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

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Abstract

This paper studies green investing in a quantitative asset pricing model with heterogeneous investors calibrated using high-quality, representative survey data of German households. We find substantial heterogeneity in green taste for both safe and risky green assets throughout the wealth distribution. Model counterfactuals show nonpecuniary benefits and hedging demands currently make green equity *more* expensive for firms. Yet, these taste effects are dominated by optimistic expectations about green equity returns, lowering firms' cost of green equity to a greenium of 1%. Looking ahead, we use our model to trace out the aggregate effects of information provision in an RCT and find green equity investment could potentially double when information about green finance spreads across the population. Regarding safe green assets, our model counterfactuals show that if green deposits could be offered at a 50 basis point interest rate spread, aggregate green investments in the economy could quadruple in the medium run.

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1 Introduction

Green investing has grown rapidly in recent years, especially in Europe. From 2019 to 2021, assets of European ESG 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 have nonpecuniary benefits from holding green assets that imply convenience yields, and hence lower average returns on those assets. Alternatively, investors may now worry about a new risk factor associated with climate change. To analyze the impact of green investing on the climate transition at the macro level, we need detailed information about investors' attitudes in the population.

This paper presents new evidence from a high-quality, representative survey of German households. By inserting hypothetical choice questions into the survey, we are able to provide a unique perspective on the distribution of green investment attitudes among the entire population of a country. We first document new facts on the cross-section of households' expectations about the returns on green and traditional assets, nonpecuniary benefits from holding green assets, green hedging motives, as well as actual portfolio holdings of green and other assets. We find that green investing is already quite popular, although it is relatively risky: equity is the main pathway to green investment, whereas green bank deposit accounts are rare. We also find strong heterogeneity in households' attitudes. Some households receive nonpecuniary benefits from holding green assets, while others have high nonpecuniary costs. Similarly, some households believe green equity is a hedge against future bad states, while others think that traditional equity provides that insurance.

We then use the data to quantify an asset pricing model with heterogeneous households to assess the impact of green investing on asset prices and investment. We also feed the treatment effects from an RCT in the survey into our model to assess the importance of more information about climate finance. We find that convenience yields and hedging currently make equity *more* expensive for green firms. Still, the distinction between green and traditional equity leads to a form of market segmentation that lowers the average return on green equity by 1 percentage point compared to traditional equity, mainly because households who are more optimistic about green equity start participating in its market and bid up its price. Our model counterfactuals identify two promising avenues for green finance. First, there is a substantial demand for green safe assets. If green bank deposits could be offered at a 50 basis point lower interest rate than traditional deposit accounts, green investments in the economy would overall quadruple in the medium run. Second, an RCT that provides more information about green finance suggests that households who are already concerned about climate change would dramatically increase their green investments. Since there is substantial wealth behind this group of households, investments in green equity would double.

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

Our survey modules include several hypothetical choice questions to measure convenience yields and hedging demands for green assets. To directly measure green convenience yields, we elicit the annual interest-rate spread that households would give up (or require) to have a green bank deposit account. We find that 42% of households would accept lower interest rates on a green account, with 25% willing to sacrifice more than one percentage point. However, 28% of households would only use a green bank account if it paid a higher interest rate. In other words, many households have negative convenience yields for green deposits. In the cross-section, convenience yields are higher for younger households and voters of parties that advocate for more emission reductions. However, convenience yields are not strongly correlated with wealth. Aggregating across households, we find that if green deposits paid the same interest rate as traditional deposits, more than 75% of deposit demand would be green.

To identify the demand for equity, we not only elicit households' subjective expected returns and relative risk of green and traditional equity funds but also ask households to rank these funds as vehicles for extra savings. While most rankings are consistent with mean-variance efficiency, about 20% choose dominated assets with lower mean and/or higher risk. A natural explanation for these findings is climate hedging: an investor might prefer a green equity fund not only because of its risk and return but because it provides insurance against a bad state of the world (for example, 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.

Depending on whether households think of either green equity or traditional equity as a hedge against climate risk, their green equity demand can be either higher or lower than the mean-variance benchmark. For example, households might worry about events that stifle climate action, when green equity would perform particularly badly. These households would naturally be extra cautious when it comes to green equity investing — effectively, traditional equity provides them with insurance against climate inaction and might be preferred even if the household is optimistic about green equity. In line with this hypothesis, we find evidence of negative hedging demand for green equity even among the population of households who hold green equity.

To understand the quantitative importance of convenience yields and climate hedging on aggregate investment, we build an asset pricing model with heterogeneous households. The basic building block of our model is a household savings and portfolio choice problem with Epstein-Zin utility that allows for both convenience yields from green assets (equity or bonds) and climate hedging captured by a state-dependent utility. We take the model directly to the survey data and determine the household-specific utility and belief parameters to jointly match answers to the hypothetical questions and the cross-section of portfolio holdings. An essential 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 as well as safe assets. For counterfactuals, we determine equity prices by matching aggregate demand to exogenous asset supply under various scenarios.

Our first set of counterfactuals is designed to understand how households' return expectations, convenience yields, and hedging demands shape current equilibrium asset prices and investments. We view the rise of green investing as the combination of two changes in household behavior. First, households now perceive convenience yields depending on an asset's "color" and the need to hedge climate risks. When we shut these down, the value of green equity actually *increases*. In other words, deviations from mean-variance benchmarks currently hold back green investing. The reason is that many green investors currently hold green equity mainly because of their positive convenience yields and hedging demands, not because they believe that green equity has attractive financial returns. If convenience and hedging are muted, these investors may exit the market for green equity. The selection of green investors who continue to hold green equity are attracted by its financial returns. Conversely, many traditional investors find green equity attractive in a mean-variance sense but currently do not hold green equity for negative convenience and hedging reasons. If convenience and hedging are muted, these households start to invest in green equity. Both forces lead to a population of green investors who are more optimistic about green equity in the counterfactual. With short sale constraints, there is market segmentation, so their optimism drives up green equity prices.

