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. Equity is the most important green asset class, while green bank account are rare. For both safe and risky green assets, asset-specific taste matters for portfolio choice but can either increase or decrease demand. On net, nonpecuniary benefits and hedging demand currently make green equity more expensive for firms. Nevertheless, the rise of sustainable investing has reduced the relative risk premium on green stocks by about 1pp, mostly because investors who are now aware of such stocks bid up their prices. Widespread adoption of green bank accounts is desired by households and 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 lead to a further burst in green equity investment as well.

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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 acccounts 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 80bp, 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 thus contain rich information on demographics, income, and wealth. We draw on two waves in 2021-22, where we added questions on green investment. 34% of households own *some* green financial product worth 11% of household financial wealth. With an equity share of more than half, the green investment portfolio is more risky than the overall wealth portfolio that has only one third equity. 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 for the following year. Households who actually own green securities, however, are more optimistic about them and expect no greenium. In the cross section, households who are more optimistic about green equity funds typically also perceive those funds as less risky.

Our survey module includes several hypothetical choice questions to measure taste for green assets. We first elicit interest-rate spreads that people would give up (or require) to invest in 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 strong 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, making green stocks perform particularly badly. They would then be naturally extra cautious with respect to green stocks—effectively, traditional funds provide insurance to them and might be preferred even if the household is optimistic about green stocks. Accordingly, we find evidence of negative hedging demand for green funds even among the population of households who own a green investment account.

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 riskfree bonds. For counterfactuals, we determine equity prices by matching aggregate demand to exogenous 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 convenience yields and 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 a green (in)convenience yield as well as green hedging demand currently holds back green finance. The reason is that the pool of current green investors contains a sizeable number of investors who take a cautious approach for hedging reasons. If those hedging demands were muted, household optimism would drive prices up.

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 the availability of sustainable investing. To gauge the effect on expectations and tastes, our survey module contains an RCT that informs households about the potential of green finance. 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. Only 9% of households hold exclusively green stock funds.

In our survey data, households hold green stock funds and traditional stock funds to different degrees. To explain heterogeneity in portfolio choice, we must go beyond negative screens and allow households more or less about green assets. 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, the individual-specific beliefs, nonpecuniary benefits and hedging motives we estimate from survey data matters for asset prices with wealth weights: richer households' opinions and concerns carry more weight in market valuation. Moreover, 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 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 directly ask investors about their beliefs and motives. This approach is especially attractive in a changing 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 that 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 are consistent with the existing survey findings. A novelty of our survey is that we ask households how they assess the risks of ESG investments and how much they would pay for riskfree green assets. Another contribution of our paper is to directly measure the cross-sectional distribution of household beliefs and tastes, and use them as an input into a quantitative model with heterogeneous households. Another advantage of our survey design is that it relies on the Bundesbank's representative household sample and contains information about demographics, income, and portfolios. Our data therefore provide important information about the population of a country as a whole and allow 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.

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 safe green 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 and Section 7 reports the model counterfactuals.

[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.

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 as well as 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 a set of 8 customized questions across two survey waves with roughly 6,000 respondents in each wave.

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 current 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 this wave, we also field a randomized control trial (RCT) with information treatments related to green investing. We split the wave randomly into a control group with approximately 2,000 (untreated) respondents and a treatment group with approximately 1,000 respondents. The treatment makes climate change more salient by describing a report by the United Nations about the risks posed by climate change. The treatment then provides information that green investment funds can contribute to its mitigation.

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 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.

[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 the 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.

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. Green equity is mainly held by older and wealthier households. 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 ?

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". Data come from the May 2022 survey wave, with the exception of the share of green deposits, which we add in from the November 2021 wave. The first column reports aggregate portfolio shares of all households, while the second focuses on household who own some equity. The third column shows the share of green investment within an asset class. The last two columns report unconditional participatiuon rates as well as participation rates conditional on having some position in the asset class, respectively.

The most important financial asset held by German households is bank deposits. Almost all households (99%) have some deposits; 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 of 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% in Germany as well as the Euro Area as a whole. We show in Appendix [3] Industry estimates for the total U.S. household portfolio in ESG accounts range from $8-20 trillion.[4] The overall aggregate portfolio share of green assets in U.S. portfolios is thus in the range of 8-19%, which is in a similar range as the aggregate portfolio share of all green financial assets of German households of 11% from Table 1.

[3] In contrast, U.S. households tend to hold a larger share of risky assets, but a similar share of green assets compared to German households. 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. Source: Financial Accounts of the United State Z.1 Line 9 for 2020.

[4] Source: https://www.bloomberg.com/news/articles/2022-12-13/esg-market-in-us-significantly-smaller-than-previously-reported.

Consider now the role of green asset positions. Equity is clearly the most important pathway to green investment. Indeed, 18% of households, or 42% of equity holders, report at least some green equity holdings. These investments amount to 6% of total financial assets, or 17% of the equity portfolio of held directly by German households. Other asset classes are used less to build green positions. In particular, only 5% of households report having green deposit accounts, and the share of green deposits is 4%, 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 products 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.

We conclude that while green investing is already fairly popular in Germany, it is currently risky relative to the overall portfolio. Suppose we view equity as risky and deposits as safe, with risk in bonds and pensions uncertain. The aggregate portfolio then has a risky share of at least one third and at most one half. Green holdings of any kind make up 11% of financial assets. The aggregate green portfolio has a risky share of at least 55% that 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 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 accounts. In contrast, households with more than 90% of their financial portfolio in equity hold only a quarter in green accounts.

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 own most financial assets. Figure 1(d) illustrates the share of total equity holdings held by each age group.

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 from the November 2021 and May 2022 waves of the Bundesbank Survey of Household Expectations.

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.

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 can be found in appendix table B.1.

4 Demand for a Green Safe Asset

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

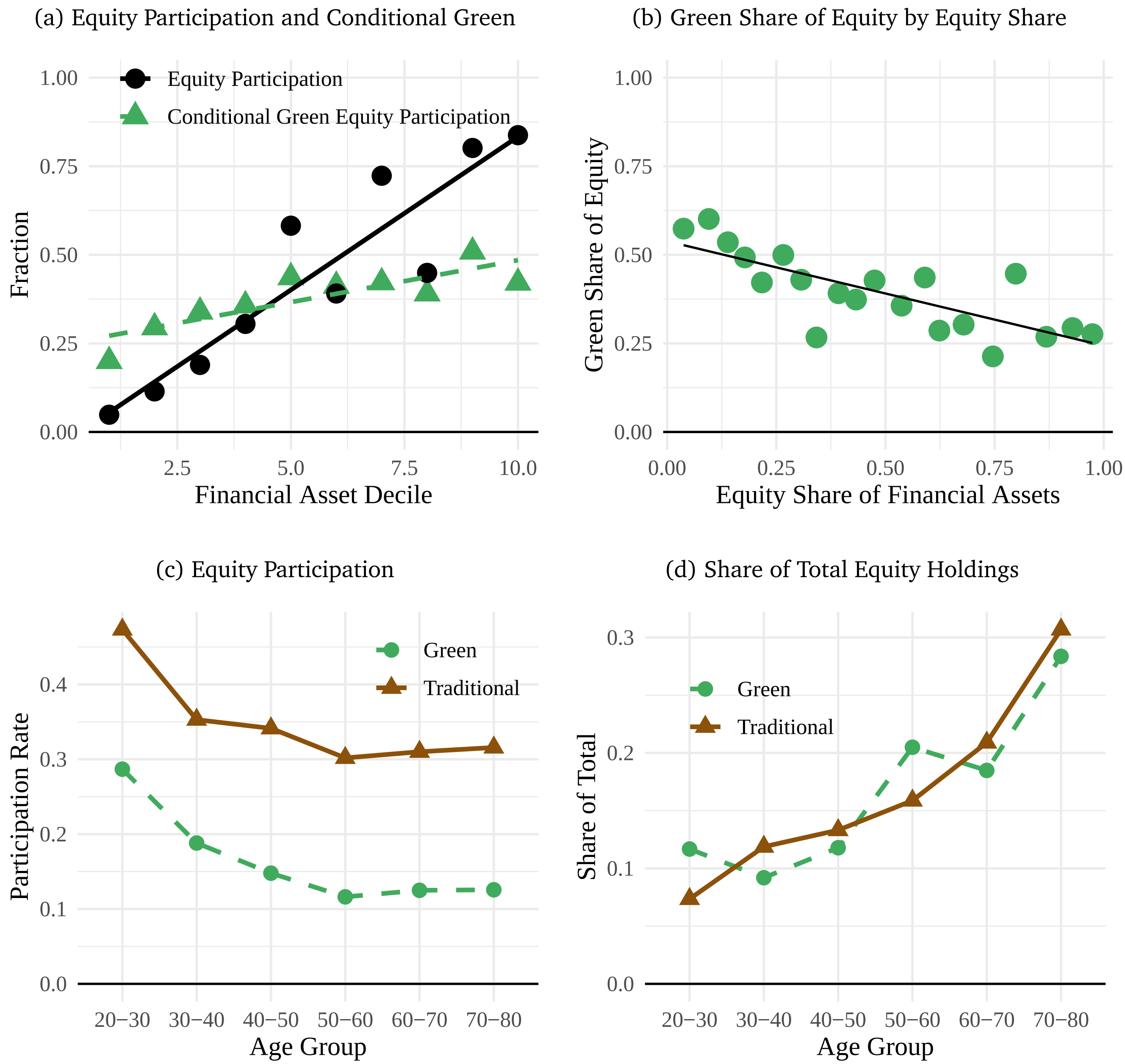
4.1 Measuring Taste for a Safe Green Asset

We measure taste for a safe green 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 on a green deposit account relative to a traditional bank account, ranging from −2% to 2%. Respondents were asked to make a binary decision for either the traditional or the green savings account for each spread. The complete translated text of the question continues as follows:

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.

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

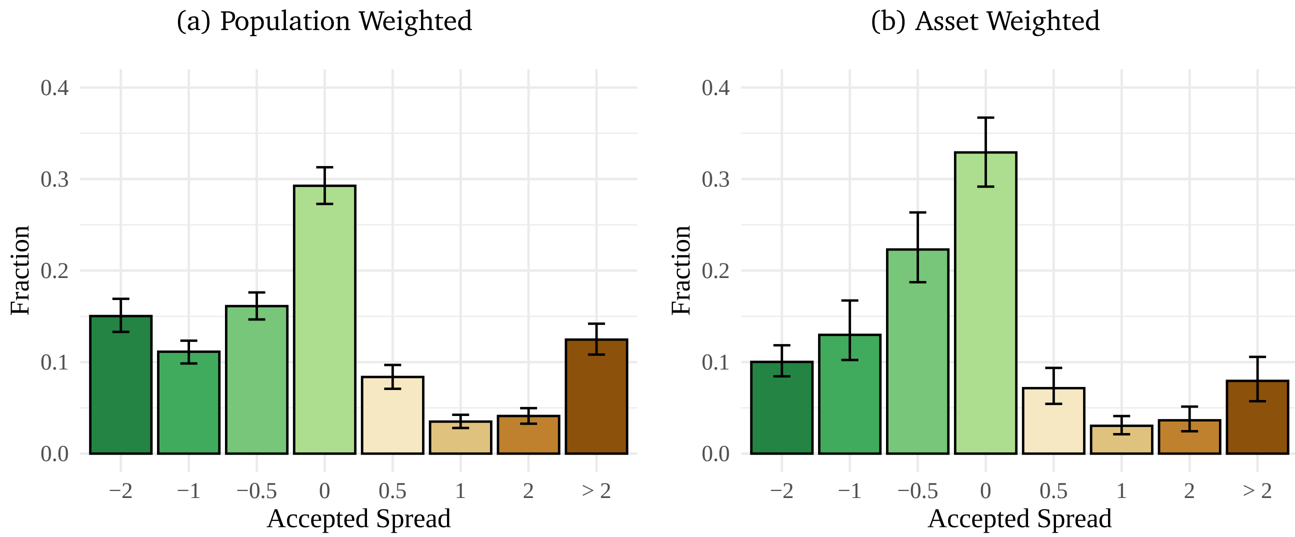
Comparing interest rates across banks and worrying about deposit yields is salient for German households in the low-interest rate environment of the past few years. We are confident that most survey respondents understood the sequence of questions, as close to 90% of respondents answers' were complete and consistent. A set of responses is *consistent* if once an individual chooses the green deposit account, they do so for all larger spreads. For example, if they choose the green account when the spread over the traditional account is 0, they must 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 their minimum accepted spread on a green deposit account. For example, respondents who choose the green account in all cases are classified as having a 2% convenience yield for safe green assets and a taste for green. Suppose respondents only choose the green account when the rate on the green account is equal to or higher than the traditional account. In that case, 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 asset is not always neutral or positive. While many respondents report they are willing to sacrifice financial returns to hold a safe green asset, a substantial fraction would require financial compensation to hold such an asset. Figure 2(a) plots the distribution of minimum accepted spreads 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 the Accepted Spread on a Green Savings Account



