the same. One concerns among investors is the green bond label itself, both in terms of the potential for environmental change as well as the earmarking of proceeds with proper evaluation for climate related actions. At worse, green bonds may be self-labelled by issuers, lacking verification which enables green-washing. Because it is difficult for individual investors to assess the real climate impact of green bonds issued, investors rely on information through voluntary disclosures by issuers (Tang & Zhang, 2020). In addition, third-party verification has emerged in response to investors' demand. Consequently, green bonds with externally verified labels tend to trade at a premium (Ehlers & Packer, 2017; Bachelet, Becchetti, & Manfredonia, 2019; Simeth 2022; Teti et al., 2022), which is not taken into account in this study. There are also important differences in second-party classifications and standards. One avenue of research would analyze investor preferences across different green bonds. Having more variation in the type of green bonds could show if, and if so, which investors are able to distinguish between green bonds types with their latent demand. Our analysis only performed an additional analysis that focused on sustainability-linked bonds, where preferred habitat by institutional investors in Europe seems very similar to green bonds.

Second, our study benefits from analyzing a broad variety of different investors. For example we find that mutual funds are significant investors in green bonds. However, we are unable to distinguish between fixed income mutual fund mandates which may explain portfolio allocations towards green and non-green assets (see e.g. Ammann et al, 2019; Reboredo &

Otero, 2021; Amzallag, 2022). We expect that much of the demand by mutual funds is in fact indirectly driven by insurance corporation and pension funds, institutional investors with long-term commitments. These large institutional investors often rely on specific mutual funds with environmental goals. It would therefore be of interest to analyze both the type of mutual funds that hold green bonds from the perspective of their broader investment strategies, as well as to understand who participants are of these mutual funds.

Third, the preferred habitat framework suggests that the demand for green bonds will be more sticky among certain investor groups that have a preference to hold green bonds above all else. Analyzing the flows over time in a segmented market setting with shocks would allow for further testing the preferred habitat framework. Still, our results suggest that the demand for green bonds is relatively stable over time as our pre-pandemic sample also highlights a preferred green bond habitat among institutional investors of similar magnitude as in 2022-Q4.

Fourth, our work on green bond investors is linked to research on the effectiveness of green bonds to stir environmental outcomes. First, studies link green bond issuances to green innovation at the firm level in terms of number of patents (Wang et al, 2022; García et al., 2023;). Second, research shows that green bonds issuers experience faster CO_2 emission reductions after issuances (Fatica et al., 2021; Flammer, 2021), although this link is disputed (Ehlers, Mojon & Packer, 2020; Mazzacurati et al., 2021; Yeow & Ng, 2021; De Angelis, 2022; García et al., 2023). Finally, using asset backed green bonds, Devine and McCollum (2022) find that such green bonds improve energy efficiency on houses of the underlying mortgages. In summary, green bond preferred habitat investors, in particular European mutual funds and pension funds, would be very interested in future evidence on a causal link between green bonds and the *additionality* of the funded environmental-friendly projects. Without such evidence on the contribution of green bonds to combat climate change, having a green bond label may discontinue to sway investor clientele for green bonds.

Finally, the green bond market has rapidly changed over the past few years. Prior studies may therefore no longer be representative as the composition of the green bond markets has changed drastically. In relation to the greenium debate, Liaw (2020) argues that the divergent results on the existence of a greenium are likely explained by "differences in sample selections, time periods, methodologies, and the properties of the respective issuing entity and the bond." Our analysis benefits from a much broader sample, giving rise to greater

statistical power which may have been lacking in other studies aiming to control for a multitude of other factors. This holds especially for the studies on green bond investors, because they only focus on a segment of the market and tend to lack information of different investors. However, shifts in the structural nature of the green bond market may also apply to the green bond preferred habitat that we associate with only European mutual funds and pension funds. For example, shifts in regulation may instigate excess demand for green bonds by insurance corporations and banks. Future research will further expand the sample size and associated statistical power to better estimate green bond preferred habitat by certain groups of bond investors. These studies may also be able to fortify causal claims on the relationship between green bonds and demand by particular investors as future regulatory shifts can enable quasi-experimental testing.

References

Ammann, M., Bauer, C., Fischer, S., & Müller, P. (2019). The impact of the Morningstar Sustainability Rating on mutual fund flows. *European Financial Management, 25*(3), 520-553.