A second important component of the rise of green investing is attention allocation. Households now distinguish between types of equity that they previously viewed as indistinguishable. In particular, the emergence of a climate risk factor may drive households to see green and other equity as imperfect substitutes. To assess this effect, we design a counterfactual that not only shuts down convenience and hedging but also modifies beliefs so that households view green equity 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 premium.

We also perform two counterfactuals to assess the future potential of green investing. The first studies the widespread availability of green bank deposit accounts. A potential side effect of making risk-free green assets available to households is that it could reduce demand for risky green equity and lead only to substitution, rather than expansion of green finance as a whole. However, we show that such substitution is minor, making green deposits a promising avenue to expand green finance. Second, we assess what is likely to happen as households learn more about climate change and the availability of sustainable investment products. To gauge the effect of such information, our survey module contains an RCT that informs households about the risks posed by climate change and the potential of green finance to contribute to a green transition. We find that a subset of households who are concerned about climate change respond to the information with a substantial upward revision of their green excess return expectations. Feeding these treatment effects from the RCT into the model delivers large macro 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 payoffs (e.g., Fama and French 2007). In particular, other 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 equity holders, very few households have such a strong taste for green that they decide not to participate in the market for traditional equity. Among all households, 4% of households hold exclusively green equity, representing 6% of financial assets.

In our survey data, roughly half of the households who own equity have some green equity. Moreover, households hold green and traditional equity to varying degrees. To explain this observed heterogeneity in portfolio choice, we must go beyond negative screens and capture that households choose a mix of green and traditional assets in their portfolio. Here we build on recent theoretical work that studies the intensive margin of green investing assuming exponential utility (Pedersen, Fitzgibbons and Pomorski 2021; Pástor, Stambaugh and Taylor 2021; Zerbib 2022). The utility or disutility from holding green assets captures positive or negative convenience yields. A state-dependent marginal utility captures hedging demands. An important feature of our quantitative approach is that we allow for Epstein-Zin utility. As a result, richer households matter more for market valuation; our asset pricing formulas weigh individual-specific beliefs, convenience yields, and hedging motives from our survey by household wealth. To evaluate these formulas, it is thus important to have an accurate joint empirical distribution of household characteristics that is representative of the entire economy. We measure this distribution based on high-quality, representative survey data.[1]

The asset pricing literature has documented substantial differences in expected returns across stocks. For this type of work, obtaining many stock return observations from a stable environment is crucial. These conditions are absent when measuring the greenium. Over the last decades, there has been a constant flow of new information about the risks of climate change, and investors have become more worried, 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 empirical asset pricing literature has produced conflicting results about the greenium (for a recent survey, see Giglio, Kelly and Stroebel 2021). While many papers document lower expected returns for green assets (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). Data from corporate conference calls suggest that CEOs of green companies perceive a lower cost of capital than other CEOs (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 that directly ask investors about their beliefs and motives are an especially attractive approach in a changing investment environment, such as the climate context. Several papers ask academics and/or professionals about climate change and document significant concerns about the associated risks (Drupp, Freeman, Groom, Nesje et al. 2015; Krueger, Sautner and Starks 2020; Stroebel and Wurgler 2021). Other papers ask investors about their expected returns on ESG assets (Riedl and Smeets 2017; Heeb, Kölbel, Paetzold and Zeisberger 2023; Giglio, Maggiori, Stroebel, Tan, Utkus and Xu 2023) and document substantial heterogeneity in investor beliefs. These studies document a *lower* expected ESG return on average across investors—consistent with a greenium, and also our survey findings. Related to the potential channels underlying ESG investments, Riedl and Smeets (2017) play a trust game with fund investors at a large Dutch asset management company

[1] An alternative approach by Koijen, Richmond and Yogo (2023) is to identify institutional investors with ESG mandates and analyze their demand systems. We take a household perspective because we want to be able to analyze the macro consequences of green investing. Moreover, we want to separately study its implications for the short run, where the supply of assets does not adjust, and the medium run with perfectly elastic supply.

and show that investors who reveal stronger prosocial preferences in the game are also more likely to invest in ESG funds. Heeb, Kölbel, Paetzold and Zeisberger (2023) document that investors report a high willingness to pay for impact funds but are not sensitive to the quantitative impact of these funds (whether, for example, they reduce emissions by 0.5 versus 5 tons.) Giglio, Maggiori, Stroebel, Tan, Utkus and Xu (2023) document that Vanguard investors who care more about climate change are more likely to hold ESG funds for both ethical reasons and to hedge climate risks.[2]

Our goal is to assess the impact of green investing at the macro level. To this end, it is crucial for us to have representative survey data for the population of an entire country, and to measure essential model ingredients such as the risk of green investments, convenience yields, and hedging demand. The unique combination of this survey evidence and a quantitative asset pricing model with heterogeneous agents allows us to uncover new results on the role of green tastes and beliefs for green premia. The quantitative model enables us to assess counterfactual scenarios about the future of green investing, documenting a large potential role for safe green assets in the form of bank deposits. Moreover, we use the combination of RCT and model as an innovative way of tracing out the macro effects of information provisions on the aggregate demand for green equity.

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

2 Household Survey Data

This paper uses data from the Deutsche Bundesbank Household Survey on Consumer Expectations, a large representative survey of German households. The survey is a key data source for the Bundesbank on inflation and income expectations, as well as household consumption behavior. Each survey wave collects rich demographic, income, and wealth data about households and their general economic expectations. The monthly survey is administered online by the survey company Forsa

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

and has been running since April 2019.[3] We fielded customized questions across two survey waves, with roughly 6,000 respondents in each wave. The survey sample is representative of the financial portfolios and "green" preferences of German households. Appendix A contains more details on the representativeness of the sample and the response quality.

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 deposit accounts. Here, we asked not only whether households currently have such accounts but also elicited 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 as well as their preference for investing hypothetical additional savings in a green or traditional equity fund.

