Household Climate Finance: Theory and Survey Data on Safe and Risky Green Assets

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Abstract

This paper studies sustainable investing using data from a representative survey of German households and a quantitative asset pricing model with heterogeneous investors. About a third of households have green investments worth 11% of household wealth. Green investments are currently relatively risky, with equity as the main pathway, while green bank accounts are rare. We find substantial heterogeneity in green taste for both safe and risky green assets throughout the wealth distribution, which can either increase or decrease demand for these assets. Model counterfactuals show that nonpecuniary benefits and hedging demands currently make green equity more expensive for firms. Nevertheless, the rise of sustainable investing has introduced a greenium of about 1%, as investors who are now aware of green stocks bid up their prices. Many households desire green bank accounts which could substantially increase overall green finance. Feeding treatment effects from an RCT in the survey into our model suggests that greater awareness of climate finance could also lead to a further burst in green equity investment.

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1 Introduction

Sustainable investing has grown rapidly in recent years, especially in Europe. From 2019 to 2021, net assets of European sustainable funds almost tripled, reaching nearly 2 trillion euros, or 16% of assets under management. Economic theory suggests several mechanisms through which an increase in demand for green securities could affect their prices and, ultimately, the cost of capital of their issuers. Investors may enjoy a nonpecuniary benefit from holding green assets that implies a convenience yield, and hence lower premia on those assets. Alternatively, the climate transition might lead investors to pay attention to a new risk factor that is now reflected in investor beliefs regardless of taste. At this point, we know little about who holds green securities and why. Since investors are heterogeneous and the role of taste and risk compensation might also work differently for risky equity versus safe debt, we do not yet know how important they are for the climate transition.

This paper studies green investing using data from a representative survey of German households. We first document new facts on the cross section of beliefs, green tastes, and portfolio holdings. We then quantify an asset pricing model with heterogeneous households to assess the impact of sustainable products on asset prices and investment. We find that sustainable investing is already quite popular in Germany, although it is relatively risky: equity is the main pathway to green investment, whereas green bank accounts are rare. We identify household tastes for safe and risky green assets from hypothetical choice questions and show that such tastes are important but heterogeneous. On net, tastes currently make green equity *more* expensive for firms. Nevertheless, we estimate that the rise of sustainable investing lowers return premia on green stocks by roughly 1 percentage point, mainly because investors who are optimistic about green stocks bid up their prices. Looking ahead, we show that there is a substantial unmet demand for green bank accounts. Moreover, feeding treatment effects from an RCT in the survey into our model suggest that even greater awareness of climate finance could also lead to a further burst in green equity investment.

Our survey data come from the Bundesbank's Survey on Consumer Expectations and contains rich information on demographics, income, and wealth. We draw on two waves in 2021-22, where we added question modules on green assets. We find that 34% of households own *some* green assets, which comprise 11% of aggregate household financial wealth. Housholds' green investment portfolio is much riskier than the overall wealth portfolio, with more than half of green investment in equity compared to one-third overall. While bank deposits are by far the most important financial asset for German households, only 5% of households have a green bank account. The average household who owns securities perceives a "greenium", that is, a positive expected excess return on traditional equity over green equity. Households who actually own green securities, however, are more optimistic and do not perceive a greenium. The vast majority of households have return expectations that embed a risk-return trade-off: they expect higher returns for equity funds that they perceive to be riskier.

Households also seem to be well aware of risk-return trade-offs, as they don't update their beliefs in response to an information treatment that explains the principle of risk-return trade-offs.

Our survey module includes several hypothetical choice questions to measure taste for green assets. As a direct measure of taste for green assets, we elicit the annual interest-rate spread that people would give up (or require) to have a green deposit account. We find that 42% of households would forego interest for a green account, with 25% willing to sacrifice more than 1pp. However, 28% of households would only go green when paid a higher interest rate. In other words, taste does not always work like a positive convenience yield but can induce *nonpecuniary costs* of holding an asset. In the cross section, taste for green bank accounts is stronger for younger households as well as for voters of parties that advocate for more climate action. At the same time, it does not strongly comove with wealth. Aggregating, we show that there is currently a substantial unmet demand for green bank accounts.

To identify demand for equity, we elicit not only households' subjective expected returns and relative risk of green and traditional equity funds but also ask households to rank a green or traditional fund as a vehicle for an additional small amount of savings. While most rankings are consistent with myopic mean-variance optimization, about 20% choose dominated assets with lower mean and/or higher risk. A natural explanation is climate hedging: an investor might prefer a green fund not only because of its risk and return but because it provides insurance against a state of the world where the climate transition is accelerated, and green stocks do particularly well. Consistent with this interpretation, the choice of a dominated asset is more common when the asset is perceived to be more risky.

Climate hedging can either encourage or discourage green investment relative to a mean-variance benchmark. For example, households might worry less about climate emergencies over the next year but more about events that stifle climate action, when green equity would perform particularly badly. These households would then be naturally extra cautious with respect to green equity—effectively, traditional funds provide insurance to them and might be preferred even if the household is optimistic about green stocks. In line with this hypothesis, we find evidence of negative hedging demand for green equity funds even among the population of households who hold green equity funds.

The basic building block of our model is a household savings and portfolio choice problem that allows for both convenience yields from green assets (equity or bonds) and climate hedging captured by a state-dependent utility. We determine household-specific utility and belief parameters to jointly match answers to the hypothetical questions and the cross section of portfolio holdings. An important ingredient is short-sale constraints that allow us to fit participation choices. The distribution of preferences and beliefs determines aggregate demand for green and traditional equity funds as well as safe assets. For counterfactuals, we determine equity prices by matching aggregate demand to exogenous asset supply under various scenarios.

One set of counterfactuals is designed to understand how tastes and beliefs shape current equilibrium prices. We view the rise of sustainable investing as the combination of two changes in household behavior. First, households now perceive nonpecuniary benefits and costs, as well as the need to hedge. When we shut down taste parameters to eliminate this effect, the value of green equity actually *increases*. In other words, the presence of green (in)convenience yields and green hedging demands currently hold back green finance. The reason is that many green investors currently hold green equity mainly because of their taste, not because they believe that green equity has attractive financial returns. If tastes are muted, households who sort themselves into holding green equity are attracted by its financial returns, driving up green equity prices.

A second important component of the rise of sustainable investing is attention allocation: households now distinguish between groups of stocks that they previously viewed as indistinguishable. In particular, the emergence of a climate risk factor may drive households to see green and other stocks as imperfect substitutes. To assess this effect, we design a counterfactual that not only shuts down the taste parameters for green but also modifies beliefs so that households view green funds as just a random selection from the cross section of stocks. We show that the current equilibrium has a substantially lower equity premium on green stocks relative to this counterfactual world. The reason is that once households disagree about the attractiveness of green stocks, green funds allow optimists to overweight those stocks, bid up their prices, and thereby reduce their equity premium.

We also perform two counterfactuals to assess the future potential of sustainable investing. The first studies the widespread adoption of green bank accounts. A potential side effect of such accounts could be that it reduces incentives for households to invest in green equity and leads only to substitution, rather than expansion of green finance as a whole. We show, however, that such substitution is small, making more green deposits a promising avenue to expand green finance. Second, we assess what is likely to happen as households learn more about climate change and the availability of sustainable investment products. To gauge the effect on expectations and tastes, our survey module contains an RCT that informs households about the risks posed by climate change and the potential of green finance to contribute to mitigate climate change. We find that a subset of households who are concerned about the climate respond with a substantial upward revision of their green excess return expectations. A counterfactual that feeds treatment effects from the RCT into the model delivers large effects. Without a change in supply, the price of green stocks would rise to increase the measured greenium (as observed by an econometrician) by almost 5pp. If supply could adjust elastically, the size of the green equity market would double.

Related Literature. Non-pecuniary benefits or costs from holding certain assets have long been recognized as a potential investment motive complementing the monetary payoff (e.g., Fama and

French 2007). In particular, models of green investing similarly feature a taste for green assets that lowers the compensation that these investors demand in equilibrium for holding these assets, thereby generating a "greenium". Early models of green taste assume that investors apply negative screens, which is the most common practice of ESG funds (Heinkel, Kraus and Zechner 2001; Geczy, Stambaugh and Levin 2021; Berk and van Binsbergen 2021). A negative screen excludes stocks with the lowest ESG ratings and thereby imposes a constraint on portfolio optimization. The equilibrium in a model in which some investors apply a negative screen involves market segmentation: investors without green taste hold all screened-out stocks and are compensated with higher expected returns. In our survey data, we find that, among stockholders, only very few households have such a strong taste for green that they decide not to participate in the market for traditional equity. Among all households, 3.9% of households hold exclusively green equity, representing 3.6% of financial assets. Among equity holders, 9% of households hold exclusively green equity, representing 4.9% percent of financial assets.

In our survey data, households hold green stock funds and traditional stock funds to different degrees. To explain this heterogeneity in portfolio choice, we must go beyond negative screens and capture that households choose a mix of green and traditional assets in their portfolio. Here we build on recent theoretical work that studies the intensive margin of green investing (Pedersen, Fitzgibbons and Pomorski 2021; Pástor, Stambaugh and Taylor 2021; Zerbib 2022). In particular, the desire to hedge climate events in our model is related to section 5 of Pástor, Stambaugh and Taylor (2021) that studies hedging in an exponential utility framework. An important feature of our quantitative approach is that we allow for Epstein-Zin utility with state-dependent marginal utility. As a result, richer households matter more for market valuation: individual-specific beliefs, nonpecuniary benefits, and hedging motives from our survey data enter wealth-weighted in our asset pricing formulas. Moreover, the correlation across different preference parameters we measure is relevant: for example, households who expect low returns on green stocks tend to have a positive hedging demand for green stocks, and vice versa.

The asset pricing literature has documented substantial differences in expected returns across stocks. For this type of work, it is crucial to obtain many stock return observations from a stable environment. These conditions are absent with the greenium: investors are receiving more information about climate change and are getting more worried about it, but only fairly recently. During a transition, *realized* returns on green assets might thus be higher despite lower *expected* returns (Pástor, Stambaugh and Taylor 2021). The existing empirical asset pricing literature has indeed produced conflicting results about the greenium (for a recent survey, see Giglio, Kelly and Stroebel 2021). While many papers document that green assets have lower expected returns (for example, Hong and Kacperczyk 2009; Zerbib 2019; Bolton and Kacperczyk 2021, 2023; Baker, Bergstresser, Serafeim and Wurgler 2022a), others show the opposite (for example, Kempf and Osthoff 2007; Garvey, Iyer and Nash 2018; In, Park and Monk 2019; Glossner 2021; Cheema-Fox, LaPerla, Serafeim, Turkington and Wang 2021). Interestingly, data from corporate conference calls suggest that CEOs of green companies *perceive* a lower cost of capital than CEOs of brown companies (Gormsen, Huber and Oh 2023). Moreover, several studies find that investors are willing to give up average returns to invest according to their preferences (Barber, Morse and Yasuda 2021; Baker, Egan and Sarkar 2022b).

Surveys which directly ask investors about their beliefs and motives, are an especially attractive approach in a changing investment environment such as the climate context. Several papers ask academics and/or professionals about climate change and document significant concerns about the associated risks (Drupp, Freeman, Groom, Nesje et al. 2015; Krueger, Sautner and Starks 2020; Stroebel and Wurgler 2021). Other papers ask investors about their expected returns on ESG assets (Riedl and Smeets 2017; Heeb, Kölbel, Paetzold and Zeisberger 2023; Giglio, Maggiori, Stroebel, Tan, Utkus and Xu 2023) and document substantial heterogeneity in investor beliefs. These studies document a *lower* expected ESG return on average across investors—consistent with a greenium, and also our survey findings. Like us, these papers separate beliefs from other motives for ESG investments.[1] For example, Riedl and Smeets (2017) play a trust game with fund investors at a large Dutch asset management company and show investors who reveal stronger prosocial preferences in the game are also more likely to invest in ESG funds. Heeb, Kölbel, Paetzold and Zeisberger (2023) document that investors report a high willingness to pay for impact funds but are not sensitive to the quantitative impact of these funds (whether, for example, they reduce emissions by 0.5 versus 5 tons.) Giglio, Maggiori, Stroebel, Tan, Utkus and Xu (2023) document that Vanguard investors who care more about climate change are more likely to hold ESG funds for both ethical reasons as well as to hedge climate risks.

Our results confirm and extend these existing findings. The main contribution of our paper is to directly measure the cross-sectional distribution of household beliefs and tastes and to use the joint distribution as an input into a quantitative model with heterogeneous households. An advantage of our survey design is that it relies on the Bundesbank's representative household sample and contains rich information about demographics, income, and portfolios. Our data therefore provide accurate information about the population of a country as a whole and allows us to study the quantitative macro implications of green investing. We use the model to conduct counterfactual exercises that investigate the introduction of green deposit accounts and the potential of green finance overall. With regards to the empirical facts we document, another novelty of our survey is that we ask households how they assess not only the expected returns but also the risks of ESG investments. Our survey questions also place households in hypothetical portfolio choice situations that reveal their positive

[1] Relatedly, Anderson and Robinson (2019) show that investors who experience extreme weather events in Sweden hold more ESG assets in their retirement accounts. Bernard, Tzamourani and Weber (2022) show that people are more willing to pay for CO2 offsets on their flights after receiving information about the importance of personal behavior for climate change mitigation.

and negative hedging demands for green versus traditional equity. Finally, we enquire households about the interest rate they would give up or demand to hold safe green assets.

The rest of the paper proceeds as follows. Section 2 introduces our data, and Section 3 provides an overview of green investing in Germany. Section 4 presents our measure of taste for green safe assets and derives a demand curve for green deposit accounts. Section 5 reports beliefs about equity returns and evidence of hedging demand. Section 6 presents our model and quantification and studies the role of taste for aggregate demand. Section 7 reports the model counterfactuals.

2 Household Survey Data

This paper uses data from the Deutsche Bundesbank Household Survey on Consumer Expectations, a large representative survey of German households. The survey is a key data source for the Bundesbank on inflation and income expectations as well as household consumption behavior. Every survey wave collects rich demographic, income, and wealth data about households and their general economic expectations. The survey is administered online by the survey company Forsa and has been running monthly since April 2019.[2] We field eight customized questions across two survey waves with roughly 6,000 respondents in each wave. The survey sample is representative of the financial portfolios and "green" preferences of German households. More details are in Appendix A.

In the November 2021 wave of the survey, we introduced three new question modules aimed at understanding the joint distribution of preferences and expectations about green assets. The first module focuses on general attitudes towards climate change. The second module was designed to measure household preferences for green bank accounts. Here, we asked not only whether households currently have such accounts but also elicit the spread, or interest rate differential, that would make them indifferent between traditional and green accounts. Finally, a third set of questions asked households about their expectations about the return and risk of green and traditional equity.

In the May 2022 wave of the survey, we added a further question module that asked households to provide a detailed breakdown of their financial portfolio holdings. Specifically, we asked households to report their holdings in euros for bank deposits, pensions (that is, life insurance as well as savings agreements for private pension schemes), equity (including individual shares, equity funds, and ETFs), and fixed-income securities (including government bonds, corporate bonds, and bond funds). For the latter three categories, respondents were asked to provide the amount, in euros, of

[2] While the survey is internet-based, respondents were recruited offline by Forsa to avoid potential sample selection effects of online recruiting. The website of the Bundesbank Survey on Consumer Expectations provides additional details about its methodology, access to its data, and full questionnaires from all waves (in English and German). The link to the survey website is: https://www.bundesbank.de/en/bundesbank/research/survey-on-consumer-expectations.

their “sustainable" holdings. Throughout the survey, we defined sustainable as assets that hold shares in enterprises that operate in a comparatively environmentally-friendly manner, are engaging more in "green" projects, or a fund that invests in such enterprises.

3 Current Household Holdings of Green Assets

In this section, we describe the current financial asset portfolio of German households. The survey data show that green assets are popular and constitute a significant share of the aggregate portfolio of households, especially their equity holdings. At the same time, while deposit accounts are the most important asset for many households, green deposits are still a niche product.

3.1 Green Investing: How Much and What Asset Class?

Green investing is widespread among German households and makes up a sizable share of the aggregate household portfolio. Table 1 reports portfolio shares and participation rates for equity, deposits, pensions, and bonds. We further break down asset positions by green holdings and a residual labeled "traditional." The first column reports the aggregate portfolio shares of all households, while the second focuses on households who own some equity. The third column shows the breakdown between green and traditional investments within an asset class. The final two columns report unconditional participation rates and, respectively, participation rates conditional on having some position in the asset class.

The most important financial asset held by German households is bank deposits. Almost all households (99%) have some deposits, and the aggregate portfolio weight is roughly one-half (49%). While equity also has a sizable aggregate weight of about one-third, only 43% of households participate in equity markets. Private pensions are similarly held by only 42% of households and represent only 15% of the aggregate portfolio. We do not know precisely what types of securities households select in their pension accounts—in principle, this could be either equity or debt. Finally, direct holdings of bonds are rare and make up a negligible share of aggregate financial assets. The composition of German household financial portfolios is broadly representative of European portfolios. The share of household assets invested in deposits, pensions, and bonds is 67% both in Germany and in the Euro

Table 1: Aggregate Portfolio Holdings and Participation Rates

	Aggregate Portfolio	Equity Holders' Portfolio	Share of Asset Class	Participation	Conditional Participation
Equity					
Total	0.33	0.43	1.00	0.43	1.00
Green	0.06	0.08	0.17	0.18	0.42
Traditional	0.27	0.36	0.83	0.39	0.91
Deposits					
Total	0.49	0.39	1.00	0.99	1.00
Green	0.02	0.02	0.04	0.05	0.04
Traditional	0.47	0.37	0.96	0.94	0.96
Pensions					
Total	0.15	0.14	1.00	0.42	1.00
Green	0.02	0.02	0.16	0.13	0.31
Traditional	0.13	0.12	0.84	0.37	0.88
Bonds					
Total	0.03	0.03	1.00	0.07	1.00
Green	0.01	0.00	0.16	0.02	0.32
Traditional	0.02	0.03	0.84	0.06	0.90

Note: This table reports portfolio holdings and participation rates in equity, deposits, private pensions, and bonds. Equity contains individual shares, equity funds, and ETFs. Pensions include savings in private pension funds and life insurance contracts. Households classify their holdings as "green" versus traditional assets. The first column of numbers represents aggregate portfolio weights (for example, the share of equity in total financial assets). The second column is like the first column but only for equity holders. The third column contains the share of a particular asset in the overall holdings of that asset (for example, the share of green equity in total equity.) The fourth column reports participation rates (for example, the fraction of households who hold equity). The final column reports conditional participation rates (for example, the fraction of households who hold green equity among equity-owning households). Data come from the May 2022 survey wave, except for the share of green deposits, which we add in from the November 2021 wave.

Area as a whole.[3]

Consider now the role of green asset positions. Overall, 34% of households have green asset position that add up to 11% of household wealth. The most important green investment vehicle is equity: 18% of households, or 42% of equity holders, report green equity holdings. These in-

[3]In contrast, U.S. households tend to hold a slightly larger share of risky assets. U.S. households had roughly $105 trillion worth of financial assets in 2020 with 49.4% of their portfolio in deposits, direct bond holdings, life insurance, and pensions, and 35% in mutual funds and corporate equity (Financial Accounts of the United State Z.1 Line 9 for 2020). Data on green investing in the US is limited. Industry estimates of ESG accounts owned by U.S. households range from $8-20 trillion, or 8-19% of the household portfolio, nge of , similar to the aggregate portfolio share of all green financial assets of German households of 11% from Table 1.

vestments amount to 6% of total financial assets or 17% of the equity portfolio held by German households. In contrast, only 5% of households report having green deposit accounts, and the share of green deposits is 4% of deposits, or 2% of total assets. The numbers for pensions and bonds are in the middle between equity and deposits. A likely explanation is that green assets are currently relatively risky. As a result, they are contained in green pension accounts, possibly in the form of equity, but they are not used by banks to back deposits.

The main takeaway is that while green investing is already fairly popular in Germany, it is currently risky relative to the overall portfolio. To see this, compare portfolio shares on risky versus safe assets in the aggregate portfolio of green holdings versus the overall portfolio. A natural classification labels equity as risky and deposits as safe, with bonds and pensions somewhere in between. The share of deposits in a portfolio thus serves as a lower bound for the share of safe assets, whereas the share of equity serves as a lower bound for the share of risky assets. For the aggregate portfolio, we can thus conclude that the risky share is between one-third and one-half. Among the green holdings, in contrast, the risky share is at least 55% and could be as high as 78%.

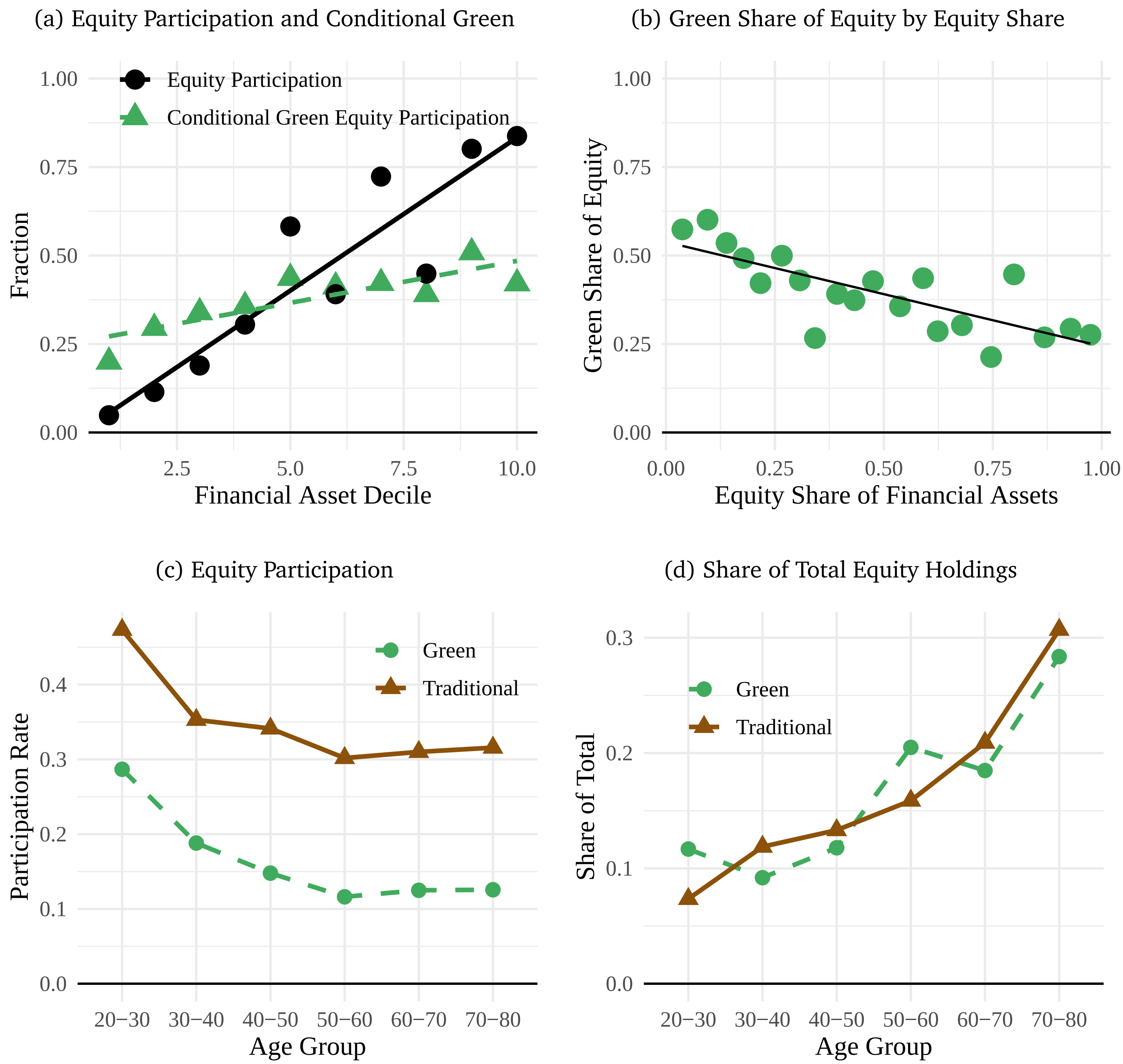
3.2 The Cross Section of Green Investor Households

There are large differences in the financial portfolios of households by wealth and age. Richer and older households are more likely to participate in the stock market and hold a larger share of their financial portfolio in stocks. Figure 1(a) plots the equity participation rate (in black) across the wealth distribution and the conditional participation rate in green equity (in green). There is a very steep wealth profile in equity participation. Fewer than 10% of households in the bottom decile of the wealth distribution hold any equity, while over 80% of households in the top decile hold equity. The wealth gradient in green equity participation, conditional on equity participation, is less pronounced.