Note: The height of the colored bars shows the fraction of respondents who choose a green deposit account at that spread over a traditional deposit account or a higher spread. Panel (a) shows the distribution of minimum accepted spreads 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 brown preferences. Figure 2(b) plots the distribution of the accepted spread on a green deposit account weighted by households' reported asset holdings. Respondents who are willing to accept a negative spread (and thus have a taste for green) have 45% of aggregate financial wealth, households with an aversion to green or with a taste for brown 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 spreads that people are willing to accept on a green bank account are large but not unreasonable. To translate these responses to euros, we use data about the survey respondents' bank deposits. We find that the median willingness to pay for a green bank account, conditional on accepting a negative deposit spread, is 150€ in annual foregone returns. The median required payment to accept a green bank account, conditional on accepting a positive deposit spread, is 112€ in annual forgone returns.[6] Given that the median household income of survey respondents is roughly 40,000€, these

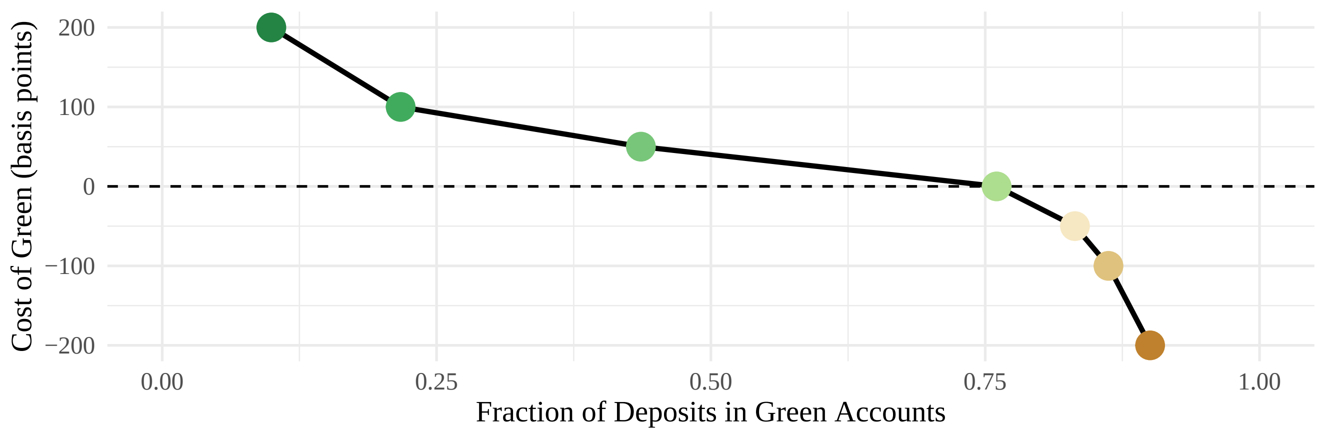
[5]Our elicited range of spreads leads to substantial censoring at the tails of the true taste distribution. Roughly 13% of people do not choose green deposits for any of the spreads offered, while 15% choose green deposits in all cases.

[6]Both distributions are heavily skewed with a long right tail. The mean willingness to pay for a green bank account conditional on accepting a negative deposit spread is 371€ in annual foregone returns (with a standard deviation of 728€). The mean required payment to accept a green bank account conditional on accepting a positive deposit spread is 611€ in annual forgone returns (with a standard deviation of 1,579€).

numbers are not unreasonable when interpreted as an annual charitable donation.[7]

We also combine the distribution of green taste with households' bank deposits to construct a demand curve for a safe green financial product. 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 had the same interest rate as traditional deposits, more than 75% of deposits would be held in such accounts. For a spread 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 spread of green deposit accounts, we compute the fraction of deposits allocated to green deposit accounts based on households' answers to the question about accepted spreads. A negative (positive) green spread means that the green deposits would offer a lower (higher) interest rate than traditional deposits.

4.3 Heterogeneity in Taste for a Green Safe Asset

There is rich heterogeneity in taste for a safe green asset. Green taste correlates with other measures of green preferences and priors about who is most likely to have green preferences in the German population. There is a strong age gradient in the taste for green. Figure 4(a) plots the distribution of accepted spread within each age group. Young people are much more likely to have a negative

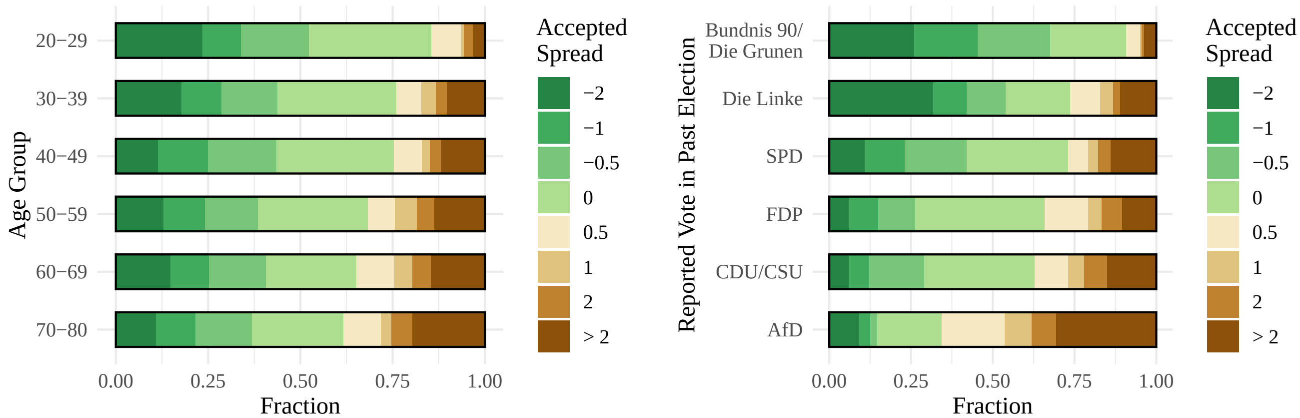
[7] Another way to judge whether these accepted spreads are reasonable is to compare their standard deviation with the distribution of deposit spreads across banks. For a panel of U.S. banks, Egan, Hortaçsu and Matvos (2017) estimate this standard deviation to be 0.7 percentage points. Moreover, the 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.

accepted spread while older individuals are more likely to have a positive expected spread.[8]

Figure 4: Heterogeneity in Taste for a Safe Green Asset

(a) Accepted Spread by Age

(b) Accepted Spread by Party Vote



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.

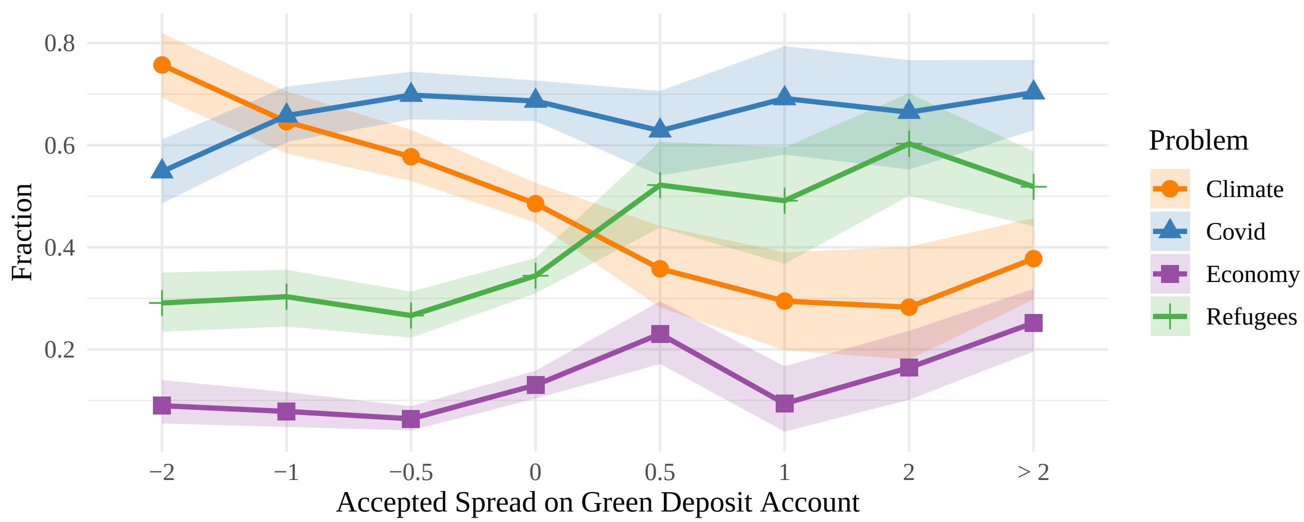
Green taste, as measured by willingness to pay for a green deposit account, is strongly correlated with another measure of green preferences: voting for political parties. In the survey, we ask people to report their vote in the 2021 Bundestag election, which took place shortly before our survey. We 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 4(b) plots the distribution of accepted spreads by reported vote in past elections. The ordering of parties based on the share of respondents who accept a negative spread matches the 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

[8] There are also significant differences in accepted spread on a green deposit account by other demographic characteristics. For example, women, college graduates, and West Germans are more likely to accept a negative deposit spread. However, taken together, demographics, income, and wealth explain only a small share of the variation in taste in the population (see Appendix Table xx for details.)

actions, demand a positive spread to hold a green bank account, close to 10% choose the green account even when it pays 2% less. Similarly, a very small but non-zero fraction of Bündis 90/ Die Grünen voters and other left-leaning parties have a very high positive accepted spread. It is not unreasonable to think that these voters may believe that market solutions to climate issues are a distraction and prevent effective government action or that market solutions if anything, are fraudulent. People with this view might not want the green deposit account independent of the return and would be classified as accepting a spread greater than 2%.

Figure 5: Correlation of Accepted Spread with Alternative Measure of Green Preferences



Note: The figure shows the fraction of individuals 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 individuals 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.

While party vote is a potential measure of an individual's taste for green financial products, political votes 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 5 plots the fraction of people for each accepted deposit spread who rank each of the four issues as Germany's top problem. These numbers do not sum to one since individuals often give their highest ratings to multiple issues. Of people who accept at least 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 of people who demand at least a 2% spread to accept a green bank account, 38% rank climate as the most important issue. Another pattern that emerges is that people who demand a positive spread to hold a green bank account are much more likely to rank refugees as a top problem. Of people who accept a deposit spread of -2% only 27% view refugees as among the most pressing issues.

5 Demand for Green Equity

Our survey questions ask households to provide their expected returns and risk perceptions for both a green and a traditional equity fund. We find that most households expect higher returns on equity funds that they perceive as (weakly) riskier. In addition, 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 their taste (or distaste) for green assets scales with the perceived risk of these funds, such as 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 are managed by a professional fund manager. 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 assume that the value would fall, please enter a negative number
>
> (a) traditional equity fund: input field percent
>
> (b) sustainable equity fund: input field percent

A significant proportion of the survey respondents reported that they did not know the returns of the traditional and green equity funds. This outcome seems to reflect the relatively low level of participation in equity funds in Germany rather than a lack of information about green equity products. The response rates for the traditional and green equity return questions were comparable, with

48% of households answering the traditional equity return question and 47% answering the green equity return question. Moreover, a considerable proportion of households, nearly 45%, answered both questions, with only minor attrition across the two questions. 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%.

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 accounts:

> 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 the green and traditional account:

> 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 rates to these qualitative questions were much higher. Overall, 64% of all households and 80% of households with non-zero securities holdings answered both questions.[9]

Households who answered these questions completely were more likely to have securities and slightly more likely to have "greener" tastes as measured by our deposit question. More details are in Appendix Table A.2. For our main quantitative exercises, all results are robust to re-weighting

[9] 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%.

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.[10] 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 roughly zero: the nominal average annual returns for traditional and green equity funds are 7.2% and 7.3%, respectively. Weighting by financial assets, the expected returns are higher for the traditional equity fund (7.9%) than for the green equity fund (7.0%), implying a *positive* greenium.[11]

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

	Traditional Equity	Green Equity	Greenium
Population Weighted	7.2	7.3	−0.1
Financial Asset Weighted	7.9	7.0	0.9
Non-zero Equity	8.4	7.1	1.4
Non-zero Green Equity	7.9	7.9	0.0
Top Quartile Financial Assets	8.2	7.0	1.2
Bottom Quartile Financial Assets	7.4	7.7	0.3
Age <30	7.9	7.0	0.9
Age >60	7.3	7.0	0.3
Positive Convenience yield	6.8	7.5	−0.7
Negative Convenience yield	9.2	4.8	4.4
AfD	8.4	3.9	4.5
Bündis 90/ Die Grünen	7.1	8.4	−1.3

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 demographic, wealth, and attitude towards green subgroups. Expected returns on each type of equity, as well as excess returns on green are Winsorized at ±20. For every row except the population weighted row, households are weighted by their population weight × their reported financial assets.

There is rich heterogeneity in households' expected returns. While 49% of households expect the traditional equity fund to have higher returns, 25% of households expect the green equity fund

[10] 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%.

[11] 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.

to have higher returns. Households who report non-zero securities holdings and those in the top quartile of financial assets have slightly higher than average expected returns for traditional equity. The expected returns for green equity are more similar across these households, implying a positive greenium.

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 outperform traditional equity. In 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 last election, expect green equity to substantially underperform relative to the traditional equity account. Hence, beliefs about the financial returns of green assets are correlated with individuals' tastes and potentially with their underlying views about the likely course of the green transition.

