Who pays the greenium?

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Abstract: Merging a sample of matched green-conventional bond pairs with data on their ownership structure, we document that the greenium (the yield differential between green and conventional bonds) is largely borne by banks, investment funds, pension funds, insurances and their clients. Strikingly, while investment funds and pension funds pay the greenium largely due to their clients' general green preference, banks display no such pattern. Rather, banks overweight certain bonds that display a sizeable greenium, pointing towards an interaction between the greenium and bank-specific financial frictions. Overall, our findings shed light on the question who finances the green transition and who ultimately pays the costs arising from greening investment portfolios.

Keywords: Green bonds, sustainable investment, greenium, ownership structure, securities holdings

JEL: G11, Q01

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1 Introduction

The transition towards a climate-neutral economy is one of the biggest challenges of our times and will require massive investments. For example, in 2019 the European Union announced its so-called Green Deal, aiming to mobilize 1 EUR trillion in investments until 2030 to make Europe the first continent with net zero carbon emissions by 2050. At the same time, the market for sustainable investments is growing at tremendous speed, with an increasing number of investors explicitly seeking funding for green projects. For instance, according to Refinitiv Lipper, the assets under management of ESG-related investment funds in Europe amounted to 5.4 trillion EUR (representing 37% of the total assets under management) as of 2022-Q1. Against this background, our paper makes progress concerning three important research questions: (i) Who finances the green transition, i.e., who invests in green projects or assets? (ii) Who pays for it, i.e., how are the profits/costs from greening investment portfolios shared among investors? (iii) What determines these shares?

Studying these questions requires granular information on the funding structure of green and otherwise equivalent non-green projects, which is – at the current juncture – often hampered by data availability issues. We overcome this challenge by focusing on one particularly relevant market segment that provides a unique laboratory for this purpose, namely green bonds. Green bonds are bonds whose proceeds are tied to the financing of specific environmental and climate-friendly projects. The respective commitment of the issuers is usually certified by an external agency like the Climate Bonds Standard Board. A general consensus has emerged that sustainable (clean, green, etc.) assets have higher prices and thus lower expected returns than otherwise equivalent non-sustainable assets.[1] Consequently, also green bonds tend to trade at a premium relative to otherwise comparable conventional bonds – a finding which we confirm for our specific sample.

To address the three research questions stated above, we construct a unique dataset that allows us to explore the relationship between the pricing of green bonds and their ownership structure. More precisely, following the literature, we match green bonds with conventional "twins" of the same issuer along a set of standard matching criteria. Our final sample consists of 161 green-conventional bond pairs from issuers domiciled in developed economies over the period from January 2015 up until March 2022. We then merge this sample with confidential data on the dynamic ownership structure of each bond by investor group from the Eurosystem's Securities Holdings Statistics (SHS). The average yield differential between a green bond and its conventional twin on the secondary market – labeled as "greenium" throughout the paper – amounts to roughly minus 3 basis points across our sample. Stated differently, the average green bond investor pays a greenium, i.e., forgoes a few basis points in bond yield as compared to an otherwise equivalent conventional investment. These numbers are economically relevant: according to statistics from the BIS, the total amount outstanding of green bonds was approximately 2 trillion USD in 2022-Q2. If the global green bond universe displayed a comparable greenium, these 3 basis points would thus correspond to roughly 600 million USD.

[1] See, e.g., Pedersen, Fitzgibbons, and Pomorski (2021), Pastor, Stambaugh, and Taylor (2022), Bolton and Kacperczyk (2021), Ilhan, Sautner, and Vilkov (2021).

Based on our dataset, we document a set of novel findings that address the research questions above. First, the greenium is largely borne by banks, investment funds and insurance companies (and their respective clients), which are the key investor groups in this market. Second, investment funds and pension funds overweight green over matched conventional bonds on average, potentially reflecting strong green preferences of their clients. By the same measure, banks and insurances tend to display negative green preferences. Third, despite these negative green preferences, banks (and their clients) still bear a significant share of the overall greenium. More precisely, banks display a tilt towards a subset of green bonds with a relatively pronounced greenium. This tilt is particularly sizeable among young bonds, small bonds, or bonds issued by the financial sector. We draw the tentative conclusion that banks (and their clients) pay a significant greenium because they hold specific green bonds for motives other than general green preferences, like financial intermediary frictions or intermediary services offered by banks.

To address question (i) – who finances the green transition –, our analysis starts from the shares of each investor group in the overall holdings of green bonds. Banks, investment funds and insurances are the largest investor groups in green bonds. As such, a substantial part of the green transition is financed through them. We then compare these green bond ownership shares to the ownership shares in the conventional counterparts. The average degree of over-/underweighting can be interpreted as a rough proxy for the general green preferences of the respective sector. We find a substantial average green overweighting for investment funds and pension funds. For instance, investment funds have an average ownership share of 29% in the green bonds in our sample, as opposed to 24% in the respective conventional twins. Arguably, these two groups closely stick to an investment mandate given by their clients, so we conclude that the clients of investment and pension funds appear to have particularly strong green preferences.[2] This intuition is confirmed by the respective green preference term of private households' direct bond investments - notwithstanding that the size of these direct investments is relatively small. On the other hand, by the same measure, we find that banks and insurance companies tend to exhibit negative green preferences. In other words, these investor groups tend to overweight conventional over green bonds on average. For example, banks' average ownership share in green bonds is 15% as opposed to 18% in conventional twins.

The greenium displays considerable cross-sectional and time-series variation in our sample. For instance, the average of about minus 3 basis points is estimated with a standard error of 1.6 basis points. Moreover, the greenium becomes more pronounced in the second half of our sample, i.e., after 2019. This variation allows us to elaborate on question (ii) above, namely who pays the greenium, because investors could in principle decide to primarily invest in green bonds that display no greenium whatsoever. Arguably, such investors could claim to finance the green transition (i.e., invest in green bonds) without having to pay for it. To this end, we split the average greenium into sector-specific shares and find that the greenium is largely shared by institutional investors such as insurances, banks and investment funds. Given the documented

[2] While anecdotal evidence suggests that retail clients display particularly strong green preferences, our dataset does not allow us to check whether investment funds and pension funds in our sample are predominantly retail-owned. This is due to the fact that the bond ownership data in the SHS are only provided at the aggregate investor sector level, not at a more granular institutional portfolio level. For the same reason, we also cannot see to what extent banks or investment funds can pass the additional costs from investing in green assets on to their customers, i.e. how the greenium is actually split up between shareholders and clients of these sectors.

negative general green preferences in the case of banks, it is remarkable that a large fraction of the greenium can be attributed to this investor group.

To further understand this finding, we decompose the greenium of each group into three distinct subcomponents: the first component is a *benchmark greenium* that would be paid/earned if the shares of each investor group in each green bond were exactly identical to the shares in the respective conventional twin. We view this benchmark as representing a simple null hypothesis, quantifying a sector's greenium that would be observed if the sector treated green and conventional bonds identically and thus simply replicated the ownership shares. The second component is the part of the greenium which is paid/earned because an investor group over-/underweights green bonds relative to conventional bonds on average, across the entire green bond market. It is a multiple of the *general green preference* of a sector discussed above. The third component reflects the part of the greenium which is paid/earned through *bond-specific over-/underweighting* of green bonds whose greenium deviates from the average. Economically, the third component subsumes the part of the group-specific greenium which is paid for reasons other than (I) replicating the equivalent conventional bond portfolio or (II) general green preferences.

Importantly, we find that the benchmark greenium does not fully explain the total greenium. It is close to, but slightly smaller than the total greenium for both investment funds and pension funds. The deviations tend to be larger in the case of banks and insurances. Hence, across investor groups, the other two components must play a role. As stated above, the (perhaps client-induced) green preference component is significantly negative for both investment funds and pension funds, and significantly positive for banks and insurances. In other words, banks and insurances rather capitalize on the green preferences of other investors and earn an extra yield on their green bond portfolios through this channel.

On the other hand, the third component is insignificant for all major groups except banks, for which it is strongly negative. This suggests that banks (or their clients) actually pay the greenium largely due to a very specific tilt towards green bonds with a sizeable greenium. Additional analyses reveal that this tilt is particularly pronounced in subsamples of young bonds, small bonds, and bonds issued by the financial sector. These results point towards a potential conflict between the objective of earning (or at least, avoiding to pay) the greenium and other services of banks. Examples may be market making activities, bond underwriting services or other forms of liquidity transformation. The trade-off between such alternative objectives and avoiding the greenium may be particularly relevant, for instance, when operating in the segment of small or young bonds. Interestingly, the third component has the opposite (i.e., positive) sign for private households' direct bond investments. We interpret this finding as confirming the link between intermediary frictions and the greenium because private households who invest in bonds directly are arguably the least subject to such frictions.