Some households invest little in equity but seem to participate in equity markets specifically to invest in green assets. The last column of Table 1 shows that, among households who own equity, 91% of households hold some traditional equity, implying that 9% of households hold exclusively green equity. Additionally, the binscatter in Figure 1(b) shows a negative relationship between the share of green invested as equity and the equity share of financial assets. Households with less than 10% of their financial assets in equity hold over half their equity in green equity funds. In contrast, households with more than 90% of their financial portfolio in equity hold only a quarter in green equity funds.

Figure 1(c) plots the age profile of equity participation, illustrating that younger households are more likely to participate in both traditional and green equity markets than their older counterparts. While younger households are more likely to participate in equity markets, older households hold

Figure 1: Equity Participation and Portfolio Weights by Wealth and Age



Note: Equity contains individual shares, equity funds, and ETFs. Pensions include savings in private pension funds and life insurance contracts. Households classify their holdings as "green" versus traditional assets. Panel (a) shows the participation rate in equity and the conditional participation rate in green equity by decile of the financial asset distribution. Panel (b) shows a binscatter of the green equity share as a function of the equity share in financial assets. Panel (c) shows the participation rate in green and traditional equity by age group. Panel (d) shows the share of total equity held by age group. Sample includes all respondents in the May 2022 wave of the Bundesbank Survey of Household Expectations.

the majority of financial assets. Figure 1(d) illustrates the share of total equity holdings held by each age group. Households over 50 years hold the majority of both green and traditional equity assets. Although households under 40 are more likely to hold green assets, their impact on the aggregate household portfolio is limited as they own only 20% of total financial assets.[4]

4 Demand for a Green Safe Asset

To elicit respondents' taste for a green safe asset, we use a sequence of questions about interest rates on a hypothetical green bank account. We find large heterogeneity in households' *convenience yields*, which we define as the nonpecuniary compensation from holding a green safe asset. Some households have large positive convenience yields, which make them willing to sacrifice substantial returns to hold a green safe asset. Other households need to be paid substantial returns to hold a green safe asset, indicating that they perceive nonpecuniary costs from holding it or *negative* convenience yields. Despite strong household demand for a green safe asset, most mainstream financial institutions have yet to offer such an asset.

4.1 Measuring Taste for a Green Safe Asset

We measure taste for a green safe asset by presenting survey respondents with a menu of interest rates on a hypothetical bank account to be offered by their own bank relative to the interest rate on a traditional bank account. All individuals are first shown the following definition of a green savings account:

> Some banks offer "green savings accounts" that guarantee that your deposits are used to fund sustainable investments. Imagine your bank offered both traditional savings accounts and green savings accounts.

To avoid potential concerns regarding the perceived risk of a bank offering green deposit accounts, the survey explicitly states that the hypothetical green deposit account is at the same bank as the respondent's current deposit account. Respondents are then presented with a sequence of interest-rate spreads between the traditional bank account and the green bank account, ranging from 2% to −2%. For each spread, respondents were asked to make a binary decision for either the traditional or the green savings account. The complete translated text of the question continues as follows:

[4]There are additional dimensions of heterogeneity in the current distribution of green asset holdings that vary by asset type. For example, households who are more concerned and/or informed about climate change are more likely to invest in green equity or to have a green bank account. More details on who participates in green financial products can be found in Table B.1.

In which cases would you choose the traditional account or the green account?

(a) the interest rate on the green savings account is 2% lower per year

(b) the interest rate on the green savings account is 1% lower per year

(c) the interest rate on the green savings account is 0.5% lower per year

(d) the interest rate on the green savings account is the same

(e) the interest rate on the green savings account is 0.5% higher per year

(f) the interest rate on the green savings account is 1% higher per year

(g) the interest rate on the green savings account is 2% higher per year

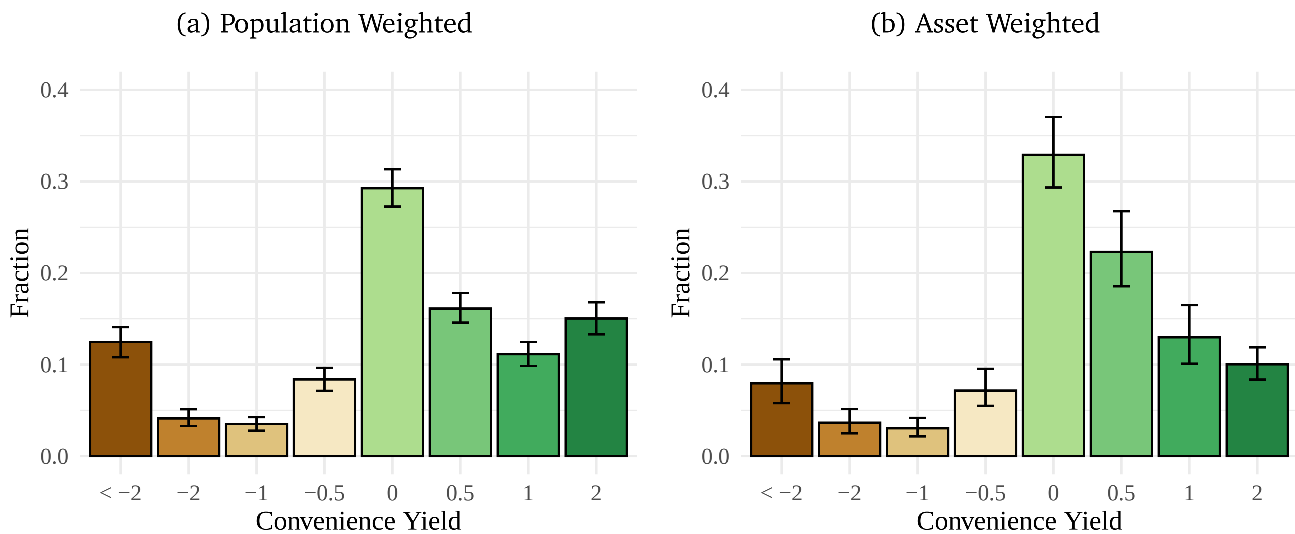
Worrying about interest rates on deposits and comparing rates across banks is salient for German households in the low-interest rate environment of the past few years. We are confident that most survey respondents understood the sequence of questions, as close to 90% of respondents' answers' were complete and consistent: respondents who choose the green deposit account for some spread also choose it for all larger spreads. For example, if they choose the green account when the spread over the traditional account is 0, they also choose the green account when the spread is positive. Approximately 8% of respondents gave inconsistent answers, and 5% did not respond or only partially responded to the questions.

Our definition of a respondent's convenience yield on a green deposit account is based on the highest spread between the traditional and green bank accounts that they are willing to pay for a green bank account. For example, respondents who choose the green account in all cases are classified as having a 2% convenience yield for green safe assets and a taste for green. When respondents only choose the green account if it pays the same interest rate as the traditional account, they are classified as having a convenience yield of 0 and having a slight taste for green since they break the "tie" in favor of the green asset. If respondents choose the traditional account in all cases, they are classified as having a negative convenience yield of −2% and a distaste for green. The classification goes on accordingly for intermediate accepted spreads.

4.2 Positive and Negative Taste for a Green Safe Asset

We find that taste for a green safe asset is not always positive. While many respondents report they are willing to sacrifice interest to hold a green safe asset, a substantial fraction would require higher interest to hold such an asset. Figure 2(a) plots the distribution of convenience yields on a green deposit account using population weights. We find that 42% choose green deposits when they pay a lower interest rate than traditional deposits, 30% choose green deposits only when they pay at least the same interest rate as traditional deposits, and 28% only choose green deposits if they have a higher interest rate than the traditional account.[5]

Figure 2: Distribution of Convenience Yields on Green Deposit Accounts



Note: The height of the colored bars shows the fraction of respondents with the indicated convenience yield, which is the highest interest-rate spread between the traditional and green deposit accounts for which they still choose the green deposit account. Panel (a) shows the distribution of convenience yields using population weights, while panel (b) shows the distribution using asset weights. The black error bars show the 95% confidence interval for the fraction of the population in each bin based on 1,000 bootstrap samples. The sample includes all respondents in the November 2021 wave of the Bundesbank Survey of Household Expectations.

There is substantial wealth behind both green and anti-green preferences. Figure 2(b) plots the distribution of convenience yields weighted by households' reported asset holdings. Respondents with positive convenience yields (and thus a taste for green) hold 45% of aggregate financial wealth, households with negative convenience yields or an aversion to green hold 22% of aggregate wealth, and households with a slight taste for green hold 33% of aggregate wealth. Households with more financial assets have less extreme, but on average, slightly more green taste than the population overall.

The convenience yields are large but not unreasonable. To translate these responses to euros, we use data on survey responses about households' actual bank deposits. We find that the median willingness to pay for a green bank account among households with green taste is 150€ in annual foregone returns. The median required payment to accept a green bank account among households with aversion to green is 112€ in annual forgone returns.[6] Given that the median household income

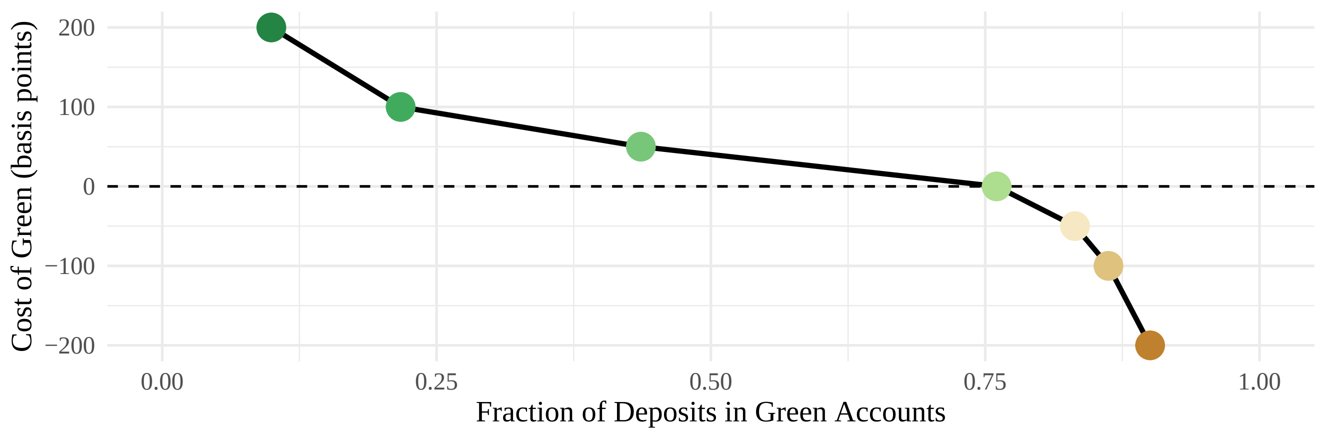
[5]Our elicited range of interest-rate spreads leads to substantial censoring at the tails of the true taste distribution. Roughly 13% of people do not choose green deposits for any of the spreads offered, while 15% choose green deposits in all cases.

[6]Both distributions are heavily skewed with a long right tail. The mean willingness to pay for a green bank account among households with a green taste is 371€ in annual foregone returns (with a standard deviation of 728€). The mean required payment to accept a green bank account among households with an aversion to green is 611€ in annual forgone returns (with a standard deviation of 1,579€).

of survey respondents is roughly 40,000€, these numbers are not unreasonable when interpreted as an annual charitable donation.[7]

We also combine the distribution of convenience yields with households' actual bank deposits to construct a demand curve for a green safe asset. For each interest-rate spread on the green deposit account, Figure 3 plots the cumulative deposits of households who would accept that spread. We find that if green deposits pay the same interest rate as traditional deposits, more than 75% of deposits would be green. For a cost of 1 percentage point, that fraction would still be roughly 20%, and hence far larger than the negligible role that green bank accounts in Germany currently play.

Figure 3: Demand Curve for Green Deposit Accounts



Note: Demand curve for green deposit accounts for all respondents in the November 2021 wave of the Bundesbank Survey of Household Expectations. For any given cost of green (interest-rate spread between traditional and green deposit accounts) in basis points measured along the vertical axis, we plot the fraction of deposits allocated to green deposit accounts based on households' answers to the hypothetical bank account question and their actual deposit holdings.

Appendix B.2 documents how the taste for a green safe asset correlates with age and with other measures of green preferences. Young households are much more likely to have nonpecuniary benefits from green deposits, while older households are more likely to have nonpecuniary costs. There are also significant differences in convenience yields by other demographic characteristics. For example, women, college graduates, and West Germans are more likely to have positive convenience yields. However, taken together, demographics, income, and wealth explain only a small share of the variation in green taste in the population. Moreover, green taste is also strongly correlated with voting for political parties. Voters of the AfD are much more likely to demand a higher interest rate

[7]Another way to judge whether these convenience yields are reasonable is to compare their standard deviation with the distribution of deposit spreads across banks. For a panel of U.S. banks, Egan, Hortaçsu and Matvos (2017) estimate this standard deviation to be 0.7 percentage points. Moreover, the spreads we find are smaller than the effective spreads U.S. investors accept for ESG-oriented index funds from a recent survey by Baker, Egan and Sarkar (2022b). Of course, expected returns in their context may also reflect differential risks of the different funds, while households in our survey compare green versus traditional safe assets.

on green deposits than voters of the Alliance 90/ the Greens. Finally, households are more likely to have positive convenience yields when their number one concern is climate change. Households whose number one concern is immigrants are more likely to have negative convenience yields.

5 Demand for Green Equity

We elicit households' expected returns and risk perceptions for both a green and a traditional equity fund. Most households expect higher returns on equity funds that they perceive as (weakly) riskier. Households seem well aware of risk-return trade-offs, as they do not respond to an information treatment that explains the principle of risk-return trade-offs. Moreover, many households choose equity funds that are *dominated*: households rank these funds as riskier while expecting similar or lower returns on these funds. These household choices suggest that taste (or distaste) for green assets scales with the perceived risk of these funds, consistent with a hedging motive.

5.1 Measuring Expectations

To measure expectations about green investment products, we directly asked survey respondents to report their expected returns for both a traditional and a green equity fund and the relative risk of the two funds. Additionally, we posed a hypothetical investment scenario and asked respondents to indicate which fund they would prefer.

Before being asked any questions, all respondents were first shown the following information:

> Equity funds consist of multiple shares that a professional fund manager manages. In contrast to traditional equity funds, sustainable equity funds invest more heavily in enterprises that operate in a comparatively climate-friendly manner. Imagine you were to invest part of your annual salary in shares today. You would invest the full amount in either a traditional equity fund or a sustainable equity fund.

Respondents were then asked to provide their expected returns for each type of equity fund:

> By what percentage do you think the value of your investment would change over the next twelve months? Note: Please enter a value in each input field (values may have one decimal place). If you expect the value to fall, please enter a negative number
>
> (a) traditional equity fund: input field percent
>
> (b) sustainable equity fund: input field percent

Two qualitative questions followed the questions on expected returns. The first asked respondents to rank the risk of a traditional equity fund compared with a sustainable equity fund on a qualitative scale. The phrasing of this question was designed to capture a qualitative understanding of the relative variance of the two equity funds:

> In your opinion, is the risk involved in a traditional equity fund higher or lower than in a sustainable equity fund? Please provide your assessment for the risk that the actual value could be below your expectations after twelve months. The risk involved in a traditional equity fund compared with a sustainable equity fund is ...
>
> (a) significantly lower
> (b) somewhat lower
> (c) roughly the same
> (d) somewhat higher
> (e) significantly higher
> (f) don't know

Finally, we ask respondents to make a hypothetical investment decision between green and traditional equity funds:

> Imagine you have saved part of your annual earnings and wish to invest this money in an equity fund starting today. Would you rather invest in a traditional equity fund or a sustainable equity fund?
>
> (a) traditional equity fund
> (b) sustainable equity fund
> (c) don't know

The response rate to these questions was significantly lower than to our green deposit module likely reflecting the much lower participation in equity markets by German households. More details can be found in A.2. For our main quantitative exercises, all results are robust to re-weighting to account for differential sample attrition by green taste as measured by either the deposit spread question or the 2021 Bundestag election outcome.

5.2 Expected Returns

Households' reported return expectations are in a reasonable range. Table 2 reports the average expected returns for the two equity funds and the average *greenium*: the expected excess return on traditional equity over green equity. The population-weighted greenium is slightly negative: the nominal average annual returns for traditional and green equity funds are 7.4% and 7.7%, respectively.[8] Weighting by financial assets, the expected returns are higher for the traditional equity fund (8.4%) than for the green equity fund (7.6%), implying a *positive* greenium of 80 basis points.[9] Overall, there is rich heterogeneity in households' expected returns. While 49% of households expect traditional equity to have higher returns, 25% of households expect green equity to have higher returns.

Table 2: Average expected returns on traditional and green equity funds

	Traditional Equity	Green Equity	Greenium
Population Weighted	7.4	7.7	−0.3
Financial Asset Weighted	8.4	7.6	0.8
Non-zero Equity	8.7	7.7	1.0
Non-zero Green Equity	8.4	8.5	−0.1
Top Quartile Financial Assets	8.8	7.5	1.2
Bottom Quartile Financial Assets	7.4	7.9	−0.5
Age <30	6.4	6.1	0.3
Age >60	7.7	7.5	0.2
Positive Convenience yield	7.5	8.3	−0.9
Negative Convenience yield	9.6	5.0	4.5
AfD Voter	10.0	5.2	4.9
Alliance 90/ The Greens Voter	7.8	8.8	−1.1

Note: This table reports average expected returns on traditional and green equity funds and the greenium for the sample as a whole as well as various subgroups by demographics, wealth, and attitude towards green. Expected returns are winsorized at −5% and 15% which corresponds to the 0.5 and 75th percentile of the expected return distributions. For every row except the population weighted row, households are weighted by their population weight × their reported financial assets.

Table 2 shows a connection between households' expected returns and their actual portfolio holdings. Households who report non-zero equity holdings and those in the top quartile of financial assets have higher than average expected returns for traditional equity. The expected returns for green equity are more similar across these households, implying a positive greenium. Moreover, households who own green equity expect higher green returns, which lowers their greenium.

Table 2 also documents a connection between households' expected returns and their taste for green. Households with a taste for green, as measured by a positive convenience yield on a green deposit account in our survey or their reported vote for the Green Party, expect green equity to

[8]While these expected returns are slightly higher than historical returns for German stocks, the survey was fielded during a stock price boom in Germany, which ended with the Russian invasion of Ukraine. The realized nominal annual return on the DAX, a stock index of 40 German blue chip companies, was on average 6% from 2000-2019. In the 12 months before our survey, DAX returns were quite high, averaging 15%.

[9]The positive greenium for wealthy respondents is consistent with Giglio et al. (2023) who report an average −1.4% expected 10-year annualized return of ESG investments relative to the overall stock market among Vanguard investors.

outperform traditional equity. By contrast, households with a distaste for green, measured by a negative convenience yield on a green deposit account or who voted for the AfD in the previous election, expect green equity to substantially underperform relative to traditional equity.

5.3 Measuring the Impact of Information on Expectations

To assess the impact of information about green investing we embedded a randomized control trial (RTCs) with information treatments in our survey module in November 2021. We allocate our 6,000 respondents into 5 groups, to which respondents are assigned randomly. The control group receives no information treatment and consists of roughly 2,000 respondents. The treatment groups each consist of roughly 1,000 respondents.[10]

We consider several pieces of information. The first treatment (T1) explains that traditional equity funds make unconstrained investment choices and are therefore expected to outperform sustainable equity funds. A second treatment (T2) provides information about the past performance of traditional and sustainable equity funds. Here we provide purely financial information without any connection to the climate transition. A third treatment (T3) explains the principle of a risk-return trade-off. A fourth treatment (T4) raises awareness about climate change and the potential of green investing for mitigation. We discuss the last two treatments in section 5.4 about households' perceived risk-return trade-offs and in section 8.2 about model counterfactuals, respectively.

We are interested in how households who receive the information treatments adjust their return expectations. We therefore positioned the treatments T1-T3 after the hypothetical green bank account question but before eliciting beliefs about equity returns. The specific wording of the first two information treatments (T) is as follows:

[10]The treatment groups are solely used for identifying the effects of the information treatments. Any post-treatment outcome from the November 2021 wave that is used in our empirical section or our model calibration is based on the unperturbed control group sample of roughly 2,000 respondents.

- T1 (Unconstrained Investments): "Traditional equity funds (i)[a] have more freedom in their investment decisions than sustainable equity funds (i). Therefore, traditional equity funds expect to see greater gains in value over the long term than sustainable equity funds."

- T2 (Past Performance): "Equity market data can be used to compare the gains in value of sustainable equity funds (i) with those of traditional equity funds (i). Over the last ten years, the gains in value of a typical sustainable equity fund were, on average, around 3 percent higher per year than those of a comparable traditional equity fund."

- Control group: no information shown.

[a]Individuals can click on infoboxes, marked as (i), containing explanations that characterize equity funds in general, and sustainable equity funds, or traditional equity funds in particular.

Formally, we estimate treatment effects by regressing post-treatment outcomes Y_i^{post} on a treatment indicator X_i^k which is equal to one if household i received treatment k and zero otherwise, as well as on the interaction of the treatment indicator with a concern indicator C^i equal to one if the household mentioned climate as a top concern and zero otherwise:

$$Y_i^{post} = \alpha + \sum_{k=1}^{K} \beta_k \left(X_i + \beta_2 X_i C^i \right) + \mathbf{W_i}\phi + \epsilon_i. \qquad (1)$$

The coefficient β_k thus measures the average effect of treatment k for respondents not concerned about the climate relative to the outcome in the control group (α), whereas the coefficient β_2 on the interaction term measures the effect on the concerned group, relative to the unconcerned part of the same treatment group. We also include a vector of controls W_i that contains demographic, income and wealth characteristics. Due to random assignment of the treatment groups, the control term $\mathbf{W_i}\phi$ is by construction close to orthogonal to the treatments and mainly serves to increase the precision of the estimates.

Table 3 presents results from estimating equation (1). We consider two post-treatment outcomes. The first column reports results for households' expected return on traditional equity funds, while the second column reports results for their expected return on sustainable equity funds. The first row in Table 3 shows households respond to the information that traditional equity funds are unconstrained in their investments (T1 information) by increasing their expected returns on traditional equity funds while not changing their expected returns on green funds, thus widening their perceived greenium. The second row in Table 3 shows that households respond to the strong recent performance of sustainable equity funds (T2 information) by lowering their expected returns on traditional equity funds,

Table 3: Expected returns and information treatments

	Dependent variable: Expected returns		
	Traditional Equity	Green Equity	Greenium
Unconstrained Investments (T1)	0.760**	−0.257	1.017***
	(0.314)	(0.319)	(0.279)
Past Performance (T2)	−0.596*	−0.114	−0.482*
	(0.317)	(0.322)	(0.281)
Demographic Controls	✓	✓	✓
Income/Wealth Controls	✓	✓	✓
Observations	1,728	1,728	1,728
R^2	0.056	0.031	0.130

Note: This table reports effects of information treatments for the expected returns on traditional and green equity funds. In each regression we control for voting for the green party, rating climate change the top issue facing Germany, age, age squared, gender, college education or higher, household income, household income squared, securities holdings, securities holdings squared, green equity holdings, convenience yields. Returns are winsorized at -5% and 15% which corresponds to the 0.5 and 75th percentile of the return distributions. *p<0.1, **p<0.05, ***p<0.01.

while not changing expected returns on green funds, thus reducing their greenium.