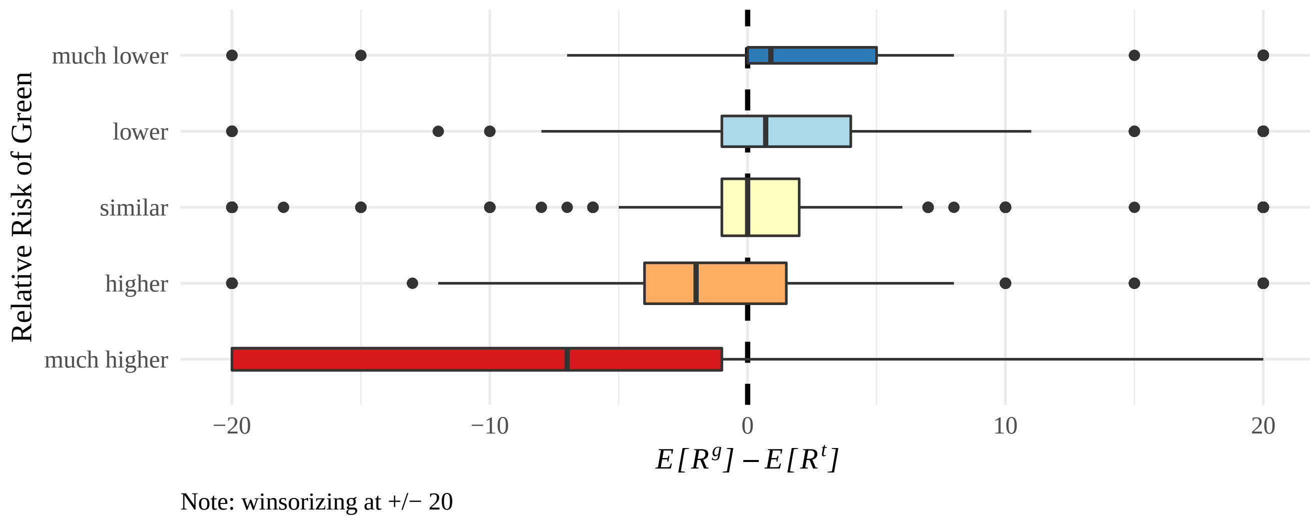
5.3 Relative Risk Rankings

Most households (82%) have higher return expectations for the equity fund that they rank as weakly higher risk. For example, when a household has a higher return expectation 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.

Figure 6 shows the cross-sectional distribution of these expectations. The vertical axis measures the relative risk of green, while the horizontal axis measures the expected excess return on green funds. Households who are located towards the upper-right in this graph find green equity funds more attractive; they believe they have higher expected returns and lower risk than traditional equity funds. The colored bars in each row in the figure show the interquartile range of expected excess returns on green funds for a given risk ranking. The graph reveals a *negative* cross-sectional correlation between households' expected excess returns on green and risk perceptions: the colored bars move from bottom-left to top-right. Since the precise relationship between expected excess returns and risk varies among households, this negative correlation is still consistent with the fact that most households have higher return expectations for weakly riskier funds.

These patterns in expectations are robust. They are not driven by households with no experience with these types of assets or no understanding of investment trade-offs. The negative correlation between risk and return is robust across reported education, wealth, securities holdings, and green investment holdings. Moreover, telling households explicitly about risk-return trade-offs does not affect their expected excess returns or their rating of the relative risk of green versus traditional equity funds. These information treatments had no statistically significant impact on the distribution

Figure 6: Distribution of Expected Excess Returns on Green by Relative Risk Ranking



Note: Each row in the figure shows the distribution of expected excess returns on sustainable equity funds over traditional equity funds ($E[R^g]-E[R^t]$) 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 expected excess returns, the solid line within the box plots the location of the median of the distribution of expected excess returns, and the whiskers extend to ±1.5 the interquartile range.

of return expectations and risk perceptions.[12]

5.4 Taste for Risky Green Assets

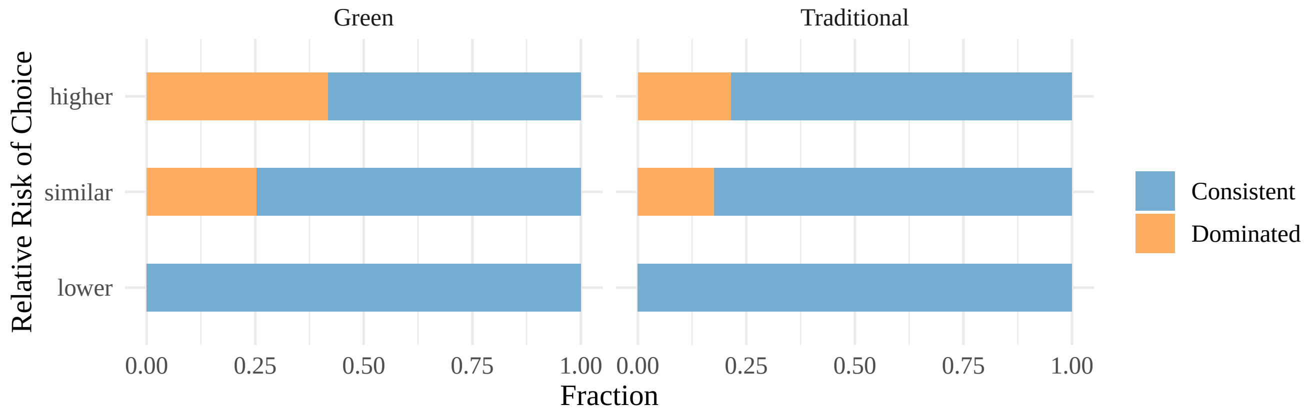
Many households make hypothetical investment choices in which they select equity funds that they believe are *dominated*: households rank these funds as riskier while expecting similar or lower returns on these funds. These choices suggest that households perceive an extra motive (or deterrent) to invest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

Figure 7 plots the fraction of households who choose dominated equity funds in orange, while the blue households choose the more attractive 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

[12]Before answering the set of four equity questions, 750 respondents were shown this information about risk-return trade-offs:"*Equity funds differ not only in terms of the expected gains in value but also in terms of risk. A greater average gain in value usually accompanies greater risk.*" These informed respondents still featured a robust percentage of expectations for which expected returns did not comove with perceived risk.

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 7: Hypothetical choice of equity funds by relative risk



Note: This figure illustrates the fraction of households within an equity fund choice and relative risk ranking bin 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 y-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.

Incorporating the nonpecuniary benefit or cost of holding green as measured by a respondent's answer to the green deposit account question does not 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 minimum accepted spread on the green deposit account), 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, such as 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, households have a negative hedging demand for green equity funds when they worry about a slower climate transition.

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 riskfree bonds—or bank accounts—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.

We allow households to have nonpecuniary benefits (or costs) from holding 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 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:

$$\log H^i = \eta_0^i + \eta_g^i (\log R_t - \log R_g), \tag{1}$$

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

$$
\begin{aligned}
\max_{c_0, w_1, e_t, e_g, b_t, b_g} \quad & \log c_0 + \beta \log E^i \left[w_1^{1-\gamma^i} \right]^{\frac{1}{1-\gamma^i}} \\
\text{s.t.} \quad & c_0 + e_t + e_g + b_t + b_g = w_0^i \\
& w_1 = H^i \left(R_t e_t + \theta^i R_g e_g + R_t^f b_t + \theta^i R_g^f b_g \right) \\
& e_t, e_g, b_t, b_g \geq 0.
\end{aligned}
\tag{2}
$$

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.

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 effective returns 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 riskfree asset, and this choice is determined by the taste parameter θ^i alone. Since interest rates are deterministic, the green riskfree asset is strictly preferred if $\theta^i R_g^f > R_t^f$, while the traditional riskfree asset is strictly preferred if the inequality is reversed. The household is indifferent if effective returns on the two riskfree assets are the same. For given market rates R_g^f and R_t^f, we can therefore read off the choice of riskfree assets 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 riskfree bond.

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 optimal weights maximize utility from effective wealth at date 1 per unit of total savings at date 0:

$$\max_{\omega_t, \omega_g \geq 0} E^i \left[\left(H^i R^{i,f} + \omega_t H^i (R_t - R^{i,f}) + \omega_g H^i (\theta^i R_g - R^{i,f}) \right)^{1-\gamma^i} \right]^{\frac{1}{1-\gamma^i}}. \tag{3}$$

The household earns $R^{i,f}$ on riskfree 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.

We decompose portfolio demand into three pieces

$$\omega^i = \omega^i_{mv} + \omega^i_{cy} + h^i, \tag{4}$$

Here, the first component ω_{mv} is a standard myopic demand familiar from mean-variance optimization: it describes the solution in the absence of nonpecuniary benefits when $\theta^i = H^i = 1$. The second component ω^i_{cy} is demand due to a perceived convenience yield $\theta^i - 1$ from green assets. Finally, h^i is a position that hedges the climate transition or future risk in the factor H^i. While the decomposition is always available, explicit formulas differ depending on how many risky assets a 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 by σ^i_t and σ^i_g, 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 $(\gamma^i {\sigma^i_t}^2)^{-1}$. Analogously, for households who invest only in the green fund, the only element is the bottom right corner element equal to $(\gamma^i {\sigma^i_g}^2)^{-1}$.

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

$$\omega^i_{mv} = T^i \begin{pmatrix} E^i[r_t] + \frac{1}{2}{\sigma^i_t}^2 - r^f_t \\ E^i[r_g] + \frac{1}{2}{\sigma^i_g}^2 - r^f_t \end{pmatrix} \tag{5}$$

This portfolio achieves the optimal risk-return trade-off over the next period when the riskfree asset is the traditional riskfree bond. 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 riskfree 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 the convenience yield, let B^i_g denote a dummy variable equal to one when the household invests in the green riskfree bond and zero otherwise. We then have

$$\omega_{cy}^{i} = \log\theta^{i} T^{i} \left(e_2 - B_g^{i}\iota\right), \tag{6}$$

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 the convenience yield alters the incentives to take risk. For households who invest in a green riskfree asset ($B_g^i = 1$), $\log\theta^i$ also increases the effective riskfree 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 a green bank account ($B_g^i = 0$), 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 log returns $r = (r_t \; r_g)^\top$ with the preference shifter H^i:

$$h^i = (1-\gamma^i) T^i cov^i(r, \log H^i) = \frac{\gamma^i - 1}{\gamma^i} \begin{pmatrix} -\eta_g^i \\ \eta_g^i \end{pmatrix} =: \begin{pmatrix} -h_g^i \\ h_g^i \end{pmatrix}. \tag{7}$$

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 (1), 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 (1)) 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 above. First, we study choice by a sample of equity holders; we do not attempt to explain households' decision to participate in equity. An advantage of this approach is that equity holders have much higher response rates to questions in our November 2021 equity module, which are important for calibration below. We restrict attention here to households with complete answers to the equity questions. This sample selection implies that aggregate statistics differ slightly from their counterparts in Section 2, 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 riskfree 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 log excess returns on the risky assets relative to the traditional riskfree rate r_t^f:

$$\mu^i = \begin{pmatrix} \mu_t^i \\ \mu_g^i \end{pmatrix} = \begin{pmatrix} E^i[r_t] + \frac{1}{2}{\sigma_t^i}^2 - r_t^f \\ \log\theta^i + E^i[r_g] + \frac{1}{2}{\sigma_g^i}^2 - r_t^f \end{pmatrix}. \tag{8}$$

We include the taste parameter θ^i here since its effect is the same as an increase in the expected return. We also assume that the riskfree rate for all households is the traditional interest rate, which we set to zero. 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 introduces green deposit accounts as a counterfactual.

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

$$\Sigma^i = {\sigma_t^i}^2 \begin{pmatrix} 1 & \lambda^i\rho^i \\ \lambda^i\rho^i & {\lambda^i}^2 \end{pmatrix}, \tag{9}$$

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 risk.

Household responses to our survey questions identify the parameters of our model. Table 3 lists the 8 parameters that are household-specific. We distinguish two groups. The top panel collects the ingredients of the vector of expected excess returns μ^i 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 account, we interpret their answer as telling us their expected level returns $E^i\left[R_t\right] = E^i\left[r_t\right] + \frac{1}{2}{\sigma_t^i}^2$ and $E^i\left[R_g\right] = E^i\left[r_g\right] + \frac{1}{2}{\sigma_t^i}^2{\lambda^i}^2$, respectively. We directly observe the interest rate r_t^f that households expect to receive on a deposit account over the same 12-month horizon as the equity-fund investments. 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

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 3: Household Parameters

Parameter	Definition	Source
$E^i\left[r_g\right] + \frac{1}{2}{\sigma_t^i}^2{\lambda^i}^2$	expected return on green equity	expected return question
$E^i\left[r_t\right] + \frac{1}{2}{\sigma_t^i}^2$	expected return on traditional equity	expected return question
r_t^f	traditional risk-free return	deposit rate question
θ^i	non-pecuniary green return	green deposit spread question
$\gamma^i{\sigma_t^i}^2$	risk sensitivity	calibration
λ^i	relative risk	calibration
ρ^i	correlation of returns	calibration
h_g^i	hedging demand	calibration

The bottom panel in Table 3 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 survey data on households' beliefs and 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 the traditional fund and infer only the product $\gamma^i{\sigma_t^i}^2$ that captures households' overall risk sensitivity. We then measure the perceived risk of the green fund relative to that of the traditional fund.