In this wave, we also field a randomized control trial (RCT) with information treatments related to green investing. We split the sample randomly into a control group with approximately 2,000 (untreated) respondents and multiple treatment groups with approximately 1,000 respondents each. Respondents in each treatment group were shown a brief information statement before answering our questions. The treatments provided information on (i) risk-return trade-offs in risky investments and (ii) the potential for green investment funds to contribute to climate change mitigation.[4] The precise wording of each treatment is described in sections 5.3 and 8.2.[5]

In the May 2022 survey wave, we added a further question module that asked households to provide a detailed "color" breakdown of their financial portfolio holdings. In particular, we asked households to report the green and traditional holdings of each asset category. 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,

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

[4]A third treatment provided information about the investment freedom of traditional equity funds compared to green equity funds. A fourth treatment provided information about the historical performance of green equity funds relative to traditional funds. The response to these treatments did not provide additional information for understanding household investment decisions and so are not included in this paper.

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

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.

3 Current Household Holdings of Green Assets

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

3.1 Green Investing: How Much and What Asset Class?

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

The most important financial asset held by German households is bank deposits. Almost all households (99%) have some deposits, and the aggregate portfolio weight is roughly one-half (49%). While equity also has a sizable aggregate weight of about one-third, only 43% of households participate in equity markets. Private pensions are similarly held by only 42% of households and represent only 15% of the aggregate portfolio. We do not know precisely what types of securities households select in their pension accounts—in principle, this could be either equity or debt. Finally, direct household holdings of bonds are rare and make up a negligible share of aggregate financial assets.[6] The composition of German household financial portfolios is broadly representative of European portfolios. The share of household assets invested in deposits, pensions, and bonds is 67% both in Germany and

[6] Pástor, Stambaugh and Taylor (2022) document that green bonds issued by the German federal government have a 7 basis points lower yield than comparable non-green bonds. These bonds have long maturities and are thus risky. Table 1 shows that only 2% of households participate in this market. The current share of green bonds in the German government debt portfolio is 3.7% according to https://www.deutsche-finanzagentur.de/en/federal-securities/types-of-federal-securities/federal-bonds.

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	0.07	0.08	0.17	0.18	0.42
Traditional	0.26	0.36	0.83	0.39	0.91
Deposits					
Total	0.49	0.39	1.00	0.99	1.00
Green	0.02	0.02	0.04	0.05	0.04
Traditional	0.47	0.37	0.96	0.94	0.96
Pensions					
Total	0.15	0.14	1.00	0.42	1.00
Green	0.02	0.02	0.16	0.13	0.31
Traditional	0.13	0.12	0.84	0.37	0.88
Bonds					
Total	0.03	0.03	1.00	0.07	1.00
Green	0.01	0.00	0.16	0.02	0.32
Traditional	0.02	0.03	0.84	0.06	0.90

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

in the Euro Area as a whole.[7]

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

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

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

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

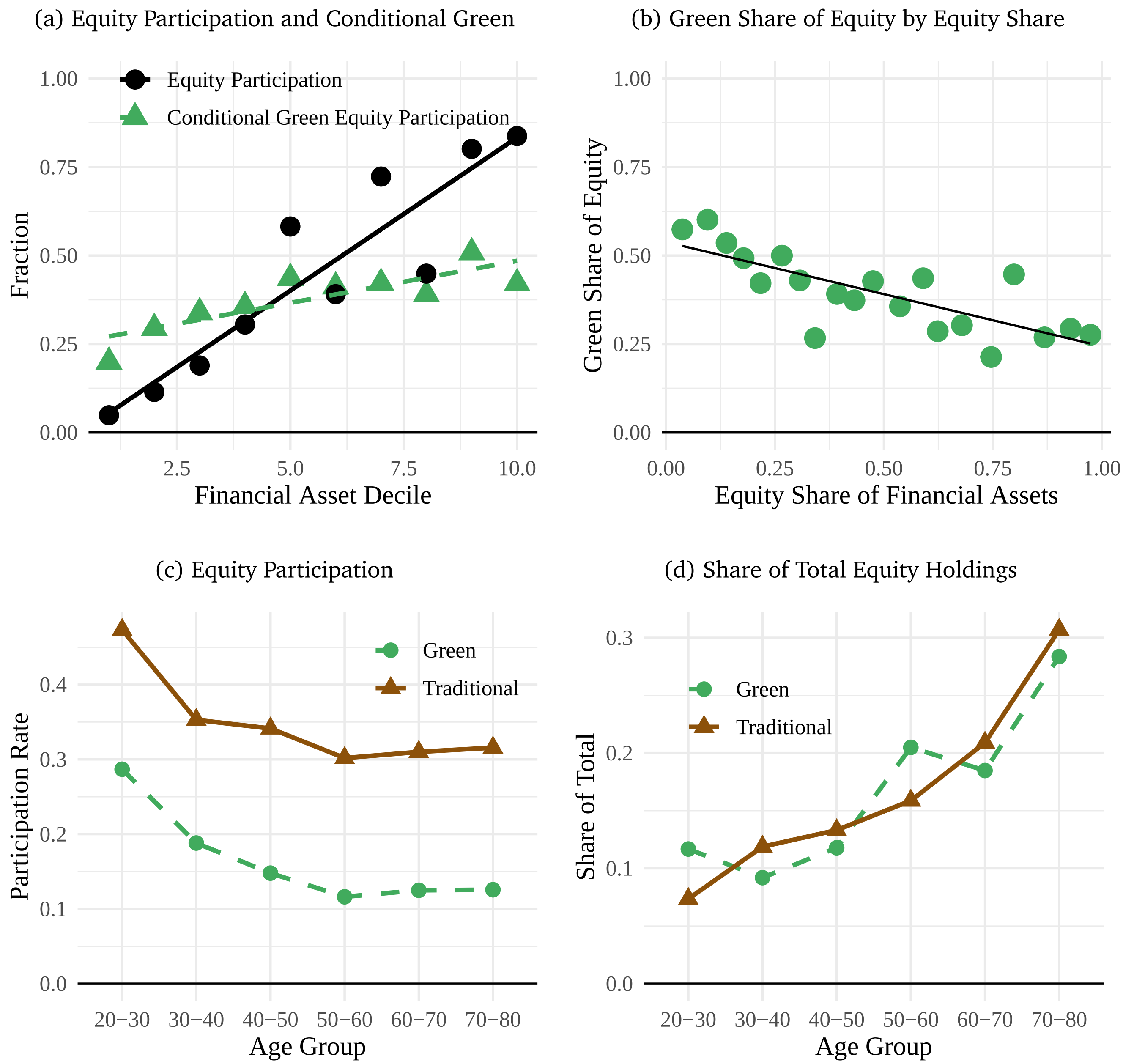
3.2 The Cross Section of Green Investor Households