5.4 Relative Risk Rankings

The vast majority of households have expectations about returns that embed a trade-off between risk and return. More specifically, 82% households have higher return expectations for the equity fund that they rank as weakly riskier, and lower return expectations for the equity fund that they rank as lower risk. For example, when households have higher return expectations for the green equity fund than the traditional equity fund, they rank it as similar or higher risk than the traditional equity fund, and vice versa. Indeed, most households rank green equity funds as similar (47%) or higher risk (36%). A smaller group of households (17%) believe green equity funds are lower risk.

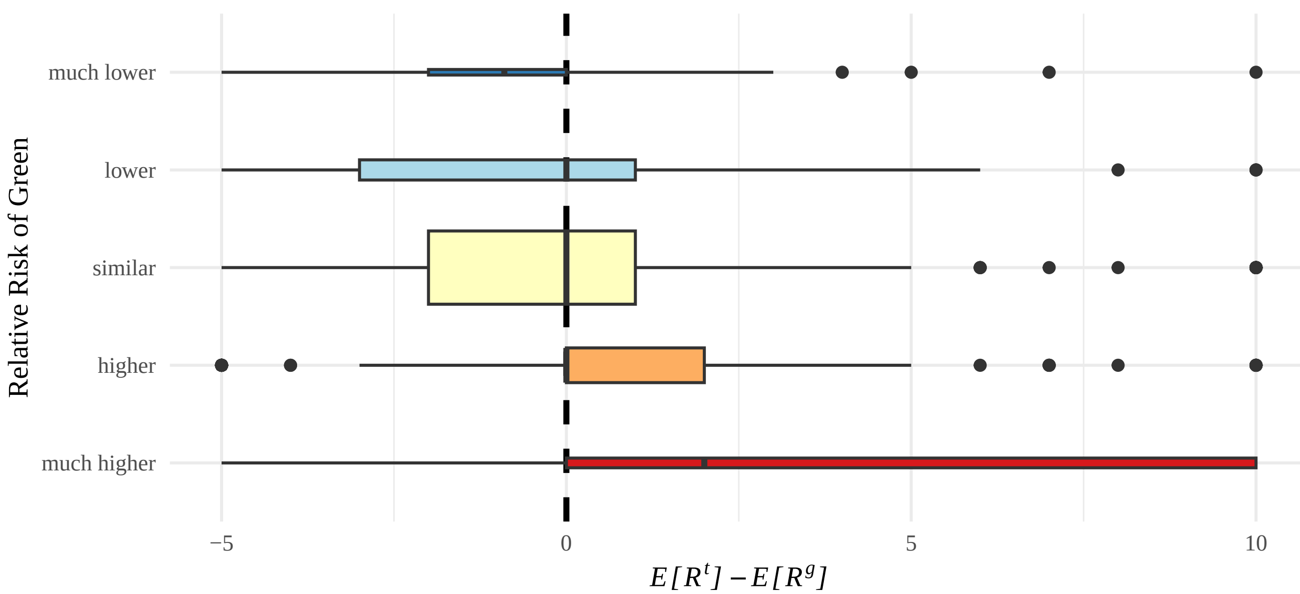
More generally speaking, we find that households are well aware of risk-return trade-offs. Indeed, the distribution of households' expected returns and risk rankings does not change in response to an information treatment about risk-return trade-offs. As mentioned in the previous subsection, our information treatment (T3) is placed (together with T1-T2) after the hypothetical green bank account question but before eliciting beliefs about equity returns. The precise wording is:

- T3 (Risk-return trade-off): "Equity funds (i) differ not only in terms of the expected gains in value, but also in terms of risk. Greater risk is usually accompanied by a greater average gain in value."

Households do not update their return expectations in response to this information treatment. Their expected returns and risk rankings are essentially unchanged.

Figure 4 shows the cross-sectional distribution of expectations. The vertical axis measures the relative risk of green, while the horizontal axis measures the perceived greenium, the expected excess returns on traditional equity over green equity. The colored bars in each row in the figure show the interquartile range of the perceived greenium for a given risk ranking. The graph reveals a *negative* correlation between greenium and the relative risk of green; the colored bars move from top-left to bottom-right. Since the precise relationship between risk and return varies among households, this negative correlation is still consistent with the fact that most households have higher return expectations for weakly riskier funds and vice versa. This negative cross sectional correlation is robust across reported education, wealth, securities holdings, and green investment holdings.

Figure 4: Distribution of the Perceived Greenium by Relative Risk Ranking



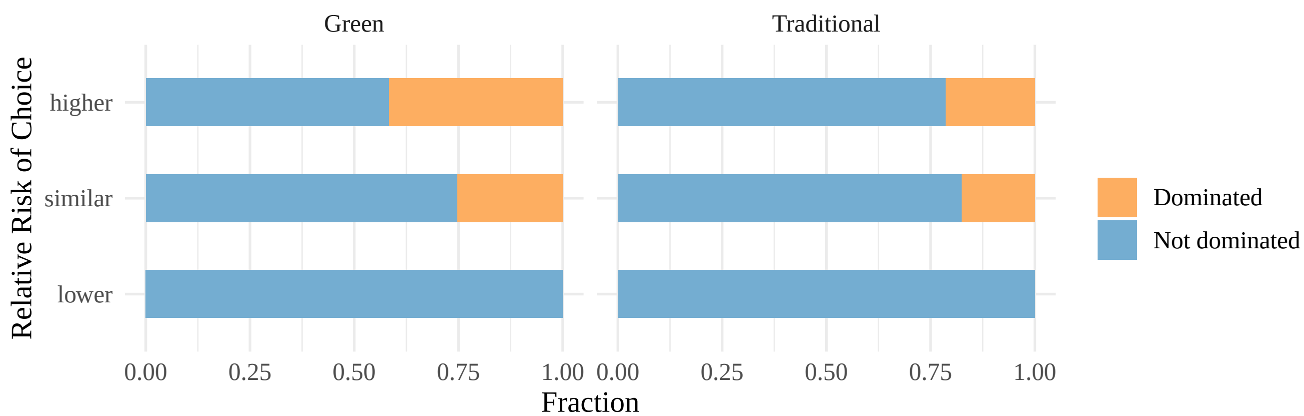
Note: Each row in the figure shows the distribution of the perceived greenium $E[R_t]-E[R_g]$ for a given risk ranking of green funds relative to traditional funds. For each relative risk ranking, the colored box shows the 25th-75th percentile of the greenium, the solid line within the box plots the location of the median of the distribution of the greenium, and the whiskers extend to ±1.5 the interquartile range.

5.5 Taste for Risky Green Assets

Many households make hypothetical investment choices in which they select equity funds that they believe are *dominated*: riskier and with similar or lower expected returns. These choices suggest that households perceive an extra motive (or deterrent) to invest in green or traditional equity funds that scales with risk, consistent with a worry about a faster or slower climate transition.

Figure 5 plots the fraction of households who choose dominated equity funds in orange, while the blue households choose funds with higher expected returns and similar or lower risk. We plot these fractions by equity fund choice and the relative risk ranking of the household's choice. For *both* the green and traditional equity funds, more households make dominated choices when they believe that the funds they are choosing have higher risk. Overall, we find that 18% of households choose the equity funds that they believe are dominated by the other funds. Among households who choose the green equity fund, 24% are making a dominated choice, while 10% of households who choose the traditional equity fund make a dominated choice.

Figure 5: Hypothetical choice of equity funds by relative risk



Note: This figure measures on the horizontal axis the fraction of households who are making the dominated choice. The left column illustrates this for households who choose green equity funds. The right column illustrates this for households who choose traditional equity funds. The vertical axis shows the relative risk ranking (lower, similar, higher) for the funds chosen by the household. For example, the top right bar shows in orange the fraction of households who choose traditional equity funds, believe traditional funds are relatively higher risk, and make a dominated choice.

Convenience yields cannot explain these choices. If we define the effective expected return on green equity funds as the stated expected financial return plus the convenience yield (based on the highest interest-rate spread between the traditional and green deposit account that the household is willing to accept), the number of households making dominated choices does *not* change substantially. The overall fraction making the dominated choice with this alternative return concept is 16%. Among households who choose green equity funds, now 20% are making a dominated choice, while

8% of households who choose traditional equity funds make a dominated choice.

The fact that more households make a dominated choice when they believe that their choice is riskier suggests that there is an additional motive for green or traditional investments that scales with the risk of equity funds, consistent with a hedging motive for climate risk. For example, a household may have positive hedging demand for green equity funds because they provide a hedge against the risk of an accelerated climate transition: future states of nature in which there is a political consensus about fighting climate change, and traditional equity performs poorly. Conversely, one out of ten answers indicates a negative hedging demand for green equity funds. These households may, for example, worry about a slower climate transition and hold traditional equity to hedge this risk despite its perceived dominated returns.

6 Quantitative Portfolio Choice Model

The previous sections have documented new features of household beliefs and preferences. This section first develops a portfolio choice model that incorporates these features. We then use the cross section of household survey responses to quantify the model. Finally, we add a supply side and define equilibrium to prepare the ground for the counterfactuals in the next sections.

6.1 Household Problem

We consider a model with two periods, date 0 ("this year") and date 1 ("next year"). The economy is populated by many households indexed by i. At date 0, household i starts with wealth w^i and chooses date 0 consumption and a portfolio of assets. There are two risky assets: a traditional equity fund and a green equity fund with uncertain gross returns R_t and R_g per unit of investment. These returns are jointly lognormally distributed under household i's subjective belief. There are also traditional and green safe assets that pay certain gross real interest rates R_t^f and R_g^f, respectively. We impose short-sale constraints on all assets. Households care about date-0 consumption and date-1 wealth. Household i's preferences are represented by Epstein-Zin utility with discount factor β^i, unitary elasticity of substitution, and coefficient of relative risk aversion γ^i.

Supported by our empirical findings, households in our model can derive nonpecuniary benefits or costs from holding green assets. We thus distinguish between financial wealth – the sum of payoffs from investments – and *effective* wealth that enters utility and has a nonpecuniary component. We consider two sources of nonpecuniary benefits. First, households may like or dislike holding wealth in green assets relative to traditional assets. We assume that the contribution to effective wealth of a unit invested in a green asset is given by a scalar θ^i times the contribution of a traditional asset with the same financial return properties. If $\theta^i > 1$, the household enjoys green equity or debt more even if the financial return is the same as for a traditional investment: the green investment provides a *convenience yield*. In contrast, a household with $\theta^i < 1$ suffers when wealth is stuck in a green investment. For example, the negative taste could be politically motivated or rooted in distrusting green labels.

A second source of nonpecuniary benefits is that households' enjoyment of future wealth may depend on the path of the climate transition. We thus allow for state-dependence in the marginal utility of financial wealth: the contributions of all assets to effective wealth are multiplied by a common uncertain factor H^i with mean one that generates a demand for hedging. To ensure that hedging demand is driven by concern with climate risk, we assume that the factor H^i is proportional to the return difference between traditional and green equity:

$$\log H^i = \eta_0^i + \eta_g^i (\log R_t - \log R_g), \tag{2}$$

where η_0^i and η_g^i are scalars. We choose the parameter η_0^i such that the mean of H^i under the household's subjective belief equals one. As a result, H^i only matters through its covariance with returns. A household with $\eta_g^i > 0$ has low effective wealth when green stocks do relatively well over the next year (for example, when the climate transition is faster than expected.) In contrast, a household with $\eta_g^i < 0$ has high effective wealth in this scenario.

Household i is endowed with initial wealth w_0^i, preference parameters $\beta^i, \gamma^i, \eta_0^i, \eta_g^i$ and θ^i as well as a subjective belief about risky returns and solves

$$\begin{aligned} \max_{c_0, w_1, e_t, e_g, b_t, b_g} \; & \log c_0 + \beta \log E^i \left[w_1^{1-\gamma^i} \right]^{\frac{1}{1-\gamma^i}} \\ \text{s.t. } & c_0 + e_t + e_g + b_t + b_g = w_0^i \\ & w_1 = H^i \left(R_t e_t + \theta^i R_g e_g + R_t^f b_t + \theta^i R_g^f b_g \right) \\ & e_t, e_g, b_t, b_g \geq 0. \end{aligned} \tag{3}$$

The first constraint is the budget constraint at date 0. The second constraint defines effective wealth at date 1. The inequalities represent the short-sale constraints.

Solution. We derive the solution in detail in Appendix C.1. Here, we only summarize key properties relevant for our results below. We first note that, with Epstein-Zin utility and tradability of wealth, the savings and portfolio decisions separate. In particular, a unitary elasticity of intertemporal substitution implies that the household saves a share $\beta^i/(1+\beta^i)$ independently of either the distribution of returns or nonpecuniary tastes from assets. Intuitively, the household has log preferences over current consumption and the certainty equivalent of future effective wealth, which takes into account risk aversion as well as green taste. Any change in the effective return on an asset thus has offsetting income and substitution effects on consumption and does not alter the savings rate.

We further observe that it is optimal for a household to invest in precisely one safe asset, and this choice is determined by the taste parameter θ^i alone. Since interest rates are deterministic, the green safe asset is strictly preferred if $\theta^i R_g^f > R_t^f$, while the traditional safe asset is strictly preferred if the inequality is reversed. The household is indifferent if effective returns on the two safe assets are the same. For given market rates R_g^f and R_t^f, we can therefore read off the safe asset choice from the parameter θ^i; no other parameter matters. We define $R^{i,f} = \max\{\theta^i R_g^f, R_t^f\}$ as household i's individual-specific effective interest rate on an optimally chosen safe asset.

Since Epstein-Zin preferences are homothetic, optimal portfolio holdings are linear in initial wealth. We define the vector of portfolio weights on the two risky assets, that is, the ratios of expenditure to total savings, by $\omega = (\omega_t, \omega_g)^\top = (e_t, e_g)^\top / s$. The weights maximize utility from effective wealth at date 1 per unit of total savings at date 0:

$$\max_{\omega_t, \omega_g \geq 0} E^i \left[\left(H^i R^{i,f} + \omega_t H^i (R_t - R^{i,f}) + \omega_g H^i (\theta^i R_g - R^{i,f}) \right)^{1-\gamma^i} \right]^{\frac{1}{1-\gamma^i}}. \tag{4}$$

The household earns $R^{i,f}$ on safe investments and can add excess returns on risky assets by putting positive portfolio weights on those assets. To characterize the solution, we follow Campbell and Viceira (2004); we derive an approximation that exploits the lognormality of returns and works well for short periods such as a year.

Decomposition of household portfolio demand. The risky asset demand has three components

$$\omega^i = \omega^i_{mv} + \omega^i_n + h^i. \tag{5}$$

The first component ω_{mv} is a standard myopic demand familiar from mean-variance optimization, which describes the solution in the absence of nonpecuniary benefits (i.e. $\theta^i = H^i = 1$). The second component ω_n^i is demand due to nonpecuniary benefits (or costs) θ^i of holding green assets. The third component h^i is demand that hedges the climate transition, as represented above in the risk factor H^i. Every household's demand can be decomposed in this way but given short-sale constraints, the explicit formula depends on how many assets the household invests in.

We denote log returns on green and traditional funds by $r_g = \log R_g$ and $r_t = \log R_t$, and household i's subjective standard deviations of these log returns by σ_t^i and σ_g^i, respectively. It is also helpful to define, for every household, a *risk tolerance* matrix T^i that summarizes the effect of risk aversion and subjective risk perception on portfolio choice. For households who invest in both risky assets, we set $T^i = (\gamma^i \Sigma^i)^{-1}$. For households who invest in only the traditional fund, we define

T^i as a matrix of zeros except for the top left corner element equal to $(\gamma^i {\sigma_t^i}^2)^{-1}$. Analogously, for households who invest only in the green fund, the only element is the bottom right corner element equal to $(\gamma^i {\sigma_g^i}^2)^{-1}$.

With this notation in place, we can write the standard formula for myopic demand as

$$\omega_{mv}^i = T^i \begin{pmatrix} E^i[r_t] + \frac{1}{2}{\sigma_t^i}^2 - r_t^f \\ E^i[r_g] + \frac{1}{2}{\sigma_g^i}^2 - r_t^f \end{pmatrix}. \tag{6}$$

This portfolio achieves the optimal risk-return trade-off over the next period when the safe asset is traditional. It depends only on risk aversion and the distribution of excess returns. The household should locate on the efficient frontier and move closer to the safe asset if risk aversion is higher. The nature of the frontier considered by the household depends on the set of assets.

To write demand due to nonpecuniary benefits, let B_g^i denote a dummy variable equal to one when the household invests in the green safe asset and zero otherwise. We then have

$$\omega_n^i = \log \theta^i T^i \left(e_2 - B_g^i \iota \right), \tag{7}$$

where e_2 is the second unit vector and ι is a vector of ones. This component is nonzero only if θ^i differs from one. It clarifies how nonpencuniary benefits alter the incentives to take risk. For households who invest in a green safe asset ($B_g^i = 1$), $\log \theta^i$ also increases the effective interest rate $r^{i,f}$. For such households, the taste $\theta^i > 1$ for green assets does not affect the expected excess return on the green fund but lowers that on the traditional fund, discouraging risk taking overall. For households without green safe asset ($B_g^i = 0$), in contrast, the green taste $\theta^i > 1$ increases the expected excess return on green equity while leaving the expected excess return on traditional equity unchanged, thus overall encouraging risk taking.

Hedging demand reflects the covariance of returns $r = (r_t \; r_g)^\top$ with the preference shifter H^i:

$$h^i = (1-\gamma^i) T^i cov^i(r, \log H^i) = \frac{\gamma^i - 1}{\gamma^i} \begin{pmatrix} -\eta_g^i \\ \eta_g^i \end{pmatrix} =: \begin{pmatrix} -h_g^i \\ h_g^i \end{pmatrix}. \tag{8}$$

As usual, a log investor with $\gamma^i = 1$ behaves myopically and does not hedge. More generally, hedging demand represents a trade that goes long one risky asset and short the other, thus reallocating only within the portfolio of risky assets. Intuitively, this is because households worry about risk described by the return differential (2), the excess return on a long-short strategy in traditional and green equity.

The direction of portfolio reallocation due to hedging depends on risk aversion and how strongly marginal utility moves with the return difference. When risk aversion is larger than one, the household is relatively unwilling to substitute effective wealth across states of nature and therefore wants to shift resources into states where H^i is low. Households with positive $\eta_g^i > 0$ experience low H^i when green stocks do well (as implied by equation (2)) and believe that green stocks are assets that hedge them against this risk. This provides a motive to increase the weight ω_g^i on green stocks because this portfolio shift keeps effective wealth more similar across states of nature. Conversely, households with $\eta_g^i < 0$ tilt their portfolio away from their optimal portfolio in a myopic setting and towards traditional equity, which they perceive to hedge against low H^i.

6.2 Mapping Survey Responses to Model Primitives

Our quantitative exercise considers choice between green or traditional risky equity and safe assets. We thus narrow our focus in two dimensions relative to the broader perspective in our empirical work in prior sections. First, we study choice by households with mostly complete survey answers in the November 2021 wave. This sample selection implies that aggregate statistics from the model slightly overweigh equity holders and thus differ from their counterparts in Section 3, where we used the raw data whenever possible. Second, our model does not speak to pensions and risky bonds. For simplicity, we treat both items as safe traditional assets.

To characterize the solution and explain how we use survey data to calibrate the model, it is helpful to introduce additional notation for the distribution of risky log returns. We define the vector μ^i of household i's expected excess returns on the risky assets relative to the traditional interest rate:

$$\mu^i = \begin{pmatrix} \mu_t^i \\ \mu_g^i \end{pmatrix} = \begin{pmatrix} E^i[r_t] + \frac{1}{2}{\sigma_t^i}^2 - r_t^f \\ E^i[r_g] + \frac{1}{2}{\sigma_g^i}^2 - r_t^f \end{pmatrix}. \tag{9}$$

Here, all households face the traditional interest rate. As we have seen, green deposits are still a niche market, so we calibrate to an initial equilibrium where households are unaware of their existence. Section 7 explores the effect of introducing green safe assets as a counterfactual.

We further parameterize household i's subjective covariance matrix of log returns as

$$\Sigma^i = {\sigma_t^i}^2 \begin{pmatrix} 1 & \lambda^i \rho^i \\ \lambda^i \rho^i & {\lambda^i}^2 \end{pmatrix}, \tag{10}$$

where σ_t^i is the standard deviation of log traditional returns r_t, λ^i is the ratio of standard deviations of green relative to traditional log returns, and ρ^i is the correlation coefficient. This parametrization is useful since λ^i relates directly to our survey question about relative green risk.

Household responses to our survey questions identify the parameters of our model. Table 4 lists the 8 parameters that are household-specific. We distinguish two groups. The top panel lists the parameters that we can directly measure from the survey data. In particular, when households report their 12-month expected return on a traditional or green equity funds, we interpret their answers as telling us their expected level returns. To relate these answers to the moments of log returns, we use that $\log E^i[R_t] = E^i[r_t] + \frac{1}{2}\sigma_t^{i\,2}$ and $\log E^i[R_g] = E^i[r_g] + \frac{1}{2}\sigma_t^{i\,2}\lambda^{i\,2}$, respectively. We directly observe the interest rate $R_t^f = \exp(r_t^f)$ that households expect to receive on their deposits over the same 12-month horizon as the equity-fund investments.[11] Taken together, these answers pin down households' expected excess returns μ^i in equation (9). We further use households' convenience yields on green deposit accounts to identify their taste parameter $\log\theta^i = \log(1 + \text{minimum accepted spread})$.

Table 4: Household Parameters

Parameter	Definition	Source
$E^i[R_t]$	expected return on green equity	survey question about green expected return
$E^i[R_t]$	expected return on traditional equity	survey question about traditional expected return
R_t^f	traditional risk-free return	survey question about deposit rate
θ^i	non-pecuniary green return	survey question about green deposit spread
$\gamma^i\sigma_t^{i\,2}$	risk sensitivity	inference (see text)
λ^i	relative green risk	inference (see text)
ρ^i	correlation of returns	inference (see text)
h_g^i	hedging demand	inference (see text)

The bottom panel in Table 4 contains parameters that describe households' beliefs and attitudes towards risk, which we cannot measure directly from the survey. However, we can infer these parameters using our model with data on households' survey responses regarding their beliefs, hypothetical choices, and actual portfolio positions. We note that we cannot separately identify risk aversion and the scale of subjective risk. Given our assumption on preferences, doubling risk aversion generates the same risk tolerance matrix T^i and thus household behavior as multiplying all subjective variances by one-half. We scale all variances by the variance of traditional equity and infer only the product $\gamma^i\sigma_t^{i\,2}$ that captures households' overall *risk sensitivity*.

Inference of risk parameters. To identify the risk parameters in the bottom panel of Table 4, we

[11] The complete translated text of the question in the survey reads as follows:

> What do you expect interest rates on savings accounts to be on average over the next twelve months? Note: Please enter a value in the input field (values may have two decimal places). If you assume that interest rates will be negative, please enter a negative value.
>
> input field percent

proceed in three steps. We first use combined data from the November 2021 and May 2022 waves of the survey to estimate the vector of portfolio weights ω^i for each household. Second, we use survey responses on households' relative risk rankings and hypothetical portfolio decisions to obtain inequality constraints on the risk parameters. Together with equations that relate *observed* portfolio weights to preferences parameters, we thus obtain, for every household, a set of possible parameter values consistent with observed behavior. Finally, we select a vector of risk parameters for every household by minimizing a quadratic distance of parameters from benchmark values motivated by historical averages. We now sketch each step briefly; a detailed description is in the Appendix.