Inference of risk parameters now proceeds 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 accounts, $\omega_t^i + \omega_g^i$, as well as whether or not the household reports holding a green account. 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 value of 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 Appendix C.3.

Our second step derives inequality constraints on the risk parameters. The first inequality constraint comes from households' ranking of the relative risk of the two investment accounts on the discrete scale of "much lower" risk to "much higher" risk. It restricts the ratio of the standard deviations of the returns on the two investment accounts, λ^i. If households view the green account as "riskier" or "much riskier" than the traditional account, then we restrict λ^i to be greater than 1. Conversely, if households view the green account as the "safer" or "much safer" option, then λ^i is restricted to be less than 1. For households who view the risk of the two accounts as similar, λ^i is restricted 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, we ask households whether they would place an extra amount of money in a green or a traditional investment account. 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 the green and traditional account. We interpret the household's answer as ranking a 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 consistent with this ranking, independently of the size of the amount of extra money the household is thinking about.

The precise shape of the constraint depends on whether or not the household holds a green account. For a household who invests in green, we have

$$\mu_g^i - \frac{1}{2}\gamma^i {\sigma_t^i}^2 {\lambda^i}^2 + \gamma^i {\sigma_t^i}^2 h_g^i \lambda^i (\lambda^i - \rho^i) > \mu_t^i - \frac{1}{2}\gamma^i {\sigma_t^i}^2 + \gamma^i {\sigma_t^i}^2 h_g^i (\rho^i \lambda^i - 1). \tag{10}$$

Intuitively, if belief parameters are such that myopic demand would favor the traditional account, the hedging motive most be strong enough (here h_g^i large enough) to justify the observed choice of green. Appendix C.2 derives this result and presents an analogous constraint for households who do not invest in green.

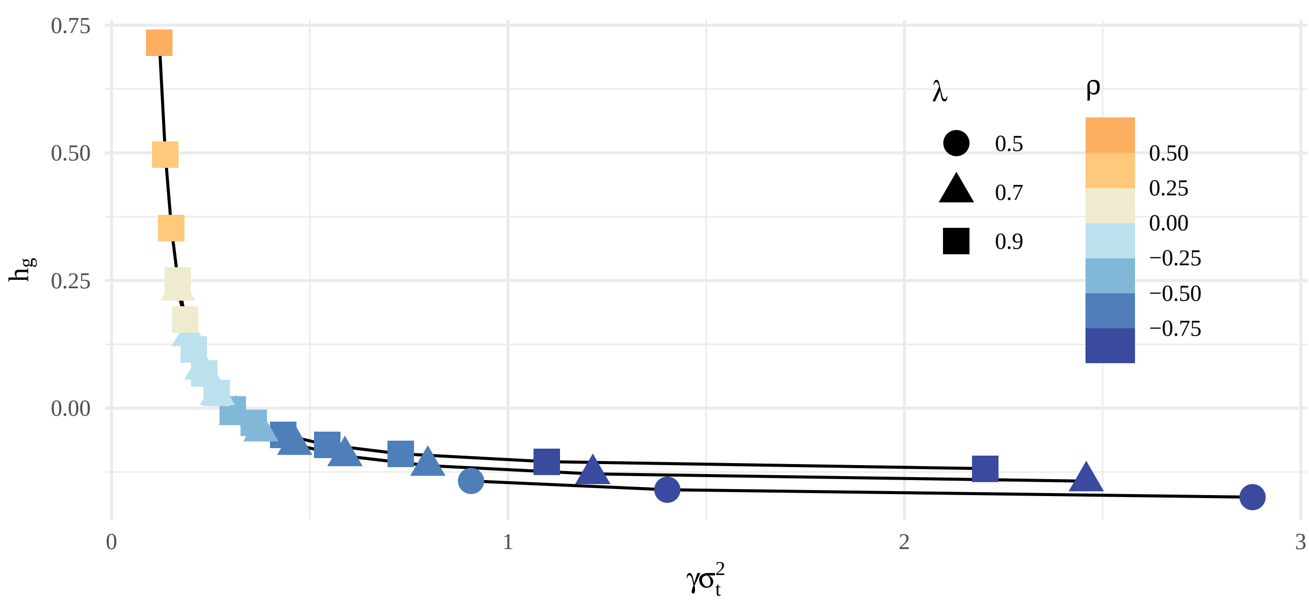
For every household, the vector of four risk parameters $\{\lambda^i, \rho^i, \gamma^i {\sigma_t^i}^2, h_g^i\}$ must not only satisfy the two inequality constraints but also be consistent with the households' ob served portfolio holdings in green and traditional assets. For example, for households who hold both green and traditional equity, we have the two equations

$$\omega^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\mu_r^i + \frac{\mu_g^i}{{\lambda^i}^2} - \rho^i \frac{\mu_t^i + \mu_g^i}{\lambda^i}\right), \tag{11}$$

$$\omega_g^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\frac{\mu_g^i}{{\lambda^i}^2} - \frac{\rho^i \mu_t^i}{\lambda^i}\right) + h_g^i. \tag{12}$$

We have now described a set of parameter values for each household. Figure 8 illustrates the set of possible parameter values for a household that holds both green and traditional equity funds, chooses green in the hypothetical choice question, and believes that the green equity fund is dominated: it has lower expected return and higher risk than the traditional equity fund. MORE INTUITION

Figure 8: 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 that holds both green and traditional assets, chose green in the hypothetical account question, and believes that the green equity fund has lower expected return and higher risk than the traditional equity fund. The lines trace out supported values for a given value of relative standard deviation of the two accounts, λ, varying the correlation of returns on the two accounts ρ.

The correlation ρ of returns is an important parameter for governing the portfolio choice, because low correlation makes the equity funds less substitutable. When the correlation is negative, diversification provides a strong motive for holding both equity funds, even if one of them is dominated. The diversification motive is strengthened further when the household has high risk sensitivity. At the same time, low correlation and high risk sensitivity lower the household's hedging demand (31) for green equity. When the correlation is positive, diversification is a weaker motive for holding both assets. To explain why the household chooses to hold a dominated fund, hedging demand must be strong, which requires low risk sensitivity.

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 really call for 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 baseline value of .9 that reflects recent close comovement of traditional and green investment fund returns.

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

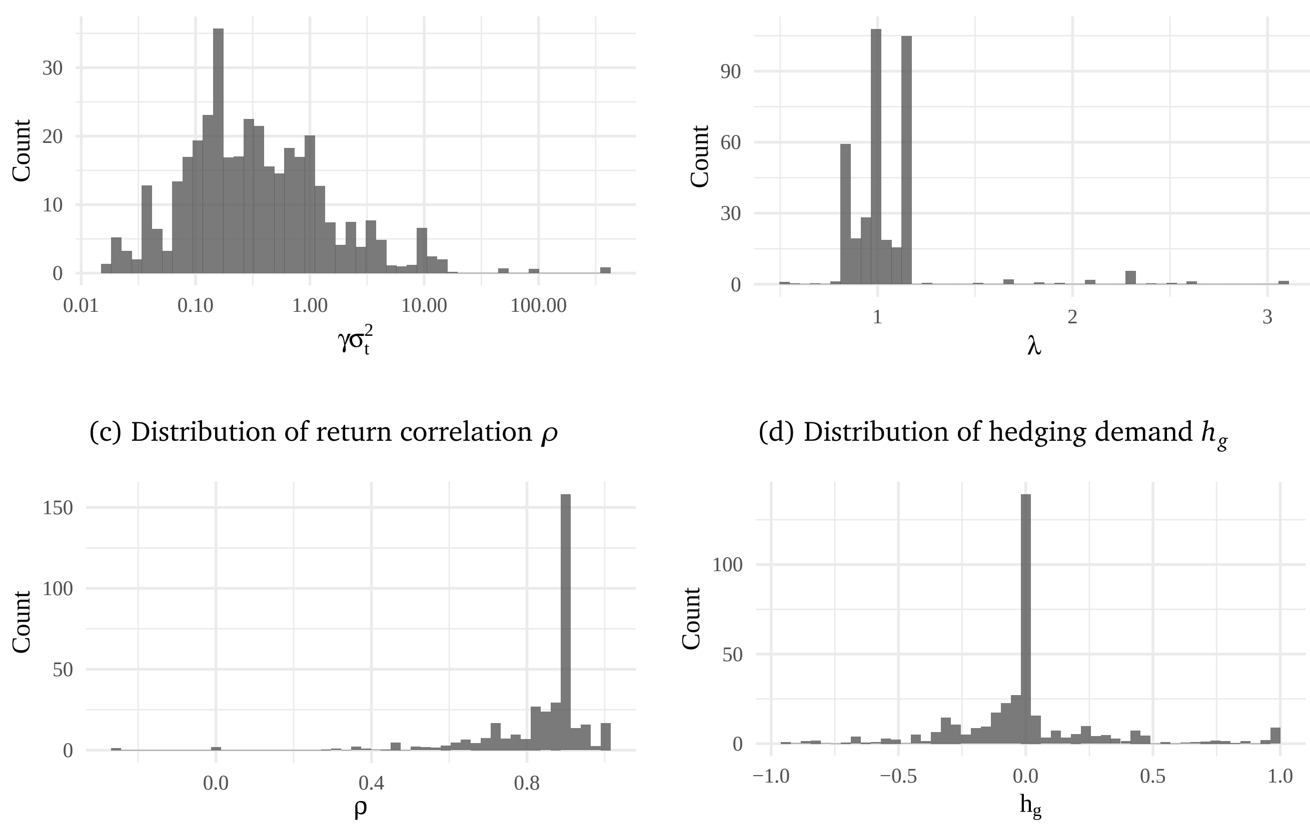
$$\left(h_g^i\right)^2 + \left(\rho^i - 0.90\right) + \left(\lambda^i - 1\right)^2 \tag{13}$$

subject to two portfolio formulas and the two inequality constraints. For our example household who holds a green investment account, the portfolio formulas are given by (12) and the inequalities are (10) as well as bounds for λ^i.

The estimation reveals substantial heterogeneity across households. Figure B.4 shows the cross-sectional distribution of risk perceptions, relative risk rankings, correlation coefficients, and hedging demands. 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 risk λ ranges between .8 and 1.2, so the perceived volatility of green funds is within 10pp of that for traditional funds.

Both hedging demand for green assets and the correlation coefficient display large spikes at the benchmark values zero and .9, respectively. Values of hedging demand that do differ from the benchmark typically go along with large relative risk of green assets: the correlation coefficient between h_g and λ is .64. Intuitively, households who view green funds as riskier but still hold them must have stronger positive hedging demand to rationalize their holdings. Similarly, households who view green as less risky than traditional but do not hold a large fraction of their portfolio in the green account must have larger negative hedging demand. No other parameters are significantly correlated.

Figure 9: Household heterogeneity



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

(b) Distribution of relative risk λ

(c) Distribution of return correlation ρ

(d) Distribution of hedging demand h_g

6.3 Equilibrium

So far in this section we have estimated a demand system for green and traditional equity funds and riskfree bonds by inferring the distribution of parameters for German households' portfolio choice problems. 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 to 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 bonds 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 shares can be identified with the value of capital that 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 quantity changes. This perspective is meant to give a medium-term response and can serve as an upper bound on the immediate quantity impact of demand shifters: 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 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 wealth or initial savings. 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 a share of resources to each of the two equity funds, as well as to bonds.

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 use the decomposition of individual weights and write

$$\bar{\omega} = \sum \frac{s^i}{\bar{s}} T^i \mu^i + \sum \frac{s^i}{\bar{s}} T^i \log \theta e_2 + \sum \frac{s^i}{\bar{s}} T^i \left(1-\gamma^i\right) \mathrm{cov}^i \left(r, \log H^i\right) \tag{14}$$

where e_2 is the second unit vector. To explore counterfactual changes in demand (such as the taste for green investment captured by θ^i and H^i, or expected returns), we recompute aggregate investment for the same distribution of savings. Importantly, we recompute households' 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

$$\underbrace{\begin{pmatrix} 0.32 \\ 0.08 \end{pmatrix}}_{\overline{\omega}} = \underbrace{\begin{pmatrix} 0.31 \\ 0.09 \end{pmatrix}}_{\text{myopic demand}} + \underbrace{\begin{pmatrix} -0.01 \\ 0.00 \end{pmatrix}}_{\substack{\text{demand due to} \\ \text{convenience yields } \theta^i}} + \underbrace{\begin{pmatrix} 0.01 \\ -0.01 \end{pmatrix}}_{\text{hedging demand } h^i}. \tag{15}$$

The decomposition shows that myopic demand accounts for the bulk of aggregate demand. On aggregate, taste plays a negligible role. However, the small average contribution of taste masks large differences at the individual level. We have already seen that the distribution of convenience yields 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 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 total 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. Normalizing the tree price to one, we can view return expectations as expectations about one-period-ahead payoffs, defined as the sum of dividend and future price. 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 bonds are 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 bonds. 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.[13]

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 definition of a share is arbitrary. To achieve a price of one, we set the number of trees equal to the aggregate portfolios weights $\bar{\omega}$ in the data (and hence in the initial equilibrium). The 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 market for trees, that is, it equates the aggregate expenditure on trees to the value of the fixed supply of shares $(P_t \bar{\omega}_t, P_g \bar{\omega}_g)^\top$.