Overall, our findings contribute to the ongoing debate about price differentials between green and conventional financial assets and their sources. The most prominent theoretical channel is put forward, among others, by Pedersen et al. (2021) or Pastor, Stambaugh, and Taylor (2021). These authors argue that a premium arises because a subset of investors has a non-pecuniary preference for sustainability. More precisely, they study preference functions that are determined by three inputs: expected return, volatility of return and sustainability. This results in investors preferring sustainable assets for reasons that are orthogonal to the risk-return trade-off which usually determines optimal portfolios. In equilibrium, sustainable assets then trade at a premium compared to non-sustainable assets. The green preference narrative is also corroborated by empirical evidence from surveys.[3] Our results on the green bond market broadly confirm this general line of theory, since the greenium that investment funds and pension funds (and their clients) pay appears to be largely driven by their green preferences.

On the other hand, our findings on the banking sector leave ample room for further channels. For instance, Larcker and Watts (2020) argue for a link between intermediary asset pricing and the greenium. The greenium might be larger, the more a green bond is held by marginal investors, which are typically banks. More broadly, frictions in the financial intermediary sector, like liquidity concerns or regulatory credit constraints, may amplify the price differential between sustainable and non-sustainable assets. While we cannot directly test such hypotheses within our empirical setup, our results may still give support for them. Importantly, however, this intuition also points towards a possible reverse causality argument: certain green assets may trade at a particularly high premium *because* they are held mostly by banks for reasons other than just being green. Generally, our current analysis does not allow us to make causal statements in this regard. However, we view our results as evidence that prices and quantities, i.e. eventually supply and demand, on the market for sustainable assets are driven by more than just the green preferences of investors.

2 Literature

Our paper is linked to several strands of literature. First, there has been an active debate about the existence and the magnitude of the greenium on the green bond market. While Baker, Bergstresser, Serafeim, and Wurgler (2022) document a greenium of about six basis points in the primary market for U.S. municipal and corporate green bonds, Larcker and Watts (2020) find no significant greenium in the primary market for U.S. municipal bonds and conclude that the greenium may be difficult to detect in situations where investors with green preferences are not marginal. Karpf and Mandel (2017) even find a green bond discount in the secondary market for U.S. municipal green bonds. In a broad global sample that ends in 2017, Zerbib (2019) finds a greenium of about two basis points in the secondary market. Using international data, Tang and Zhang (2020) again find no significant greenium for green corporate bonds in the primary market. Dorfleitner, Utz, and Zhang (2021) document a greenium of up to five basis points in the secondary market based on a broad international dataset. Kapraun, Latino, Scheins, and Schlag (2021) argue that the most important determinant for the greenium is green-credibility of the issuer and of the entity which issues the green label. In a similar vein, Fatica, Panzica, and Rancan (2021) argue that a greenium exists for supranational and corporate issuers, but not for green bonds issued by financial institutions. Zhang (2022) finds that the greenium also depends on the stringency of climate policy across countries.

[3] See, e.g., Krueger, Sautner, and Starks (2020) or Sangeorgi and Schopohl (2021a,b).

A related strand of literature studies the effects of green bond issuance on firms' equity prices. Most prominently, Flammer (2021) and Tang and Zhang (2020) document that the issuance of green bonds is viewed as a positive signal by investors: equity prices increase in response to it. This is confirmed by surveys that try to elicit the motives of different players in the market for sustainable assets. Krueger et al. (2020) provide evidence from a survey among institutional investors and argue that green preferences indeed exist, for instance for a subset of the clients of these institutional investors. In a similar survey, Sangeorgi and Schopohl (2021b) document a strong (unmet) demand for green bonds from non-financial corporates. They argue that unclear and poor reporting is the largest obstacle for such investors. Using a survey among issuers, Sangeorgi and Schopohl (2021a) document that reputational benefits and the signaling power of green bonds are the most important reasons to issue green bonds, in line with the green preference hypothesis explained above.

There is also a literature studying the ownership structure of green bonds. Closely related is the paper of Pietsch and Salakhova (2022) who find that, among others, the demand from retail investors is a significant driver of the greenium. Baker et al. (2022) document that green bonds have more concentrated ownership and green bonds are more often held by green investors (as measured through hand-collecting socially responsible investors by the names of the respective investment funds). Bremus, Schütze, and Zaklan (2021) study the effects of central bank asset purchases, more precisely the ECB purchase programs on yields of green bonds. They find that the yield of green bonds that are eligible for these purchase programs decreases in response to the announcements of the programs. Yang (2021) studies green investor clientele effects and documents that green bonds are generally more resilient to liquidity shocks than conventional bonds because investors with green preferences alleviate search frictions in OTC markets. Brøgger and Kronies (2021) separate institutional investors into groups, taking into account whether they are constrained or unconstrained in their investment mandates. They document that the prices of high-ESG stocks go up, leading to lower expected returns going forward, when ESG-motivated investors buy these stocks. In a similar vein, Starks, Venkat, and Zhu (2019) document that long-horizon (i.e., low turnover) investors tilt their portfolios towards stocks of high-ESG firms.

Lastly, our paper is linked to the fast-growing broader literature on sustainable investing. Giving a comprehensive overview of this enormous field goes beyond the scope of this paper. Theoretical and empirical contributions have been made, among others, by Pedersen et al. (2021), Pastor et al. (2021), Oehmke and Opp (2020), Pastor et al. (2022), Bolton and Kacperczyk (2021), Zerbib (2022), Ilhan et al. (2021). Our paper also has connections to a recently growing literature on potential real effects from sustainable investing. Most likely, such real effects are shaped by differences in the ownership structure of green assets. For instance, De Haas and Popov (2021) argue that carbon emissions are generally lower in economies that are more equity-financed. Azar, Duro, Kadach, and Ormazabal (2021) observe a strong negative association between equity ownership by the Big Three (BlackRock, Vanguard and State Street Global Advisors) and firms' subsequent carbon emissions.

3 Data and Descriptive Statistics

3.1 Data

We merge data from three different datasets: first, we obtain a historical list of green bonds from issuers domiciled in developed economies (incl. supranationals and sovereigns) from Eikon. Based on this list, we also extract data on all conventional bonds of the same issuers and their characteristics from the Eurosystem's Centralized Securities Database (CSDB). As we explain in more detail below, we then match each green bond with the most similar conventional bond of the same issuer. For these matched bond pairs, we obtain data on monthly yields from Eikon. Lastly, we draw upon the Eurosystem's Securities Holdings Statistics (SHS), which allows us to track the dynamic ownership structure of matched bond pairs in our sample. More specifically, the SHS contains the quarterly securities holdings by investor group as reported by euro area custodians. The sectoral classification is based on the European System of Accounts (ESA) 2010 and we focus on the main investor groups of our sample bonds, namely *monetary financial institutions* (MFIs; S 122) *investment funds* (IFs; S 124), *insurance companies* (ICs; S 128), *pension funds* (PFs; S 129), the *Eurosystem* (EuSys; S 121), and private households (HHs; S 14 and S 15). We aggregate smaller sectors (such as non-financial companies) and unallocated investors in a category labeled as *others*. Since bonds may be held at custodians outside the euro area, we define a residual sector labeled *foreign*. This ensures that, for any given bond, the total holdings across all investor groups x will correspond to the bond's total amount outstanding.

To make sure that the investor groups of interest are economically important for our sample bonds, we focus on bond pairs where euro area investors, on average, hold at least 50% of a green bond's total amount outstanding.[4] Our final sample covers 161 green-conventional bond pairs with 3,142 observations over the period January 2015 until March 2022. Reflecting the massive growth of the green bond market in recent years, the bulk of observations are in the second half of the sample period, and we have only around 150 observations prior to 2018. Bond yields are winsorized at the 1st/99th percentile.

3.2 Matching

Following standard practice, we apply a matching approach that pairs each green bond with its most similar conventional "twin". We only take into account conventional bonds from the same issuer that have the same (nominal) currency, the same bond type, the same coupon type and the same seniority and thus in particular also the same credit risk. Moreover, we allow both the issue date and the maturity date of the paired bonds to differ by at most one year, and we require the green bond's total amount outstanding to be within 50% and 200% of the amount outstanding of the conventional bond. In case there are multiple conventional bonds that match all of the above requirements for a given green bond, we pick the conventional bond with the smallest normalized (Euclidean) distance in terms of issue date, maturity date and total amount outstanding.

[4] In additional robustness analyses, we checked that our main findings are qualitatively similar for lower thresholds (e.g., 25% or 33% cutoffs).