Our first step constructs the combined sample from the two waves of the survey. In the November wave, we field questions on return expectations and also observe each household's total share of financial assets in equity funds, $\omega_t^i + \omega_g^i$, as well as whether or not the household reports holding green equity funds. However, we do not observe the euro value of the household's green holdings, ω_g^i. In the May wave, in contrast, we observe households' entire financial portfolio broken out by green and traditional assets. To estimate the weight ω_g^i for households in the November wave, we match households in the two waves based on observable portfolio characteristics. We also account for the range of values for the green portfolio share that are consistent with the household's stated expected returns and risk. A detailed description of the matching procedure is provided in Appendix C.3.

We now observe portfolio holdings ω_g^i and ω_t^i for every household. The vector of four risk parameters $\{\gamma^i {\sigma_t^i}^2, \lambda^i, \rho^i, h_g^i\}$ must be consistent with the households' observed portfolio holdings. For example, for households who hold both green and traditional equity, we have equations for the sum of the risky portfolio weights and the weight on green equity (derived in Appendix C.1):

$$\begin{aligned} \omega_t^i + \omega_g^i \quad &= \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\mu_t^i + \frac{\mu_g^i + \log\theta^i}{\lambda^{i2}} - \rho^i \frac{\mu_t^i + \mu_g^i + \log\theta^i}{\lambda^i}\right), \\ \omega_g^i \quad &= \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\frac{\mu_g^i + \log\theta^i}{\lambda^{i2}} - \frac{\rho^i \mu_t^i}{\lambda^i}\right) + h_g^i. \end{aligned} \tag{11}$$

Our second step derives additional inequality constraints on the risk parameters. The first inequality constraint comes from households' ranking of the risk of green equity relative to traditional equity. Households rank the relative green risk on a discrete scale from "much lower" to "much higher". The ranking restricts the ratio λ^i of the standard deviations of green returns relative to traditional returns. If households view green equity as relatively "riskier" or "much riskier" than traditional equity, then we restrict λ^i to be greater than 1. Conversely, we restrict λ^i to be less than 1 if households view green equity as relatively "safer" or "much safer". For households who view the risk of the two types of equity as similar, we restrict λ^i to be close to 1 (more precisely, between 0.9 and

1.1).

We derive a second inequality constraint from households' hypothetical asset choice. As described in Section 5.5, we ask households whether they would place an extra amount of savings from income in a green or a traditional equity fund. This question conveys more information than what is contained in optimal portfolio choice since it provides a ranking of two portfolios that are not optimal since the money cannot be split between green and traditional equity. We interpret the household's answer as ranking an equity portfolio that is all green to one that is all traditional. We show in Appendix C.2 that, given our assumptions on preferences, a household who is at an interior optimum for portfolio choice will always answer consistently with this ranking, independently of the extra amount that the household is thinking about.

The precise shape of the constraint depends on whether the household chooses green or traditional equity. For a household who chooses green, we have

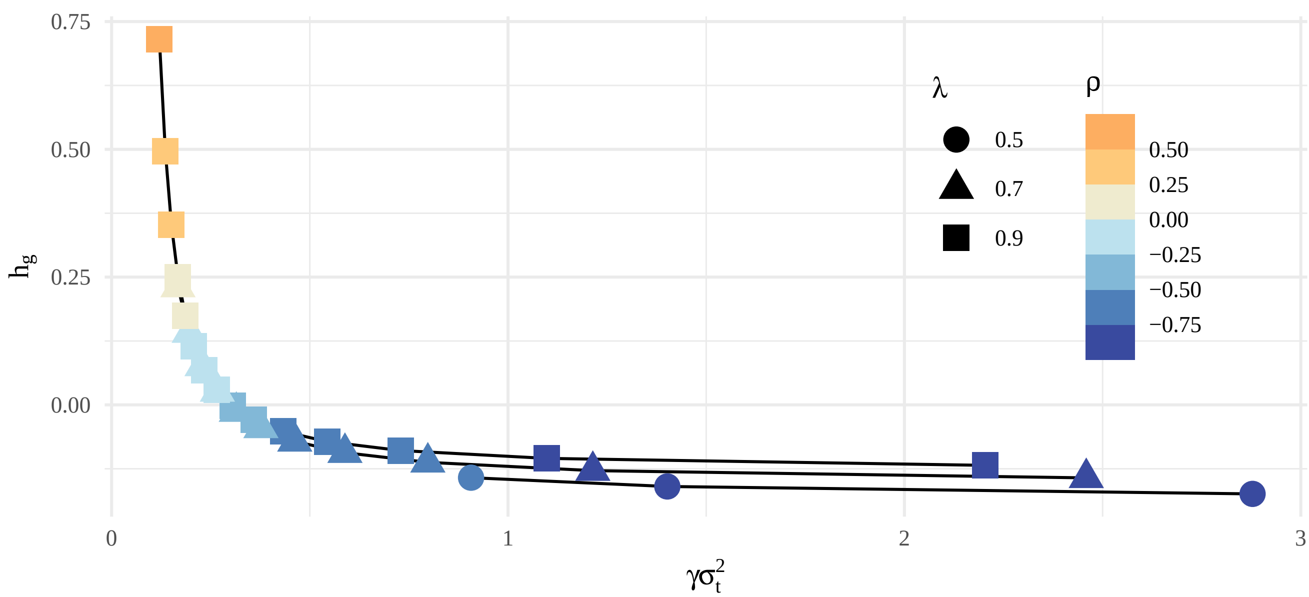
$$\mu_g^i + \log\theta^i - \frac{1}{2}\gamma^i {\sigma_t^i}^2 {\lambda^i}^2 + \gamma^i {\sigma_t^i}^2 h_g^i \lambda^i(\lambda^i - \rho^i) > \mu_t^i - \frac{1}{2}\gamma^i {\sigma_t^i}^2 + \gamma^i {\sigma_t^i}^2 h_g^i (\rho^i\lambda^i - 1). \tag{12}$$

Intuitively, if belief parameters are such that myopic demand would favor traditional equity, the hedging motive must be strong enough (h_g^i large enough) to justify the observed choice of green. For a household who chooses traditional, the inequality flips. Appendix C.2 derives these results.

Intuition for identification. We now have a set of possible parameter values for each household. Figure 6 illustrates this set for a household who holds both green and traditional equity funds (with portfolio weights described in equations (11)), chooses green in the hypothetical choice question (implying that inequality (12) holds), and believes the green equity fund is dominated (i.e., the household expects lower returns and more risk from the green fund.)

The household's perceived correlation ρ^i of returns is crucial for portfolio choice because it governs the degree of substitutability between green and traditional equity funds. When the correlation is low, traditional equity funds cannot be easily substituted for green equity funds. When the correlation is negative (as in the blue circles, triangles, and squares in Figure 6), diversification provides a strong motive for holding both equity funds, even if one of them is dominated. In the equation that determines the green portfolio weight (11), the negative correlation pushes up the green expected return. The diversification motive is strengthened further when the household has high risk sensitivity, measured on the horizontal axis. At the same time, low correlation and high risk sensitivity lower the household's hedging demand h_g^i for green equity in equation (8) along the vertical axis. When the correlation is positive (as in the orange squares), diversification is a weaker motive for holding both assets. To explain why the household chooses a dominated fund, hedging demand must be strong (high on the vertical axis), which requires low risk sensitivity.

Figure 6: Illustrating the role of individual parameter values



Note: Illustration of the set of possible parameter values that reconcile a household's stated beliefs, hypothetical choice, and portfolio holdings. The plotted values are for a household who holds both green and traditional equity funds, choses green in the hypothetical equity fund question, and believes that the green equity fund has lower expected returns and higher risk than the traditional equity fund. The lines trace out supported values for a given value of relative green risk, λ, varying the correlation of returns on the two equity funds ρ.

Shrinking towards homogeneity. To obtain determinate parameter values for each household, we minimize an objective function that shrinks parameters towards a common set of values. The idea here is to start from a baseline of homogeneity, motivated by historical numbers, and allow for heterogeneity only if the data demand it. As baseline values for hedging demand and the risk ranking, we choose zero and one, respectively. These values would apply in a world where households do not distinguish green and traditional assets. For the correlation coefficient, we choose a high baseline value of 90% that reflects the close historical comovement of traditional and green equity fund returns estimated by Berk and van Binsbergen (2021).

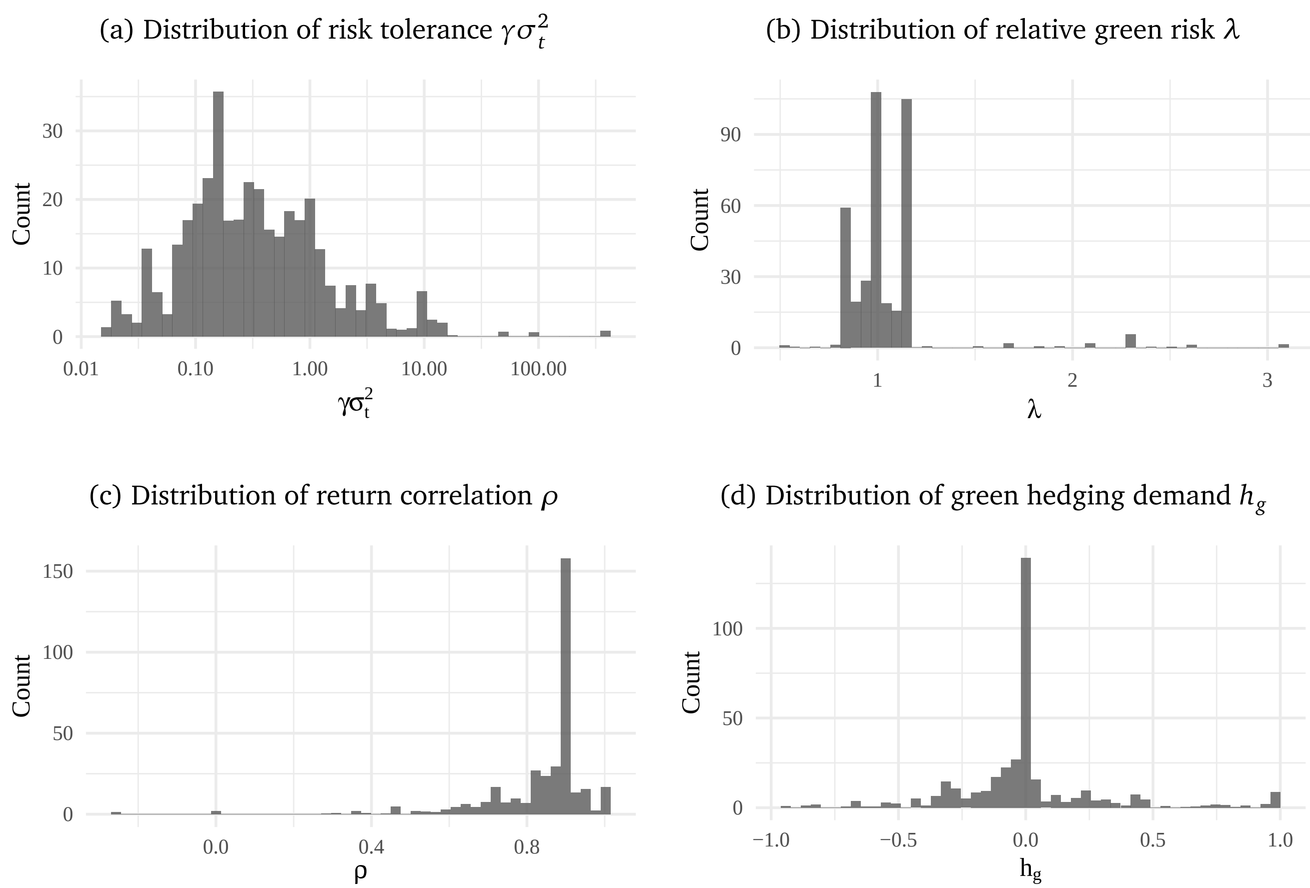
Formally, given data on portfolio weights and mean parameters, we choose risk parameters for every household to minimize

$$\left(h_g^i\right)^2 + \left(\rho^i - 0.90\right) + \left(\lambda^i - 1\right)^2 \tag{13}$$

subject to two portfolio formulas and two inequality constraints. For our example-household who holds green equity funds, the portfolio formulas are given by (11), while the inequalities are (12) and bounds for the relative green risk λ^i.

Distribution of estimated household parameters. The estimation reveals that substantial heterogeneity is necessary to explain household behavior. Figure 7 shows the cross-sectional distribution of risk tolerance, relative green risk, correlation coefficients, and green hedging demands. While there is substantial heterogeneity in these parameters across households, the range of values is quite reasonable and in line with standard estimates. Risk sensitivity, defined as the product of risk aversion and the variance of the traditional fund, mostly sits between .1 and 1. For a coefficient of risk aversion of 10, a typical number in quantitative models with portfolio choice, the corresponding range of standard deviations for annual returns is between 10% and 32%, and hence brackets typical historical estimates. Typical estimates of relative green risk λ^i range between .8 and 1.2, so the perceived volatility of green funds is within 10pp of that for traditional funds.

Figure 7: Cross Sectional Distribution of Household Parameters



(a) Distribution of risk tolerance $\gamma\sigma_t^2$

(b) Distribution of relative green risk λ

(c) Distribution of return correlation ρ

(d) Distribution of green hedging demand h_g

A few key parameter values are correlated with each other. Households with higher green hedging demand tend to perceive green equity to be relatively risky; the correlation coefficient between h_g^i and λ^i is 64%. Intuitively, households who view green funds as riskier but still hold them must have stronger positive hedging demand. Similarly, households who view green equity as less risky than traditional equity but do not hold much green equity must have greater negative green hedging demand. No other parameters are significantly correlated.

6.3 Equilibrium

So far in this section we have estimated a demand system for the riskfree assets and the green and traditional equity funds by inferring the distribution of parameters that govern households' portfolio choices. We now add a supply side, define equilibrium and explain how we perform counterfactuals. We are interested in particular in how demand shifts, such as taste parameters or expectations, alter equilibrium prices and investment. Equilibrium responses to demand shifts depend on the elasticity of supply: typically prices move less, and quantities more, when supply is more elastic. Since we do not have detailed data on supply, we consider two scenarios that we use below to answer two different counterfactual questions: perfectly elastic supply and fixed supply.

Equilibrium with elastic equity supply. For our elastic supply scenario, we assume that the supply of equity and the riskfree asset is perfectly elastic at current prices. Consider an economy with linear technology and no adjustment costs to capital. In such an economy, the value of the stock market equals the quantity of capital (which trades at a price of one), and beliefs about returns correspond to beliefs about the marginal product of capital. With elastic supply, asset payoffs respond maximally to changes in demand shifters; since prices are constant, all adjustment in asset values is due to changes in quantity and thus payoffs. This perspective provides a medium-term response to demand shifters and can serve as an upper bound on the immediate quantity impact: it incorporates adjustment of firms and the financial industry to offer more or less green capital as financing conditions for such capital change.

Formally, we can study equilibrium with elastic supply by checking how portfolio weights respond to changes in demand parameters. It is not necessary to solve for equilibrium equity prices since supply pins them down at one. Our model further takes as given an initial distribution of wealth across households. Since we have assumed an intertemporal substitution elasticity of one that makes the savings rate independent of beliefs, savings are proportional to initial wealth. Since utility is homothetic, we can normalize aggregate savings or initial wealth. For convenience, we set aggregate savings to one and denote the share of household i's savings by s^i. An *asset market equilibrium with elastic equity supply* then consists of an allocation of savings to the riskfree asset and the two equity funds.

Aggregate investment in equilibrium is now given by the wealth-weighted sum of portfolio weights. To clarify the contribution of different features of individual behavior, we start from the decomposition (5) of individual weights and find the aggregate portfolio weights

$$\bar{\omega} = \sum \frac{s^i}{\bar{s}} T^i \mu^i + \sum \frac{s^i}{\bar{s}} T^i \log \theta e_2 + \sum \frac{s^i}{\bar{s}} h^i, \tag{14}$$

where e_2 is the second unit vector. To explore counterfactual changes in aggregate demand (for example, the taste for green investment captured by θ^i and H^i, or expected returns), we recompute aggregate investment given the same distribution of savings. Importantly, we recompute households' individual optimal portfolios as the counterfactual parameters change their choices both at the extensive and the intensive margin.

Evaluating the expressions for the three components of demand yields the decomposition

$$\begin{matrix}\text{traditional}\\ \text{green}\end{matrix} \underset{\bar{\omega}}{\begin{pmatrix} 0.32 \\ 0.08 \end{pmatrix}} = \underset{\text{myopic demand}}{\begin{pmatrix} 0.31 \\ 0.09 \end{pmatrix}} + \underset{\substack{\text{demand due to} \\ \text{nonpecuniary benefits } \theta^i}}{\begin{pmatrix} -0.01 \\ 0.00 \end{pmatrix}} + \underset{\text{hedging demand } h^i}{\begin{pmatrix} 0.01 \\ -0.01 \end{pmatrix}}. \tag{15}$$

The decomposition shows that myopic demand accounts for the bulk of aggregate demand. Demand due to nonpecuniary benefits plays a negligible role. Hedging demand for green equity is *negative* on aggregate and is roughly the size of one-tenth of aggregate demand. The small average contribution of taste masks large differences at the individual level. We have already seen that the distribution of nonpecuniary benefits for green assets has a wide support even after wealth weighting. Accordingly, positive convenience yields contribute 3 percentage points to the demand for the green equity fund or a third of aggregate green demand. However, negative convenience yields generate an offsetting component. Similarly, positive hedging demand contributes 4 percentage points to green demand or about half of aggregate green demand. Again there is a strong offsetting force of −5 percentage points from households with a negative hedging motive.

Equilibrium with fixed equity supply. For our fixed supply scenario, we hold the supply of equity shares fixed. Consider an economy with two types of trees that each promise some fixed payoffs. In such an economy, the tree price is the present value of payoffs. Fixed supply means that payoffs do not respond to changes in demand: with constant quantities, all adjustments in asset values are due to price changes. This perspective is meant to diagnose the role of different demand parameters for the current equilibrium, rather than predict a future change.

Formally, computing equilibrium in this scenario finds market-clearing prices given payoff expectations, as in the quantitative temporary equilibrium approach in Landvoigt, Piazzesi and Schneider (2015) and Leombroni, Piazzesi, Rogers and Schneider (2021). While we fix equity supply, we continue to assume that the safe asset is supplied elastically at the interest rate r^f. This assumption is motivated by Germany's integration into the world market for safe assets. We also continue to work with a fixed distribution of savings. In an economy with trees, where prices adjust, this assumption is restrictive: it is accurate only if initial wealth is entirely price inelastic, for example, because it consists only of labor income or safe assets. In principle, demand might respond to prices because of wealth redistribution. Robustness checks suggest that such effects are relatively small in our context compared to the direct effects of prices on return expectations.[12]

We think of the two risky assets as trees with uncertain date 1 payoffs $D = (D_t, D_g)^\top$ that trade at date 0 at prices $P = (P_t, P_g)^\top$. We again normalize aggregate savings to one. We also normalize tree prices to one *in the initial equilibrium* that informs our calibration. This normalization is needed because the number of trees is arbitrary. The number of trees is then equal to their aggregate portfolio weights $\bar{\omega}$ in the data (and hence in the initial equilibrium). This normalization is convenient since initial beliefs about payoffs D_j are now the same as beliefs about returns R_j. An *equilibrium with fixed equity supply* consists of an allocation as well as a price vector that clears the trees market: the aggregate expenditure on trees equals the value of the fixed tree supply $(P_t \bar{\omega}_t, P_g \bar{\omega}_g)^\top$.

To write an intuitive formula for equilibrium prices, it is helpful to define $\bar{T} = \sum_i T^i s^i / \bar{s}$ as the wealth-weighted average of the risk tolerance matrices T^i. We note that while individual $T^i s$ are singular when a household invests in only one risky asset, average risk tolerance $\bar{T}$ is invertible as long as one households invests in both risky assets; this is the case we consider. Rearranging the equation for aggregate investment (14) and using the definition of the expected excess return (9), the vector of equilibrium log equity prices is then

$$p = -r^f \iota + \sum \frac{s^i}{\bar{s}} \bar{T}^{-1} \left(T^i \left(E^i [d] + \log \theta^i e_2 \right) + h^i \right) - \bar{T}^{-1} \bar{\omega}, \tag{16}$$

where ι is a vector of ones and $d = \log D$.

Equilibrium prices reflect weighted averages of individual households' expected payoffs as well as their compensation for risk and taste. The interest rate expression $-r^f \iota$ discounts the contribution of future payoff expectations $E^i[d]$ weighted by a product of two weights. Richer households matter more for prices because the weight $s^i / \bar{s}$ puts more weight on their payoff expectations. The matrix $\bar{T}^{-1} T^i$ of weights captures the distribution of risk sensitivities across households. If all households have the same risk sensitivity (e.g., they have the same risk aversion coefficient and covariance matrix), we get the identity matrix, and equilibrium prices reflect simply a wealth-weighted average of

[12]As an example, we might expect that an increase in the price of green trees redistributes wealth towards initial holders of green trees, who then save more and induce more of a taste for green trees in aggregate demand. Accurately measuring this effect requires identifying the cross sectional distribution of saving rates and hence additional data. However, experimenting with typical numbers for saving rates suggests that for the exercises below this type of effect is not particularly important: while price movements can be sizeable on aggregate, they have small effects through the wealth distribution.

discounted payoff expectations. This is true in particular when all households are risk-neutral so that all other terms are zero.

Households' risk aversion both alters the weighting of payoff expectations and introduces risk premia. The role of the weighting $\bar{T}^{-1}T^i$ is understood most easily in the special case when all households believe that payoffs are uncorrelated, so the matrices T^i and $\bar{T}$ are diagonal. In this case, forecasts of traditional fund payoffs do not matter for the valuation of green payoffs and vice versa. Indeed, the weight on household i's forecasts in the pricing equation for the traditional fund, say, is simply the inverse ratio of household i's risk sensitivity $\gamma^i(\sigma_t^i)^2$ divided by the wealth-weighted harmonic mean of all households' risk sensitivities. In other words, the weight is a measure of the relative risk tolerance of household i with respect to holding traditional equity funds that is decreasing in both risk aversion and their perceived risk. Household i's forecasts thus carry greater weight if the household tolerates more risk and takes a bolder position in the equity market.

More generally, valuation of the two assets is interdependent if households perceive payoffs to be correlated. For example, traditional equity is worth less if green equity offers a close substitute (a highly correlated risk) about which the household is more optimistic. This is why in general the matrix $\bar{T}T^i$ of weights is not diagonal: a household's forecast about green returns also matters for the valuation of traditional equity and vice versa. Again, both households' relative wealth and their relative risk tolerance matter for the degree to which their views are incorporated into the price. We emphasize that it is important for the pricing equation that we work with a utility function that allows for wealth effects. In contrast, the exponential function form that is common in studies of heterogeneous beliefs and taste gives rise to *equally weighted* averages of opinions.

Consider now the determination of premia. The last term in (16) is a risk premium. If households have the same risk aversion γ and agree on the covariance matrix Σ, then it takes the familiar form $\gamma\Sigma\bar{\omega}$: risk aversion multiplied by the covariance of the trees with the market portfolio $\bar{\omega}$. With heterogeneous risk tolerance, what matters is the wealth-weighted average risk tolerance, again giving more weight to richer households who take larger positions. The middle terms in (16) reflect compensation for nonpecuniary tastes related to green investing. Both θ^i and hedging demand enter like shifters to the expected payoff: as a result, they are weighted the same way: hedging motives of bolder and richer household carry more weight for equilibrium prices.