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

Some households invest little in equity but seem to participate in equity markets specifically to invest in green assets. The last column of Table 1 shows that, among households who hold 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 equity invested as green and the equity share of financial assets. Households with less than 10% of their financial assets in equity hold over half their equity in green equity funds. In contrast, households with more than 90% of their financial portfolio in equity hold only a quarter in green equity funds.

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

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



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

the majority of financial assets. Figure 1(d) illustrates the share of total equity holdings held by each age group. Households over 50 years hold the majority of both green and traditional equity assets. Although households under 40 are more likely to hold green assets, their impact on the aggregate household portfolio is limited as they hold only 20% of total financial assets.[8]

4 Demand for a Green Safe Asset

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

4.1 Measuring Convenience Yields

We measure taste for a green safe asset by asking survey respondents to choose between a traditional and green bank deposit account for a range of interest-rate spreads between the two accounts. All individuals are first shown the following definition of a green deposit 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 account is at the same bank as the respondent's current deposit account. Respondents are then presented with a sequence of interest-rate spreads between the traditional and green deposit accounts, ranging from 2% to −2%. For each spread, respondents were asked to decide where to put their savings, either the traditional or the green deposit account. The complete translated text of the question continues as follows:

[8] 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 deposit account. More details on who participates in green financial products can be found in Table B.1.

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

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

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

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

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

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

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

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

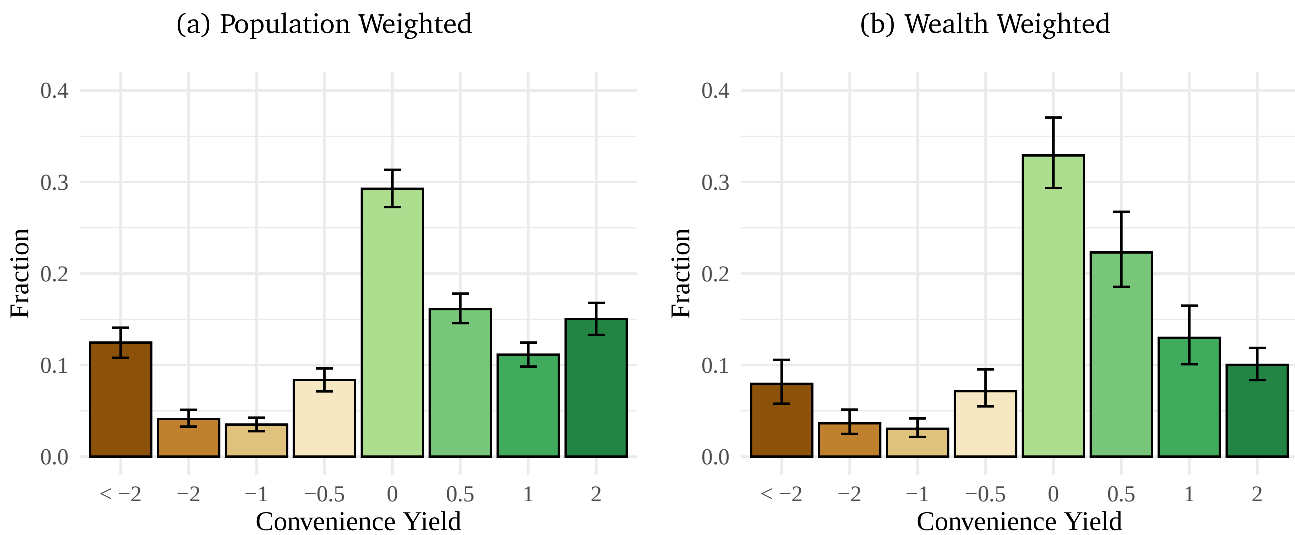
Paying attention to interest rates on deposit accounts and comparing rates across banks is salient for German households given the low-interest rate environment that persisted before the recent inflation episode. We are confident that most survey respondents understood the sequence of questions, as close to 90% of respondents' answers were complete and "consistent". We call answers consistent when a respondent who chooses the green deposit account for some spread between green and traditional deposit accounts also selects green for all larger spreads. For example, if they choose the green account when the spread over the traditional account is 0, they also select it when the spread is positive. Approximately 8% of respondents gave inconsistent answers, and 5% did not respond or only partially responded to the questions.

Our definition of a respondent's convenience yield on a green deposit account is based on the highest spread between the traditional and green deposit accounts they are willing to accept to hold green deposits. For example, respondents who choose green deposits in all cases are classified as having a 2% convenience yield for green safe assets and a taste for green. When respondents only choose green deposits if they pay the same interest rate as traditional deposits, 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 green deposits. If respondents choose traditional deposits in all cases, they are classified as having a negative convenience yield of -2% and a distaste for green. The classification is applied similarly for intermediate accepted spreads.