These strict matching criteria reduce our sample size substantially, i.e., many green bonds do not have a conventional twin according to this specification. We end up with a total number of 436 matched bond pairs for which monthly secondary market yields are available from Eikon. After applying the SHS coverage filter, this number drops further to 161 bond pairs. Table 1 reports basic summary statistics on our matched sample. Table A.1 in the Online Appendix compares the sample composition before and after the application of the SHS coverage filter. Naturally, as we would expect, our final sample consists predominantly of EUR-denominated bonds from Euro area issuers. The sample is also dominated by financial issuers with investment-grade rating (often above BBB).[5]

	(1) Green	(2) Conventional
Bond size (in EUR million)	457.317	545.181
Original maturity (in years)	8.861	8.907
Yield (in percent)	0.533	0.561
Observations	3,142	
Bond-pairs	161	

Table 1: Summary statistics on matched bond-pairs.

3.3 Descriptive statistics

We introduce some notation that will be useful also in subsequent sections.[6] We denote the yield-to-maturity for a given pair of green and conventional bonds i by y_i^G and y_i^C, respectively. The EUR amounts that sector x has invested in green or conventional bond i are denoted by $n_{i,x}^G$ and $n_{i,x}^C$, respectively. From these amounts, we can compute the share of a bond i that is held by sector x:

$$s_{i,x}^C = \frac{n_{i,x}^C}{\sum_y n_{i,y}^C}, \quad s_{i,x}^G = \frac{n_{i,x}^G}{\sum_y n_{i,y}^G} \tag{1}$$

Note that the denominator is equal to the total amount outstanding of bond i in our sample, such that the shares sum up to one:

$$\sum_x s_{i,x}^G = 1 \text{ and } \sum_x s_{i,x}^C = 1 \ \text{ for all } \ i. \tag{2}$$

We denote the greenium of bond pair i as $g_i = y_i^G - y_i^C$. Importantly, throughout the paper, differences are always taken as “green minus conventional” (not “conventional minus green”).

[5]There are several instances in our sample, where a non-financial company owns a financial subsidiary which acts as the official issuer of the firm's corporate bonds. We therefore manually correct the sector classification from the CSDB. For the sake of completeness, we also run our empirical tests with the non-corrected sample and find that our results are generally robust.

[6]For ease of notation, we drop time subscripts t in the following. Unless stated otherwise, the empirical analyses are based on the pooled sample.

We denote equally weighted averages by a bar, e.g.

$$\bar{g} = \frac{1}{\#i} \sum_i g_i. \tag{3}$$

Similarly, we denote the average share of green bonds that is held by sector x by

$$\bar{s}_x^G = \frac{1}{\#i} \sum_i s_{i,x}^G. \tag{4}$$

3.3.1 Greenium

We first provide some descriptive statistics on our matched sample. Of particular interest is the (average) greenium. Figure 1 depicts the development of the unconditional, equal-weighted average greenium $\bar{g}$ over time. The vertical bars denote the 95% confidence interval at each point in time. Similarly, Figure 2 presents the average greenium when the bonds are value-weighted, based on bond size.

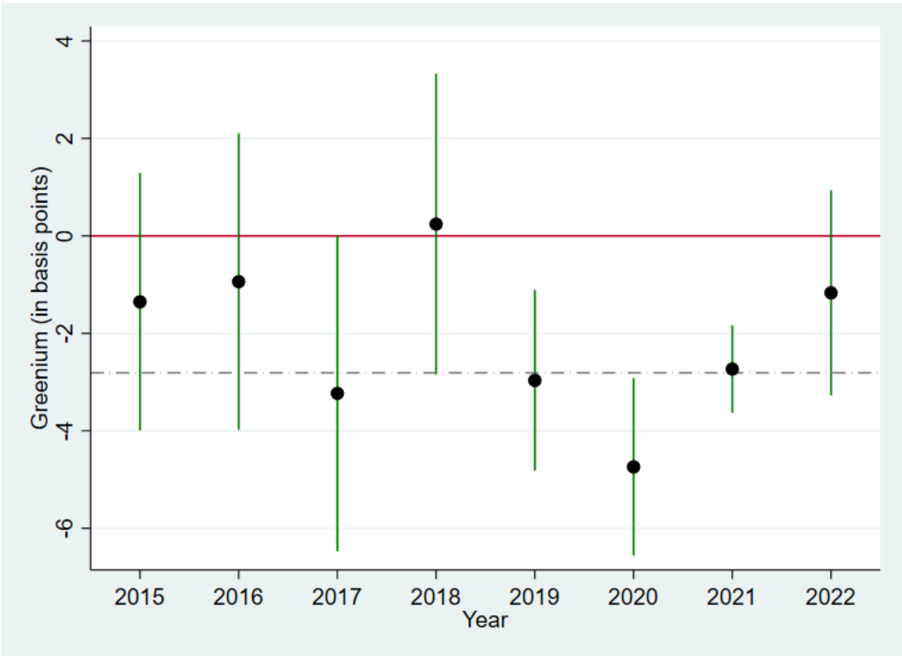

Figure 1: Greenium Over Time (Equal-Weighted).

Black dots indicate the (equal-weighted) average greenium $\bar{g}_t$ in our sample. The vertical lines indicate the 95% confidence intervals of the greenium in each cross-section (robust standard errors). The dashed gray line shows the full sample equal-weighted average greenium of -2.8 basis points.

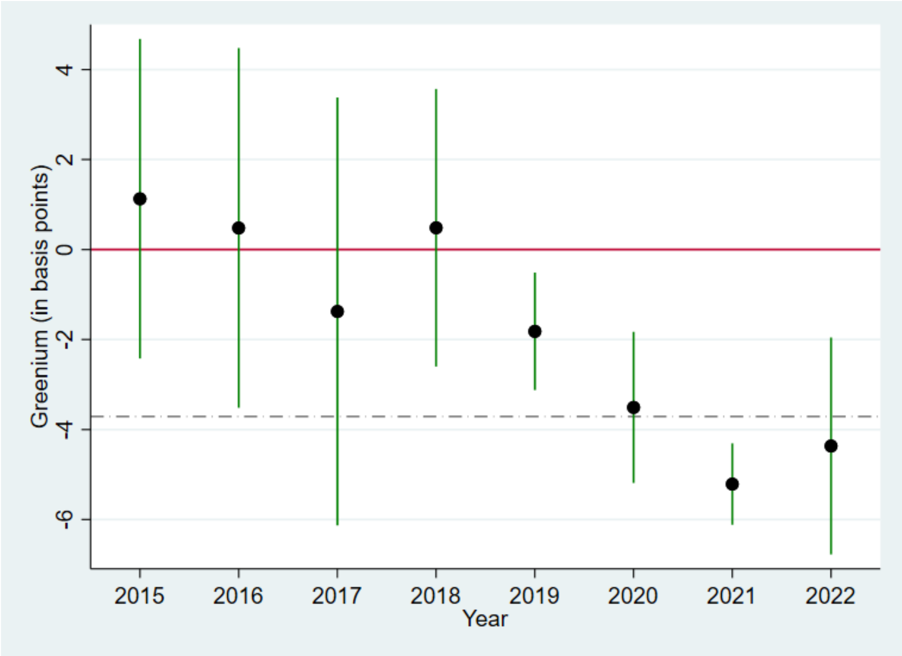

Figure 2: Greenium Over Time (Value-Weighted).

Black dots indicate the (value-weighted) average greenium $\bar{g}_t$ in our sample. The vertical lines indicate the 95% confidence intervals of the greenium in each cross-section (robust standard errors). The dashed gray line shows the full sample value-weighted average greenium of -3.7 basis points.

In line with previous work (e.g., Baker et al. (2022), Zerbib (2019)), we find that the average greenium tends to be negative. Hence, green bonds trade at lower yields (and higher prices) than their conventional counterparts. Moreover, the greenium has become more pronounced over time, which is in line with empirical evidence for other asset classes like equity, derivatives or corporate loans (see, e.g., Bolton and Kacperczyk (2021), Ilhan et al. (2021), Delis, de Greiff, and Ongena (2021)). This trend potentially reflects the increasing relevance of environmental concerns and climate-related risks for investors in general. In terms of economic magnitude, the greenium fluctuates around 3-4 basis points in the most recent years, where the bulk of our sample is concentrated. Both the negative time trend since 2018 and the magnitude of the greenium are more pronounced in the value-weighted analysis. Larger (and potentially more liquid) bonds display a larger greenium of around 6 basis points in the most recent sample. We will return to this point below.