Amzallag, A. (2022). Fund portfolio networks: A climate risk perspective. *International Review of Financial Analysis, 84*, 102259.

Andersson, M., Bolton, P., & Samama, F. (2016). Hedging climate risk. *Financial Analysts Journal, 72*(3), 13-32.

De Angelis, T., Tankov, P., & Zerbib, O. D. (2022). Climate impact investing. *Management Science.*

Bachelet, M. J., Becchetti, L., & Manfredonia, S. (2019). The green bonds premium puzzle: The role of issuer characteristics and third-party verification. *Sustainability*, *11*(4), 1098.

Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2022). The pricing and ownership of US green bonds. *Annual Review of Financial Economics*, *14*.

Boermans, M.A. (2022). A literature review of securities holdings statistics research and a practitioner's guide. *DNB Working Paper No. 757*.

Boermans, M. A., & Vermeulen, R. (2020). International investment positions revisited: Investor heterogeneity and individual security characteristics. *Review of International Economics,* 28(2), 466-496.

Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics, 142*(2), 517-549.

Boutabba, M. A., & Rannou, Y. (2022). Investor strategies in the green bond market: The influence of liquidity risks, economic factors and clientele effects. *International Review of Financial Analysis*, *81*, 102071.

Chiesa, M., & Barua, S. (2019). The surge of impact borrowing: The magnitude and determinants of green bond supply and its heterogeneity across markets. *Journal of Sustainable Finance & Investment*, *9*(2), 138-161.

Climate Bonds Initiative (2023). Q4 2022 Market Summary.

Devine, A., & McCollum, M. (2022). Advancing energy efficiency through green bond policy: Multifamily green mortgage backed securities issuance. *Journal of Cleaner Production, 345*, 131019.

Dyck, A., Lins, K. V., Roth, L., & Wagner, H. F. (2019). Do institutional investors drive corporate social responsibility? International evidence. *Journal of Financial Economics, 131*(3), 693-714.

ECB (2015). Who holds what? New information on securities holdings. *ECB Economic Bulletin, 2*, 72-84.

ECB (2023). Experimental indicators on sustainable finance. *European Central Bank.*

Ehlers, T., & Packer, F. (2017). Green bond finance and certification. *BIS Quarterly Review*.

El Ghoul, S., Guedhami, O., Kim, H., & Park, K. (2018). Corporate environmental responsibility and the cost of capital: International evidence. *Journal of Business Ethics, 149*, 335-361.

Fatica, S., & Panzica, R. (2021). Sustainable investing in times of crisis: evidence from bond holdings and the COVID-19 pandemic. *Mimeo*.

Febi, W., Schäfer, D., Stephan, A., & Sun, C. (2018). The impact of liquidity risk on the yield spread of green bonds. *Finance Research Letters*, *27*, 53-59.

Fernando, C. S., Sharfman, M. P., & Uysal, V. B. (2017). Corporate environmental policy and shareholder value: Following the smart money. *Journal of Financial and Quantitative Analysis, 52*(5), 2023-2051.

Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, *142*(2), 499-516.

García, C. J., Herrero, B., Miralles-Quirós, J. L., & del Mar Miralles-Quirós, M. (2023). Exploring the determinants of corporate green bond issuance and its environmental implication: The role of corporate board. *Technological Forecasting and Social Change, 189*, 122379.

Gianfrate, G., & Peri, M. (2019). The green advantage: Exploring the convenience of issuing green bonds. *Journal of Cleaner Production*, *219*, 127-135.

Hacıömeroğlu, H. A., Danışoğlu, S., & Güner, Z. N. (2022). For the love of the environment: An analysis of Green versus Brown bonds during the COVID-19 pandemic. *Finance Research Letters, 47*, 102576.

Hyun, S., Park, D., & Tian, S. (2021). Pricing of green labeling: A comparison of labeled and unlabeled green bonds. *Finance Research Letters*, *41*, 101816.

ICMA (2020). Sustainability-Linked Bond Principles. *International Capital Market Association.*

MacAskill, S., Roca, E., Liu, B., Stewart, R. A., & Sahin, O. (2021). Is there a green premium in the green bond market? Systematic literature review revealing premium determinants. *Journal of Cleaner Production*, *280*, 124491.

Maltais, A., & Nykvist, B. (2020). Understanding the role of green bonds in advancing sustainability. *Journal of Sustainable Finance & Investment*, 1-20.