4.2 The Distribution of Convenience Yields

We find that convenience yields are not always positive. While many respondents report they are willing to sacrifice interest income to hold a green safe asset, a substantial fraction would require a higher interest rate to hold such an asset. Figure 2(a) plots the distribution of convenience yields on a green deposit account using population weights. We find that 42% choose green deposits when they pay a lower interest rate than traditional deposits, 30% choose green deposits only when they pay at least the same interest rate as traditional deposits, and 28% only choose green deposits if they have a higher interest rate than traditional deposits.[9]

Figure 2: Distribution of Convenience Yields on Green Deposit Accounts



Note: The height of the colored bars shows the fraction of respondents with the indicated convenience yield, which is the highest interest-rate spread between the traditional and green deposit accounts for which they still choose the green deposit account. Panel (a) shows the distribution of convenience yields using population weights, while panel (b) shows the distribution using weights based on financial wealth. 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 which asks about green bank deposit accounts.

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

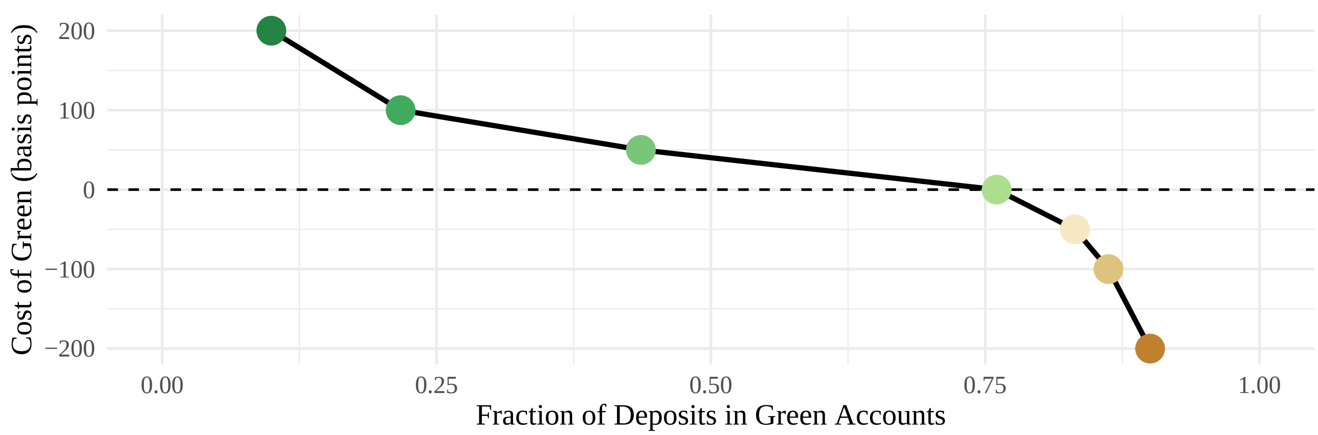
Our measures of the convenience yields are large but not unreasonable. To translate these responses to euros, we use data on survey responses about households' actual bank deposits. We find that the median willingness to pay for a green bank deposit account among households with positive convenience yields is 150€ in annual foregone returns. The median required payment to accept a green bank account among households with negative convenience yields is 112€ in annual forgone

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

returns.[10] Given that the median household income of survey respondents is roughly 40,000€ , these numbers are not unreasonable when compared with an annual charitable donation.[11]

By combining the distribution of convenience yields with households' actual bank deposits, we can construct a demand curve for a green bank deposit account. For each interest-rate spread on the green deposit account, Figure 3 plots the cumulative share of bank deposits that households would put in a green bank deposit account. We find that if green deposits pay the same interest rate as traditional deposits, more than 75% of deposits would be green. For a cost of 1 percentage point, that fraction would still be roughly 20%, and hence far larger than the 4% share of green deposit accounts in Germany today.

Figure 3: Demand Curve for Green Deposit Accounts



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

Appendix B.2 documents how taste for a green safe asset correlates with age and with alternative measures of green preferences. Young households are much more likely to have positive convenience yields from green deposits, while older households are more likely to have negative convenience

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

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

yields. There are also significant differences in convenience yields by other demographic characteristics. For example, women, college graduates, and West Germans are more likely to have a positive convenience yield. However, taken together, demographics, income, and wealth explain only a small share of the variation in green taste in the population. Instead, green taste is more correlated with voting for political parties. Voters of the AfD, a party that has called for an end to all major climate actions, are much more likely to demand a higher interest rate on green deposits than voters of the Alliance 90/ the Greens.[12] Finally, households who report that climate change is the number one concern facing Germany today are more likely to have a positive convenience yield. Households who report that their number one concern is refugees are more likely to have a negative convenience yield.

5 Demand for Green Equity

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

5.1 Measuring Households' Expectations

To measure households' 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.

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

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

[12] Somewhat surprisingly, we also find that a small but non-zero fraction of the Alliance 90/ the Greens voters and other left-leaning parties have a negative convenience yield. It is not unreasonable to think that these voters may believe that market solutions to climate issues are fraudulent or prevent effective government action. Households with this view might not want green assets.

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

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

We also asked households to rank the risk of a traditional equity fund compared with a sustainable equity fund. The phrasing of this question was designed to capture a qualitative understanding of the relative variance of the two equity funds:

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

The response rates to these questions were significantly lower than to those to our green bank account questions, likely reflecting German households' lower participation in equity markets. Appendix A.2 contains more details on who answered these questions. For our main quantitative exercises, all results are robust to re-weighting to account for differential sample attrition by green taste as measured by either the deposit spread question or the 2021 German parliamentary election outcome.

5.2 Expected Returns on Risky Assets

Households' reported return expectations are in a reasonable range given historical equity returns. The first two columns of Table 2 report the average expected returns for the two equity funds. The third column contains the *greenium*, the expected excess return on traditional equity over green equity. The population-weighted greenium is slightly negative: the nominal average annual returns for traditional and green equity funds are 7.4% and 7.7%, respectively.[13] Weighting by financial wealth, the expected returns are higher for the traditional equity fund (8.4%) than for the green equity fund (7.6%), implying a *positive* greenium of 80 basis points.[14] Overall, there is rich heterogeneity in households' expected returns. While 49% of households expect traditional equity to have higher returns, 25% of households expect green equity to have higher returns.