3.3.2 Who finances the green transition? Bond ownership structure

Before exploring the relationship between the greenium and a bond's ownership structure in more detail, Figures 3 and 4 illustrate the typical ownership structure of the green and conventional bonds in our sample. More precisely, the top panel of Figure 3 shows the average shares $\bar{s}_x^G$ and their respective counterparts $\bar{s}_x^C$, i.e., it quantifies which fraction of the green or conventional bonds in our sample is held by which investor group. Figure 4 shows the respective value-weighted averages (based on bond size). The top left panels allow us to answer our first research question: banks, investment funds, and insurances are the most important investors in green bonds. Arguably, it is the clients of these sectors who provide financing for the green transition.

The results are more nuanced in the case of private households: their direct investments in bonds (both green and conventional) are indicated by the green bars in Figures 3 and 4. The relative shares are quite sizeable when all bonds are equally weighted, but negligible when they are value-weighted. This indicates that private households' direct investment is largely focused on relatively small bonds.

The lower panels then depict the average ownership differentials by investor group, based on the average holdings in the top panels. These average differentials indicate how much each sector over-/underweights green bonds relative to their conventional counterparts in general. As such, these differentials can serve as rough proxies for a given sector's general green preference. This interpretation is roughly in line with theoretical models like the ones by Pedersen et al. (2021) or Pastor et al. (2021). Assuming that the "greenness" of all bonds in our sample is of a similar magnitude, a group of investors that is guided solely by green preferences should be expected to invest the same fraction of wealth in each available green asset, irrespective of any differences across the greeniums of these assets. When viewed from such a perspective, our results indicate that investment funds have the largest green preference, followed by private households and pension funds. This is in line with anecdotal and survey evidence (see, e.g., Krueger et al. (2020) or Sangeorgi and Schopohl (2021b)). Investment and pension funds manage portfolios on behalf of their clients, such that the green preferences of these clients arguably carry over to

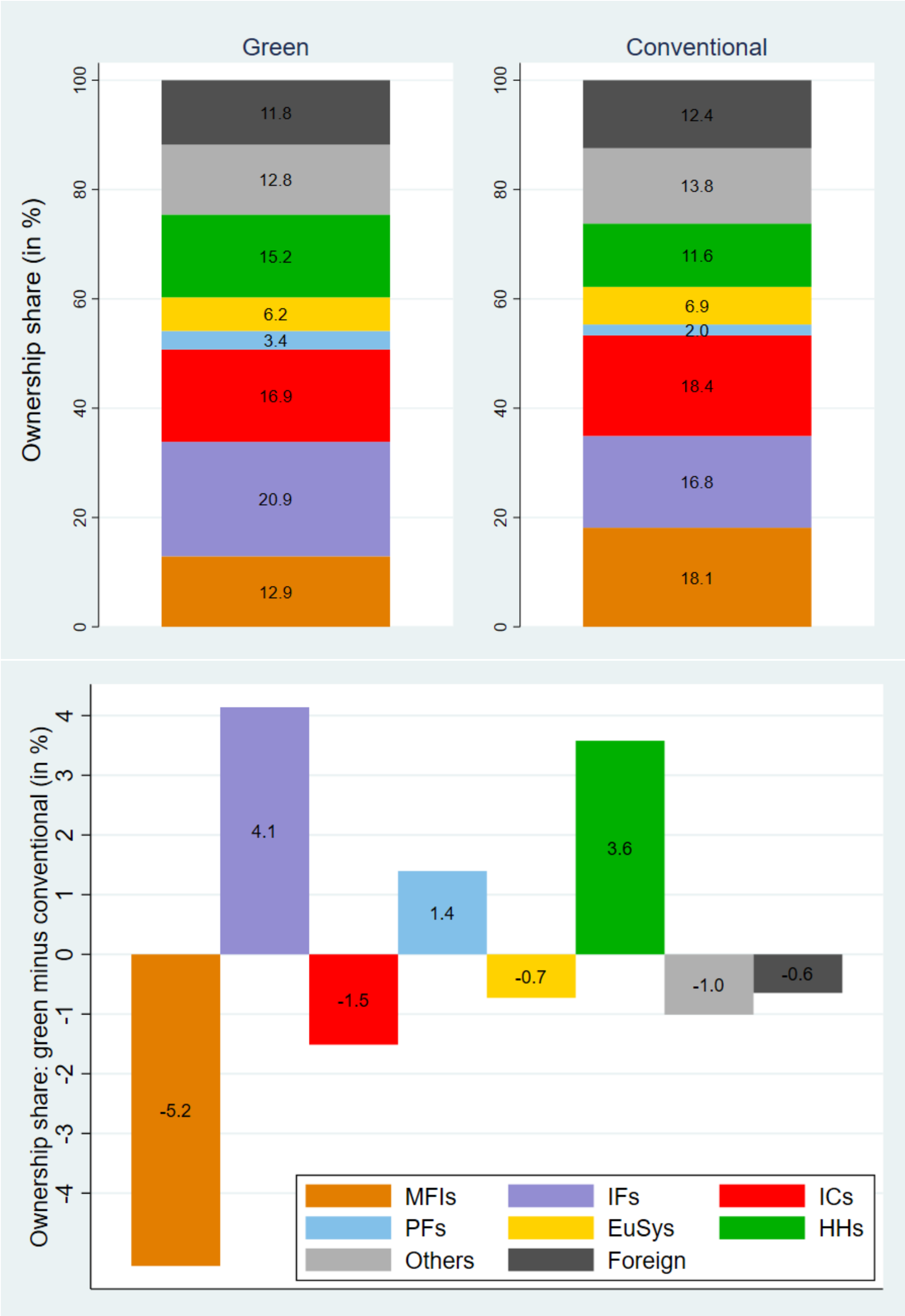

Figure 3: Ownership Structure (Equal-weighted).

The figure displays the average (equal-weighted) ownership structure of green and conventional bonds in our sample. The bottom graph depicts the difference between the numbers in the two upper graphs. The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), the Eurosystem (EuSys), and private households (HHs).

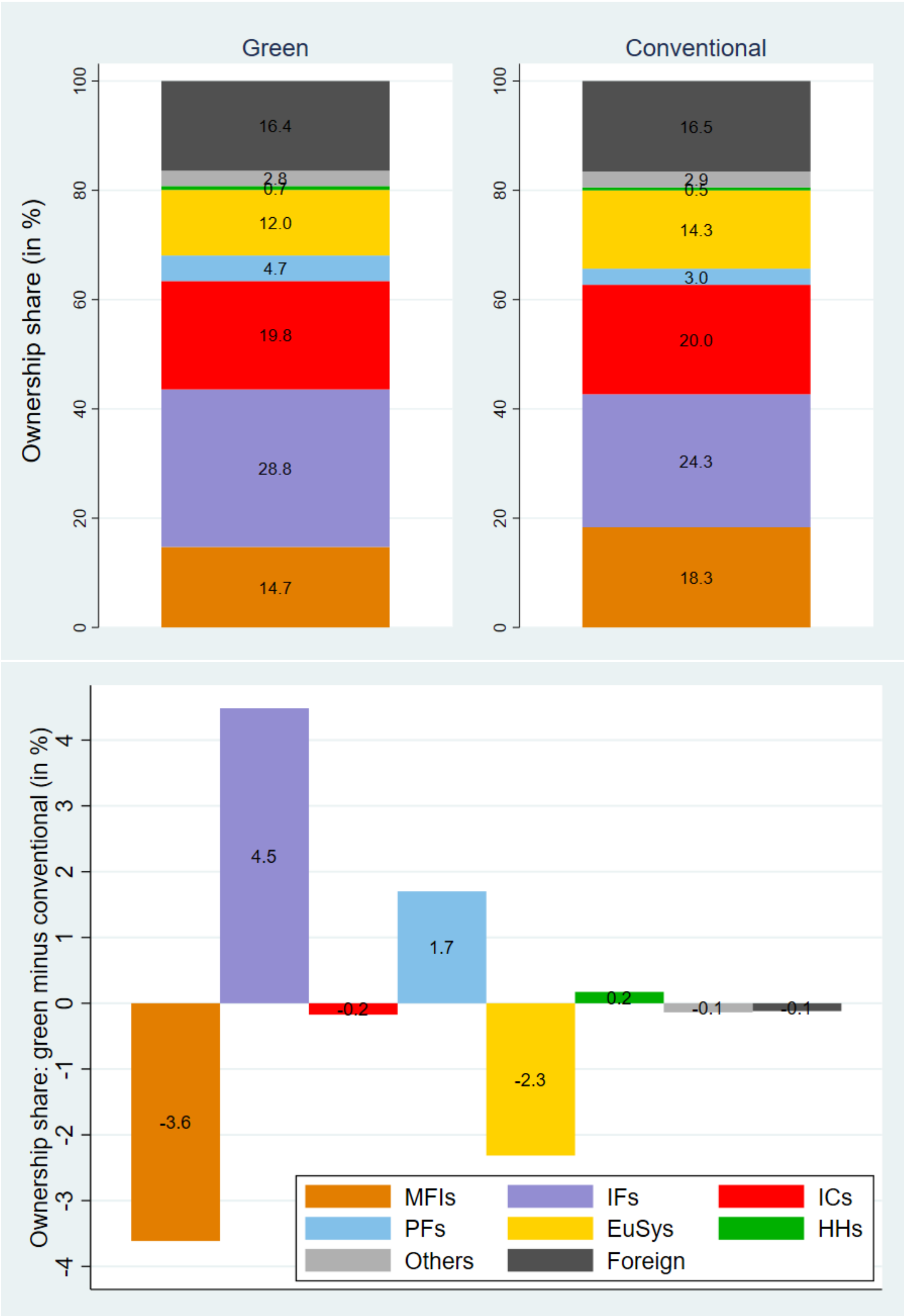

Figure 4: Ownership Structure (Value-weighted).