Consider now a change in the environment, for example, a change in preferences or payoff expectations that affects asset demand. The optimal policy derived from the objective function (4) delivers portfolio weights given any beliefs about returns. For any candidate price vector P, we can further compute households' beliefs about returns $R_j = D_j/P_j$, holding fixed their beliefs about payoffs. We can therefore use the optimal portfolio policy to compute portfolio weights given any candidate price vector. We obtain an excess demand function for equity by summing up individual demand and subtracting the value of aggregate supply $(P_t \bar{\omega}_t, P_g \bar{\omega}_g)^\top$. We thus find equilibrium prices that make investors willing to hold the fixed supply given their new demand parameters, including expectations of future asset payoffs.

For changes in the environment that alter preference parameters, we can interpret price changes from counterfactuals as changes in premia. Indeed, consider an econometrician who observes data from our model and measures the expected excess return on the green fund. The econometrician will construct a measure of conditional expected payoffs using repeated observations of prices, dividends, and other information variables. The measured premium is the econometrician's expected log payoffs less the log price. For any change in the environment that does not affect the econometrician's expected payoff, a counterfactual change in price will thus contribute to the premium that the econometrician measures. For example, if a counterfactual change in preferences raises prices, the econometrician would have measured a smaller premium under the counterfactual preferences. Put differently, the contribution of some features of preferences to measured premia can be measured as the difference between prices in baseline versus the counterfactual economy.

7 Counterfactuals: the Impact of Green Investing Today

How did the rise of sustainable investing affect asset prices and investment? We now perform a series of counterfactuals to answer this question. In particular, we compare the impact of two new market forces. Section 7.1 considers convenience yields and hedging demand, captured in our model by taste parameters. A counterfactual shuts down both features, but otherwise maintains the setting of the previous section: households invest in two distinct funds, with beliefs given by the survey. In other words, households in the counterfactual world still pay attention to how green a fund is. Section 7.2 then takes into account that a distinction between green and traditional is itself a novel feature of investing that emerged only in the last few years – before that, households did not pay attention to that distinction. We thus perform a counterfactual that also shuts down attention to how green a fund is. Both taste and attention are shape asset demand, and we vary them by changing the parameters of our estimated model of demand for different supply scenarios.

7.1 The Role of Taste

Our first set of experiments studies the role of nonpecuniary benefits θ^i and hedging demand h^i. We shut down those two elements of preferences and recompute equilibrium. We do this for both supply scenarios introduced in the previous section. Table 5 summarizes the results. Panel A characterizes the initial equilibrium and hence provides a baseline for all counterfactuals. Panels B and C present results under elastic and fixed equity supply, respectively. The first rows in Panel B and C show what happens when we shut down green taste. The other rows are other counterfactuals that we discuss below. The first two columns show percentage changes in the value of equity. The final three columns provide statistics about the green investor population that help interpretation.

Table 5: Counterfactual Results

	value (share of wealth)		green investor population		
	traditional	green	wealth share	avg $E[d_g - d_t]$	weight ω_g
Panel A: Initial equilibrium	.31	.08	.42	.00	.18
Panel B: Elastic equity supply	% change in quantity				
shut down taste	−9.3	+29.3	−.01	+.01	+.06
info treatment	−23.9	+87.6	+.06	+.02	+.19
Panel C: Fixed equity supply	% change in price				
shut down taste	−0.2	+0.5	−.08	+.02	+.04
shut down taste & attention	−0.6	−1.7		0	
info treatment	−0.1	+3.0	−.15	+.03	+.09
Panel D: Green safe asset	% change in equity		value (share of aggregate wealth)		
(elastic equity supply)	traditional	green	green safe assets	all safe assets	green assets
$r_t^f - r_g^f = .01$	−0.5	−1.5	.15	.62	.23
$r_t^f - r_g^f = .005$	−1.2	−3.5	.29	.62	.37

Note: Panel A reports statistics about the initial equilibrium. The first two columns contain the value of traditional and green equity as a share of aggregate household wealth. The third column has the wealth share of green investors. The fourth column is the difference in wealth-weighted expected log payoffs $\log D_g/D_t$ by green investors. The last column is green investors' wealth-weighted portfolio weight on green equity. The first two columns of Panels B and C report counterfactual percentage changes (relative to the initial equilibrium) in the value of traditional and green equity, respectively. The remaining columns of Panel B and C report the increase (+) or decrease (−) of each variable in the counterfactual compared to the initial equilibrium. Units are the same as in the original equilibrium reported in Panel A. The first two columns of panel D report counterfactual percentage changes (relative to the initial equilibrium) in the value of traditional and green equity when a green safe asset is offered at the indicated spread. The remaining columns are the value of green safe assets, all safe assets, and green assets as a share of aggregate household wealth.

Consider first elastic equity supply. When households perceive neither green convenience yields nor worry about the climate transition (first row of Panel B), their demand for green equity is roughly 30% larger, while their demand for traditional equity is about 10% smaller. The presence of green taste currently makes green investment substantially *smaller* than it would otherwise be. Relating these changes to the initial equilibrium (in Panel A) implies that counterfactual aggregate investment in green equity *increases* by 3pp of total household wealth, whereas investment in traditional equity funds declines by 3pp. With fixed supply (first row of Panel C), shutting down green taste increases the price (and hence decreases the premium) of green equity by 50bp while lowering the price (and increasing the premium) on traditional equity by 20bp. Without green taste, the cost of capital of a green firm selling a marginal new tree is thus 70bp lower than that of a traditional firm.

Why does the presence of green taste *lower* the value of green equity? The broad theme that green taste holds back green investment already appeared in the demand decomposition (15). The effect here is substantially larger, however. The reason is that portfolio demand is a nonlinear function of parameters because of short-sale constraints. While the demand decomposition (15) simply shuts down taste for every household, the counterfactual in Table 5 recomputes the optimal portfolio, including along the *extensive margin* of whether or not to participate in green equity. In this experiment, households who have positive convenience yields or positive hedging demands for green equity but who do not have high expectations about green equity returns reoptimize and exit the green market. At the same time, households with negative convenience yields or negative hedging demands but who are quite optimistic about green equity choose to enter the green market in the counterfactual and may be willing to take on substantial stakes.

Columns 3-5 of Table 5 illustrate this effect. We consider the share of total savings due to participants in green equity, the difference in (wealth-weighted) expected log payoffs $d_g - d_t = \log D_g / D_t$ perceived by those households for green relative to traditional equity, and finally the average portfolio weight that those households place on green equity. The top line shows levels in the initial equilibrium. For each exercise, we then report the change due to reoptimization. With fixed supply (Panel C), for example, shutting down green taste lowers the wealth share of green investors by 8pp, but makes the average (wealth-weighted) green investor perceive a 2pp higher payoff on green equity and hence choose a 4pp higher portfolio weight. Qualitatively, the same effects occur with elastic supply. Higher optimism among green market participants is the key driver of higher green equity valuations in the counterfactual. As the price of green stocks is bid up, the least optimistic households exit the green market. This results in an even more optimistic population of households who participate in the green market, so the price—and hence the value—of green equity in the counterfactual goes up.

7.2 The Role of Attention

We now turn to the effect of attention allocation: how do prices reflect that investors today make a distinction between firms contained in green and traditional funds? We know from the survey that households perceive different expected returns and risk on the two funds. Our estimated model further shows that, in the baseline equilibrium that describes the current environment, households perceive imperfect correlation between firms contained in traditional and green equity funds, and hence treat those firms as imperfect substitutes. We want to contrast the baseline equilibrium with a counterfactual where households view the two funds as simply randomly selected large subsets of stocks and hence treat the two groups of firms as perfect substitutes. We are interested in the effect on the stock market as a whole, as well as the relative prices of green and traditional firms. We focus on a counterfactual with fixed supply in order to understand the effect of attention allocation on currently observed prices.

The counterfactual places households in a world with only one tree that subsumes all stocks, whether or not green equity funds invest in them. We assume that household beliefs about returns on this single tree are given by their current beliefs about the traditional equity fund.[13] The idea is that households who do not distinguish between green and other equity treat all equity as traditional. We further shut down convenience yields and hedging, as in the previous exercise. The portfolio choice problem in the counterfactual economy is thus simpler than in our baseline: households select only one weight on a single risky tree, as opposed to a vector of weights for the two equity funds. We denote by p_1 the price of the single tree in the counterfactual equilibrium. Retaining the normalization from the previous section, the total number of shares of the single tree is $\bar{\omega}'\iota$, the sum of the green and traditional tree shares in the baseline. The value of the stock market in the counterfactual is $p_1\omega'\iota$, so the effect of attention allocation on the aggregate market is given by $(1-p_1)\omega'\iota$.

Consider now the effect of attention allocation on relative prices. A key difference to the previous section is that investors in the counterfactual here treat green and traditional equity as perfect substitutes: the two funds are identical copies of each other that only differ by label. As a result, demand for individual funds is indeterminate. The relative value of green funds in the counterfactual equilibrium follows from supply: it depends on the share of payoffs on the single tree that are promised by green firms. We denote the vector of the payoff shares by α^p and hold it fixed when moving from the initial to the counterfactual equilibrium. The interpretation is that the same firms issue the same claims to future payoffs – the only difference is that investors treat them just like traditional equity. In the counterfactual equilibrium, where all equity trades at the same price, the total value of green equity is therefore $\alpha_g^p\bar{\omega}'\iota$. We emphasize that the payoff share α_g^p of green equity is generally different from the market share of green equity in the initial equilibrium, defined by $\alpha_g^m = \bar{\omega}_g/\bar{\omega}'\iota$. This is because market shares in the initial equilibrium reflect convenience yields, hedging and possibly other effects that are unrelated to payoff.

We estimate the payoff shares α^p in the initial equilibrium from households' average expected payoffs. Here we use that we know every household's expected payoffs on the two trees: since we have normalized the price of trees in the initial equilibrium to one, the aggregate portfolio weights $\bar{\omega}$ represent the number of available trees. Multiplying by an individual household's expected return

[13] It is not important whether the set of firms the funds invest in are mutually exclusive – we are only interested in how the valuations of the two funds change between the counterfactual world and the initial equilibrium.

thus delivers the household's expected aggregate payoffs from traditional and green firms. For example, $E^i[R_g]\bar{\omega}_g$ is what household i expects the green sector of the economy to pay out. We note that an individual household's expected share of payoffs from green trees can be high because either (i) green trees are an important part of the economy or (ii) the household is relatively more optimistic about green trees. We assume, however, that the *average* belief of equity holders only reflects the relative size of the payoffs: while households disagree about the performance of green equity, the average expected payoffs are driven by the size of the green sector of the economy.

Formally, we measure the green payoff share

$$\alpha^p = \frac{E[R_g]\bar{\omega}_g}{(E[R_g]\bar{\omega}_g + E[R_t]\bar{\omega}_t)} = .2001, \tag{17}$$

where expectations are taken under the wealth-weighted average belief of equity investors. If average expected returns were equal, we would obtain a payoff share equal to the market share in the initial equilibrium, $\alpha^p = \alpha^m$. This is what we would have expected if investors in the initial equilibrium had treated the two trees as identical. In the survey data, however, average expected returns on green equity are below those on traditional equity, so the estimated payoff share is slightly lower than the estimated payoff share.

Consider now the change in the value of the trees from the baseline to the counterfactual. In units of aggregate wealth, the change in the value of green trees is $p_1\alpha\bar{\omega}'\iota - \bar{\omega}_g$. Dividing by the values $\bar{\omega}$ in the baseline equilibrium, we can write the percentage changes in the values of green and traditional trees as $p_1\alpha_g^p/\alpha_g^m - 1$ and $p_1\alpha_t^p/\alpha_t^m - 1$, respectively. With fixed supply, these changes in value reflect price changes. If investors in the initial equilibrium treat the trees as identical, so $\alpha^m = \alpha^p$, then the prices of the two trees change by the same percentage, given by $p_1 - 1$. More generally, the change in the price of green trees is smaller than that for brown trees if and only if $\alpha^m > \alpha^p$. When the market share of green trees in the baseline equilibrium is higher than the payoff share, then the price of green trees should become relatively lower once attention to green versus traditional equity is switched off so trees are valued only for their payoffs. Put differently, we can conclude in this case that attention allocation is currently propping up the value of green trees – it is generating a greenium relative to traditional stocks.

The second row of Panel C in Table 5 reports the difference between the value of equity in the counterfactual versus the initial equilibrium, $\alpha_j^p p_1\bar{\omega}'\iota - \bar{\omega}_j$, for $j = g, t$. The counterfactual price is $p_1 = .992$, which implies that both price changes are negative. In the counterfactual economy, the value of green equity is 1.7 percentage points lower, while the value of traditional equity is 60 basis points lower. Since this calculation holds expected payoffs fixed, we can conclude that sustainable investing reduced the premium of green equity relative to the safe interest rate by 1.7 percentage points. It has also reduced the premium of traditional equity but by a smaller amount. Sustainable investing has thus opened up a 110 basis point greenium. The table further shows that the rise of sustainable investing boosted the stock market overall. Indeed, the counterfactual equity market trades $0.60(1-\alpha)+1.7\alpha = 80$ basis points below the baseline equilibrium, so the equity premium is 80bp higher.

As we have seen, these effects are not due to a shift in taste, in the sense of our parameters θ^i and h^i, which actually hold down the value of the green fund.[14] Instead, the price movement reflects the fact that investors have "woken up" to the distinction between green and other equity that are imperfectly correlated and form heterogeneous beliefs about them. Relative to the counterfactual equilibrium, where the distinction is shut down, prices in the initial equilibrium reflect a clientele of enthusiastic investors who sort into holding green equity. This has two effects. On the one hand, demand for green equity drives up its price. On the other hand, as green investors invest less in traditional equity, they matter less for prices in that market, which increases prices there as well. Short sale constraints reinforce this effect as investors who strongly prefer green leave the traditional market altogether. The overall effect of attention is to increase the demand for green equity so much that it more than offsets the dampening effect of green taste.[15]

8 Counterfactuals: the Future of Green Investing

In this section, we perform two counterfactuals that are meant to assess the future potential of green investing. Section 8.1 considers widespread availability of a green safe asset, such as a green bank account. Section 8.2 explores the impact of more widespread information about green investment products. The key input is an RCT that measures the effect of information on expected returns.

8.1 Introduction of a Green Safe Asset

As we have seen in Section 4, households are willing to give up substantial interest rate spreads in order to invest in green bank accounts. Figure 3 already suggested that household demand for green deposits is strong. In our model, green and traditional safe assets may pay different interest rates. The introduction of a green safe asset can thus have a large effect on green investment overall.

[14] We also note that the overall decline in the stock market does not mechanically derive from the fact that we let households view both trees as traditional. To the contrary, the average investor believes that traditional stocks have higher expected payoff and are less risky. When we recompute the baseline equilibrium with equal marginal distributions for both tree payoffs, the aggregate stock market increases.

[15] While the change in perceived correlation plays some role, it is quantitatively less important. When we recompute baseline equilibrium pushing the correlation coefficient for all investors to .99, the market value declines only by a few basis points.

However, it is not clear from the earlier analysis whether the availability of green safe assets will adversely affect the green equity market. In our current equilibrium, households who have high nonpecuniary benefits from green assets have an incentive to take risk and select into green equity, because they effectively perceive higher expected excess returns on green equity. Once green safe assets are available, the effective expected excess returns on green equity decline, as we can see from the equation for risky asset demand (7) due to convenience yields.

We perform two exercises that vary the available quantity of green safe assets. Since safe assets are perfect substitutes, there is a 1-1 relationship between quantity and interest rate independently of what happens in equity markets. We report the exercises indexed by the equilibrium interest rate spread between green and traditional safe assets, reported in Panel D of Table 5. We focus on equilibria with elastic supply of equity: formally we recompute portfolio weights for all households now using their individual-specific safe rates, either green or traditional. The right-hand columns report the quantities of green safe assets, as shares of aggregate household wealth. As in Figure 3, the quantity of green safe assets increases as the spread declines (i.e., the green interest rate rises towards the traditional interest rate.)

The takeaway is that the introduction of green debt has only small effects on equity markets. There is some substitution away from equity, and green equity in particular, as households with a strong green convenience yield lower their weight on risky equity. Some households exit the green equity market altogether: at a spread of 50bp, for example, the wealth share of green investors drops by 1pp. Effects are small, however, because changes in interest rates and $\log \theta$ of a few percentage points are minor relative to the large equity premia most households expect. In terms of overall investment, green assets, reported in the last column, increase as more debt is issued mostly because of this added debt.

We conclude that green bank accounts could potentially offer a tremendous opportunity to significantly alter the “color" of the aggregate portfolio of German households without adverse consequences for green equity funds. As we write, there are already signs the market for green bank accounts is in transition, with major nationwide banks announcing plans to provide green bank accounts to a broad audience. For example, Deutsche Bank is offering a green bank account for corporate clients (per press release on March 31, 2021). ING has announced plans to launch a green bank account for retail clients (per press conference on February 3, 2023).

8.2 Information about the Potential of Green Investing

For thinking about the future of green finance, another consideration is that currently green investment products may not be well understood by many households. As climate change becomes more tangible, many private firms, governments, and international institutions are devoting more resources to address the challenges (see, e.g., Krueger, Sautner and Starks 2020; Stroebel and Wurgler 2021; van Benthem, Crooks, Giglio, Schwob and Stroebel 2022). In particular, asset managers are increasingly promoting green financial products. To assess the likely impact of more information provision, our survey module adds an RCT designed to make the potential of sustainable investing more salient to households. We use the results of the RTC to design an additional counterfactual.

We provide the following information to a treatment group of roughly 1,000 respondents before asking the questions about the hypothetical green bank account and equity return expectations:

> T4 (Potential of Green Investing): "The United Nation's latest global climate report indicates major economic and health risks posed by climate change—in Germany, too—for example as a result of extreme weather events, such as torrential rainfall and very hot weather. Sustainable equity funds can contribute to climate protection by encouraging enterprises around the world to operate in a more climate-friendly manner."

Since the treatment informs households of the potential for green investment to make a difference in the climate transition, it is plausible that the treatment effect is different depending on how concerned a household is about the climate transition. This motivates measuring not only an overall average treatment effect but also investigating how the treatment differs across subgroups that exhibit different concerns for the climate. For the treatment group, the question eliciting key issues that households are concerned about appeared in the questionnaire before the information treatment. We measure treatment effects for two groups: *concerned households* who pinpoint climate as the top issue and all other households. Finer distinctions among the "other" group have only negligible effects on the results.

Table 6 presents results from estimating equation (1). We consider two post-treatment outcomes Y_i^{post}. The first two columns report results for the subjective expected excess return of green over traditional equity by household i. For the third and fourth columns, the outcome is the interest-rate spread accepted by households to put funds into a green bank account. For each outcome, we first present the overall average treatment effects without interaction term, the coefficient for concerned households, and then the treatment effects interacted with being concerned. We highlight two controls: for each outcome, we show the effect of a dummy indicating that the household actually holds the asset in question. We find, reassuringly, that a household who owns green equity expects a more than two percent higher excess return on green equity. Moreover, a household who has a green bank account is willing to accept a one percent lower deposit spread on that account.

There are two main takeaways from the RCT. First, explaining the potential of green finance makes households relatively more optimistic about the returns on green equity. On average, treated

Table 6: Information Treatment about Potential of Green Investing

	Dependent variable:			
	Excess Green Returns		Deposit Spread	
	(1)	(2)	(3)	(4)
Potential of Green Investing (T4)	1.607**	−0.523	0.003	0.141
	(0.624)	(0.927)	(0.071)	(0.099)
Climate Top Issue	2.182***	1.182*	−0.635***	−0.563***
	(0.576)	(0.658)	(0.065)	(0.074)
T4 × Climate Top Issue		3.876***		−0.280**
		(1.252)		(0.141)
Green Equity Fund	2.330***	2.293***		
	(0.606)	(0.604)		
Green Deposit Account			−0.913***	−0.911***
			(0.139)	(0.139)
Demographic Controls	✓	✓		
Income/Wealth Controls	✓	✓		
Observations	1,289	1,289	2,085	2,085
R^2	0.083	0.089	0.143	0.144

Note: This table reports the effects of the information treatment about the Potential of Green Investing (T4). In each regression we control for voting for the green party, rating climate change the top issue facing Germany, age, age squared, gender, college education or higher, household income, household income squared, securities holdings, securities holdings squared. Returns are winsorized at -5% and 15% which corresponds to the 0.5 and 75th percentile of the return distributions. *p<0.1, **p<0.05, ***p<0.01.

respondents expect 1.6% more from green equity. Moreover, this effect is entirely driven by the subgroup of concerned households who expect close to 4% more return. Second, the information also tends to lower the accepted interest-rate spread on a green bank account. While the average effect here is small and insignificant, zooming in on the group of concerned households again reveals a significant effect of about 25bp. We conclude that more information makes concerned households more optimistic about green equity and willing to accept higher interest-rate spreads on green deposits.

What are the quantitative macro implications of these estimated effects of information? We now use the regression results from Table 6 to perform a counterfactual that increases expected returns on green equity for all concerned households in the population. We perform the exercise with both elastic and fixed supply, reported in the second row of Panels B and C in Table 5, respectively. Our temporary equilibrium approach naturally accommodates using information from an RCT to assess the effect on equilibrium prices by incorporating the treatment into households' expected payoffs.

The quantitative effect of making the potential of sustainable investing salient to concerned households is large because these households dramatically increase their demand for green equity. We thus obtain either large quantity effects (with elastic supply) or large effects on prices when supply is fixed. The right-hand columns of Table 5 show the role of adjustment along the extensive and intensive margins of green equity. With elastic supply, both move in the same direction: the pool of participants in green equity markets now has a larger wealth share and also a larger green portfolio weight. As a result, the value of green equity almost doubles. With fixed supply, concerned households drive up the price of green stocks. As a result, there is a lot of exit from green investing, as indicated by a lower wealth share of green investors. However, the optimism of the treated more than makes up for this, as the price increases by almost 5%, a substantial drop in the equity premium on green stocks.

9 Conclusion

How does green investing affect asset prices and ultimately security issuers' cost of capital? We use household survey data to calibrate a heterogeneous agents asset pricing model and show that the net effect of green investing is to increase the price of green assets and lower the cost of capital for green firms. We decompose this effect into the contributions of several key theoretical mechanisms. Green taste—nonpecuniary benefits/costs of holding green assets, and hedging demand—are actually holding back green investment. Green equity demand would be roughly 30% larger than its current level without green taste. This result is due to two forces: First, while non-pecuniary benefits of holding green assets, e.g. due to ethical considerations, are weakly positive for the majority of the population, there is a non-trivial fraction of households who would require additional returns for holding green assets Second, hedging demand is not always positive either. Many households currently invest in traditional equity to hedge a slower-than-expected transition to a green economy.

Looking ahead, we show that widespread availability of green safe assets to households, e.g. in the form of green bank accounts, could dramatically increase green investment. We quantify this effect in counterfactuals for different interest rate spreads on these green assets. If, for instance, green bank accounts could be offered at a spread, that is a cost to households, of 0.5% per annum of the deposit amount, the overall share of green assets in the economy would grow from 8% to 37% of total financial wealth. This effect is entirely driven by a rise in the share of green safe assets, while we show that the share of green equity would remain largely unchanged. We document that households' current holdings of green assets are overwhelmingly in equity, while they generally prefer to hold safe assets.

Using an information treatment, we estimate how the arrival of information about green investment opportunities affects households' tastes and beliefs regarding green assets. We find that such information increases the expected excess return on green equity for households who are already concerned about climate change. Using this shift in beliefs as a counterfactual in our model, we show that it leads to a dramatic rise in the demand for green equity. The main driving force behind this effect is the outsized importance of the myopic demand component, which is proportional to the expected excess return per unit of risk, relative to the aggregate effect of non-pecuniary benefits and hedging demands. The latter two components matter at the individual level but, to a large extent, wash out in the aggregate since they have offsetting effects for different parts of the population of investors. By contrast, the aggregate effect of beliefs is substantial. Hence, measuring actual beliefs and demand for green assets, as we do in our survey, is key for understanding who holds green assets and why, and for quantifying the asset pricing implications of green investing.