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

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

Note: This table reports average expected returns on traditional and green equity funds and the greenium for the November 2021 wave of the survey which contains this survey question. The table reports statistics for the sample as a whole as well as various subgroups by demographics, financial wealth, and attitude towards green. Expected returns are winsorized at −5% and 15% which corresponds to the 0.5 and 75th percentile of the expected return distributions. For every row except the population weighted row, households are weighted by their population weight × their reported financial assets.

Table 2 shows that households' expected returns are correlated with their actual portfolio holdings. Households who participate in equity markets or are in the top quartile of financial wealth expect higher than average returns for traditional equity. The expected returns for green equity are more similar across these households, implying a positive greenium for households who invest in equity and are richer. Moreover, households who invest in green equity expect higher green equity returns, which lowers their greenium.

Table 2 also documents a connection between households' expected returns and their taste for

[13]While these expected returns are slightly higher than historical returns for German equity, 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%.

[14]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.

green. Households with a taste for green, as measured by a positive convenience yield on a green bank account in our survey or their reported vote for the Green Party, expect green equity to outperform traditional equity (and therefore a negative greenium.) By contrast, households with a distaste for green, as measured by a negative convenience yield on a green deposit account or who voted for the AfD in the previous election, expect green equity to substantially underperform relative to traditional equity (and therefore a positive greenium.)

5.3 Relative Risk Rankings and Risk-Return Trade-Offs

The vast majority of households have expectations about equity returns that embed a trade-off between risk and return. More specifically, 82% households have higher return expectations for the equity fund that they rank as weakly riskier and lower return expectations for the equity fund that they rank as lower risk. For example, when households have higher return expectations for the green equity fund, 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 than traditional equity funds.

We find that households are well informed about risk-return trade-offs. To assess the impact of information about such trade-offs on households' expectations, we embedded a randomized control trial (RCTs) in our survey module in November 2021. We randomly selected 1,000 respondents and provided them with the following information, placed after the hypothetical green bank account question but before eliciting beliefs about equity returns. The precise wording is:

> Equity funds differ not only in terms of the expected gains in value, but also in terms of risk. Greater risk is usually accompanied by a greater average gain in value.

We find that the expected returns on risky assets and their relative risk rankings in the treatment group are indistinguishable from those in the control group. (Appendix B.3 reports these results.) In other words, households do not seem to adjust their answers when we explicitly explain the existence of risk-return trade-offs to them.

5.4 Hedging Demands for Risky Assets

After respondents report their expected returns and the relative risk ranking of green and traditional equity funds, we asked them to make a hypothetical investment decision. The exact phrasing of the question was as follows:

> 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

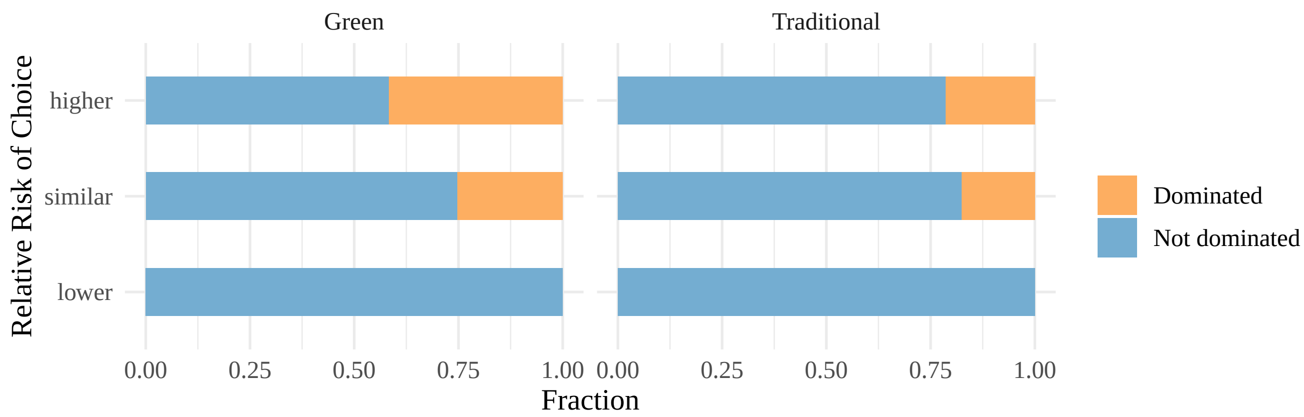
Interestingly, we find that many households choose hypothetical investments by selecting equity funds that they believe are *dominated* in a mean-variance sense. These households choose the equity fund for which they expect similar or lower returns and that they perceive to be riskier. Moreover, the share of households making such a dominated choice *increases* when they believe the dominated equity funds are riskier. These choices suggest that households perceive an extra motive (or deterrent) to invest in green or traditional equity funds that scales with risk, consistent with a worry about a faster or slower climate transition.

When households perceive the climate transition to be risky, they may have a hedging demand for green or traditional equity. For example, households who are worried about the risk of an accelerated climate transition may have a positive hedging demand for green equity funds and may thus want to tilt their portfolio towards green equity. While green equity funds may be unattractive investments from a mean-variance perspective, these households may still like to hold them as a form of insurance against future states of nature in which there is a political consensus about fighting climate change. In these states of nature, green equity funds are likely to outperform traditional equity funds and thereby provide a hedge against this risk. Conversely, households who are worried about a slower climate transition may have a negative hedging demand for green equity funds and thus tilt their portfolio away from green equity funds towards traditional equity funds. While traditional equity funds may be perceived to be dominated by these households, they can still provide a useful hedge against a slower climate transition, when traditional equity funds are likely to do relatively better.