The figure displays the average (value-weighted) ownership structure of green and conventional bonds in our sample. The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), the Eurosystem (EuSys), and private households (HHs).

the portfolios of the funds in which they invest.[7]

Banks display a strong negative green preference. Hence, they generally underweight green bonds as compared to their conventional counterparts. For insurances, we see a smaller negative green preference when all bonds are equally weighted, but the sign switches in the value-weighted case. This implies that insurances tend to underweight rather small green bonds (relative to their small conventional counterparts). For the Eurosystem, we see a slight underweighting in both cases but these deviations are not statistically significant. We view this pattern as being in line with the principle of market neutrality which guided the Eurosystem's asset purchase programs over the course of our sample period.[8]

Lastly, we find that the residual category of other investors tends to overweight green bonds in the equal-weighted case. In the value-weighted case, however, we find no differential. This suggests that these investors tend to overweight relatively small green bonds. Foreign investors, on the other hand, consistently display a strong negative green preference, i.e., are more strongly invested in conventional bonds.

In the Online Appendix, we have depicted annual time series of the share differentials shown in the lower panels in Figures 3 and 4. After 2018, as the sample grows bigger, the graphs indicate little variation over time in general, with one notable exception, namely the late arrival of private households. For them, the green preference shows a substantial increase after 2020 (at least in the equal-weighted case), in line with the findings of Pietsch and Salakhova (2022).

4 Who pays the greenium (and why)?

So far, we have established that (i) there is a small, but significant and time-varying greenium in our matched sample and that (ii) certain investor groups over-/underweight green bonds on average, thereby revealing a positive or negative general green preference. In line with the main goal of this paper, this section now takes a closer look at the relationship between the greenium and a bond's ownership structure.

4.1 Who pays the greenium on average?

To this end, we first decompose the total greenium into investor group-specific contributions. Relying on the notation introduced above, we can rewrite $\bar{g}$ as

$$\bar{g} = \frac{1}{\#i} \sum_i \underbrace{\left(\sum_x s_{i,x}^G \right)}_{=1} g_i = \frac{1}{\#i} \sum_x g_x \tag{5}$$

[7]Unfortunately, our dataset does not allow us to look through the different investor groups in our sample and find out the ultimate investors behind each group, in order to check whether, e.g., investment funds and pension funds are predominantly retail-owned. The bond ownership data from the SHS are only provided at the aggregate investor group level, but not at a more granular institutional portfolio level.

[8]For the sake of completeness, Figure A.1 in the Internet Appendix shows the ownership differentials by investor group over time.

where g_x is the greenium that sector x earns/pays for its green bond portfolio

$$g_x = \sum_i s^G_{i,x} g_i. \tag{6}$$

The first row in Table 2 reports g_x across sectors, i.e. it quantifies which sector pays which part of the greenium. All numbers in Table 2 are scaled by a factor $\frac{1}{\#i}$, so that, by construction, the numbers in the first row add up to the total greenium given in the first column. Based on these numbers, we can address the research question posed in the title of this paper. Out of the average total greenium of roughly minus three basis points, insurances bear more than half, investment funds bear one third and banks bear another quarter. Thus, these three groups of institutional investors (or their clients) pay the bulk of the greenium.[9] Table 4 below confirms that this finding for a value-weighted decomposition. In this case, both banks and investment funds bear an even larger share of the overall greenium. Given the pronounced cross-sectional heterogeneity, the point estimates for insurances are however not statistically significant in both cases.

	Total	MFIs	IFs	ICs	PFs	EuSys	HHs	Others	Foreign
Greenium (g_x)	-2.811*	-0.529**	-0.918**	-1.570	-0.090	-0.030	0.370*	0.380	-0.423**
	(-1.723)	(-2.109)	(-2.388)	(-1.329)	(-1.102)	(-0.353)	(1.869)	(1.528)	(-2.443)
I: Benchmark Greenium		0.185	-0.899***	-1.812	-0.067	-0.069	0.038	0.185	-0.372*
		(0.487)	(-2.645)	(-1.507)	(-1.661)	(-0.550)	(0.232)	(0.966)	(-1.709)
II: General green preference		0.139***	-0.120***	0.043*	-0.039***	0.018	-0.100*	0.033	0.025
		(3.759)	(-4.194)	(1.794)	(-3.122)	(1.053)	(-1.927)	(0.579)	(0.856)
III: Bond-specific deviations		-0.854***	0.102	0.198	0.017	0.021	0.432**	0.162	-0.077
		(-2.706)	(0.805)	(1.493)	(0.244)	(0.287)	(2.411)	(0.628)	(-0.711)
Observations	3,133								

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Greenium decomposition (Equal-weighted).
Standard errors clustered by bond and date (t-statistics in parentheses). By construction, the total greenium is the sum of the sectoral greeniums in the first row. Moreover, the sectoral greenium is the sum of components I, II, and III, based on Eq. (7). The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), the Eurosystem (EuSys), and private households (HHs).

4.2 Decomposing the sector-specific greenium

Having split the total greenium into sector-specific shares above, we now seek to understand the underlying reasons why the main investor groups pay the greenium. To this end, we decompose the sector-specific greenium further. Specifically, we rewrite g_x as follows:

$$g_x = \underbrace{g^C_x}_{\text{I: Benchmark Greenium}} + \underbrace{\bar{g}\sum_i \Delta s_{i,x}}_{\text{II: General green preference}} + \underbrace{\sum_i \Delta s_{i,x}(g_i - \bar{g})}_{\text{III: Bond-specific deviations}}, \tag{7}$$

[9] Our dataset does not allow us to study to what extent these institutional investors can pass on the greenium to their clients. Therefore we remain deliberately vague regarding the question wthether it's the shareholders or the clients of these firms who actually "pay" the greenium.

with the share differential $\Delta s_{i,x} := (s^G_{i,x} - s^C_{i,x})$ and $g^C_x := \sum_i s^C_{i,x} g_i$. The three components have straightforward economic interpretations. The first component, g^C_x, is a benchmark greenium that would be paid/earned if the shares of each sector in each green bond were identical to the shares in the respective conventional bond. We view this benchmark as representing a simple null hypothesis, quantifying a sector's greenium if the sector would treat green and conventional bonds identically and thus displayed the same ownership shares. Under this simple null hypothesis, we would have $\Delta s_{i,x} = 0$, such that the other two components would disappear.

The second component, $\bar{g} \sum_i \Delta s_{i,x}$, is the part of the greenium which is paid/earned because a sector over-/underweights green bonds relative to conventional bonds on average, across the entire green bond market. As the formula shows, it is the product of the average greenium $\bar{g}$ that we have discussed in Section 3.3.1 and the average ownership share differential $\Delta s_{i,x}$ discussed in Section 3.3.2. Accordingly, we interpret this second component as the greenium that a sector x pays/earns because of its *general green preference*.

The third component, $\sum_i \Delta s_{i,x}(g_i - \bar{g})$, reflects the part of the greenium which results from *bond-specific over-/underweighting* of green bonds whose greenium deviates from the average. Technically speaking, this term can be viewed as the covariance between $\Delta s_{i,x}$ and $(g_i - \bar{g})$. It is negative when sector x overweights particularly those green bonds which have a very high (i.e. very negative) greenium. Economically, this residual term subsumes the fraction of the greenium which is paid for reasons other than (I) replicating the equivalent conventional bond portfolio or (II) general green preferences.