To write an intuitive formula for equilibrium prices, it is helpful to define $\bar{T}$ 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 eqrefaggexp and using the definition , the vector of equilibrium log equity prices is then

$$p_t = -r^f \iota + \sum \frac{s^i}{\bar{s}} \bar{T}^{-1} T^i \left(E^i d + \log \theta^i e_2 + \left(1 - \gamma^i\right) cov^i \left(r, \log H^i\right)\right) - \bar{T}^{-1} \bar{\omega}, \tag{16}$$

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 first two terms represent the contribution of payoff expectations. Both payoffs are discounted by the riskfree rate. Individual expected log payoffs $E^i d$ are then weighted by a product of two weights. The first is a wealth weight: households who save more have higher $s^i / \bar{s}$ so their payoff forecast matters more for prices. The second component is the matrix $\bar{T}^{-1} T^i$, which reflects differences in risk sensitivity, that is risk perception or risk aversion. If all households share the same risk aversion coefficient and the same subjective covariance matrix, we get the identity and the prices reflects simply a wealth-weighted average. This is true in particular when all households are risk neutral, in which case moreover 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

[13] 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.

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 forecast 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 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 funds that is decreasing in both risk aversion and perceived risk. Household i's forecast thus carries greater weight if the household tolerates more risk and takes a bolder position in the stock market.

More generally, valuation of the two assets is interdependent if households perceive payoffs to be correlated. For example, the traditional fund is worth less if the green fund offers a close substitute – a highly correlated risk – about which the household is more optimistic. This is why in general the appropriate weight is provided by matrix $\bar{T}T^i$ that is not diagonal: a household's forecast about green returns also matters for the valuation of traditional funds and vice versa. Again both households' relative wealth and their relative risk tolerance matters for the degree to which their views are incorporated into the price. We emphasise 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 $\gamma\Sigma\omega$: risk aversion multiplied by the covariance of the trees with the market portfolio $\bar{\omega}$. With heterogeneous risk tolerance, the 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 portfolio policy from (3) 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 sequence of counterfactuals to answer this question. We would like to understand the role of non-pecuniary tastes as well as a change in attention allocation, that is, the emergence of beliefs that distinguish between green and traditional equity. Both forces shape asset demand, and we can vary them by changing parameters of our estimated model of demand, for different supply scenarios. We start by isolating the role of green taste and then add attention allocation in a second experiment.

7.1 The Role of Green Taste

Our first set of experiments studies the role of green taste, captured by θ^i and 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 4 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 equity supply as well as fixed equity supply, respectively, for this and other counterfactuals that follow below. In particular, the first row of Panel B and C present what happens when we shut down taste. The first two columns show percentage changes in the value of equity. The final three columns provide statistics of the green investor population that help interpretation.

Consider first elastic equity supply. When households perceive neither a green convenience yield 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

Table 4: 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
no green funds	−.06	−1.7		0	
info treatment	−0.1	+3.0	−.15	+.03	+.09
Panel D: Green bond market	% change in equity		value (share of aggregate wealth)		
(elastic equity supply)	traditional	green	green bonds	all bonds	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

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 taste increases the price (and hence decreases the premium) on green equity by 50bp while lowering the price (and increasing the premium) on traditional equity by 20bp. Put differently, the cost of capital of a green firm selling a marginal new tree right now would be 70bp lower than that of a traditional firm if taste effects were not present.

Why does the presence of green taste lower the value of green funds? The broad theme that taste for a green convenience yield as well as worry about the climate transition hold back green investment already appeared in the decomposition (15). The effect here is substantially larger, however. The reason is that portfolio demand is not a linear function of parameters, due to the presence of short-sale constraints. In (15), we simply shut down the hedging and convenience yield components of demand for every household. The counterfactual in Table 4, in contrast, computes a new optimal portfolio, including choice along the *extensive margin*, that is, whether to participate in green funds. In this experiment, households with a positive hedging demand for green equity funds but not particularly high expected green returns reoptimize and exit the green market. At the same time, households with a negative hedging demand who are quite optimistic choose to participate in the green equity market of the counterfactual, and in fact may be willing to take on substantial stakes.

Columns 3-5 of Table 4 illustrate this effect. We consider the share of total savings due to participants in green funds, 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 funds, and finally the average portfolio weight that those households place on green funds. The top line shows levels in the initial equilibrium. For each exercise, we then report the change due to reoptimization. Regardless of the supply scenario, shutting down taste implies that the average (wealth-weighted) investor in green funds is more optimistic about green stocks and hence chooses a higher portfolio weight—this is the key driver of higher value. With elastic supply, there is also a small increase in the wealth of green investors, which works in the same direction. When supply is fixed, in contrast, the wealth of green market participants actually declines. As the price of green stocks is bid up, more pessimistic households exit the market. This results in a very optimistic population of households who participate in the green market, so the price—and hence the value—of green stocks in the counterfactual goes up.

7.2 The Role of Green Equity Funds

We now ask how the presence of green investment products shapes the relative valuation of green and other stocks. The previous counterfactual that shuts down taste, captured in our model by the convenience yield on green assets and a climate hedging demand, does not fully answer that question. Indeed, a second feature of markets in recent years is that investors distinguish green from traditional assets and form beliefs about them separately. We view this development as a change in attention allocation: investors now pay attention to asset characteristics that they previously ignored. In particular, they now perceive an imperfect correlation between traditional and green equity funds. If they were not aware of the distinction, the two funds would be treated as perfectly correlated, like a randomly selected large subset of stocks.

We thus perform a counterfactual that places households in a world with only one tree that subsumes all stocks, whether or not green funds invest in them. We assume that household beliefs about returns on this single tree are given by their current beliefs about the traditional fund.[14] The idea is that households who do not distinguish green and other stocks treat all equity as traditional. We further shut down all taste parameters, as in the previous exercise. The portfolio choice problem in the counterfactual economy is therefore 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 funds. We denote by $\bar{\omega}_1$ the aggregate weight on the single tree in the counterfactual equilibrium.

We would like to run a counterfactual with fixed supply, which tells us how investor attitudes, including now their attention, affect currently observed prices. However, since investors in the counterfactual treat the two funds as perfect substitutes and demand for individual funds is indeterminate,

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

we cannot proceed in the same way as in the previous section where we fixed a unit supply of trees in each of the funds. Instead, we compare funds by the payoffs they promise. We denote by α the share of *payoffs* from trees that the green fund holds in the original equilibrium. We then hold α fixed when moving from the original 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 stocks. In the counterfactual equilibrium, where all stocks trade at the same prices, the value of green stocks is therefore $\alpha\bar{\omega}_1$.

To compute the change in value of a fixed supply of green stocks between the counterfactual and actual equilibrium, we need to estimate the share of payoff from green funds in the actual equilibrium. While we cannot observe this share directly, we do know the expected payoff for every household. Indeed, since we have normalized the price of trees in the original equilibrium to one, the aggregate portfolio weight represents the number of trees (given our normalization), and multiplying by the household's expected return delivers the aggregate expected payoff. We note that an individual household's expected share of payoff from green trees can be high because either (i) green trees are an important part of the economy or (ii) the household is optimistic about green trees.

We now assume that the *average* belief of equity holders correctly reflects the relative value of payoff. The idea is that while households disagree about the performance of green funds, the average expected payoff is mostly driven by the size of the green sector of the economy. Formally, we measure the green payoff share

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

where expectations are taken under the wealth weighted average belief of equity investors. Average expected returns on green funds are below those on traditional funds, so the market share of green stocks is slightly larger than the estimated payoff share. This is what one would expect when market share is high in part because of optimistic market participants bidding up prices. As a result, the counterfactual will typically affect the values of green and traditional funds differently.

In the counterfactual world, the price of the single tree is .992: without sustainable investing, the aggregate stock market would trade 80bp below the current baseline equilibrium. Since this calculation holds expected payoffs fixed, we can conclude that the emergence of sustainable investing has increased the equity premium perceived by all households by 80bp. We further compute the difference $\bar{\omega}_g - \alpha\bar{\omega}_1$ between the value of green stocks in the original versus the counterfactual equilibrium. The value of the green fund is 1.67pp higher in the original equilibrium: sustainable investing has increased the price of green equity and reduced the premium on green stocks relative to the riskfree rate. At the same time, the change in the value of stocks now held by traditional funds is 58bp higher in the original equilibrium.[15] While the rise of sustainable investing has also boosted traditional funds, the effect is smaller than for green funds—sustainable investing has opened up a greenium of 109bp.

As we have seen, this effect is not due to a shift in tastes, in the sense of our parameters θ and H, which actually hold down the value of the green fund. Instead, the price movement reflects the fact that investors have "woken up" to the distinction between green and other stocks that are imperfectly correlated and form heterogeneous beliefs about them. Relative to the counterfactual equilibrium, where the distinction is shut down, prices in the baseline equilibrium reflect a clientele of enthusiastic investors who sort into holding green funds. This has two effects. On the one hand, demand for green funds drives up the price of those funds. On the other hand, as green investors invest less in traditional funds, 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 aggregate effect of attention through subjective beliefs is then to increase the demand for green equity to the extent that it is more than offsetting the dampening effect of taste.

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, described in Section 8.3.

8.1 Introduction of a Safe Green 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. In our model, green and traditional bonds are safe but may pay different interest rates. Households with taste parameters θ^i will choose how to invest in these bonds as in Figure 3. The introduction of green bank accounts can thus have a large effect on green investment overall. However, it is not clear from the earlier analysis of bond choice how easy availability of green bonds affects the equity market. In our current equilibrium, households who have a strong positive taste have an incentive to take risk and select into green equity, because

[15] The difference between the value of traditional stocks in the original equilibrium minus the counterfactual is $\bar{\omega}_t - (1-\alpha)\bar{\omega}_1$.

they effectively perceive higher expected excess returns on green equity funds (as in the portfolio demand (6) due to convenience yields.) Once green bonds are available, the effective excess returns on equity decline which could push prices and investment down.

We perform two exercises that vary the available quantity of green bonds. Since bonds 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 bonds, reported in Panel D of Table 4. We focus on equilibria with elastic supply of equity: formally we recompute portfolio weights for all households now using their individual-specific riskfree rates, either green or traditional. The right-hand columns report the quantities of green bonds, as shares of aggregate household wealth. As in Figure 3, the quantity of green bonds increases as the spread declines, that is, 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 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 More Information about Green Equity

For thinking about the future of green finance, another consideration is that currently green investment products may not be well understood by many households. Lack of information may account for low expected returns and high risk perception of such products and lead optimally to zero investment for a fraction of households. As the physical effects of climate change become more tangible, companies, governments, researchers, and international institutions are devoting ever more resources into developing and communicating ways 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.

Table 5: Results of RCT Information Treatments

	Dependent variable:			
	Excess Green Returns		Deposit Spread	
	(1)	(2)	(3)	(4)
UN Information	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)
UN Information: Climate Top Issue		3.876***		−0.280**
		(1.252)		(0.141)
Green Investment Account	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
Adjusted R^2	0.074	0.080	0.138	0.139
Note:				*p<0.1; **p<0.05; ***p<0.01

Note: This table reports effects of information treatments for green and traditional investment accounts. 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.

8.3 Measuring the Impact of Information on Expectations

To implement the RCT, we compare the control group of 2400 households that was used to calibrate the model to a treatment group of about 900 respondents. Right before beginning the part of the survey that asks about green versus traditional investment, the treatment group is presented with the following additional piece of information:

> “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."

We can therefore measure the effect of the information treatment on both answers about green bank accounts and equity return expectations.

Since the treatment informs households of the potential for green investment to make a difference for the climate transition, it is plausible that the treatment effect is different depending on how concerned a household is about the climate transition to begin with. 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: 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.

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

$$Y_i^{post} = \alpha + \beta_1 X_i + \beta_2 X_i C^i \mathbf{W_i} \phi + \epsilon_i. \tag{18}$$

The coefficient β_1 thus measures the average effect of treatment for respondents not concerned about the climate, whereas the coefficient β_2 on the interaction term measures the effect on the concerned group, both relative to the control 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 5 presents results from estimating equation (18). We consider two post-treatment outcomes

Y_i^{post}. The first two columns reports 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 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, and then the estimates including the interaction term. 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 has a green investment account expects a more than two percent higher excess return on that account. 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 returns on green funds. On average, treated respondents expect 1.6% more from a green fund. 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 spread on a green bank account. While the average effect here is weak and insignificant, zooming in on the group of concerned households reveals a borderline significant effect of about 25bp. We conclude that more information incentivizes concerned households to invest, and the effect on beliefs is large compared to the current difference in beliefs between households with and without a green account. At the same time, the effect of information on the willingness to sacrifice interest on deposits is relatively small.

How would widespread dissemination of information about green investing affect its growth? We now use the regression results from Table 5 to perform a counterfactual that increases expected returns on green funds for the "concerned subset" of households. Here, we use the fact that we observe the same household characteristics for the treated population as for the model population of households. 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.