Figure 4 plots the fraction of households who choose dominated equity funds in orange, while the blue fraction shows households who do not make such dominated choices. We plot these fractions by equity fund choice and the relative risk ranking of the household's choice. For *both* the green and traditional equity funds, more households make dominated choices when they believe that the funds they are choosing have higher risk. Overall, we find that 18% of households choose the equity funds that they believe are dominated by the other funds. Among households who choose the green equity fund, 23% are making a dominated choice, while 10% of households who choose the traditional equity fund make a dominated choice. Among households who believe that the funds they select are riskier (the top horizontal bars in Figure 4), 42% are making a dominated green choice, while 21% are making a dominated traditional choice (shown in orange.)

Convenience yields cannot account for these choices. If we define the effective expected return on

Figure 4: Hypothetical choice of equity funds by relative risk



Note: This figure measures on the horizontal axis the fraction of households who make a particular choice in response to the hypothetical investment question in the November 2021 wave of the survey. Orange households choose funds that are dominated in a mean-variance sense, while blue households choose those that are not. The left column illustrates this for households who choose green equity funds. The right column illustrates this for households who choose traditional equity funds. The vertical axis shows the relative risk ranking (higher, similar, lower) for the funds chosen by the household. For example, the top left bar shows in orange the fraction of households who choose green equity funds that they perceive as dominated by traditional funds and that they perceive to be relatively higher risk.

green equity funds as the subjectively expected financial return plus the convenience yield (measured as the cost of a green deposit account that the household is willing to pay), 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.

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 with green and traditional assets, allowing for rich household heterogeneity in expectations, risk preferences, and taste. We then use the cross-section of household survey responses to quantify the model. Finally, we model the supply of financial assets and define equilibrium to compute counterfactual scenarios.

6.1 Household Problem

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

Supported by our empirical findings, households in our model derive nonpecuniary benefits or costs from holding green assets. We introduce these nonpecuniary aspects through the specification of household preferences. In particular, we distinguish between financial wealth—the sum of monetary payoffs from investments—and *effective* wealth that enters utility and has two nonpecuniary components. First, households may like or dislike holding wealth in green assets relative to traditional assets. These attitudes are captured by a *convenience yield*, a positive or negative wedge between the contribution of a green asset's return to effective wealth and its financial returns. Second, households may like or dislike future states of the world in which the climate transition is faster than expected, and green equity does relatively well. These attitudes can raise or lower their effective wealth in these future states and thereby affect their future marginal utility which in turn creates a hedging demand for risky assets.

To capture convenience yields, we assume that the contribution 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. If $\theta^i > 1$, the household enjoys the green asset more and has a positive convenience yield. For example, the household may like investing in green assets because they provide financing for environmentally beneficial projects. In contrast, a household with $\theta^i < 1$ dislikes holding green assets even if they pay the same financial returns. Such a negative convenience yield could be, for example, politically motivated or rooted in concerns about greenwashing.

To model *hedging demands* for risky assets, we assume that the contribution of assets to effective wealth is multiplied by the random variable H^i which captures risks associated with the climate. In our model, these risks determine which equity funds perform better. The relevant risk factor is thus the return difference between traditional and green equity. We assume H^i is proportional to this climate risk:

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

where η_0^i and η_g^i are household-specific scalars. We choose the parameter η_0^i such that the expected value of H^i under the household's subjective belief equals one. As a result, the risk factor H^i only matters through its covariance with returns. A household with slope coefficient $\eta_g^i > 0$ dislikes states of the world with low excess returns on traditional equity. These states are bad for the household because they represent states in which effective wealth is low and marginal utility is high. The household can hedge this risk by purchasing more green equity funds, which amounts to a positive hedging demand for green equity. In contrast, a household with $\eta_g^i < 0$ dislikes states of the world with high excess returns on traditional equity. To hedge these bad states, the household can buy more traditional equity funds, creating a negative hedging demand for green equity.

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 subjective beliefs about risky asset returns and solves

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

where e_t, e_g denote the amounts invested into traditional and green equity, and b_t, b_g denote the amounts invested into traditional and green safe assets. Future utility is defined over effective wealth w_1 which depends on green convenience yields through the parameter θ^i and green hedging demands through the parameter η_g^i in equation (1). The first constraint is the budget constraint at date 0. The second constraint defines effective wealth at date 1. The third set of inequality constraints represents the short-sale constraints.

Solution. We derive the solution in detail in Appendix C.1. Here, we only summarize key properties relevant to 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 $\beta^i/(1+\beta^i)$ of initial wealth independent of either the distribution of returns or nonpecuniary tastes from assets. Intuitively, the household has log preferences over current consumption and the certainty equivalent of future effective wealth, which takes into account risk aversion as well as green taste. Any change in the effective return on an asset thus has offsetting income and substitution effects on consumption and does not alter the savings rate.

Another feature of the solution to the household problem is that it is optimal to invest in precisely one safe asset, and this choice is determined by the taste parameter θ^i alone. Since interest rates are deterministic, the green safe asset is strictly preferred if $\theta^i R_g^f > R_t^f$, while the traditional safe asset is strictly preferred if the inequality is reversed. The household is indifferent if effective returns on the two safe assets are the same. For given market rates R_g^f and R_t^f, we can therefore read off the safe asset choice from the parameter θ^i. We define $R^{i,f} = \max\{\theta^i R_g^f, R_t^f\}$ as household i individual-specific effective interest rate on an optimally chosen safe asset.

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

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

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

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

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

The first component ω_{mv} is the mean-variance benchmark, which describes the solution in the absence of convenience yields and hedging demands (i.e. $\theta^i = H^i = 1$) assuming the household invests in a traditional safe asset. The second component ω^i_{cy} is demand due to convenience yields θ^i of holding green assets. The third component h^i is demand that hedges the climate transition, as captured by the risk factor H^i. Every household's demand can be decomposed in this way but given short-sale constraints, the explicit formula depends on how many assets the household invests in.