The results from this decomposition are also reported in Table 2. Most importantly, we find that the total greenium cannot fully be explained by the benchmark greenium. While the benchmark greenium tends to be relatively close to the total greenium for both investment funds and pension funds, the total greenium is more pronounced (i.e., more negative) compared to the simple benchmark in both cases. The deviations between the total and the benchmark greenium are even larger in the case of banks and insurances. In particular, banks would *earn* a greenium of 0.19 basis points (rather than *pay* 0.53 basis points) if their green bond portfolio had the same structure as their conventional bond portfolio. On the other hand, insurances would pay around 0.24 basis points more if they simply replicated their conventional portfolio weights. Interestingly, in line with the concept of market neutrality that guides the asset purchase programs of the Eurosystem throughout our sample period, we find that neither of the three components are significantly different from zero for the Eurosystem.

We therefore conclude that components II and/or III must play a role across the four main investor groups. Indeed, consistent with the descriptives in Figure 3, the second component is negative and significant for investment funds, pension funds and private households. In other words, these groups (or their clients) pay part of the greenium due to their strong general green preferences. This finding is in line with recently developed theories that try to explain the price differential between sustainable and non-sustainable assets through a preference channel.[10] Investment funds and pension funds invest on behalf of their clients and typically have to follow specific investment mandates. It is arguably their clients who seem to exhibit the strongest

[10] See, e.g., Pedersen et al. (2021) or Pastor et al. (2021).

green preference.[11] In contrast, the general preference term is positive and significant for banks and insurances. This indicates that banks and insurances actually earn an extra yield of 0.14 and 0.04 basis points, respectively, on their green bond portfolios by capitalizing on the green preferences of other investors.

The third component is insignificant for all major sectors with two exceptions: for banks it is strongly negative at minus 0.85 basis points. In fact, the negative contribution from bond-specific over-/underweighting exceeds the positive general preference term, so that banks pay an average greenium of minus 0.53 basis points altogether.[12] For private households, we find a strongly positively significant third component of 0.43 basis points. In other words, besides their general green preference, households tend to underweight green bonds with a large greenium. For insurances and investment funds we also find a positive, albeit statistically insignificant third component of 0.10 and 0.18 basis points, respectively. This indicates that these sectors also tend to slightly underweight bonds with a large greenium.

By construction, the third component is the part of the greenium that arises for reasons other than (I) replicating the equivalent conventional bond portfolio and (II) general green preferences. In order to gain further intuition concerning the drivers of this strong negative term for banks, we conduct several sample splits. The first exercise is a median split based on bond size, as measured by total amount outstanding, separately for each quarter of our sample. Second, we perform a median split based on bond age, as measured by the time since issuance, separately for each quarter of our sample. This exercise potentially also captures liquidity differences between on-the-run (young) and off-the-run (old) bonds. Third, to capture potential market segmentation effects regarding bonds in different maturity buckets, we also conduct a sample split based on the remaining time until maturity. The last sample split differentiates between financial issuers and all other issuers. Green bonds issued by banks are somewhat special since banks do not execute the respective green projects themselves, but rather invest the proceeds from the green bonds into green loans (Flammer (2021)). In addition, banks may hold other banks' bonds for reasons unrelated to sustainability, e.g., when they provide underwriting or market making services.[13]

Table 3 reports the third component of Eq. (7) for the different sample splits. The first column documents that, for banks, this component is much more pronounced and remains highly statistically significant when the sample is restricted to small bonds, young bonds, bonds with a longer remaining maturity, and bonds issued by financials. Compared to the full sample estimate of -0.85 bps in Table 2, the values are less pronounced for large bonds, old bonds, bonds closer to maturity, and bonds from non-financial issuers. The exact opposite pattern is observed for private households, who effectively profit from holding specifically those small or young green bonds with a relatively small (or even positive) greenium.

These findings are confirmed by another exercise whose results are reported in Table 4. Remem-

[11]See, e.g., the survey evidence in Krueger et al. (2020) or Sangeorgi and Schopohl (2021a,b).

[12]In additional analyses we find that the MFI results are largely due to German banks. This could be due to the fact that Germany hosts one of the largest banking systems in the euro area (market share of 28% as of 2022-Q2). More granular datasets would be needed to dig deeper into institution-specific bond holdings.

[13]For example, Bekaert and Breckenfelder (2019) document that European banks hold 28% of all bank-issued securities. This is much higher than their share in the overall securities holdings, which amounts to 18%. The authors find this pattern to be particularly pronounced for long-term debt instruments.

III: Bond-specific deviations Sample splits	MFIs	IFs	ICs	PFs	EuSys	HHs	Others	Foreign
Size (total amount outstanding)								
Small	-0.955**	0.041	0.120	0.031	0.039	0.619**	0.339	-0.234*
	(-2.103)	(0.280)	(1.135)	(0.322)	(0.412)	(2.363)	(0.886)	(-1.708)
Large	-0.578**	0.230	0.293	-0.022	-0.018	-0.001	-0.150**	0.246**
	(-2.140)	(1.047)	(0.883)	(-0.412)	(-0.167)	(-0.058)	(-2.224)	(2.006)
Age (time since issuance)								
Young	-1.223**	0.026	0.249**	-0.003	-0.007	0.546**	0.457	-0.045
	(-2.384)	(0.216)	(2.158)	(-0.068)	(-0.173)	(2.018)	(0.982)	(-0.489)
Old	-0.449**	0.203	0.114	0.074	0.051	0.165	-0.084	-0.075
	(-2.122)	(1.295)	(0.573)	(0.703)	(0.433)	(1.093)	(-0.863)	(-0.462)
Residual maturity								
Low	-0.653**	0.131	0.326*	0.038	0.045	0.094	0.136	-0.119
	(-2.041)	(0.646)	(1.835)	(0.305)	(0.394)	(0.931)	(0.751)	(-0.658)
High	-1.063*	0.071	0.065	-0.006	-0.005	0.782**	0.188	-0.033
	(-1.987)	(0.618)	(0.452)	(-0.157)	(-0.109)	(2.325)	(0.386)	(-0.320)
Issuer industry								
Financials	-1.183**	0.070	0.370**	0.009	0.008	0.566**	0.281	-0.122
	(-2.604)	(0.409)	(2.280)	(0.101)	(0.242)	(2.354)	(0.768)	(-0.864)
Rest	-0.101	0.171	-0.191	0.086	0.020	0.004	-0.061	0.071
	(-1.329)	(0.997)	(-0.794)	(0.975)	(0.097)	(0.211)	(-0.805)	(0.551)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Sample-splits for bond-specific deviations (component III in Eq. (7)).
Standard errors clustered by bond and date (t-statistics in parentheses). The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), the Eurosystem (EuSys), and private households (HHs).

ber that all entries in Table 2 are scaled by the factor $\frac{1}{\#i}$, i.e. the contributions of all bonds to these average values are equally weighted. In Table 4, we report the same quantities as in Table 4, but value-weighted, based on bond size. The corresponding estimate for bond-specific deviations for banks in the last row is about half as large as in Table 2 (-0.47 bps versus -0.87 bps), confirming the finding that the bond-specific over-/underweighting effect is much more pronounced for small green bonds as opposed to large green bonds.

	Total	MFIs	IFs	ICs	PFs	EuSys	HHs	Others	Foreign
Greenium (g_x)	-3.714**	-0.929**	-1.355**	-0.592	-0.185*	-0.104	-0.025*	-0.110*	-0.412**
	(-2.278)	(-2.219)	(-2.455)	(-1.218)	(-1.731)	(-0.847)	(-1.727)	(-1.780)	(-2.206)
I: Benchmark Greenium		-0.525	-1.367***	-1.013*	-0.120	-0.151	-0.018	-0.015	-0.505*
		(-1.413)	(-2.726)	(-1.687)	(-1.539)	(-0.937)	(-1.625)	(-0.258)	(-1.953)
II: General green preference		0.062	-0.124***	0.059	-0.059***	0.024	-0.003	0.011	0.031
		(1.644)	(-3.038)	(1.617)	(-3.144)	(0.950)	(-0.890)	(0.816)	(1.071)
III: Bond-specific deviations		-0.467**	0.136	0.363	-0.006	0.022	-0.004	-0.106**	0.062
		(-2.081)	(0.746)	(1.554)	(-0.077)	(0.253)	(-0.389)	(-2.032)	(0.463)
Observations	3,133								

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Greenium decomposition (Value-weighted).
Standard errors clustered by bond and date (t-statistics in parentheses). By construction, the total greenium is the sum of the sectoral greeniums in the first row. Moreover, the sectoral greenium is the sum of components I, II, and III, based on Eq. (7). The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), the Eurosystem (EuSys), and private households (HHs).