In sum, we provide fundamental empirical and theoretical building blocks for household climate finance, which could be built upon by other researchers in this area. For instance, we show that households on average do not respond to information about the risk and return of green relative to traditional assets but do respond to qualitative information about the role of green financial products. Furthermore, we point out the potentially dramatic impact of green bank accounts on boosting green investment. Investigating the introduction of these assets from a banking perspective and studying its consequences for climate change mitigation and adaptation could be another interesting avenue for future research.

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A Survey Quality

A.1 Representativeness of Survey Sample

To have confidence in extrapolating our findings to the German population overall, the survey sample must be representative of the financial portfolios and "green" preferences of German households.

Demographics. Figure A.1 compares the age distribution in the survey sample with the actual population age distribution. Unlike many online surveys, the Deutsche Bundesbank Household Survey on Consumer Expectations over-samples older households. For our analysis, this is a strength of the survey sample since older households hold the majority of financial assets. The survey sample is weighted to match the joint distribution of population age and education distribution by region.

Figure A.1: Demographic Composition of Survey Sample

Note: This figure compares the raw age distribution of survey respondents (shown in red circles) with the Statistches Bundesamt official population age distribution (shown in black triangles) for individuals between the ages of 18 and 80.

Comparison with HFCS. The financial portfolios of households in our survey closely match German household's financial portfolios from the European Central Bank's Household Finance and Consumption Survey (HFCS). [16] The survey collects detailed household portfolio information comparable to the US Federal Reserve Survey of Consumer Finances. Like the Bundesbank survey, the HFCS collects self-assessed household values.

Financial asset participation rates are roughly comparable between the two surveys, however,

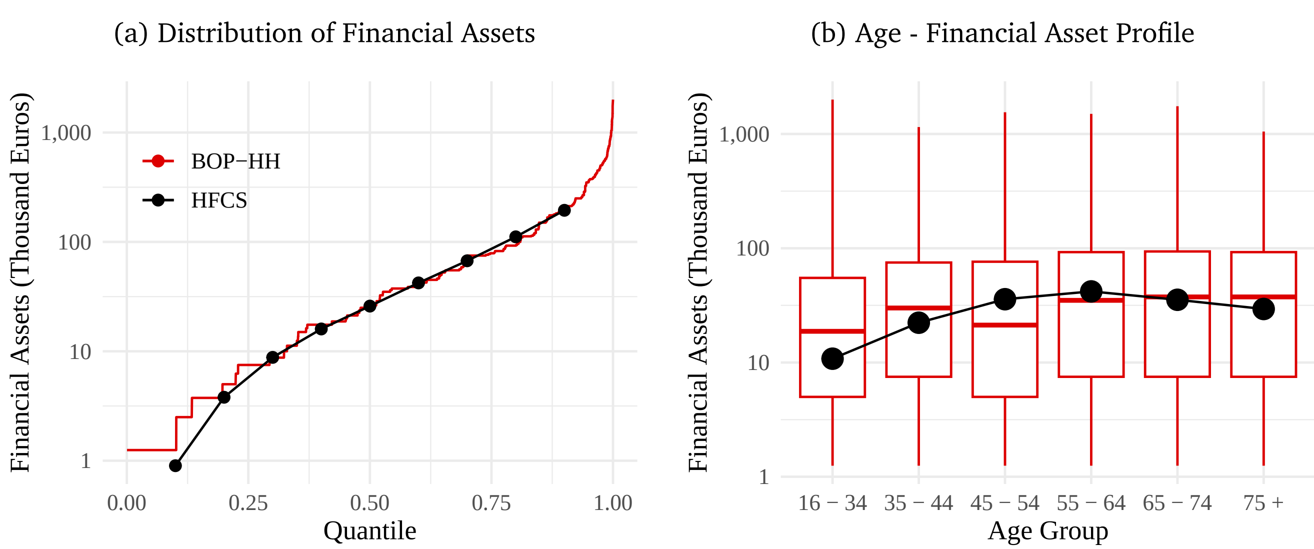
[16]We use data from the 2021 wave of HFCS. The HFCS interviews were conducted between April 2021 through January 2022. The sample size for Germany was 4,119 households.

there is not a direct mapping between all variables across the two surveys. 58.5% of households in the Bundesbank survey report holding securities, defined as shares, bonds including funds, and ETFs. In the HFCS, 20.6% of households report holding mutual funds. 3.1% bonds, 15.4% publicly traded shares, and 42% hold voluntary pensions or who life insurance policies. Respondents to the Bundesbank survey are also much more likely to have real estate wealth and hold relatively more of their portfolio in real estate.

The distribution of financial assets is quite similar between the two samples. Figure A.2a compares the cumulative financial asset distribution in the two surveys. Financial assets include deposits (sight and saving accounts), mutual funds, bonds, shares, money owed to the households, the value of voluntary pension plans, whole life insurance policies of household members, and other financial assets: private non-self-employment businesses, assets in managed accounts, and different types of financial assets. The financial assets deciles from the HFCS match the BOP-HH survey financial asset distribution closely.

The age profile of financial assets holdings is also broadly similar. Figure A.2b shows a box plot of the financial asset holdings by age group compared to the median financial asset holdings reports in the HFCS. While the medians of the BOP-HH samples does not line up exactly with the HFCS sample, they are close and the pattern of increasing financial asset holdings through age 50 and then

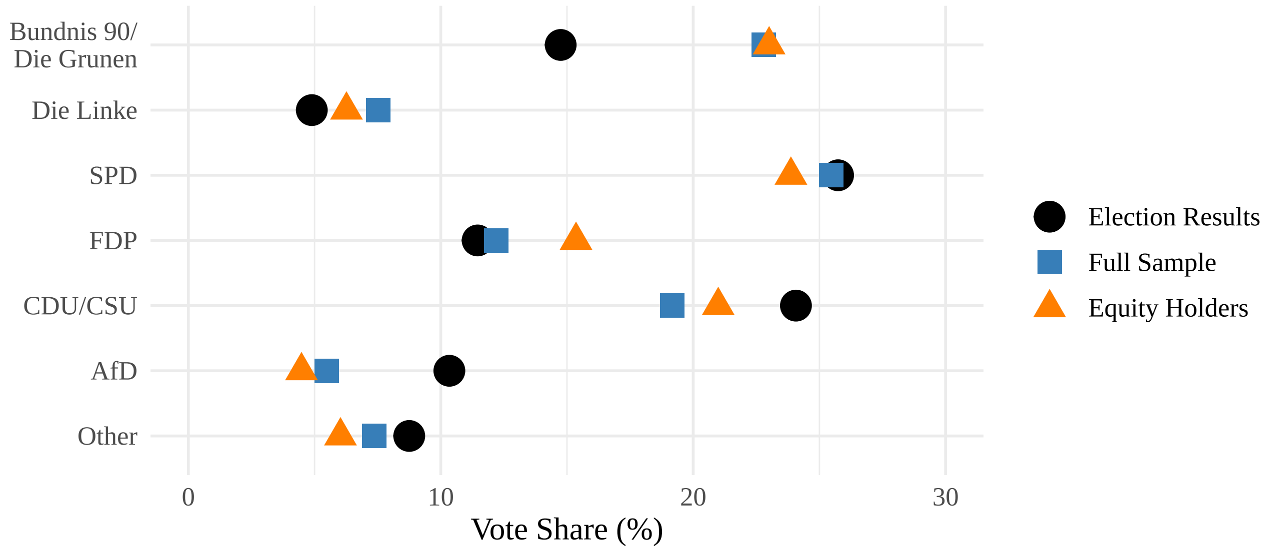
Figure A.2: Comparison with HFCS



Note: Financial assets include deposits (sight and saving accounts), mutual funds, bonds, shares, money owed to the households, value of voluntary pension plans and whole life insurance policies of household members and other financial assets item - which includes private non-self-employment businesses, assets in managed accounts and other types of financial assets. Medians and deciles are conditional, among households owning any sort of financial asset.

Comparison to Election Results. The survey sample also matches the overall 2021 Bundestag election results reasonably well. Figure A.3 plots respondents reported voting behavior and actual election results. The survey sample overstates support for the green party and understates support for the CDU/CSU and AfD parties. This appears driven by the geographic distribution of respondents. The survey under represents people in the eastern regions of Germany as well as those in more rural locations. Therefore to ensure the representativeness of our results for the German population as a whole, we report all of our main results re-weighted to match election outcomes.

Figure A.3: Reported Vote in the 2021 Bundestag Election and Election Results



Note: This figure compares respondents answers to the question: "Which party did you vote for in the recent German general election in September using your second vote?" with the actual September 2021 Bundestag election results. Each point represents the vote share of a political party. Official election results are shown in black circles, the results from the full survey sample are shown in blue squares, results from the sub-sample of respondents who report holding equity is show in orange triangles.

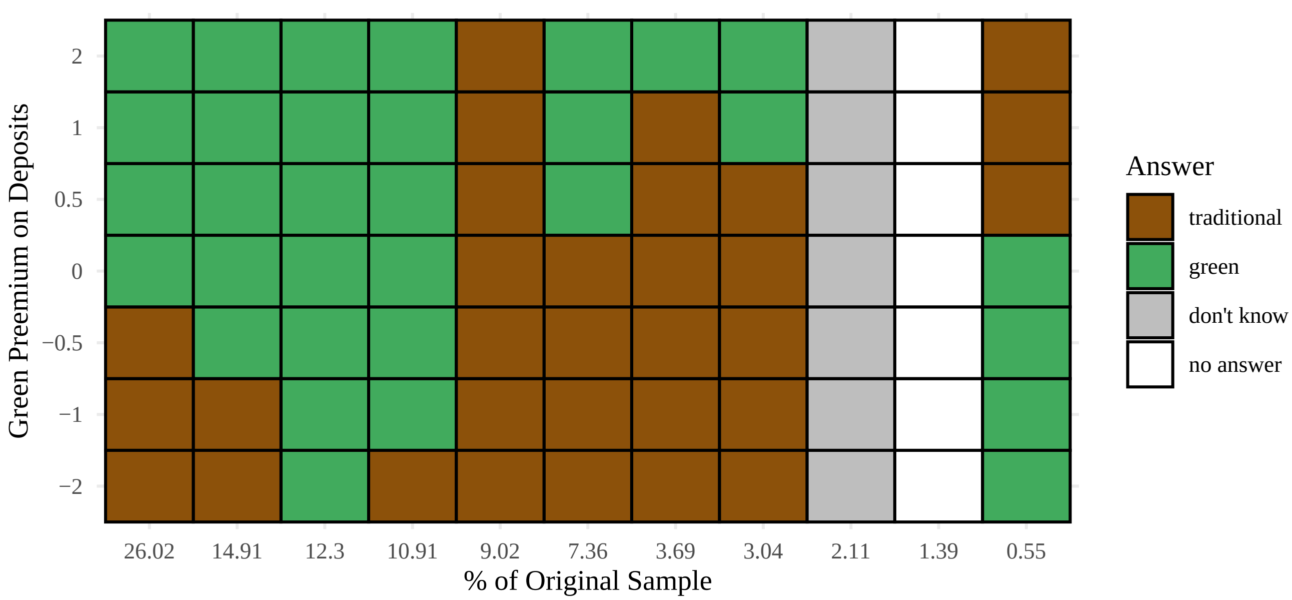
A.2 Response Rates

Green Deposit Account. Most respondents understood the sequence of green deposit spread questions and responded in a consistent manner. A consistent set of responses is a set of responses where if a respondents chooses the green deposit account at spread x, they then choose the green deposit account at any spread larger than x. Figure A.4 plots the most frequent response patterns to the sequence of 7 questions. Each tile shows the choice of account going from a 2% to -2% spread of the green deposit account over the traditional deposit account. Each column shows the response patter for a fraction of respondents in decreasing frequency going from left to right.

As can be seen in the first column of the figure, the most frequent response was to choose the green deposit account in all cases where the green deposit account offered the same return or higher as the traditional deposit account. Only 2% of respondents answered don't know to all questions and fewer than 2% of respondents failed to answer any of the questions. Overall approximately 5% of respondents did not respond or only partially responded to the questions.

The far right column shows a set of responses that we would classify as inconsistent. In fact it appears as if this small group of people mis-interpreted the question. Overall roughly 8% of respondents gave inconsistent answers.

Figure A.4: Response Patterns to Green Deposit Questions



Note: This figure shows the most frequent response patterns to the set of 7 deposit account spread questions. Each tile shows the choice of account going from a 2% to -2% spread of the green deposit account over the traditional deposit account. Each column shows the response patter for a fraction of respondents in decreasing frequency going from left to right.

Equity Expectations. The response rate to our equity questions module was lower. We asked respondents to write in their expectations for annual returns for a traditional and green equity funds, to rank the relative risk of the two accounts, and to choose one account in which to invest. Many respondents answered "don't know" to these questions. Table A.1 shows the response rate to each of the four questions.

Table A.1: Response Rates to Equity Module Questions

Question	Response Rate
Traditional Return	0.50
Green Return	0.49
Relative Risk of Green	0.78
Investment Decision	0.74
Qualitative Questions	0.65
All Questions	0.40

Note: This table reports the response rates to the equity questions module among respondents who received no information treatment.

Respondents struggled most with the equity returns questions. The response rates to these questions were roughly 50%, and similar across traditional and green equity funds. The response rates to the qualitative questions on relative risk ranking and investment choice were much higher. Moreover, a considerable proportion of households, nearly 45%, answered both questions, with only minor attrition across the two questions. This number is comparable to the 43% of households who report holding any equity in their portfolios. When restricting the sample to households holding non-zero securities, the response rates increased to 67% for the traditional equity return question and 64% for the green equity return question, delivering a joint response rate of 62%.

The response rates to the qualitative questions (about the relative risk and the choice between the traditional and green investments) were much higher. Overall, 64% of all households and 80% of households with non-zero securities holdings answered both questions. Roughly 77% of all households answered the risk question while 74% answered the investment choice question. Among households holding non-zero securities, the response rate to the risk question was 91% and the response rate to the hypothetical investment choice was 85%.

Table A.2 reports the coefficients on various demographic, income, and wealth characteristics in an OLS and Logistic regression where the dependent variable is whether the respondent answered all four equity questions. Those who answered all the equity questions were more likely to hold securities and in particular to report having green equity funds. They were also more likely to have at least a college degree and the rate climate change as the top issue facing Germany.

Table A.2: Who answered all the equity questions?

	Dependent variable:	
	Answered All Equity Questions	
	OLS	*logistic*
	(1)	(2)
Climate Top Issue	0.059***	0.057***
	(0.021)	(0.015)
Vote Green	0.032	0.031*
	(0.026)	(0.019)
Age	0.004	0.005*
	(0.004)	(0.003)
Age^2	−0.0001**	−0.0001***
	(0.00004)	(0.00003)
Male	0.137***	0.134***
	(0.020)	(0.014)
College	0.142***	0.132***
	(0.025)	(0.018)
Securities (10,000 EUR)	0.029***	0.029***
	(0.004)	(0.003)
$Securities^2$	−0.0005***	−0.0005***
	(0.0001)	(0.0001)
Income (10,000 EUR)	0.280	0.275**
	(0.187)	(0.135)
$Income^2$	−0.175	−0.175
	(0.201)	(0.145)
Green Equity Fund	0.119***	0.110***
	(0.025)	(0.018)
Constant	0.114	−1.837
	(0.088)	
Observations	2,083	2,083
Adjusted R^2	0.138	
McFadden Adj. R Sq.		0.11

Note: This table reports the coefficients of OLS and Logistic regressions where the dependent variable is whether the respondent answered all four of the green equity questions. The first two columns report results for the set of respondents who received no information treatment before answering the question. *p<0.1, **p<0.05, ***p<0.01.

B Additional Tables and Figures

This section presents additional tables and figures which complement the empirical analysis of current household holdings of green assets, demand for a green safe asset, and demand for green equity.

B.1 Current Household Holdings of Green Assets

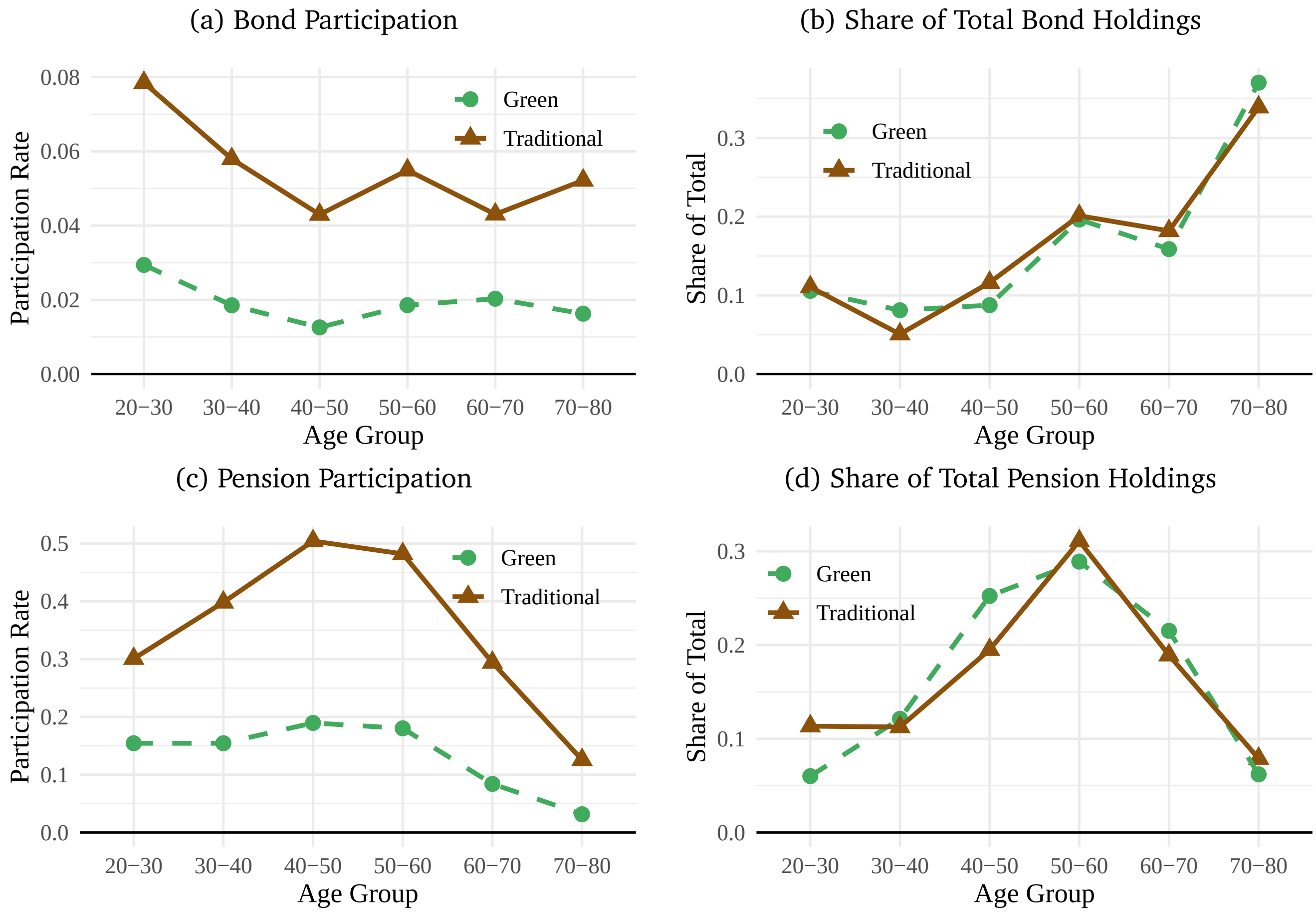
Many of the cross-sectional patterns for green equity holders are similar for other financial assets such as bonds and pensions (Figure B.1), and deposits (Figure B.2). The age patterns for bond holdings are nearly identical to those for equity where younger households are more likely to participate in the green asset but only hold a small share of total assets. The patterns are more hump-shaped for pension participation, where middle-aged households are much more likely to have pensions and hold the majority of pension assets.

Deposit holdings are quite different. The youngest households hold most green deposits and are most likely to participate. The participation rate in green deposit accounts among households over age 40 is tiny.

There are many dimensions of heterogeneity in who holds green assets of different classes. Table B.1 reports the coefficients of OLS regressions where the dependent variable is whether the respondent reports holding any Euros in a "green" version of that asset. For columns (1) - (3), green equity, bonds, and pensions, the data come from the May wave of the survey and correspond to individuals reporting non-zero holdings in sustainable accounts for that asset type. For column (4), green bank accounts, the data come from the November wave of the survey and correspond to individuals reporting that they have a green bank account.

The age profiles for holding different types of green assets also differ. Younger individuals are more likely to report holding green equity or having a green bank account while older individuals are more likely to hold green pensions (though this is likely due to the fact that young households are unlikely to have a pension account). Individuals who rate climate change as the top issue facing Germany are more likely to hold green equity or to have a green bank account. Households that hold more securities (shares, bonds, funds/ETFs) are more likely to report holding green equity or green bonds.

Figure B.1: Bond Participation and Holdings by Age

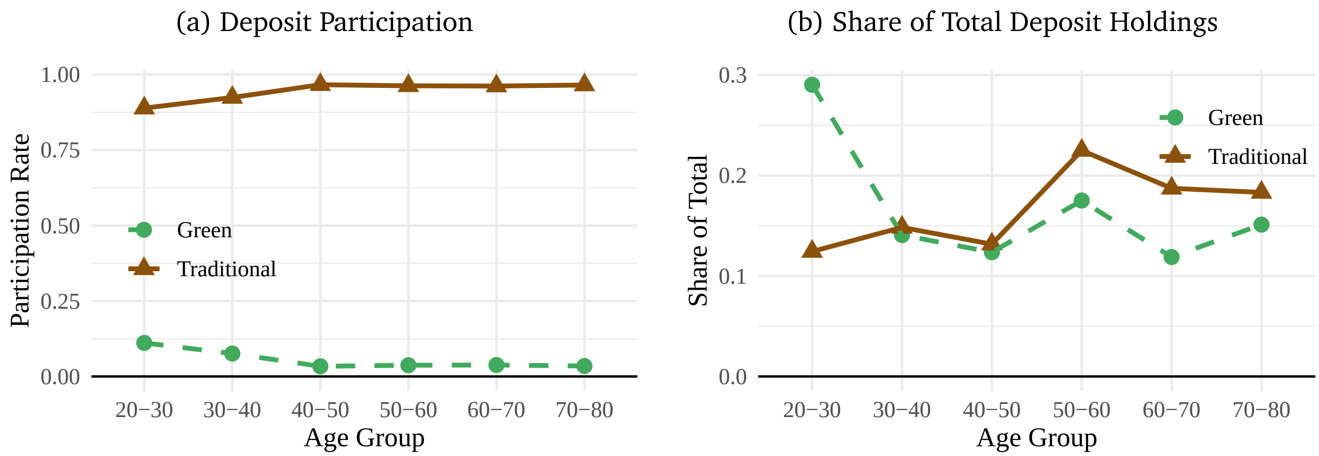


Note: Households classify their holdings as “green" versus traditional assets. Panel (a) shows the participation rate in green and traditional bonds by age group. Panel (b) shows the share of total bonds held by an age group. Pensions include savings in private pension funds and life insurance contracts. Panel (a) shows the participation rate in green and traditional pensions by age group. Panel (d) shows the share of total pensions held by an age group. Sample includes all respondents in the May 2022 wave of the Bundesbank Survey of Household Expectations.

B.2 Demand for a Green Safe Asset

In the survey, we ask people to report their vote in the 2021 Bundestag election, which took place shortly before our survey. We give people the choice of one of the seven major political parties, another party, or that they did not vote in the election. While political parties differ across many dimensions, their perceived ranking on climate issues during the election campaign was (ordered from most to least advocacy for action to mitigate climate change): Alliance 90/ the Greens (Bündis 90/ Die Grünen), The Left (Die Linke), Social Democratic Party (SPD), Free Democratic Party (FDP), Christian Democratic Union of Germany/Christian Social Union in Bavaria (CDU/CSU), Alternative for Germany (AfD). Figure B.3(b) plots the distribution of accepted spreads by reported vote. The ordering of parties based on the share of respondents who accept a negative spread matches the

Figure B.2: Deposit Participation and Holdings by Age



Note: Households report whether they have a green bank account. We assume households hold all their deposits in a single account. Panel (a) shows the participation rate in green and traditional deposits by age group. Panel (b) shows the share of total deposits held by an age group. Sample includes all respondents in the November 2021 wave of the Bundesbank Survey of Household Expectations.

ordering across parties on climate issues.