Nguyen, T., Alpert, K., & Faff, R. (2021). Relative bond-stock liquidity and capital structure choices. *Journal of Corporate Finance*, *69*, 102026.

Kölbel, J. F., & Lambillon, A. P. (2022). Who pays for sustainability? An analysis of sustainability-linked bonds, *Mimeo*.

Krueger, P., Sautner, Z., & Starks, L. T. (2020). The importance of climate risks for institutional investors. *Review of Financial Studies, 33*(3), 1067-1111.

Lau, P., Sze, A., Wan, W., & Wong, A. (2022). The Economics of the Greenium: How Much is the World Willing to Pay to Save the Earth?. *Environmental and Resource Economics*, *81*(2), 379-408.

Liaw, K. T. (2020). Survey of green bond pricing and investment performance. *Journal of Risk and Financial Management, 13(*9), 193.

Levels, A., Lambert, C., & Wedow, M. (2023). Green bond home bias and the role of supply and sustainability preferences, *DNB Working Paper No. 767.*

Oehmke, M., & Opp, M. M. (2023). A theory of socially responsible investment. *Mimeo*.

Pástor, Ľ., Stambaugh, R. F., & Taylor, L. A. (2021). Sustainable investing in equilibrium. *Journal of Financial Economics, 142*(2), 550-571.

Pedersen, L. H., Fitzgibbons, S., & Pomorski, L. (2021). Responsible investing: The ESG-efficient frontier. *Journal of Financial Economics, 142*(2), 572-597.

Pietsch, A., & Salakhova, D. (2022). Pricing of green bonds: Drivers and dynamics of the greenium. *ECB Working Paper No. 2728*.

Pohl, C., Schüler, G., & Schiereck, D. (2023). Borrower-and lender-specific determinants in the pricing of sustainability-linked loans. *Journal of Cleaner Production, 385*, 135652.

Reboredo, J. C., & Otero, L. A. (2021). Are investors aware of climate-related transition risks? Evidence from mutual fund flows. *Ecological Economics, 189*, 107148.

Sangiorgi, I., & Schopohl, L. (2021). Why do institutional investors buy green bonds: Evidence from a survey of European asset managers. *International Review of Financial Analysis*, *75*, 101738.

Seltzer, L. H., Starks, L., & Zhu, Q. (2022). Climate regulatory risk and corporate bonds. *NBER Working Paper No. 29994*.

Simeth, N. (2022). The value of external reviews in the secondary green bond market. *Finance Research Letters, 46*, 102306.

Seltzer, L. H., Starks, L., & Zhu, Q. (2022). Climate regulatory risk and corporate bonds. *NBER Working Paper No. 29994*.

Tang, D. Y., & Zhang, Y. (2020). Do shareholders benefit from green bonds?. *Journal of Corporate Finance*, *61*, 101427.

Teti, E., Baraglia, I., Dallocchio, M., & Mariani, G. (2022). The green bonds: Empirical evidence and implications for sustainability. *Journal of Cleaner Production, 366,* 132784.

Tolliver, C., Keeley, A. R., & Managi, S. (2020). Drivers of green bond market growth: The importance of Nationally Determined Contributions to the Paris Agreement and implications for sustainability. *Journal of Cleaner Production, 244*, 118643.

Vayanos, D., & Vila, J. L. (2021). A preferred-habitat model of the term structure of interest rates. *Econometrica*, *89*(1), 77-112.

Wang, T., Liu, X., & Wang, H. (2022). Green bonds, financing constraints, and green innovation. *Journal of Cleaner Production, 381*, 135134.

Vulturius, G., Maltais, A., & Forsbacka, K. (2022). Sustainability-linked bonds–their potential to promote issuers' transition to net-zero emissions and future research directions. *Journal of Sustainable Finance & Investment*, 1-12.

Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, *98*, 39-60.

Table 1: Total bond holdings by investor sector

Investor sector	Total	Green	% Green bonds	n
Banks	3,856	71	1.9%	70,852
Other financial intermediaries	295	5	1.6%	37,143
Mutual funds	4,041	212	5.5%	227,204
Insurance corporations	2,435	97	4.2%	112,390
Pension funds	615	40	6.9%	53,417
Households	309	6	2.0%	76,850
Non-financials	150	4	2.8%	41,272
Government	490	12	2.5%	29,357
Total	**12,191**	**446**	**3.7%**	**648,485**

Notes: Total investment positions (market values including accrued interest) in portfolio holdings by investor sector, full portfolio and green bond portfolio based on SHS-S data for 2022-Q4.