Making the potential of sustainable investing salient to a subset of households substantially increases those households' demand for green funds. We thus obtain either large quantity effects (with elastic supply), or large effects on prices when supply is fixed. The right-hand columns show the role of adjustment along the extensive and intensive margins. With elastic supply, both move in the same direction: the pool of participants in green funds now has a larger wealth share, and also a larger green portfolio weight. As a result, the value of green funds almost doubles. With fixed supply, the treated subset of 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? Using household survey data to calibrate a heterogeneous agents asset pricing model, we show the net effect of green investing is to increase the price of green assets and hence c.p. to lower the cost of capital for green firms. We decompose this effect into the contributions of several key theoretical mechanisms. It turns out that green taste, in the form of non-pecuniary benefits or 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 if these taste effects were not present. 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 individuals who would require additional returns for holding green assets, possibly related to political attitudes or scepticism regarding financial markets more generally and green assets in particular. Second, hedging demand is not always positive either. Many individuals may currently use traditional assets as a hedge against a slower than expected transition to a green economy.

Looking ahead, we show that a 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 essentially entirely driven by a rise in the share of safe green 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' taste and beliefs regarding green assets. We find that such information increases the expected excess return on green assets for individuals 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 demand. 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

Figure 10: Effect of Treatments on Expected Greenium

	Dependent variable:			
	Expected Excess Return on Green			
	(1)	(2)	(3)	(4)
Climate Most Important	3.180**	4.527***	2.787**	3.234***
	(1.290)	(1.135)	(1.292)	(0.759)
Vote Green	5.976***	7.656***	7.732***	5.711***
	(1.483)	(1.306)	(1.303)	(0.875)
Negative Deposit Spread	−0.975			
	(1.388)			
Positive Deposit Spread	−7.646***			
	(1.927)			
Equity Risk Information				0.802
				(1.060)
Traditional vs Sustainable Equity Expectations				−0.437
				(1.052)
Traditional vs Sustainable Equity Returns				1.403
				(1.028)
UN Information		3.101**	−0.631	2.801**
		(1.233)	(1.816)	(1.136)
Climate Most Important:UN Information			6.880***	
			(2.463)	
Observations	1,046	1,408	1,408	2,624
R^2	0.072	0.083	0.088	0.051
Demographic Controls	✓	✓	✓	✓
Income/Wealth Controls	✓	✓	✓	✓
Note:	*p<0.1; **p<0.05; ***p<0.01			

Treatment effects for all participants in the November 2021 wave of the Bundesbank Survey of Consumer Expectations. Dependent variable is the post-treatment subjectively expected excess return of green over traditional equity, that is $X_i^{post} = E_i[r^g] - E_i[r^t]$. Robust standard errors in parentheses. The treatments are: T1 (Climate Crisis and Role of Green Finance), T2 (Equity Risk Information), T3 (Equity Past Return Information), T4 (Traditional vs. Sustainable Future Equity Return Information). We control for gender, age, age squared, college education or higher (dummy), full time employment (dummy), east/west Germany (dummy), children (dummy), household income (indicator for income bracket) and homeowner (dummy), household size (indicator for size) and region (indicator for each of four German statistical regions).

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 to ultimately quantify 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 basic function of green funds. 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 adapation 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,

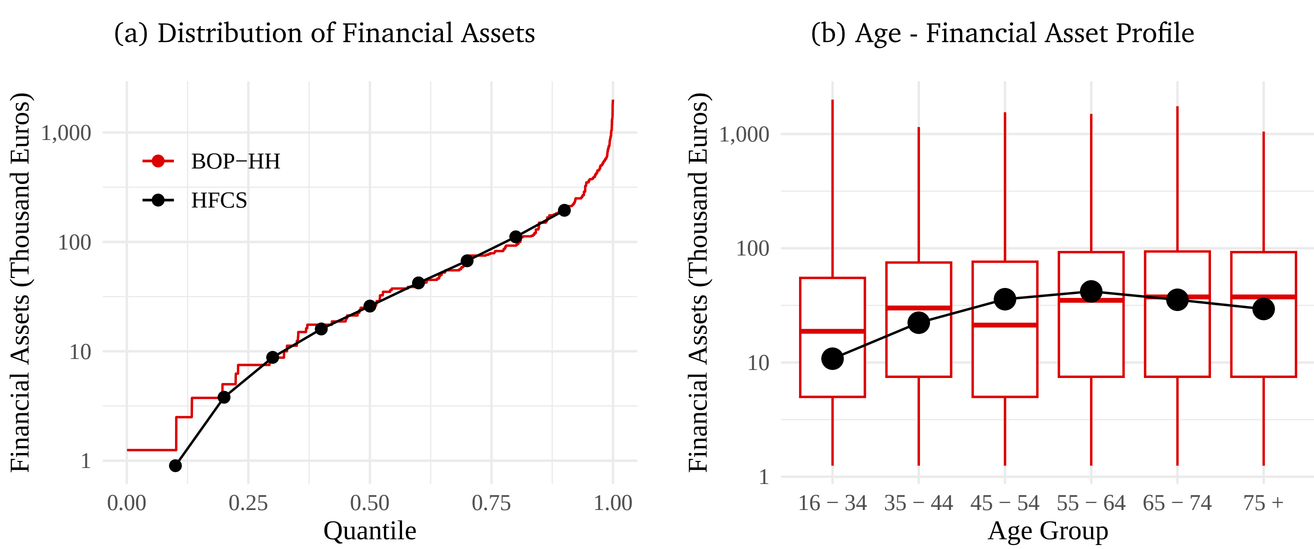
[16] We use data from the 2021 wave of HFCS. The HFCS interviews were conducted between April 2021 through January 2022. The sample size for Germany was 4,119 households.

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

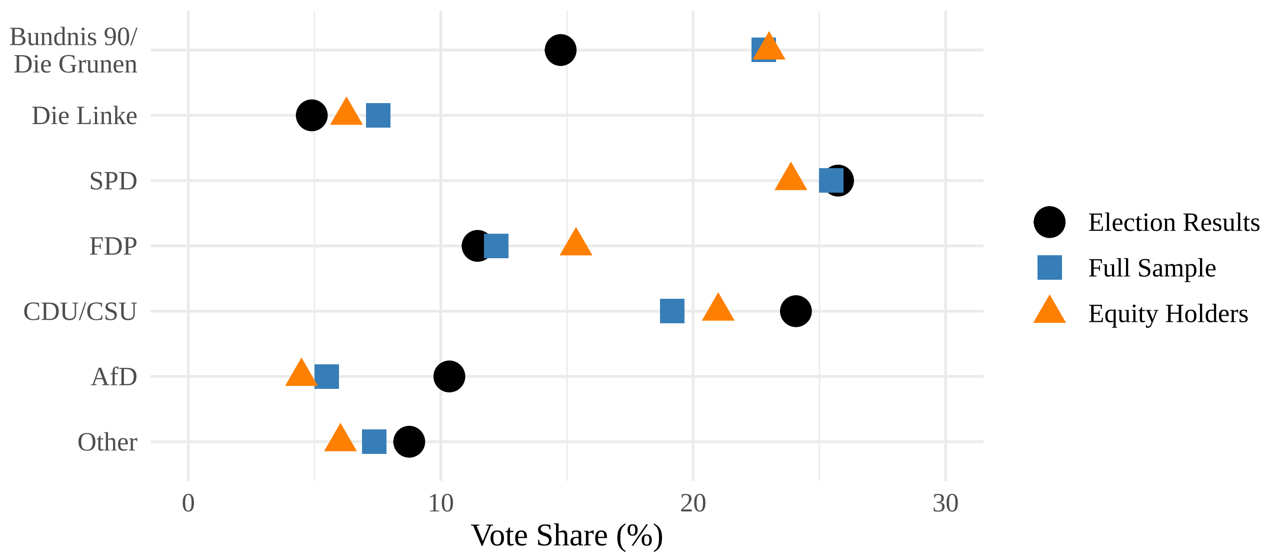
Figure A.2: Comparison with HFCS



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.

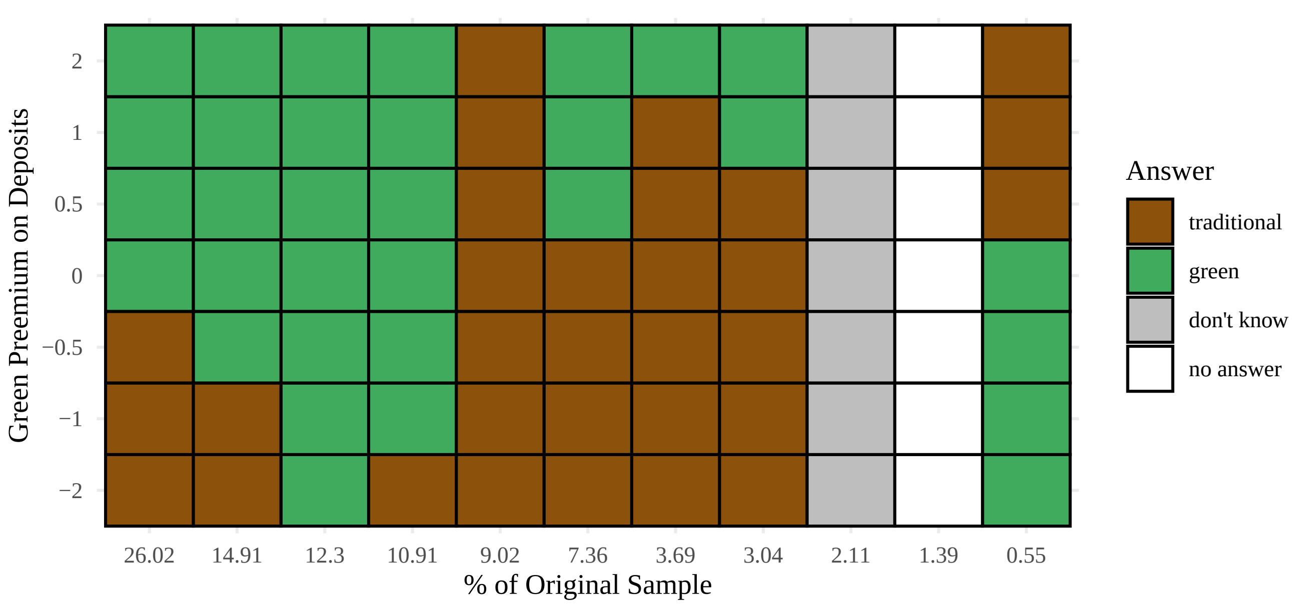
A.2 Response Rates

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 relatively low. We asked respondents to write in their expectation for annual returns for a traditional and green investment account, 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%. The response rates to the qualitative questions on relative risk ranking and investment choice were much higher. However in aggregate only 40% of respondents answered the set of four questions completely. This number is comparable to the 43% of households who report holding any equity in their portfolios.

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 a green investment account. 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 Investment Account	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:	*p<0.1; **p<0.05; ***p<0.01	

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.

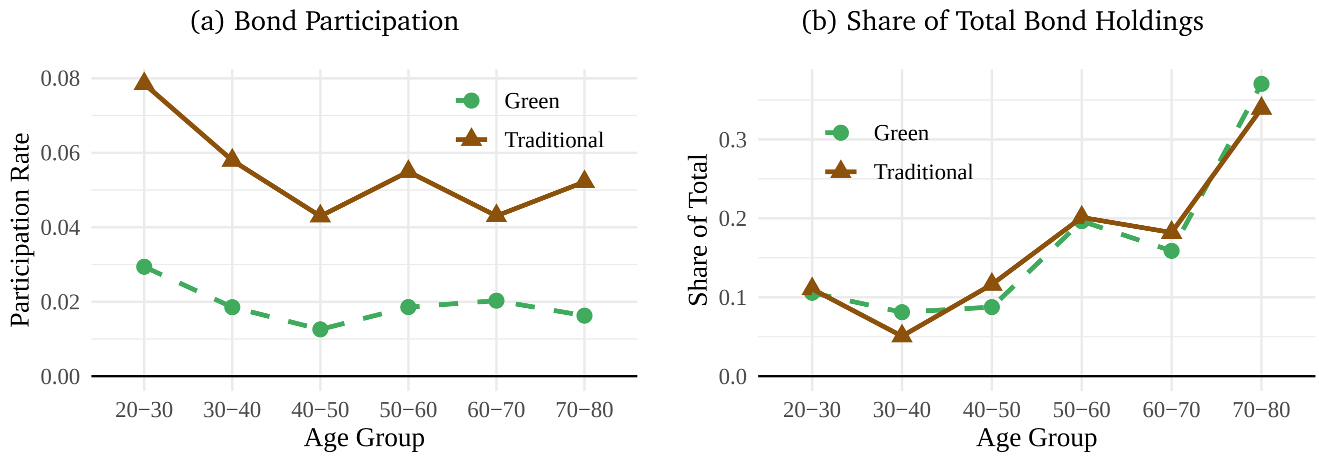
B Additional Tables and Figures

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

B.1 Current Household Holdings of Green Assets

Many of the cross section pattern for green equity holders are similar for other financial assets such as bonds (Figure B.1), pensions (Figure B.2), and deposits (Figure B.3). 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 hold a small share of total assets.