Taken together, we interpret these results as evidence that banks selectively hold specific green bonds for reasons other than avoiding to pay (or even earning) the greenium. In the segment of small or young (green) bonds, liquidity considerations may play a role. Banks may decide to hold only the most liquid green bonds and thereby incur a larger greenium. Part of the greenium that banks have to pay could thus be regarded as a liquidity premium. Moreover, one has to keep in mind that banks can in principle direct funding to possibly green projects through many ways, for instance also through bank loans. Therefore it seems likely that they engage in the green bond markets for reasons other than greening the asset side of their balance sheets, for instance in order to provide intermediary services like market making or bond underwriting. In this regard, it remains an open question to what extent banks can pass on the greenium to their clients and how the costs arising from the greenium are actually distributed between shareholders and clients.

In contrast, throughout all subcases, the bond-specific component III for private households has a positive sign. We view this finding as broadly confirming the intuition developed for banks. In particular, in contrast to the most relevant investor groups in our sample, private households that directly invest in bonds are arguably not subject to comparable (intermediary) frictions. Consequently, they are more flexible in their portfolio choice and apparently prefer to invest in green bonds with a small (or even positive) greenium.

Finally, for the sake of completeness, Table 5 reports the total sector-specific greenium g_x across the different sample splits. In contrast to the bond-specific over-/underweighting component, the total greenium is much more pronounced for (1) larger bonds, (2) older bonds, and (3) bonds from issuers that are not financials, whereas the point estimates along bonds' residual maturity are very similar. This effect is mirrored both in the first ("benchmark greenium") and second component ("general green preferences"), when we again decompose the greenium in these subsamples.[14] It seems reasonable to assume that the attention of sustainability-oriented investors to green bonds, which supposedly drives component II of the greenium, focuses on large bonds issued by non-financial corporations, where the presumed impact of sustainable investing is more directly observable. Taken together, we conclude that both, green preferences and financial intermediary frictions, are significant determinants of who eventually pays the greenium, but they operate through different channels and segments of the market.

Greenium (g_x) Sample splits	Total	MFIs	IFs	ICs	PFs	EuSys	HHs	Others	Foreign
Size (total amount outstanding)									
Small	-1.898	-0.244	-0.545	-2.115	-0.016	0.013	0.587*	0.669*	-0.249
	(-0.853)	(-0.905)	(-1.204)	(-1.195)	(-0.142)	(0.137)	(1.920)	(1.756)	(-1.212)
Large	-4.491**	-1.055**	-1.605**	-0.567	-0.226**	-0.110	-0.029*	-0.154**	-0.745**
	(-2.238)	(-2.123)	(-2.542)	(-0.829)	(-2.455)	(-0.768)	(-1.923)	(-2.343)	(-2.646)
Age (time since issuance)									
Young	-0.696	-0.547*	-0.793*	-0.296	-0.051	-0.016	0.529	0.799*	-0.321**
	(-0.553)	(-1.816)	(-1.882)	(-1.293)	(-0.807)	(-0.209)	(1.560)	(1.682)	(-2.141)
Old	-5.030*	-0.510	-1.049**	-2.908	-0.130	-0.045	0.203	-0.060	-0.531**
	(-1.833)	(-1.428)	(-2.298)	(-1.220)	(-1.192)	(-0.367)	(1.372)	(-1.128)	(-2.212)
Residual maturity									
Low	-2.823	-0.774*	-1.132*	-0.306	-0.100	0.073	-0.038	0.079	-0.625**
	(-1.519)	(-1.797)	(-1.876)	(-0.646)	(-0.701)	(0.551)	(-0.226)	(0.314)	(-2.090)
High	-2.799	-0.275*	-0.696*	-2.884	-0.079	-0.137	0.794**	0.692	-0.214*
	(-1.079)	(-1.808)	(-1.897)	(-1.242)	(-1.606)	(-1.375)	(2.207)	(1.616)	(-1.830)
Issuer industry									
Financials	-1.185	-0.727*	-0.919*	-0.170	-0.060	0.072	0.522*	0.575	-0.478**
	(-0.785)	(-1.959)	(-1.780)	(-0.752)	(-0.540)	(0.862)	(1.825)	(1.559)	(-2.056)
Rest	-6.089	-0.131	-0.916*	-4.394	-0.149	-0.235	0.064	-0.014	-0.314
	(-1.579)	(-1.299)	(-1.735)	(-1.242)	(-1.493)	(-1.219)	(0.578)	(-0.321)	(-1.303)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Sector-specific greenium - Sample-splits (Equal-weighted).
Standard errors clustered by bond and date (t-statistics in parentheses). The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), the Eurosystem (EuSys), and private households (HHs).

Importantly, we wish to emphasize that our empirical analysis is not causal. We therefore need to take into account reverse causality arguments. In this sense, our findings could, for instance, also be interpreted along the lines of intermediary asset pricing. Following this line of argumentation, the greenium should be particularly large for those green bonds which are primarily held by banks. Banks tend to function as the marginal investor in many asset markets, including the market for green bonds, for instance because they offer underwriting, market making or other transformation services.[15] Arguably, banks play this role as a marginal investor particularly for

[14] Tables A.2 and A.3 in the Online Appendix report the components I and II for the sample splits.
[15] A similar point has been raised by Larcker and Watts (2020).

young or small bonds, as the majority of old or very large bonds is typically held by long-horizon buy-and-hold investors like pension funds or insurance companies.

5 Conclusion

Mitigating climate change as well as adapting to its potential consequences requires massive investments. This paper is concerned with the broad questions of who finances the green transition and who eventually pays the costs arising from greening investment portfolios. We elaborate on these questions in the context of green bonds. Merging a sample of matched green-conventional bond pairs with confidential data on the dynamic ownership structure of each bond by investor group, we document a set of novel findings.

First, the average greenium in our sample amounts to minus three basis points, and it is largely borne by banks, investment funds and insurance companies (or their clients) which are the key investor groups in this market. Second, investment funds and pension funds generally overweight green over matched conventional bonds, potentially reflecting strong green preferences of their clients. By the same measure, banks and insurances tend to display negative green (i.e., brown) preferences. Third, despite these negative green preferences, a significant share of the overall greenium can still be attributed to banks. More precisely, banks display a tilt towards specific green bonds with a relatively pronounced greenium. This tilt is particularly sizeable when the sample is restricted to young bonds, small bonds, bonds with a long residual maturity, or bonds issued by the financial sector.

We draw the tentative conclusion that banks (or their clients) pay a significant greenium because they hold specific green bonds for motives other than green preferences. Examples may be market making, underwriting or liquidity management activities. The trade-off between offering such financial intermediation services and avoiding the greenium may be particularly relevant, for instance, when operating in the segment of small or young bonds.

Overall, our findings contribute to the broader debate about potential sources of price differentials between green and conventional financial assets. Importantly, they point towards a prominent role of drivers that go beyond investors' green preferences, such as financial intermediary frictions. Our focus on green bonds is partly driven by data availability. Looking ahead, it would thus be interesting to conduct similar analyses for other segments of the market for sustainable assets. Moreover, regarding the interaction between financial frictions and the greenium, further analysis is needed to understand which way the causality runs. Lastly, we believe that the relationship between bond ownership and price differentials in general deserves further attention.

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Online appendix for
"WHO PAYS THE GREENIUM?"

June 21, 2023

This appendix contains charts in color. Use color printer for best results.