Table 2: Summary statistics for cross-section (2022-Q4)

	Total			Green		
	mean	***s.d.***	***n***	***mean***	***s.d.***	***n***
HOLD (mln)	18.80	158.41	648,485	13.13	55.14	33,993
ln HOLD	14.23	2.44	648,485	14.53	2.13	33,993
Gravity factors:						
BOND SIZE	19.98	1.75	640,851	19.96	0.97	33,963
ln *DISTANCE*	6.78	2.64	648,485	6.33	2.56	33,993
HOME	0.11	0.31	648,485	0.12	0.32	33,993
Bond characteristics:						
USD	0.35	0.48	648,485	0.16	0.36	33,993
EUR	0.56	0.50	648,485	0.77	0.42	33,993
YIELD	5.05	3.83	593,823	4.67	2.82	32,818
ln RESID. MATURITY	7.35	1.17	633,636	7.48	0.86	33,203
FLOATING COUPON	0.16	0.36	648,485	0.11	0.32	33,993
ELIGIBLE COL.	0.30	0.46	648,485	0.47	0.50	33,993
CREDIT RATING	7.09	3.43	243,498	6.99	2.56	12,411

Notes: Total investment positions (market values including accrued interest) in portfolio holdings by investor sector, full portfolio and green bond portfolio based on SHS-S data for 2022-Q4.

Table 3: Country-level regressions on green bonds and bond investments

	(1)	(2)	(3)	(4)
GREEN	0.29***	0.17**	0.13*	0.20**
	[0.063]	[0.066]	[0.068]	[0.086]
Gravity factors:				
BOND SIZE		0.20***	0.23***	0.21***
		[0.029]	[0.029]	[0.033]
ln *DISTANCE*		-0.31***	-0.03	-0.07*
		[0.052]	[0.046]	[0.037]
HOME			1.54***	1.64***
			[0.317]	[0.370]
Bond characteristics:				
USD			0.03	0.23*
			[0.081]	[0.122]
EUR			0.92***	1.22***
			[0.274]	[0.320]
YIELD			-0.03***	-0.02***
			[0.010]	[0.006]
ln *RESID. MATURITY*			-0.01	-0.04
			[0.025]	[0.026]
FLOATING COUPON			0.18	-0.08
			[0.116]	[0.102]
ELIGIBLE COL.			0.31**	0.07
			[0.115]	[0.105]
Issuer characteristics:				
OTHER FINANCIAL			-0.34***	-0.53***
			[0.063]	[0.077]
GOVERNMENT			-0.15	-0.20**
			[0.090]	[0.090]
NON-FINANCIAL			-0.61***	-0.64***
			[0.086]	[0.097]
CREDIT RATING				0
				0
Constant	13.91***	12.29***	8.98***	9.67***
	[0.159]	[0.639]	[0.554]	[0.756]
Investor country FE	NO	NO	YES	YES
Observations	355,928	350,172	314,365	114,709
R-squared	0.001	0.09	0.193	0.206

Notes: Dependent variable is log holdings amount. Cross-sectional demand functions for 2022-Q4 based on Eq. (1). Robust standard errors in brackets where *** p<0.01, ** p<0.05, * p<0.1. For Column (4) mean VIF is 2.09, with the highest VIF score of 5.71 (for the home dummy) suggesting no issues related to multicollinearity.

Table 4: Green bond demand by investor sector (cross-sectional)

	(1)	(2)	(3)
GREEN * Banks	-0.06	0.03	0.11
	[0.049]	[0.038]	[0.190]
GREEN * Government	-0.08	-0.13*	0.12
	[0.050]	[0.068]	[0.167]
GREEN * Households	-0.20***	-0.21***	-0.29***
	[0.049]	[0.044]	[0.141]
GREEN * Insurance corporations	-0.28***	-0.10	-0.15*
	[0.040]	[0.122]	[0.087]
GREEN * Mutual funds	0.16***	0.17**	0.24***
	[0.037]	[0.094]	[0.118]
GREEN * Pension funds	0.05	0.09**	0.15*
	[0.045]	[0.050]	[0.088]
Gravity factors * *HS*	YES	YES	YES
Bond characteristics * *HS*	YES	YES	YES
Issuer characteristics * *HS*	YES	YES	YES
Observations	588,242	207,217	190,554
R-squared	0.328	0.337	0.343