Again, this figure also illustrates that although there is a strong pattern across parties, much heterogeneity remains. While most AfD voters, a party that has called for an end to all major climate actions, demand a positive spread to hold a green bank account, close to 10% choose green deposits even when they pay −2%. Similarly, a very small but non-zero fraction of Bündis 90/ Die Grünen voters and other left-leaning parties want to be paid 2% to hold green deposits. It is not unreasonable to think that these voters may believe that market solutions to climate issues are fraudulent or prevent effective government action. Households with this view might not want green deposits independent of their interest rate and would be classified as accepting a spread greater than 2%.

While party votes are a potential measure of households' tastes for green financial products, they are usually driven by consideration of more than a single issue. In the survey, respondents are asked to rate the importance of four issues facing Germany on a 1-10 scale: climate change, the COVID-19 pandemic, the economy, and refugees. To be consistent across respondents, we look at their relative ranking of issues instead of absolute numbers. Figure B.4 plots, for each accepted deposit spread, the fraction of households who rank each of the four issues as Germany's top problem. These numbers do not sum to one since households often give their highest ratings to multiple issues. Of households who accept a −2% spread on a green bank account, 76% rank climate change as the most important issue. Concern for climate change is an imprecise measure since 38% of households who demand at least a 2% spread to accept a green bank account also rank climate as the most important issue. Another pattern that emerges is that more than 50% of households who demand a positive spread

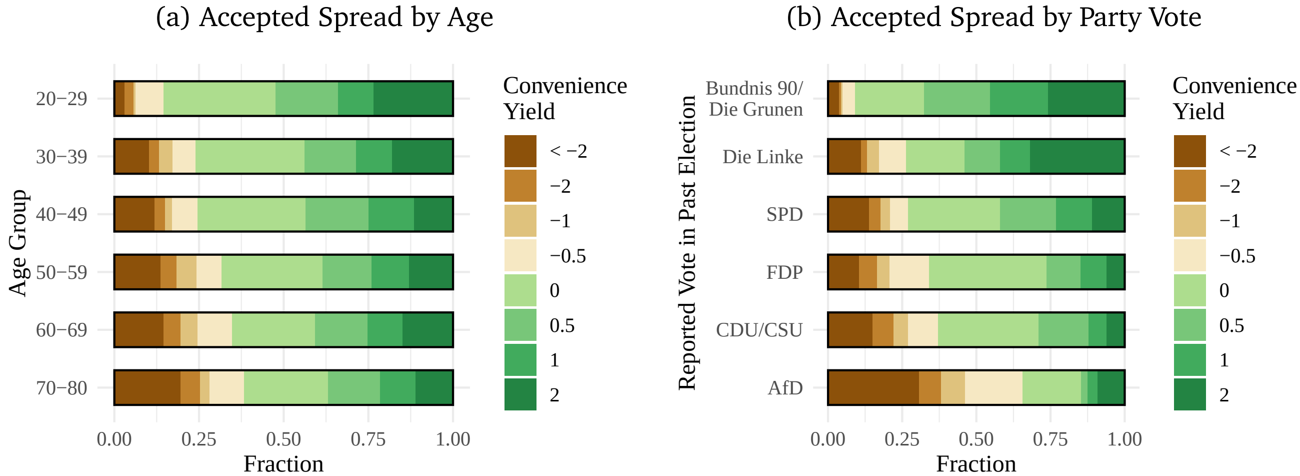
Table B.1: Who Participates in Green Financial Products?

	Participation in Green:			
	Equity	Pensions	Bonds	Bank Account
	(1)	(2)	(3)	(4)
Holds Securities	0.325***	0.002	0.029***	0.032***
	(0.012)	(0.013)	(0.005)	(0.007)
Climate Top Issue	0.038***	0.017	0.004	0.022***
	(0.010)	(0.010)	(0.004)	(0.006)
College	0.040***	−0.030**	0.020***	−0.002
	(0.012)	(0.013)	(0.005)	(0.008)
Age	−0.007***	0.009***	0.0001	−0.004***
	(0.002)	(0.002)	(0.001)	(0.001)
Age^2	0.00005**	−0.0001***	−0.00000	0.00003***
	(0.00002)	(0.00002)	(0.00001)	(0.00001)
Male	0.010	0.015	−0.005	−0.029***
	(0.010)	(0.011)	(0.004)	(0.006)
Income (10,000)	0.091	0.518***	0.044	−0.092
	(0.095)	(0.103)	(0.042)	(0.059)
$Income^2$	−0.000**	−0.000***	−0.000**	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Securities (10,000)	0.021***	0.001	0.005***	−0.0001
	(0.002)	(0.003)	(0.001)	(0.001)
$Securities^2$	−0.0004***	−0.00005	−0.0001***	−0.00001
	(0.0001)	(0.0001)	(0.00003)	(0.00003)
Constant	0.177***	−0.129**	−0.006	0.206***
	(0.049)	(0.053)	(0.022)	(0.026)
Observations	3,978	3,978	3,978	5,204
R^2	0.322	0.039	0.047	0.027

Note: This table reports the coefficients of OLS regressions where the dependent variable is whether the respondent reports holds any Euros in a "green" version of that asset. For columns (1) - (3), green equity, bonds, and pensions, the data come from the May wave of the survey and correspond to households reporting non-zero holdings in sustainable accounts for that asset type. For column (4), green bank accounts, the data come from the November wave of the survey and correspond to households reporting that they have a green bank account. $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

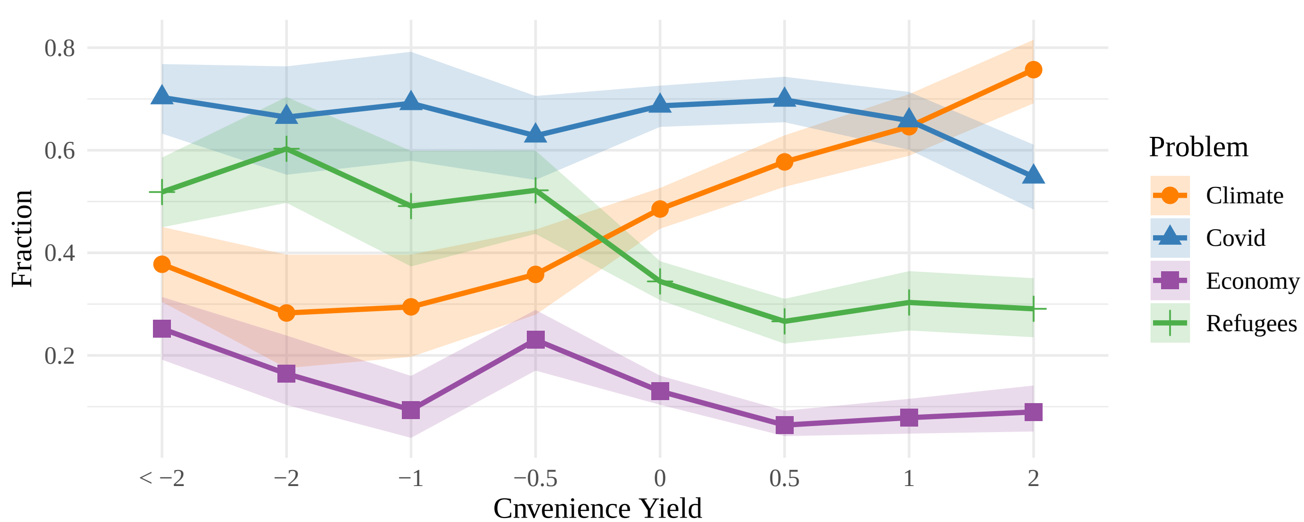
rank refugees as a top problem. Among households who accept a deposit spread of −2%, only 27% view refugees as among the most pressing issues.

Figure B.3: Heterogeneity in Taste for a Green Safe Asset



Note: Panel (a) shows the distribution of accepted spread by ten-year age bins. Color indicates the accepted spread on a green deposit account, with darker green corresponding to a more negative spread and darker brown corresponding to a more positive spread. Panel (b) shows the distribution of accepted spread by reported party vote in the 2021 Bundestag election. Sample includes all respondents in the November 2021 wave of the Bundesbank Survey of Household Expectations.

Figure B.4: Correlation of Accepted Spread with Alternative Measure of Green Preferences



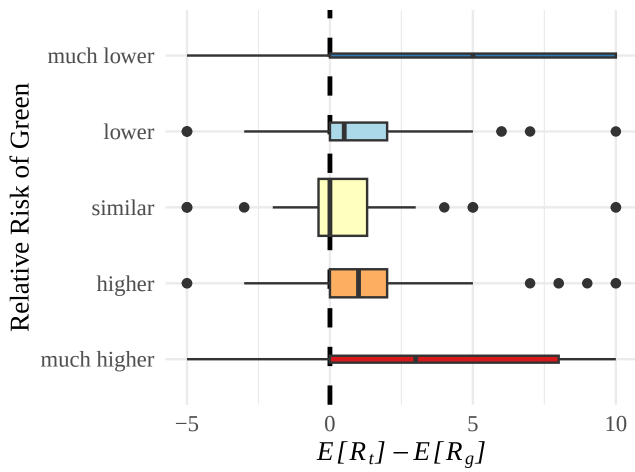
Note: The figure shows the fraction of survey respondents who rank one of the following four issues as the most important issue facing Germany: climate change, the COVID-19 pandemic, the economy, and refugees. These numbers do not sum to one since respondents often give their highest ratings to multiple issues. Standard errors based on 1,000 bootstrap samples. Sample includes all respondents in the November 2021 wave of the Bundesbank Survey of Household Expectations.

B.3 Demand for Green Equity

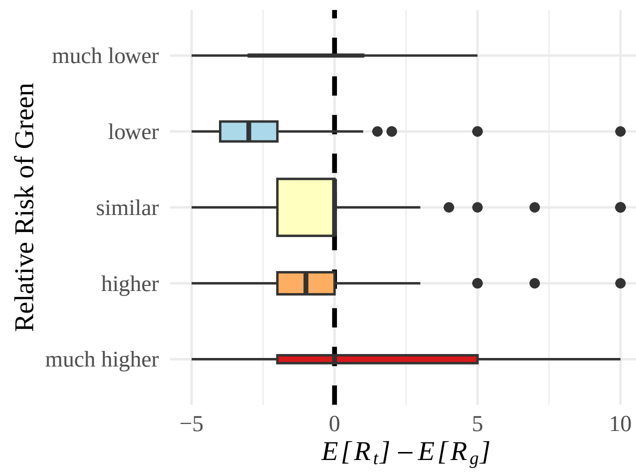
Figure B.5 plots the distribution of expected excess green returns by relative risk ranking for respondents in each of the four information treatments.

Figure B.5: Distribution of Expected Excess Green Returns

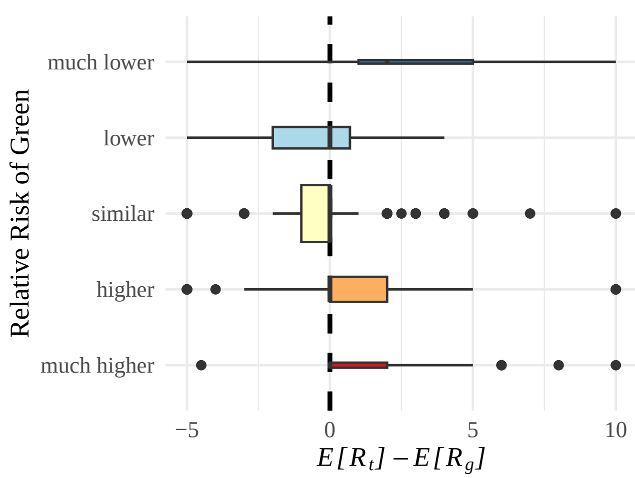
(a) Unconstrained Investments Treatment (T1)



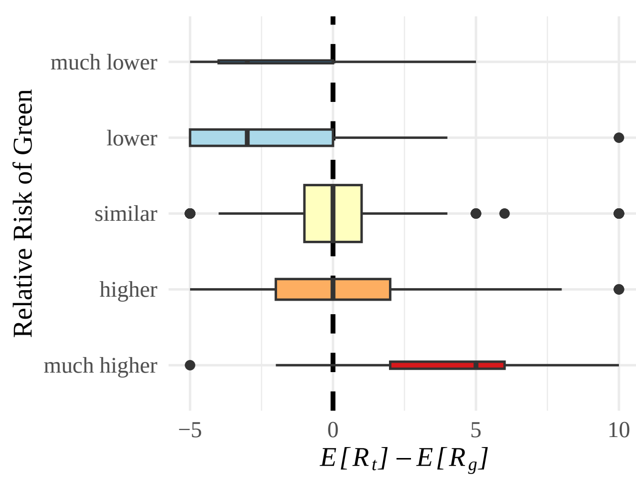
(b) Past Performance Treatment (T2)



(c) Risk-Return Trade-off Treatment (T3)



(d) Potential of Green Investing (T4)



C Model Appendix

C.1 Derivation of Optimal Portfolio Choice equations

In this section, we derive the optimal consumption-portfolio choice problem. Suppressing the household index i, the maximization problem is

$$\max_{c_0,c_1,e_t,e_g,b} \log c_0 + \beta \log\left(E\left[w_1^{1-\gamma}\right]^{\frac{1}{1-\gamma}}\right)$$
$$\text{s.t. } c_0 + e_t + e_g + b = w_0$$
$$w_1 = H\left(R_t e_t + \theta R_g e_g + R^f b\right)$$
$$e_t, e_g, b \geq 0$$

Here, $R^f = \max\left\{R_t^f, \theta R_g^f\right\}$ is the household-specific effective interest rate.

Take first order conditions with respect to e_t, which leads to the Euler equation for R_t

$$\frac{1}{c_0} = \frac{1}{1-\gamma}\beta\frac{(1-\gamma)E\left[w_1^{-\gamma}H\,R_t\right]}{E\left[w_1^{1-\gamma}\right]} \Longleftrightarrow 1 = \beta\frac{E\left[\left(\frac{w_1}{c_0}\right)^{-\gamma}H\,R_t\right]}{E\left[\left(\frac{w_1}{c_0}\right)^{1-\gamma}\right]}.$$

The FOC with respect to e_g leads to the Euler equation for R_g

$$\frac{1}{c_0} = \frac{1}{1-\gamma}\beta\frac{(1-\gamma)E\left[w_1{}^{-\gamma}H\ \theta R_g\right]}{E\left[w_1^{1-\gamma}\right]} \Longleftrightarrow 1 = \beta\frac{E\left[\left(\frac{w_1}{c_0}\right)^{-\gamma}H\ \theta R_g\right]}{E\left[\left(\frac{w_1}{c_0}\right)^{1-\gamma}\right]}.$$

Rearranging the budget equation for consumption

$$c_1 = R^w\left(w - c_0\right) \quad \text{with } R^w = \left(1-\omega_t-\omega_g\right)R^f + \omega_t R_t + \omega_g \theta R_g, \tag{18}$$

where R^w is the return on wealth. The Euler equation also holds for R^w

$$\frac{1}{c_0} = \beta\frac{E\left[w_1^{-\gamma}H\,R^w\right]}{E\left[w_1^{1-\gamma}\right]} = \beta\frac{E\left[(w-c_0)^{-\gamma}R^{w1-\gamma}H^{1-\gamma}\right]}{E\left[(w-c_0)^{1-\gamma}R^{w1-\gamma}H^{1-\gamma}\right]}$$
$$\frac{1}{c_0} = \beta\frac{1}{(w-c_0)} \Longleftrightarrow c_0 = \frac{w}{1+\beta}.$$

Since the elasticity of intertemporal substitution is equal to one, the optimal consumption in period 0 is a fixed fraction of wealth.

The optimal savings and portfolio decisions thus separate. The optimal portfolio decision solves

$$\max_{\omega_t,\omega_g} \log\left(E\left[\left(R^w H\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}\right). \tag{19}$$

Lognormal returns. We now assume that the vector $R = \left(R_t\ R_g\right)^\top$ is lognormal. The vector of log returns is $r = \log R = E\left[r\right] + \varepsilon_r$, where ε_r is a normal vector with mean zero and variance Σ. Log mean returns are $\log E\left[R\right] = E\left[r\right] + \frac{1}{2}\text{diag}(\Sigma)$. While this makes individual returns lognormal, lognormality is not preserved when returns are added together, so the return on wealth R^w in equation (18) is not lognormal.

Campbell-Viceira approximation. We start from the vector-valued function

$$g\left(z\right) = \log\left(\omega^\top \exp\left(z\right) + \left(1-\omega^\top \iota\right)\exp\left(k\iota\right)\right), \tag{20}$$

where ω is a vector of weights that sums to one, $\exp\left(z\right)$ is element-wise exponentiation, and ι is a vector of ones. We want to write $g\left(z\right) = \log f\left(z\right)$, where $f\left(z\right)$ is what is in the bracket in equation (20).

We perform a 2nd order Taylor expansion. The derivatives are

$$\begin{aligned}
\frac{dg\left(z\right)}{dz_i} &= \frac{1}{f\left(z\right)}\omega_i e^{z_i} \\
\frac{d^2 g\left(z\right)}{dz_i^2} &= -\frac{1}{f\left(z\right)^2}\omega_i^2 e^{2z_i} + \frac{1}{f\left(z\right)}\omega_i e^{z_i} \\
\frac{d^2 g}{dz_i dz_j} &= -\frac{1}{f\left(z\right)^2}\omega_i\omega_j e^{z_i}e^{z_j}; \qquad i \neq j.
\end{aligned}$$

We want to take the expansion around $z = k\iota$ (which means $z_i = k$ for every i). Note that $f\left(k\iota\right) = \exp(k\iota)$ and $g\left(k\iota\right) = k\iota$. We evaluate the derivatives at $z = k\iota$

$$\begin{aligned}
\frac{dg\left(k\iota\right)}{dz_i} &= \omega_i \\
\frac{d^2 g\left(k\iota\right)}{dz_i^2} &= -\omega_i^2 + \omega_i \\
\frac{d^2 g\left(k\iota\right)}{dz_i dz_j} &= -\omega_i\omega_j; \qquad i \neq j.
\end{aligned}$$

We can now approximate $g(z)$ around $z = k\iota$

$$g(z) \approx k\iota + \omega^\top (z - k\iota) + \frac{1}{2}\omega^\top \text{diag}\left((z-k\iota)(z-k\iota)^\top\right) - \frac{1}{2}\omega^\top (z-k\iota)(z-k\iota)^\top \omega. \tag{21}$$

Taking expectations

$$E\left[g(z) - k\iota\right] = \omega^\top (E[z] - k\iota) + \frac{1}{2}\omega^\top \text{diag}\left(\text{var}(z-k\iota)\right) - \frac{1}{2}\omega^\top \text{var}(z-k\iota)\omega.$$

Computing the variance, we obtain

$$\text{var}\left(g(z) - k\iota\right) = \omega^\top \text{var}\left(z - k\iota\right)\omega,$$

under the assumption that $z - k\iota$ is normally distributed and small. The reason is that the variance of the other terms on the right-hand size of the approximation (21) are quadratic in z and therefore equal to zero.

To summarize, the assumption that $z - k\iota$ is small and normally distributed leads to

$$g(z) - k \sim \mathcal{N}\left(\omega^\top (E[z] - k\iota) + \frac{1}{2}\omega^\top \text{diag}\left(\text{var}(z-k\iota)\right) - \frac{1}{2}\omega^\top \text{var}(z-k\iota)\omega, \omega^\top \text{var}\left(z-k\iota\right)\omega\right).$$

Approximating the distribution of the log return on wealth. We can rewrite the log return (18) on wealth as

$$\log R^w = \log\left(\omega^\top \exp\left(E[r] + \frac{1}{2}\text{diag}\left(\Sigma\right) + \log\theta e_2 + \varepsilon_r\right) + \left(1 - \omega^\top \iota\right)\exp\left(r^f\right)\right).$$

The risky part fits the above formalism (20) with $k = r^f$ and we can also expand the riskfree part to approximate

$$\log R^w - r^f \sim \mathcal{N}\left(\omega^\top\left(\mu + \log\theta e_2\right) - \frac{1}{2}\omega^\top \Sigma\omega, \omega^\top \Sigma\omega\right),$$

where $\mu = E[r] - r^f\iota + \frac{1}{2}\text{diag}(\Sigma)$.

Closed-form solution to the portfolio choice problem. Note that the moments of $\log H$ do not depend on the portfolio ω

$$\log H = \eta_0 + \eta_g \begin{bmatrix} r_t & r_g \end{bmatrix} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$
$$\text{var}\left(\log H\right) = \eta_g^2 \begin{bmatrix} 1 & -1 \end{bmatrix} \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix}.$$

Moreover, we have the covariances

$$\mathrm{cov}(r, \log H) = \eta_g \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$
$$\mathrm{cov}\left(\log R^w, \log H\right) = \omega^\top \eta_g \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

Substituting the moments into the objective function (19), and leaving out terms that do not depend on the portfolio ω, we obtain

$$\begin{aligned}
&\max_\omega \log\left(E\left[\left(R^w H\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}\right) \\
&= \max_\omega E\left[\exp\left(\left(1-\gamma\right)\left(\log R^w + \log H\right)\right)\right] \\
&= \max_\omega \left\{E \log R^w + E \log H + \frac{1}{2}\left(1-\gamma\right) \mathrm{var}\left(\log R^w + \log H\right)\right\} \\
&= \max_\omega \left\{r^f + \omega^\top\left(\mu + \log\theta e_2\right) - \frac{1}{2}\omega^\top\Sigma\omega + \frac{1}{2}\left(1-\gamma\right)\left(\omega^\top\Sigma\omega + \mathrm{var}(\log H) + 2\omega^\top\eta_g\Sigma\begin{bmatrix} 1 \\ -1 \end{bmatrix}\right)\right\} \\
&= \max_\omega \left\{\omega^\top\left(\mu + \log\theta e_2\right) - \frac{1}{2}\gamma\omega^\top\Sigma\omega + \left(1-\gamma\right)\omega^\top\eta_g\Sigma\begin{bmatrix} 1 \\ -1 \end{bmatrix}\right\}. \qquad (22)
\end{aligned}$$

Let the vector ν denote the multipliers on the short sale constraint. We have the FOCs

$$\mu + \log\theta e_2 - \gamma\Sigma\omega + \left(1-\gamma\right)\eta_g\Sigma\begin{bmatrix} 1 \\ -1 \end{bmatrix} + \nu = 0. \qquad (23)$$

Assume that Σ is nonsingular. If all assets are held in positive quantities, the short-sale constraint does not bind, and $\nu = 0$. In this case, the optimal portfolio is

$$\omega = T\left(\mu + \log\theta e_2\right) + h, \text{ where } h = \frac{1-\gamma}{\gamma}\eta_g\Sigma^{-1}\Sigma\begin{bmatrix} 1 \\ -1 \end{bmatrix} = \frac{\gamma-1}{\gamma}\begin{bmatrix} -\eta_g \\ \eta_g \end{bmatrix}, \text{ and } T = \frac{1}{\gamma}\Sigma^{-1}. \qquad (24)$$

We have thus derived equation (5).

If $\gamma = 1$, then we get optimal myopic portfolio weights. The optimal weights are on a security market line that connects the riskfree asset and the “market portfolio". The riskfree asset is located at the point $(0, r_f)$ in risk-return space and is optimally chosen if $\gamma \to \infty$. The market portfolio has weights proportional to

$$\Sigma^{-1}\left(\mu + \log\theta e_2\right).$$

In our context this line is subjective as beliefs μ, Σ and tastes θ can vary across people.