Appendix A Supplementary results

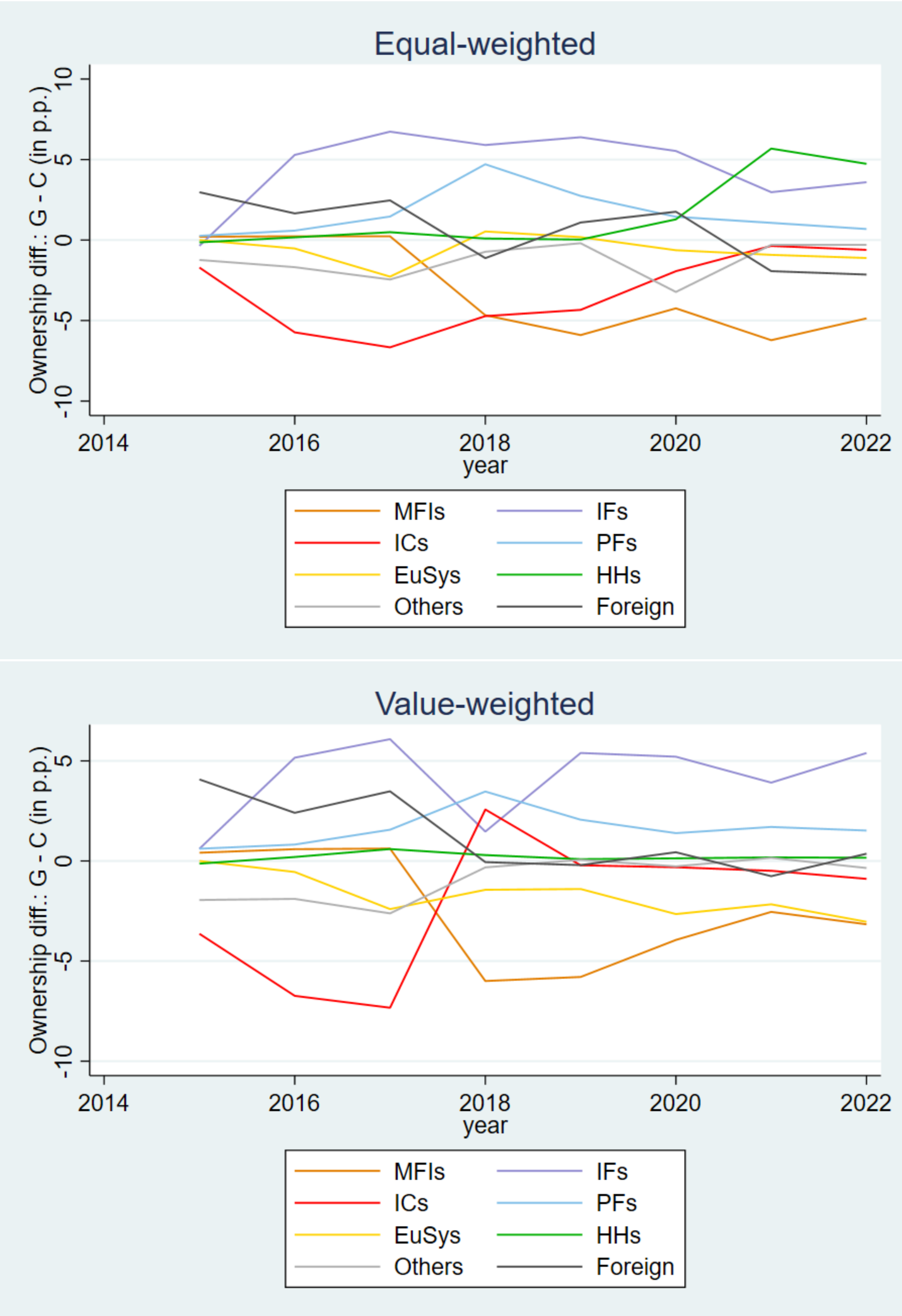

Figure A.1: Ownership Differential Over Time.

The figure displays the average equal-weighted (top) and value-weighted (bottom) ownership differential of green and conventional bonds by investor group over time. The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), and the Eurosystem (EuSys).

		SHS-Matching	
		Before	After
Region			
	Euro area	198	138
	Japan	47	2
	Supranational	22	5
	Sweden	67	4
	US	45	1
	Rest	57	11
Currency			
	EUR	214	159
	NOK	11	0
	SEK	59	1
	USD	81	1
	JPY	40	0
	Rest	31	0
Bond size			
	Below 10 Million EUR	102	59
	Between 10 and 50 Million EUR	60	12
	Between 50 and 100 Million EUR	56	3
	Between 100 and 500 Million EUR	79	7
	Above 500 Million EUR	139	80
Issuer industry			
	Financials	220	122
	Non-financials	120	24
	Sovereigns	73	10
	Supranational	23	5
Issuer rating			
	IG (Above BBB)	331	132
	IG (BBB)	50	18
	Non-IG	4	2
	Unrated	51	9
ESG Flag (Eikon)			
	CBI Aligned Green bond	315	116
	CBI Certified Green Bond	36	13
	Self-Labeled Green Bond	85	32
Total number of bond pairs		436	161

Table A.1: Sample composition before and after the SHS coverage filter.
This Table shows the number of bonds in our dataset, before and after the SHS coverage filter, broken up across a number of bond/issuer characteristics.

I: Benchmark greenium Sample splits	MFIs	IFs	ICs	PFs	EuSys	HHs	Others	Foreign
Size (total amount outstanding)								
Small	0.581	-0.511	-2.244	-0.016	-0.037	0.072	0.302	-0.045
	(1.044)	(-1.331)	(-1.262)	(-0.484)	(-0.225)	(0.283)	(1.035)	(-0.173)
Large	-0.544*	-1.614***	-1.016	-0.162*	-0.129	-0.024*	-0.029	-0.973***
	(-1.832)	(-2.774)	(-1.203)	(-1.739)	(-0.802)	(-1.940)	(-0.392)	(-2.883)
Age (time since issuance)								
Young	0.639	-0.793**	-0.551**	-0.044	-0.013	0.030	0.325	-0.288
	(1.071)	(-2.066)	(-2.225)	(-0.909)	(-0.158)	(0.098)	(0.896)	(-1.420)
Old	-0.291	-1.012**	-3.134	-0.092**	-0.128	0.046	0.039	-0.460
	(-0.726)	(-2.579)	(-1.297)	(-2.176)	(-0.645)	(0.544)	(0.647)	(-1.615)
Residual maturity								
Low	-2.823	-0.261	-1.151**	-0.692	-0.108**	0.007	-0.090	-0.080
	(-1.519)	(-0.476)	(-2.145)	(-1.172)	(-2.146)	(0.032)	(-0.596)	(-0.309)
High	-2.799	0.648	-0.639*	-2.974	-0.025	-0.148	0.171	0.461*
	(-1.079)	(1.230)	(-1.954)	(-1.276)	(-0.531)	(-1.483)	(0.572)	(1.698)
Issuer industry								
Financials	0.386	-0.939**	-0.553*	-0.060	0.059	0.017	0.278	-0.373
	(0.685)	(-2.017)	(-1.870)	(-1.051)	(0.590)	(0.070)	(0.981)	(-1.191)
Rest	-0.220	-0.819*	-4.348	-0.083*	-0.328	0.081	-0.002	-0.369*
	(-1.399)	(-1.904)	(-1.212)	(-1.813)	(-1.055)	(0.821)	(-0.031)	(-1.933)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: Sample-splits for benchmark greenium (component I in Eq. (7)).
Standard errors clustered by bond and date (t-statistics in parentheses). The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), and the Eurosystem (EuSys).

II: General green preference Sample splits	MFIs	IFs	ICs	PFs	EuSys	HHs	Others	Foreign
Size (total amount outstanding)								
Small	0.130***	-0.075***	0.009	-0.031***	0.011	-0.103*	0.028	0.031
	(3.774)	(-3.325)	(0.689)	(-2.688)	(0.873)	(-1.911)	(0.484)	(1.130)
Large	0.067	-0.220***	0.155*	-0.042*	0.037	-0.005	0.025	-0.018
	(1.194)	(-2.855)	(1.912)	(-1.941)	(0.671)	(-0.692)	(0.996)	(-0.366)
Age (time since issuance)								
Young	0.037***	-0.026***	0.006	-0.004**	0.005	-0.047**	0.018	0.012
	(2.949)	(-4.322)	(1.442)	(-2.589)	(1.427)	(-2.350)	(0.877)	(1.198)
Old	0.230***	-0.241***	0.112	-0.112***	0.032	-0.008	-0.016	0.004
	(3.043)	(-3.415)	(1.656)	(-2.815)	(0.638)	(-0.135)	(-0.205)	(0.055)
Residual maturity								
Low	0.139**	-0.112***	0.060*	-0.030**	0.021	-0.042	0.023	-0.058*
	(2.589)	(-2.848)	(1.733)	(-2.126)	(0.900)	(-0.786)	(0.383)	(-1.953)
High	0.140***	-0.128***	0.026	-0.048**	0.015	-0.160**	0.043	0.111**
	(2.909)	(-3.298)	(0.988)	(-2.479)	(0.712)	(-1.994)	(0.478)	(2.428)
Issuer industry								
Financials	0.070***	-0.050***	0.013	-0.010**	0.004	-0.061*	0.016	0.018
	(3.227)	(-3.631)	(1.283)	(-2.322)	(1.333)	(-1.877)	(0.447)	(1.063)
Rest	0.190*	-0.267**	0.145	-0.152**	0.073	-0.021*	0.049	-0.016
	(1.985)	(-2.190)	(1.296)	(-2.368)	(0.667)	(-1.732)	(1.306)	(-0.173)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: Sample-splits for general green preference (component II in Eq. (7)).
Standard errors clustered by bond and date (t-statistics in parentheses). The labels refer to monetary financial institutions (MFIs), investment funds (IFs), insurance companies (ICs), pension funds (PFs), the Eurosystem (EuSys), and private households (HHs).