Notes: Dependent variable is log holdings amount. Cross-sectional demand functions for 2022-Q4 based on Eq. (2) with investor sector heterogeneity. Robust standard errors in brackets where *** p<0.01, ** p<0.05, * p<0.1. Each Column represents a single OLS regression specification where *HS* = investor sector dummies interacted with *GREEN* (the green bond indicator). Estimates against benchmark of Other financial intermediaries and non-financials which have no preferences over green (e.g. Column (1): est. coeff. = 0.02 with s.e. 0.033), with corrected coefficients and s.e. displayed for other *HS*. All regressions include a full range of controls as included in the vector as presented in Table 3 but with interacted terms by *HS*. Column (1) is the full sample, Column (2) is a subsample of only green bond issuers and Column (3) includes only non-financials.

Table 5: Domestic green bond holdings across different investors

	(1)	(2)	(3)
GREEN * Banks	-0.00	0.31	0.23**
	[0.185]	[0.256]	[0.113]
GREEN * Government	-0.06	-0.21***	-0.10
	[0.200]	[0.058]	[0.092]
GREEN * Households	-0.17	-0.20***	-0.12
	[0.121]	[0.055]	[0.093]
GREEN * Insurance corporations	-0.30**	-0.06	-0.18**
	[0.138]	[0.044]	[0.075]
GREEN * Mutual funds	0.14	0.48***	0.24***
	[0.136]	[0.040]	[0.069]
GREEN * Pension funds	0.02	0.37***	0.18*
	[0.132]	[0.050]	[0.085]
Triple interactions:			
GREEN * Banks * *HOME*	-0.34*	-0.16	-1.73***
	[0.178]	[0.100]	[0.242]
GREEN * Government * *HOME*	-0.11	-0.17	-0.47
	[0.192]	[0.117]	[0.306]
GREEN * Households * *HOME*	-0.22	-0.58***	0.34
	[0.355]	[0.118]	[0.287]
GREEN * Insurance Corp. * *HOME*	0.25*	-0.24***	0.82***
	[0.132]	[0.082]	[0.177]
GREEN * Mutual funds * *HOME*	0.23**	0.09	0.28**
	[0.113]	[0.065]	[0.137]
GREEN * Pension funds * *HOME*	0.28	0.20**	0.57***
	[0.176]	[0.102]	[0.173]
Gravity factors * HS	YES	YES	YES
Bond characteristics * HS	YES	YES	YES
Issuer characteristics * HS	YES	YES	YES
Observations	588,242	207,217	165,265
R-squared	0.328	0.338	0.300

Notes: Dependent variable is log holdings amount. Cross-sectional demand functions for 2022-Q4 based on Eq. (2) with investor sector heterogeneity. Robust standard errors in brackets where *** p<0.01, ** p<0.05, * p<0.1. Each Column represents a single OLS regression specification where *HS* = investor sector dummies interacted with *GREEN* (the green bond indicator) multiplied with a *HOME* dummy which equals 1 if the bond is issued by a domestic issuer. All regressions include a full range of controls as included in the vector as presented in Table 3 but with interacted terms by *HS*. Column (1) is the full sample, Column (2) is a subsample of only green bond issuers and Column (3) includes only non-financials.

Table 6: Pre-pandemic green bond demand by investor sector (cross-sectional)

	(1)	(2)	(3)
GREEN * Banks	-0.13	0.01	0.18
	[0.084]	[0.090]	[0.112]
GREEN * Government	0.09	0.18	0.12
	[0.067]	[0.112]	[0.173]
GREEN * Households	-0.21**	-0.01	-0.25
	[0.093]	[0.098]	[0.171]
GREEN * Insurance corporations	-0.26***	-0.35***	-0.22
	[0.072]	[0.077]	[0.138]
GREEN * Mutual funds	0.18***	0.36***	0.29***
	[0.067]	[0.072]	[0.131]
GREEN * Pension funds	0.11*	0.25***	0.15**
	[0.060]	[0.086]	[0.063]
Gravity factors * *HS*	YES	YES	YES
Bond characteristics * *HS*	YES	YES	YES
Issuer characteristics * *HS*	YES	YES	YES
Observations	497,819	80,580	132,216
R-squared	0.331	0.361	0.297

Notes: Dependent variable is log holdings amount. Cross-sectional demand functions for 2019-Q4 based on Eq. (2) with investor sector heterogeneity. Robust standard errors in brackets where *** p<0.01, ** p<0.05, * p<0.1. Each Column represents a single OLS regression specification where *HS* = investor sector dummies interacted with *GREEN* (the green bond indicator). All regressions include a full range of controls as included in the vector as presented in Table 3 but with interacted terms by *HS*. Column (1) is the full sample, Column (2) is a subsample of only green bond issuers and Column (3) includes only non-financials.