Figure B.1: Bond Participation and Holdings by Age



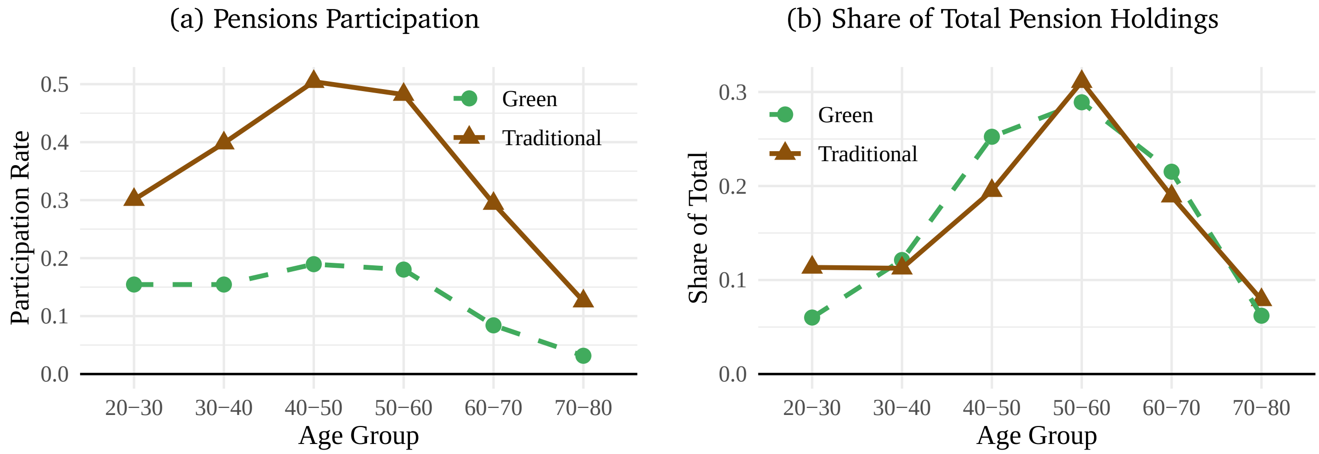
Note: Households classify their holdings as “green" versus traditional assets. Panel (a) shows the participation rate in green and traditional bonds by age group. Panel (b) shows the share of total bonds held by an age group. Sample includes all respondents in the May 2022 wave of the Bundesbank Survey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

The pattern is slightly different for pension participation where households age 40-60 are much more likely to have pensions and households age 50-60 hold the majority of pension assets.

Behaviours differ significantly for deposits. Households between the ages of 20-30 hold the majority of green deposits and are most likely to participate. The participation rate in green deposit accounts among households over age 40 is tiny but they still hold a significant share of green deposits.

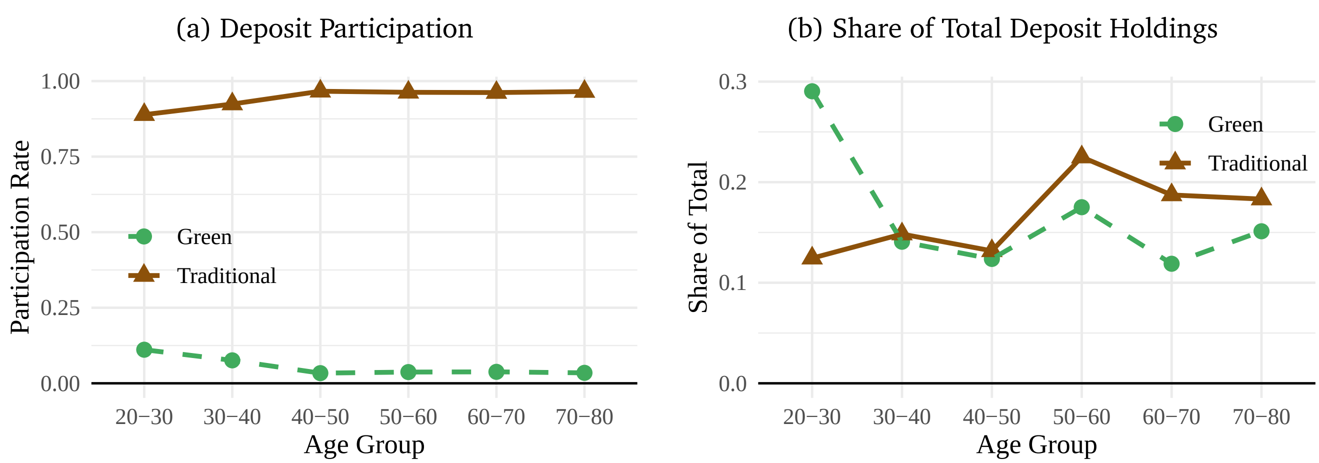
There are many dimensions of heterogeneity in who holds green assets of different classes. Table B.1 reports the coefficients of OLS regressions where the dependent variable is whether the respondent reports holds any Euros in a "green" version of that asset. For columns (1) - (3), green equity, bonds, and pensions, the data come from the May wave of the survey and correspond to individu-

Figure B.2: Pension Participation and Holdings by Age



Note: 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 green and traditional pensions by age group. Panel (b) 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.

Figure B.3: 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.

als 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 have 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.

B.2 Demand for a Green Safe Asset

B.3 Demand for Green Equity

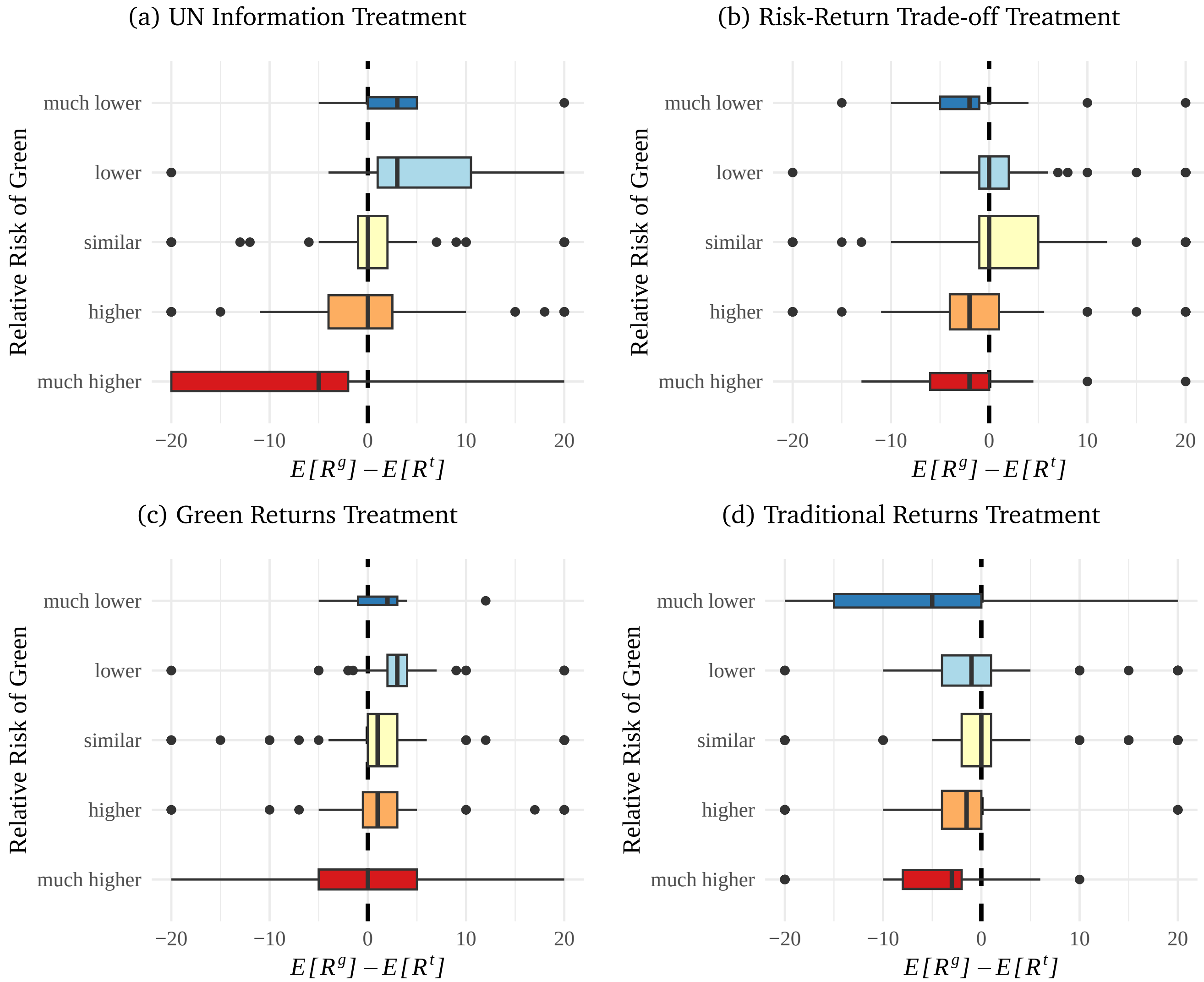
Figure B.4 plots the distribution of excess returns by relative risk ranking for among respondents in each of the four information treatments.

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

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 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.

Figure B.4: Distribution of Expected Excess Returns on Green by Relative Risk Ranking and Information Treatment



B.4 Green Returns

Table Probability Answered Qualitative/All Questions

Table Green/Brown/Excess Green

B.5 Dominated Asset Choice

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

$$c_1 = R^w\,(w - c_0) \quad \text{with } R^w = \left(1-\omega_t-\omega_g\right)R^f + \omega_t R_t + \omega_g \theta R_g, \tag{19}$$

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

$$\max_{\omega_t,\omega_g} \log\left(E\left[\left(R^w H\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}\right). \tag{20}$$

Lognormal returns. We now assume that the vector $R = \begin{pmatrix} R_t & \theta R_g \end{pmatrix}^\top$ is lognormal. We write $r = \log R = \mu_r + \varepsilon_r$, where

$$\mu_r = \begin{pmatrix} E\left[r_t\right] \\ \log\theta + E\left[r_g\right] \end{pmatrix}$$

is the vector of mean log returns, and ε_r is a normal vector with mean zero and variance Σ. The vector of mean log returns μ_r is lower than the vector of log mean returns by a Jensen's inequality term $\frac{1}{2}\mathrm{diag}(\Sigma)$. While this makes individual returns lognormal, lognormality is not preserved when returns are added together, so the return on wealth R^w in equation (19) is not lognormal.

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

$$g\left(z\right) = \log\left(\omega^\top \exp\left(z\right) + \left(1-\omega^\top\iota\right)\exp\left(k\iota\right)\right), \tag{21}$$

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 (21).

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 $g(k\iota) = k\iota$. We evaluate the derivatives at $z = k\iota$

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

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

$$g(z) \approx k\iota + \omega^\top (z - k\iota) + \frac{1}{2}\omega^\top \mathrm{diag}\left((z-k\iota)(z-k\iota)^\top\right) - \frac{1}{2}\omega^\top (z-k\iota)(z-k\iota)^\top \omega. \tag{22}$$

Taking expectations

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

Computing the variance, we obtain

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

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 (22) are quadratic in z and therefore equal to zero.

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

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

Approximating the distribution of the log return on wealth. We can rewrite the log return (19) on wealth as

$$\log R^w = \log\left(\omega^\top \exp(\mu_r + \varepsilon_r) + \left(1 - \omega^\top \iota\right)\exp\left(r^f\right)\right).$$

The risky part fits the above formalism (21) with $k = r^f$ and we can also expand the riskfree part to approximate

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

where $\mu = \mu_r - r^f\iota + \frac{1}{2}\mathrm{diag}(\Sigma)$.

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

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

Moreover, we have the covariances

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

Substituting the moments into the objective function (20), and leaving out terms that do not depend on the portfolio ω, we obtain

$$\begin{aligned}
&\max_\omega \log\left(E\left[(R^w H)^{1-\gamma} \right]^{\frac{1}{1-\gamma}} \right) \\
&= \max_\omega E\left[\exp\left((1-\gamma)\left(\log R^w + \log H\right)\right)\right] \\
&= \max_\omega \left\{ E \log R^w + E \log H + \frac{1}{2}(1-\gamma) \operatorname{var}\left(\log R^w + \log H\right) \right\} \\
&= \max_\omega \left\{ r^f + \omega^\top \mu - \frac{1}{2}\omega^\top \Sigma \omega + \frac{1}{2}(1-\gamma) \left(\omega^\top \Sigma \omega + \operatorname{var}(\log H) + 2\omega^\top \eta_g \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix} \right) \right\} \\
&= \max_\omega \left\{ \omega^\top \mu - \frac{1}{2}\gamma \omega^\top \Sigma \omega + (1-\gamma)\, \omega^\top \eta_g \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix} \right\}. \qquad (23)
\end{aligned}$$

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

$$\mu - \gamma \Sigma \omega + (1-\gamma)\, \eta_g \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix} + \nu = 0. \qquad (24)$$

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

$$\omega = T\mu + h, \text{ where } h = \frac{1-\gamma}{\gamma} \eta_g \Sigma^{-1} \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix} = \frac{\gamma - 1}{\gamma} \begin{bmatrix} -\eta_g \\ \eta_g \end{bmatrix}, \text{ and } T = \frac{1}{\gamma}\Sigma^{-1}. \qquad (25)$$

We have thus derived equation (4).