Also when γ is not one, then we have an additional hedging demand h. In particular, the household wants to sell a portfolio that represents the projection of $\log H$ onto the asset return space (the portfolio closest to $\log H$ in a regression sense).

More explicit portfolio weights. The variance of log returns and its inverse are

$$\Sigma = \sigma_t^2 \begin{bmatrix} 1 & \rho\lambda \\ \rho\lambda & \lambda^2 \end{bmatrix} \Longrightarrow \Sigma^{-1} = \frac{1}{\sigma_t^2 \lambda^2 (1-\rho^2)} \begin{bmatrix} \lambda^2 & -\rho\lambda \\ -\rho\lambda & 1 \end{bmatrix} = \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} 1 & -\frac{\rho}{\lambda} \\ -\frac{\rho}{\lambda} & \frac{1}{\lambda^2} \end{bmatrix}.$$

The optimal portfolio is therefore

$$\omega = \frac{1}{\gamma} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} 1 & -\frac{\rho}{\lambda} \\ -\frac{\rho}{\lambda} & \frac{1}{\lambda^2} \end{bmatrix} \begin{bmatrix} \mu_t \\ \mu_g + \log\theta \end{bmatrix} + h \tag{25}$$

Sum of risky weights. The sum of risky portfolio weights is the sum of myopic weights since hedging demands sum to zero. Therefore,

$$\begin{aligned} \omega_g + \omega_t &= \frac{1}{\gamma} \begin{bmatrix} 1 & 1 \end{bmatrix} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} 1 & -\frac{\rho}{\lambda} \\ -\frac{\rho}{\lambda} & \frac{1}{\lambda^2} \end{bmatrix} \begin{bmatrix} \mu_t \\ \mu_g + \log\theta \end{bmatrix} \\ &= \frac{1}{\gamma} \begin{bmatrix} 1 & 1 \end{bmatrix} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} \mu_t - \frac{\rho(\mu_g + \log\theta)}{\lambda} \\ \frac{(\mu_g + \log\theta)}{\lambda^2} - \frac{\rho\mu_t}{\lambda} \end{bmatrix} \\ &= \frac{1}{\gamma} \frac{1}{\sigma_t^2 (1-\rho^2)} \left(\frac{\left(\mu_t + (\mu_g + \log\theta\right)}{\lambda^2} - \frac{\rho(\mu_t + \mu_g + \log\theta)}{\lambda} \right). \end{aligned} \tag{26}$$

C.2 Bounds on Hedging Demand Implied by Hypothetical Asset Choice

In this section, we describe how hypothetical asset choice imposes bounds on the hedging demand h_g^i. We start from equation (22) and write utility from portfolio ω given household-specific parameters $\{\mu, h, \gamma\Sigma\}$ as

$$u(\omega) = r^f + \omega^\top(\mu + \log\theta e_2) - \frac{1}{2}\omega^\top\Sigma\omega + E[\log H] + \frac{1}{2}(1-\gamma)\left(\omega^\top\Sigma\omega + \text{var}(\log H) + 2\omega^\top\eta_g\Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix}\right)$$

As discussed in the text, we interpret the question as eliciting a ranking between two extreme portfolios that have 100% in either green or traditional equity. Let e^i denote the ith unit vector. Evaluating utility at these two portfolios, optimal choice between them is the same as ranking components of the vector

$$\mu + \log\theta e_2 + \gamma\Sigma h - \frac{1}{2}\gamma\,\text{diag}(\Sigma)$$

A household chooses green if and only the second component is larger than the first. Rearranging this expression delivers the bounds used in the text as well as in Appendices C.3 and C.4.

We now show that the same bound applies to a household with current optimal interior portfolio weights ω_t and ω_g who receives additional income worth a share x of wealth that can be invested (exclusively) in either traditional or green equity. When the household uses x to buy, say, traditional equity, the new portfolio weights are

$$\left(\frac{\omega_t+x}{1+x},\frac{\omega_g}{1+x},\frac{1-\omega_g-\omega_t}{1+x}\right).$$

We note that the ratio of green to safe weights remains unchanged.

Leaving out terms that do not depend on portfolio weights and using the definition of h in equation (8), we write the relevant terms in utility as

$$\tilde{u}\left(\omega\right)=\omega^{\top}\left(\mu+\log\theta e_2+\gamma\Sigma h\right)-\frac{1}{2}\gamma\omega^{\top}\Sigma\omega. \tag{27}$$

We write e_i for the ith unit vector: it represents the extreme portfolio weights that describe investment of the extra amount x. We therefore compare, for $i=1,2$, utilities

$$\tilde{u}\left(\omega+xe_i\right)=\frac{1}{1+x}\left(\omega+xe_i\right)^{\top}\left(\mu+\log\theta e_2+\gamma\Sigma h\right)-\left(\frac{1}{1+x}\right)^2\frac{1}{2}\gamma\left(\omega+xe_i\right)^{\top}\Sigma\left(\omega+xe_i\right)$$

Multiplying by $1+x$, we have

$$\begin{aligned}(1+x)\,\tilde{u}\left(\omega+xe_i\right)=&\left(\omega+xe_i\right)^{\top}\left(\mu+\log\theta e_2+\gamma\Sigma h\right)-\frac{1}{1+x}\frac{1}{2}\gamma\left(\omega+xe_i\right)^{\top}\Sigma\left(\omega+xe_i\right)\\ =&\omega^{\top}\left(\mu+\log\theta e_2+\gamma\Sigma h\right)-\frac{1}{1+x}\frac{1}{2}\gamma\omega^{\top}\Sigma\omega+\\ &\left(xe_i\right)^{\top}\left(\mu+\log\theta e_2+\gamma\Sigma h\right)-\frac{x}{1+x}\gamma\omega^{\top}\Sigma e_i-\frac{1}{2}\frac{x^2}{1+x}\gamma e_i^{\top}\Sigma e_i\end{aligned}$$

The first line is independent of i. The household thus chooses to invest x into green equity if and only if the expression

$$\left(xe_i\right)^{\top}\left(\mu+\log\theta e_2+\gamma\Sigma h\right)-\left(\frac{x}{1+x}\right)\gamma\omega^{\top}\Sigma e_i-\frac{1}{2}\frac{x^2}{1+x}\gamma e_2^{\top}\Sigma e_i$$

ls larger for $i=2$ than for $i=1$.

Dividing by x, we can simplify the expression to obtain

$$\begin{aligned}
&e_i^\top(\mu+\log\theta e_2+\gamma\Sigma h)-\frac{1}{1+x}\gamma\omega^\top\Sigma e_i-\frac{1}{2}\frac{x}{1+x}\gamma e_i^\top\Sigma e_i \\
&=\mu_i+e_i^\top\log\theta e_2+\gamma(\Sigma h)_i-\frac{1}{1+x}\gamma\left(\omega_i\sigma_i^2+\omega_j\rho\sigma_i\sigma_j\right)-\frac{1}{2}\frac{x}{1+x}\gamma\sigma_i^2
\end{aligned}$$

In vector notation, deciding between green and traditional equity thus amounts to comparing components of the vector

$$\pi=\mu+\log\theta e_2+\gamma\Sigma h-\frac{1}{1+x}\gamma\Sigma\omega-\frac{1}{2}\frac{x}{1+x}\gamma\operatorname{diag}(\Sigma)$$

In particular, choosing green is optimal if and only if the second component π_2 is larger than the first component.

Since the portfolio ω was chosen optimally and represents an interior solution, then it satisfies the first-order condition from maximizing (27), or

$$\mu+\log\theta e_2+\gamma\Sigma h-\gamma\Sigma\omega=0$$

Substituting, the vector of payoffs becomes

$$\begin{aligned}
\pi&=\mu+\log\theta e_2+\gamma\Sigma h-\frac{1}{1+x}\gamma\Sigma\omega-\frac{1}{2}\frac{x}{1+x}\gamma\operatorname{diag}(\Sigma)\\
&=\mu+\log\theta e_2+\gamma\Sigma h-\frac{1}{1+x}(\mu+\gamma\Sigma h)-\frac{1}{2}\frac{x}{1+x}\gamma\operatorname{diag}(\Sigma)\\
&=\frac{x}{1+x}\left(\mu+\log\theta e_2+\gamma\Sigma h-\frac{1}{2}\gamma\operatorname{diag}(\Sigma)\right). \qquad (28)
\end{aligned}$$

This argument exploits that first-order terms are zero due to optimality. Since optimal choice of green versus traditional just compares components of the vector π, it is independent of the level of x.

The household chooses green if the first element of the vector in bracket of equation (28) is smaller than the second element

$$\mu_g+\log\theta-\frac{1}{2}\gamma{\sigma_t}^2\lambda^2+\gamma{\sigma_t}^2h_g\lambda(\lambda-\rho)>\mu_t-\frac{1}{2}\gamma{\sigma_t}^2+\gamma{\sigma_t}^2h_g(\rho\lambda-1) \qquad (29)$$

which derives the inequality (12).

Terms on the left-hand side that multiply $\gamma\sigma_t^2h_g$:

$$\lambda(\lambda-\rho)-\rho\lambda+1=\lambda^2-2\lambda\rho+1$$

Therefore, we get the following lower bound for h_g

$$h_g > \frac{\mu_t - \mu_g - \log\theta + \frac{1}{2}\gamma\sigma_t^2\left(\lambda^2 - 1\right)}{\gamma\sigma_t^2\left(\lambda^2 - 2\rho\lambda + 1\right)}. \tag{30}$$

Conversely, the household chooses the traditional fund if h_g is smaller than the right-hand side, which provides an upper bound for the hedging demand for holding green.

C.3 Matching Portfolio Weights in the May Wave

In the November wave of the survey, we observe for each household their expectations about the returns on a green and a traditional equity fund. We also observe their overall share of risky assets and whether or not they report having a "green equity fund." In the May wave of the survey, we observe household's precise holdings of green and traditional equity. We match households between the two wave on demographics and wealth characteristics, while also trying to respect their stated beliefs.

For a household in the November wave who reports holding a green account, we can compute the set of possible green portfolio shares, ω_g^i, that are consistent with their stated beliefs and hypothetical choice. The set of possible values is constrained by the following considerations.

1. The household's green portfolio weight must satisfy equation (25):

$$\omega_g^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\frac{\mu_g^i + \log\theta^i}{{\lambda^i}^2} - \frac{\rho^i\mu_t^i}{\lambda^i}\right) + h_g^i > 0. \tag{31}$$

2. The household's optimal portfolio weights on risky assets must satisfy equation (26):

$$\omega_g^i + \omega_t^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\mu_t^i + \frac{\mu_g^i + \log\theta^i}{{\lambda^i}^2} - \rho^i\frac{\mu_t^i + \mu_g^i + \log\theta^i}{\lambda^i}\right). \tag{32}$$

3. The household's parameter values must also satisfy their choice of hypothetical equity fund. We want to respect either the upper or lower bound (30) on h_g, given by:

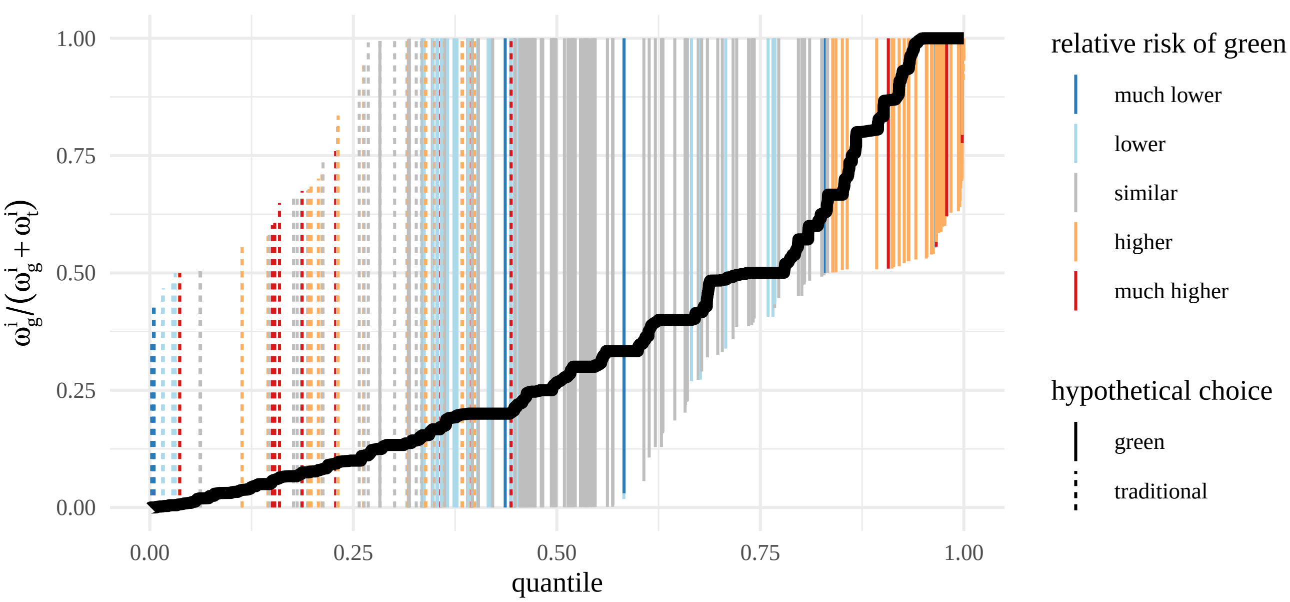
$$\frac{\mu_t^i - \mu_g^i - \log\theta^i + \frac{1}{2}\gamma^i {\sigma_t^i}^2({\lambda^i}^2 - 1)}{\gamma^i {\sigma_t^i}^2({\lambda^i}^2 - 2\rho^i\lambda^i + 1)}. \tag{33}$$

4. Finally we must respect the household's relative risk ranking which bounds λ^i.

Given values for ρ^i and λ^i, the above equations determine households' risk tolerance $\gamma^i \sigma_t^{i\,2}$ and the bound on their hedging demand h_g^i. Together, these parameters determine the minimum or maximum value of green equity share ω_g^i that households' beliefs about returns and relative risk can support. For households who say the relative risk of a green equity fund is "similar", we restrict $\lambda^i \in [0.9, 1.1]$. For households who say the relative risk of a green equity fund is "lower" or "much lower", we restrict $\lambda^i \in (0, 0.85]$. For those who say the relative green risk is "higher" or "much higher" we restrict $\lambda^i \in [1.15, \infty)$. The parameter ρ^i is restricted to be between -1 and 1.

These bounds on households' green equity share are illustrated in Figure C.1. Each vertical line illustrates the possible values that are supported by households' expected returns on the two equity funds, their relative risk ranking, and hypothetical choice of green versus traditional equity funds. Some patterns emerge. For some households who choose the hypothetical traditional equity fund, there is a theoretical upper limit on the fraction of their green equity. The upper limit derives from the bound on hedging demand (33) implied by their hypothetical choice. Similarly, some households' hypothetical choice of the green account, together with their reported expectations, implies a binding lower bound on the share of their equity holdings that are green.

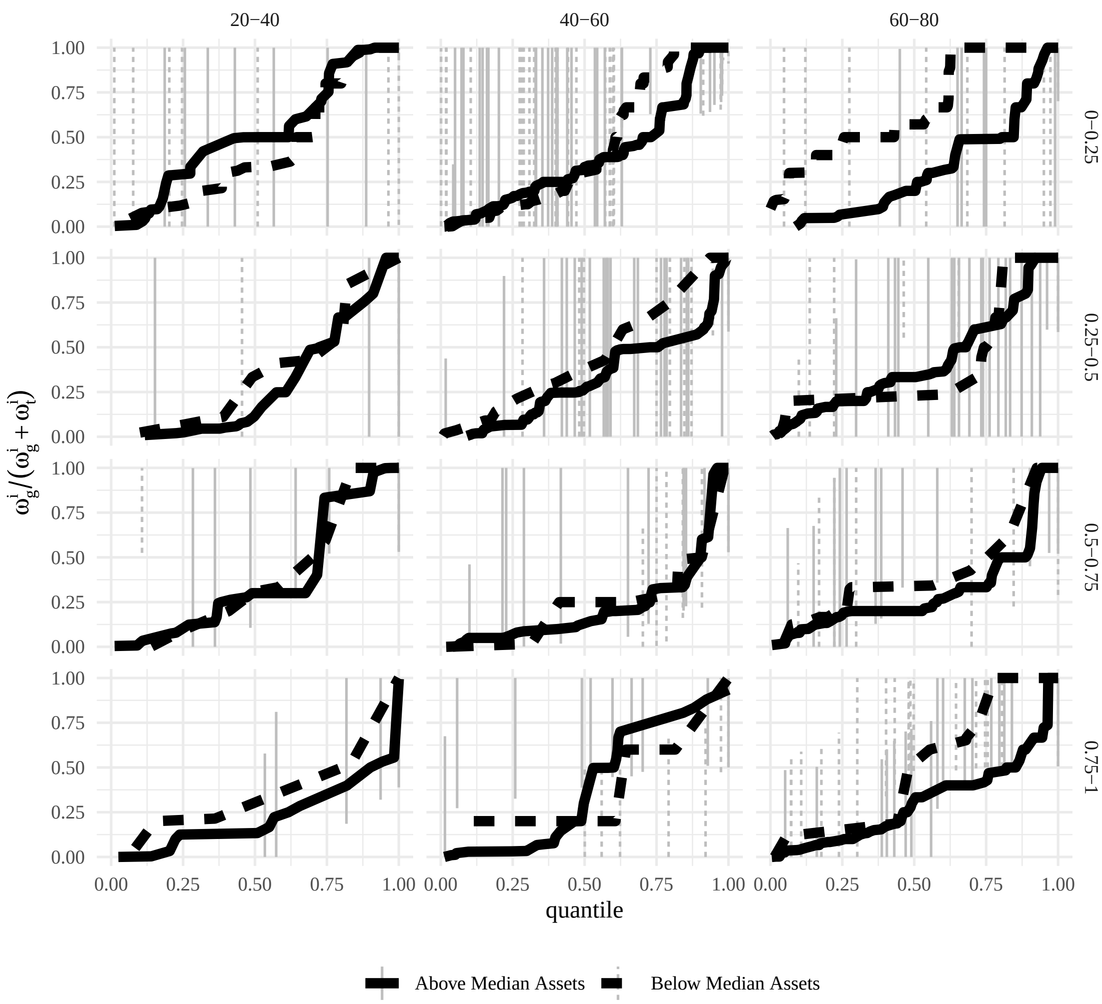
Figure C.1: Bounds on individual ω_g^i



Note: This figure illustrates the range of the fraction of green equity $\omega_g^i/(\omega_g^i + \omega_t^i)$ supported by respondents' expected returns, relative risk ranking, hypothetical asset choice, and reported total equity holdings. Households from the November wave of the survey are arranged by the quantile of the midpoint of their supported green asset share. The color of the indicates their relative risk ranking. Solid lines indicate households who chose the hypothetical green account. Dashed lines indicate households who chose the hypothetical traditional account. The solid black line illustrates the inverse cumulative density function for the share of green equity from the May wave of the survey where we observe more complete portfolio information for a different set of individuals.

Once we have computed a set of bounds for each household, we sort households into bins by 20-year age group, the fraction of their portfolio that they hold in equity, and whether they have above or below median financial asset holdings (within their age group). Figure C.2 illustrates how we match households in the November wave to households in the May wave based on their location in the distribution of supported ω_g^i's to the corresponding quantile of the $\omega_t^i + \omega_g^i$ distribution in the May wave.

Figure C.2: Assigning ω_g^i values to individuals in the November wave



Note: This figure illustrates how households in the November wave are assigned green equity shares $\omega_g^i/(\omega_g^i + \omega_t^i)$ to match the distribution of green equity shares from the May wave. Each panel illustrates one 20-year age bin (horizontal) and fraction of the financial portfolio held in equity (vertical). Within a bin, households are further divided into above or below median financial asset holdings. Households in the November wave are ordered by the quantile of the midpoint of their supported green equity holdings. The solid and dashed black lines illustrate the inverse cumulative density function for the share of green equity from the May wave of the survey for the same bin definition, split again by above or below median financial asset holdings.

C.4 Mapping Survey Responses to Model Primitives

In this section, we describe how we recover model primitives for households who do not hold both green and traditional equity.

Households who hold only traditional equity. For households who report holding only traditional equity, there are four remaining unknowns $\{\lambda^i, \rho^i, \gamma^i {\sigma_t^i}^2, h_g^i\}$. To identify these parameters, we have one equation and three inequalities:

1. The household's optimal portfolio weight ω_t^i on traditional equity must satisfy:

$$\omega_t^i = \frac{\mu_t^i}{\gamma^i {\sigma_t^i}^2} - h_g^i. \tag{34}$$

2. Given that the household holds not green, it cannot be optimal for the household to have a positive green portfolio weight ω_g^i though the weight may be negative if the household is hitting a short sale constraint. This effectively forms an upper bound on a household's hedging demand for holding green:

$$\omega_g^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2} \left(\frac{\mu_g^i + \log \theta^i}{\lambda^{i2}} - \frac{\rho^i \mu_t^i}{\lambda^i} \right) + h_g^i \leq 0. \tag{35}$$

3. The household's parameter values must also satisfy their choice of hypothetical equity fund. We want to respect either an upper or a lower bound (30) on h_g^i depending on their choice of hypothetical account, given by:

$$\frac{\mu_t^i - \mu_g^i - \log \theta^i + \frac{1}{2} \gamma^i {\sigma_t^i}^2 (\lambda^{i2} - 1)}{\gamma^i {\sigma_t^i}^2 (\lambda^{i2} - 2\rho^i \lambda^i + 1)} \tag{36}$$

4. Finally we must respect the household's relative risk ranking which bounds λ^i.

Households who hold only green equity. For households in the November wave who we match to households in the May wave with all of their equity in green equity, there are four remaining unknown parameters: $\{\lambda^i, \rho^i, \gamma^i {\sigma_t^i}^2, h_g^i\}$. To identify these parameters, we have one equation and three inequalities:

1. The household's optimal portfolio weight on green equity, ω_g^i, must satisfy:

$$\omega_g^i = \frac{\mu_g^i + \log\theta^i}{\lambda^{i2}\gamma^i\sigma_t^{i\,2}} + h_g^i \tag{37}$$

2. It cannot be optimal for the household to have a positive portfolio weight on traditional equity, ω_t^i, though the weight may be negative if they are hitting the short sale constraint. This effectively forms an upper bound on a households hedging demand for holding green:

$$\omega_t^i = \frac{1}{\gamma^i\sigma_t^{i\,2}(1-\rho^i)^2}\left(\mu_t^i - \frac{\rho^i(\mu_g^i + \log\theta^i)}{\lambda^i}\right) - h_g^i \leq 0 \tag{38}$$

3. The household's parameter values must also satisfy their choice of hypothetical equity fund. We want to respect either an upper or a lower bound (30) on h_g^i, given by:

$$\frac{\mu_t^i - \mu_g^i - \log\theta^i + \frac{1}{2}\gamma^i\sigma_t^{i\,2}(\lambda^{i2}-1)}{\gamma^i\sigma_t^{i\,2}(\lambda^{i2}-2\rho^i\lambda^i+1)} \tag{39}$$

4. Finally we must respect the household's relative risk ranking which bounds λ^i. For households who rank the risk of the two accounts as similar, we allow for small deviations from exact equality of the variance of the two account.

Households with no risky assets. For households with no risky assets, we cannot identify the parameter for their relative risk tolerance. We exclude these households from any counterfactual analysis except for the introduction of a green fixed-income market.

Households with incomplete answers. We drop households with incomplete answers in the baseline calibration. However, this introduces potential bias in the results due to non-random sample attrition. Individuals with a distaste for green as measured by their minimum accepted spread on a green deposit account were less likely to answer the set of questions on expected equity returns and risk. Table ? shows that our results are not sensitive to re-weighting the sample to match either the distribution of deposit spreads or the results of the 2021 Bundestag election.