Table 7: Demand for sustainability-linked bonds other than green bonds

	(1)	(2)	(3)
SLB * Banks	-0.11	0.01	-0.10
	[0.114]	[0.143]	[0.190]
SLB * Government	-0.30*	-0.17	0.23
	[0.152]	[0.163]	[0.154]
SLB * Households	-0.27**	0.03	-0.23
	[0.117]	[0.165]	[0.154]
SLB * Insurance corporations	-0.41***	-0.18	-0.27**
	[0.096]	[0.120]	[0.122]
SLB * Mutual funds	0.19**	0.14*	0.13
	[0.076]	[0.091]	[0.112]
SLB * Pension funds	0.21**	0.19*	0.15
	[0.074]	[0.109]	[0.134]
Gravity factors * HS	YES	YES	YES
Bond characteristics * HS	YES	YES	YES
Issuer charactistics * HS	YES	YES	YES
Observations	588,242	147,217	165,265
R-squared	0.328	0.336	0.300

Notes: Dependent variable is log holdings amount. Cross-sectional demand functions for 2022-Q4 based on Eq. (2) with investor sector heterogeneity. Robust standard errors in brackets where *** p<0.01, ** p<0.05, * p<0.1. Each Column represents a single OLS regression specification where *HS* = investor sector dummies interacted with *SLB* (the sustainability-linked bond indicator, which is always zero for green bonds). All regressions include a full range of controls as included in the vector as presented in Table 3 but with interacted terms by *HS*. Column (1) is the full sample, Column (2) is a subsample of only *SLB* bond issuers and Column (3) includes only non-financials.

Table 8: Matching analysis - average treatment effect (ATT) on green bond holdings

ATT	Green	Other	Diff.	Green (n)	Other (n)
Banks	15.08	14.86	0.21*	3573	25997
Government	13.79	14.26	-0.47***	2007	9833
Households	12.15	12.76	-0.61***	2597	20832
Insurance corp.	14.78	15.16	-0.38***	6325	33270
Mutual funds	15.32	14.6	0.72***	11553	48200
Pension funds	14.48	14.14	0.34***	3484	15221
Non-financials	13.19	13.24	-0.05	1804	11793

Note: Results are based on propensity score matching using kernel with normal density. ATT is the average treatment effect on the treated. Only issuers are included that have both green bonds and other bonds. Each row represents a subsample of different investor sector. To calculate the propensity score in the first-stage with a probit model, the following variables are used to match green bonds with other bonds: amount outstanding, currency, yields, residual maturity, coupon type, eligibility for collateral status and issuer sector.

Table 9: Green bond demand by investor sector (time-series)

	(1)	(2)	(3)
GREEN * Banks	-0.13*	0.05	0.15
	[0.084]	[0.110]	[0.104]
GREEN * Government	-0.06	0.11	0.07
	[0.154]	[0.128]	[0.132]
GREEN * Households	-0.16	-0.16*	-0.30**
	[0.142]	[0.093]	[0.131]
GREEN * Insurance corporations	-0.24***	-0.32***	-0.26**
	[0.107]	[0.119]	[0.114]
GREEN * Mutual funds	0.20	0.30**	0.29**
	[0.104]	[0.116]	[0.104]
GREEN * Pension funds	0.15	0.29*	0.25**
	[0.104]	[0.156]	[0.101]
Gravity factors * HS	YES	YES	YES
Bond characteristics * HS	YES	YES	YES
Issuer characteristics * HS	YES	YES	YES
Time FE	YES	YES	YES
Observations	12,474,824	4,101,658	3,851,234
R-squared	0.335	0.354	0.332

Notes: Dependent variable is log holdings amount. Time-series demand functions for 2016Q4-2022-Q4 based on Eq. (2) with investor sector heterogeneity and time dimension (including fixed effects). Robust standard errors clustered at investor country and investor sector in brackets where *** p<0.01, ** p<0.05, * p<0.1. Each Column represents a single OLS regression specification where *HS* = investor sector dummies interacted with *GREEN* (the green bond indicator). Estimates against benchmark of Other financial intermediaries and non-financials which have no preferences over green (e.g. Column (1): est. coeff. = 0.05 with s.e. 0.064), with corrected coefficients and s.e. displayed for other *HS*. All regressions include a full range of controls as included in the vector as presented in Table 3 but with interacted terms by *HS*. Column (1) is the full sample, Column (2) is a subsample of only green bond issuers and Column (3) includes only non-financials.