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

$$\Sigma^{-1}\mu.$$

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

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

The optimal portfolio is therefore

$$\omega = \frac{1}{\gamma} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} 1 & -\rho/\lambda \\ -\rho/\lambda & 1/\lambda^2 \end{bmatrix} \begin{bmatrix} \mu_t \\ \mu_g \end{bmatrix} + h \tag{26}$$

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

$$\begin{aligned} \omega_g + \omega_t &= \frac{1}{\gamma} \begin{bmatrix} 1 & 1 \end{bmatrix} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} 1 & -\rho/\lambda \\ -\rho/\lambda & 1/\lambda^2 \end{bmatrix} \begin{bmatrix} \mu_t \\ \mu_g \end{bmatrix} \\ &= \frac{1}{\gamma} \begin{bmatrix} 1 & 1 \end{bmatrix} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} \mu_t - (\rho/\lambda)\mu_g \\ \mu_g/\lambda^2 - (\rho/\lambda)\mu_t \end{bmatrix} \\ &= \frac{1}{\gamma} \frac{1}{\sigma_t^2 (1-\rho^2)} \left(\mu_t + \mu_g/\lambda^2 - (\rho/\lambda)(\mu_t + \mu_g) \right) \end{aligned} \tag{27}$$

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 (23) and write utility from portfolio ω given household-specific parameters $\{\mu, h, \gamma\Sigma\}$ as

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

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

$$\mu + \gamma \Sigma h - \frac{1}{2}\gamma \mathrm{diag}(\Sigma)$$

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 (7), we write the relevant terms in utility as

$$\tilde{u}(\omega) = \omega^\top (\mu + \gamma \Sigma h) - \frac{1}{2}\gamma \omega^\top \Sigma \omega. \tag{28}$$

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

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

Multiplying by $1+x$, we have

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

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

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

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

Dividing by x, we can simplify the expression to obtain

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

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

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

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 (28), or

$$\mu+\gamma\Sigma h-\gamma\Sigma\omega=0$$

Substituting, the vector of payoffs becomes

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

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.

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 investment account. We also observe their overall share of risky assets and whether or not they report having a “green investment account." 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 (26):

$$\omega_g^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2} \left(\frac{\mu_g^i}{{\lambda^i}^2} - \frac{\rho^i \mu_t^i}{\lambda^i} \right) + h_g^i > 0. \tag{29}$$

2. The household's optimal portfolio weights on risky assets must satisfy equation (27):

$$\omega_g^i + \omega_t^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2} \left(\mu_t^i + \frac{\mu_g^i}{{\lambda^i}^2} - \rho^i \frac{\mu_t^i + \mu_g^i}{\lambda^i} \right). \tag{30}$$

3. The household's parameter values must also satisfy their choice of hypothetical investment account. We want to respect either an upper or a lower bound on h_g, given by:

$$\frac{\mu_t^i - \mu_g^i + \frac{1}{2}\gamma^i {\sigma_t^i}^2 ({\lambda^i}^2 - 1)}{\gamma^i {\sigma_t^i}^2 ({\lambda^i}^2 - 2\rho^i \lambda^i + 1)}. \tag{31}$$

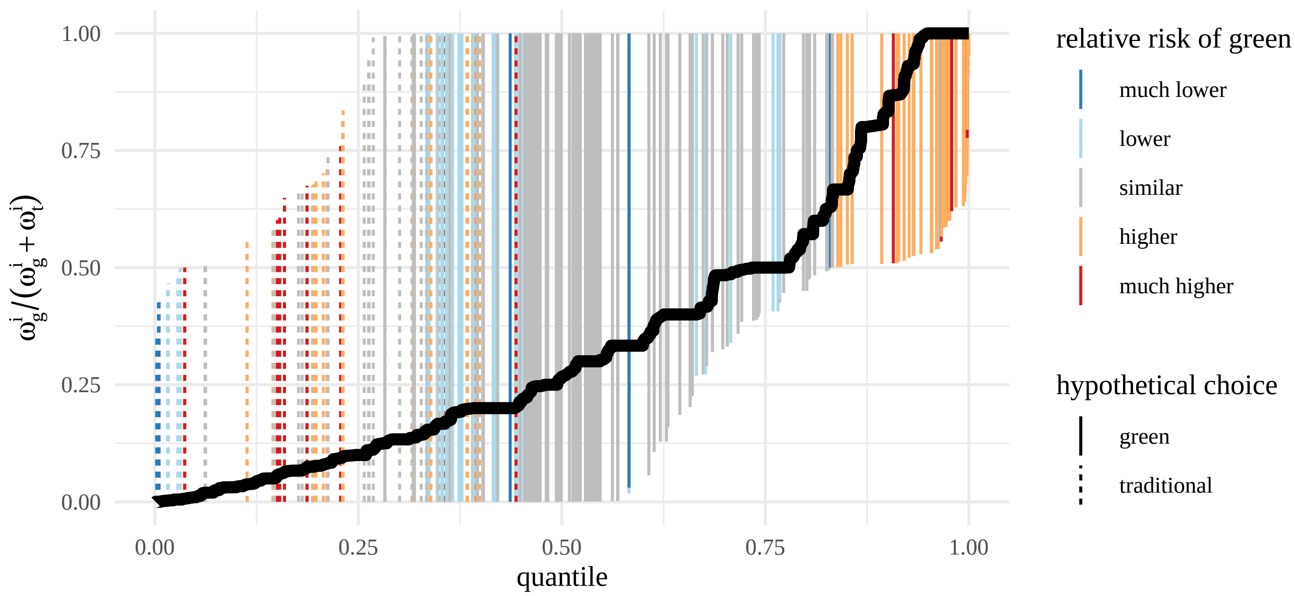
4. Finally we must respect the household's relative risk ranking which bounds λ^i.

Given values for ρ^i and λ^i the above equations determine an individual's risk tolerance $\gamma^i {\sigma_t^i}^2$ and the bound on their hedging demand h_g^i which then determines the minimum or maximum value of ω_g^i that the individual's beliefs about returns and relative risk can support. For individuals who say the the relative risk of a green account is "similar" we restrict $\lambda^i \in [0.9, 1.1]$. For individuals who say the relative risk of a green account is "lower" or "much lower" we restrict $\lambda^i \in (0, 0.85]$. For those who say the relative risk of a green account 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 individuals green share of equity assets are illustrated in Figure C.1. Each vertical line illustrates the possible values that are supported by an individuals expected returns on the two assets, relative risk ranking, and hypothetical choice of investment account. Some patterns emerge. Some individuals who chose the hypothetical traditional account can have a theoretical upper limit on the fraction of their equity that they hold in a green account. The upper limit derives from the bound on hedging demand implied by their hypothetical asset choice (Equation 31 above). Similarly some individual's choice hypothetical green account and expectation implies a binding lower bound on the share of their equity holdings that are green.

Once we have computed a set of bounds for each individual, we sort people into bins by 20-year age group, the fraction of their portfolio that they hold in equity, and whether they have above or

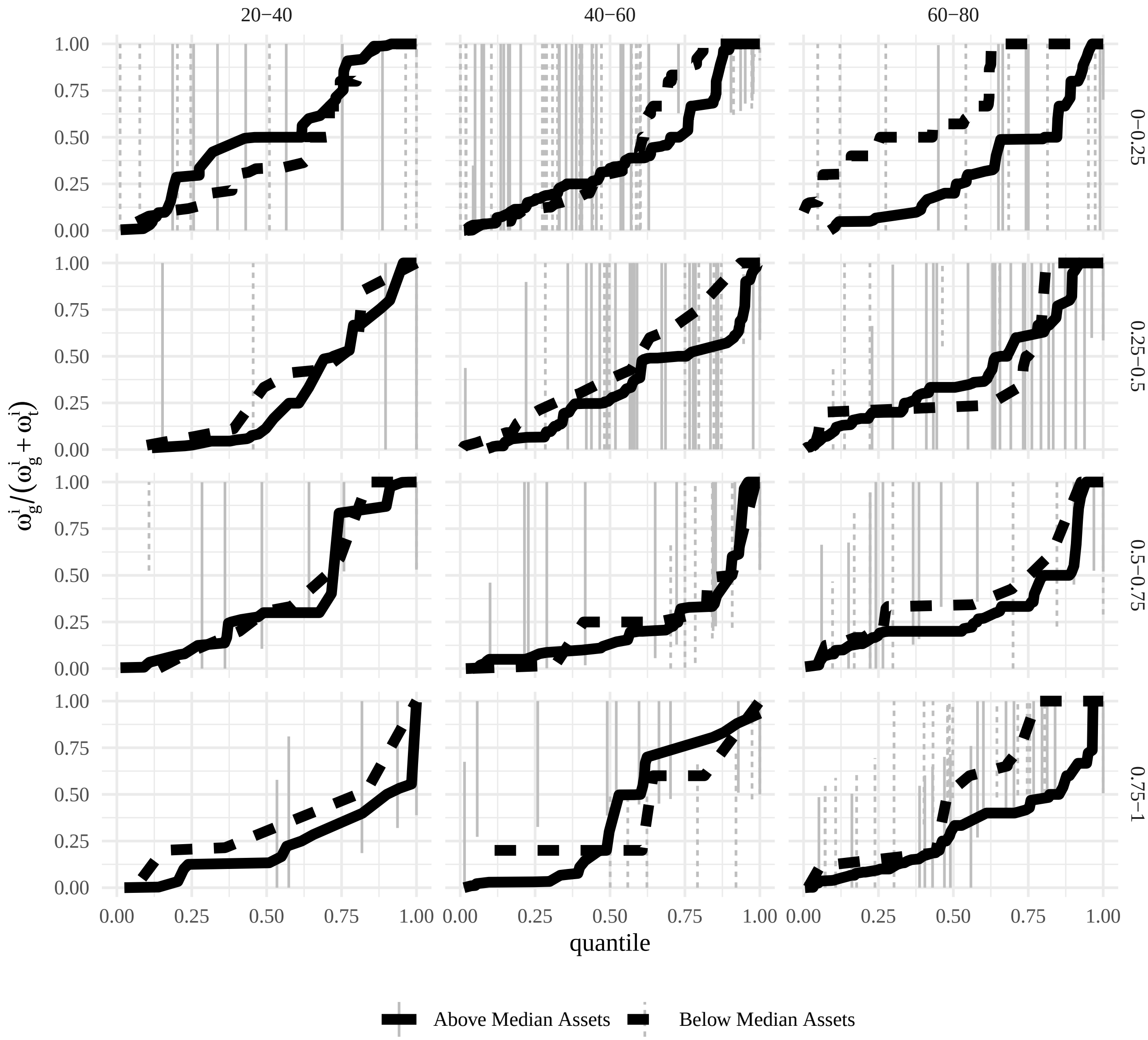
Figure C.1: Bounds on individual ω_g^i



Note: This figure illustrates the range of the fraction of equity held in green accounts $\omega_g^i/(\omega_g^i+\omega_t^i)$ supported by a 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 individuals who chose the hypothetical green account and dashed lines indicate those who chose the hypothetical traditional account. The solid black line illustrates the inverse cumulative density function for the share of equity held in green accounts from the May wave of the survey where we observe more complete portfolio information for a different set of individuals.

below median financial asset holdings (within their age group). We then match individuals in the November wave to individuals 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 as illustrated in figure C.2.

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



Note: This figure illustrates how individuals in the November wave are assigned green equity shares $\omega_g^i/(\omega_g^i+\omega_t^i)$ to match the rich cross sectional 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, individuals are further divided into above or below median financial asset holdings. Individuals in the November wave are ordered by the quantile of the midpoint of their supported green asset holdings. The solid and dashed black lines illustrates the inverse cumulative density function for the share of equity held in green accounts 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 a household who reports 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 on traditional equity, ω_t^i, must satisfy:

$$\omega_t^i = \frac{\mu_t^i}{\gamma^i {\sigma_t^i}^2} - h_g^i \tag{32}$$

2. Given that the household holds not green, it cannot be optimal for the household to have a positive portfolio weight on green, 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:

$$\omega_g^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2} \left(\frac{\mu_g^i}{{\lambda^i}^2} - \frac{\rho^i \mu_t^i}{\lambda^i} \right) + h_g^i \leq 0 \tag{33}$$

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

$$\frac{\mu_t^i - \mu_g^i + \frac{1}{2}\gamma^i {\sigma_t^i}^2 ({\lambda^i}^2 - 1)}{\gamma^i {\sigma_t^i}^2 ({\lambda^i}^2 - 2\rho^i \lambda^i + 1)} \tag{34}$$

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

Households who hold only green equity. For a household in the November wave who we match to a household in the May wave that holds 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:

$$\omega_g^i = \frac{\mu_g^i}{\lambda^{i2}\gamma^i\sigma_t^{i\,2}} + h_g^i \tag{35}$$

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:

$$\omega_t^i = \frac{1}{\gamma^i\sigma_t^{i\,2}(1-\rho^i)^2}\left(\mu_t^i - \frac{\rho^i\mu_g^i}{\lambda^i}\right) - h_g^i \leq 0 \tag{36}$$

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

$$\frac{\mu_t^i - \mu_g^i + \frac{1}{2}\gamma^i\sigma_t^{i\,2}(\lambda^{i2}-1)}{\gamma^i\sigma_t^{i\,2}(\lambda^{i2}-2\rho^i\lambda^i+1)} \tag{37}$$

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. In Table **??** we show 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.