Table 10: Green bond price sensitivity across investors

	(1)	(2)	(3)	(4)	(5)	(6)
	full		green bond issuers		bonds non-financials	
	price delta	price volatility	price delta	price volatility	price delta	price volatility
GREEN * Banks	-0.18*	-0.19*	-0.14	-0.12	-0.19	-0.13
	[0.098]	[0.113]	[0.092]	[0.106]	[0.123]	[0.131]
GREEN * Government	-0.04	-0.02	0.13	0.15	0.01	0.01
	[0.149]	[0.182]	[0.132]	[0.172]	[0.166]	[0.166]
GREEN * Households	-0.33***	-0.19*	-0.31**	0.12	-0.32**	-0.25
	[0.123]	[0.117]	[0.167]	[0.180]	[0.164]	[0.197]
GREEN * Insurance C.	-0.40***	-0.49***	-0.21*	-0.28**	-0.29***	-0.29***
	[0.121]	[0.140]	[0.117]	[0.134]	[0.136]	[0.136]
GREEN * Mutual funds	0.25*	0.29**	0.28**	0.24*	0.28***	0.23**
	[0.121]	[0.136]	[0.139]	[0.142]	[0.101]	[0.124]
GREEN * Pension funds	0.19*	0.18*	0.31**	0.34*	0.17	0.33***
	[0.092]	[0.110]	[0.132]	[0.184]	[0.146]	[0.123]
ΔPRICE	0.07	0.05	0.32**	-0.18	0.04	-0.01
	[0.107]	[0.350]	[0.140]	[0.340]	[0.135]	[0.308]
*GREEN*ΔPRICE*	1.11*	-0.75	1.13*	-0.75	1.04*	-1.64
	[0.627]	[0.998]	[0.640]	[1.034]	[0.593]	[1.127]
Triple interactions:						
*GREEN*bank*ΔPRICE*	-1.63**	0.37	-1.60**	1.07	0.18	-1.64
	[0.712]	[1.262]	[0.773]	[1.406]	[1.131]	[1.127]
*GREEN*gov*ΔPRICE*	0.07	0.05	-0.20	0.10	-1.12	2.50
	[1.181]	[1.693]	[1.371]	[1.996]	[1.063]	[1.591]
*GREEN*hhold*ΔPRICE*	0.00	0.28	-0.01	0.29	-0.37	0.42
	[0.845]	[1.237]	[0.966]	[1.410]	[0.912]	[1.369]
*GREEN*insur*ΔPRICE*	-1.24*	3.32***	-0.80	2.38*	-1.38	3.81***
	[0.732]	[1.201]	[0.826]	[1.289]	[0.878]	[1.272]
*GREEN*mutfd*ΔPRICE*	-0.90	1.48	1.50**	1.90*	1.45	1.35
	[0.734]	[1.127]	[0.713]	[1.121]	[1.036]	[1.236]
*GREEN*pfd*ΔPRICE*	0.37	-0.59	0.06	0.75	1.84**	-0.05
	[1.096]	[1.248]	[1.051]	[1.034]	[0.793]	[1.269]
Gravity factors * HS	YES	YES	YES	YES	YES	YES
Bond character. * HS	YES	YES	YES	YES	YES	YES
Issuer character. * HS	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Observations	9,586,147	9,365,776	3,134,458	3,046,409	2,922,245	2,855,066
R-squared	0.337	0.337	0.358	0.359	0.334	0.335

Notes: Dependent variable is log holdings amount. Time-series demand functions for 2016Q4-2022-Q4 based on Eq. (3) with investor sector heterogeneity and time dimension (including fixed effects). Robust standard errors clustered at investor country and investor sector in brackets where *** p<0.01, ** p<0.05, * p<0.1. Each Column represents a single OLS regression similar to Table 5 but with the main interaction terms further interacted with *ΔPRICE*. Columns (1-2) are the full sample, Column (3-4) are subsamples of only green bond issuers and Column (5-6) include only non-financials.

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