We denote log returns on green and traditional funds by $r_g = \log R_g$ and $r_t = \log R_t$, and household i's subjective standard deviations of these log returns by σ^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 nonzero entry 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 the mean-variance efficient portfolio demand as

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

where B^i_g is a dummy variable equal to 1 if the household chooses a green safe asset and zero otherwise. This portfolio achieves the optimal risk-return trade-off. It depends only on risk aversion and the subjective distribution of excess returns. The household should locate on the efficient frontier and move closer to the safe asset if risk aversion is higher. For households who invest in a green safe asset ($B^i_g = 1$), the riskfree rate is r^f_g, while households who do not ($B^i_g = 0$) face the traditional riskfree rate r^f_t. The nature of the frontier depends on the set of assets the household invests in.

The demand due to convenience yields can be expressed as

$$\omega^i_{cy} = \log\theta^i T^i \left(e_2 - B^i_g \iota\right), \tag{6}$$

where e_2 is the second unit vector and ι is a vector of ones. This demand is nonzero only if the household has a nonzero convenience yield $\log\theta^i$. This decomposition clarifies how convenience yields change the incentives to take risk. For households who invest in a green safe asset ($B^i_g = 1$), a positive convenience yield $\log\theta^i > 0$ increases the effective riskfree rate. For such households, the convenience yield does not affect the expected excess return on the green equity fund but lowers that on the traditional equity fund, thus discouraging overall risk taking. For households who do not invest in a green safe asset ($B^i_g = 0$), in contrast, a positive convenience yield increases the expected excess return on green equity while leaving the expected excess return on traditional equity unchanged, overall encouraging risk taking.

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

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

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 measured by the return difference (1), i.e. the excess return on a long-short strategy in traditional and green equity.

The direction of portfolio reallocation due to hedging motives 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 future 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 potential future states of the climate transition. Conversely, households with $\eta_g^i < 0$ tilt their portfolio away from their mean-variance efficient portfolio towards traditional equity, which they perceive to hedge against low H^i.

6.2 Mapping Survey Responses to Model Primitives

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

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

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

Here, riskless investments earn the traditional interest rate. As we have shown, green bank accounts are still a niche market. Therefore, we calibrate to an initial equilibrium where households are unaware of their existence. Section 7 uses the fully quantified model to explore the effect of a widespread introduction of green bank accounts in counterfactuals.

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 the relative risk of green equity.

Household responses to our survey questions directly identify many parameters of our model.

Table 3 lists the 8 household-specific parameters. We divide the parameters into two groups. The top panel lists the parameters that we can directly measure from the survey data. In particular, when households report their 12-month expected return on a traditional or green equity fund, we interpret their answers as telling us their expected level returns. To relate these answers to the moments of log returns, we use that $\log E^i\left[R_t\right] = E^i\left[r_t\right] + \frac{1}{2}{\sigma_t^i}^2$ and $\log E^i\left[R_g\right] = E^i\left[r_g\right] + \frac{1}{2}{\sigma_t^i}^2{\lambda^i}^2$, respectively. We directly observe the interest rate $R_t^f = \exp(r_t^f)$ that households expect to receive on their deposits over the same 12-month horizon as the equity-fund investments.[15] Taken together, these answers pin down the vector of households' expected excess returns μ^i in equation (8). We further use households' convenience yields on green deposit accounts to identify their taste parameter $\log\theta^i$.

Table 3: Household Parameters

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

The bottom panel in Table 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 combined with data on households' survey responses regarding their beliefs, hypothetical choices, and actual portfolio positions. We note that we cannot separately identify risk aversion and the scale of subjective risk. Given our assumption on preferences, doubling risk aversion generates the same risk tolerance matrix T^i and thus household behavior as doubling all subjective variances. We scale all variances by the variance of traditional equity and infer only the product $\gamma^i{\sigma_t^i}^2$ that captures households' overall *risk sensitivity*.

Inference of risk parameters. To identify the risk parameters in the bottom panel of Table 3, we proceed in three steps. We first use combined data from the November 2021 and May 2022 waves of the survey to estimate the vector of portfolio weights ω^i for each household. Second, we use survey responses on households' relative risk rankings and hypothetical portfolio decisions to obtain inequality constraints on the risk parameters. Together with equations that relate *observed* portfolio

[15]The survey asks the question: "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."

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, but a detailed description is in Appendix C.

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

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

$$\begin{aligned}
\omega_t^i + \omega_g^i \quad &= \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\mu_t^i + \frac{\mu_g^i + \log\theta^i}{{\lambda^i}^2} - \rho^i \frac{\mu_t^i + \mu_g^i + \log\theta^i}{\lambda^i}\right), \\
\omega_g^i \quad &= \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\frac{\mu_g^i + \log\theta^i}{{\lambda^i}^2} - \frac{\rho^i \mu_t^i}{\lambda^i}\right) + h_g^i.
\end{aligned} \tag{10}$$

Our second step derives additional inequality constraints on the risk parameters. The first inequality constraint comes from households' ranking of the risk of green equity relative to traditional equity. Households rank the relative green risk on a discrete scale from "much lower" to "much higher". The ranking restricts the ratio λ^i of the standard deviations of green returns relative to traditional returns. If households view green equity as relatively "riskier" or "much riskier" than traditional equity, then we restrict λ^i to be greater than 1. Conversely, we restrict λ^i to be less than 1 if households view green equity as relatively "safer" or "much safer". For households who view the risk of the two types of equity as similar, we restrict λ^i to be close to 1 (more precisely, between 0.9 and 1.1).

We derive a second inequality constraint from households' hypothetical asset choice. As described in Section 5.1, we ask households whether they would place an extra amount of savings from income in a green or a traditional equity fund. This question implies bounds for the hedging component of portfolio demand, which go beyond the information implied by the optimal portfolio choice. We show in Appendix C.2 that, given our assumptions on preferences, households who are at an interior optimum for portfolio choice will always answer consistently with this ranking, independently of the specific amount of money the households are considering. For households who are not at an interior optimum, we interpret the household's answer as ranking an equity portfolio that is all green to one that is all traditional.

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

$$\mu_g^i + \log\theta^i - \frac{1}{2}\gamma^i {\sigma_t^i}^2 {\lambda^i}^2 + \gamma^i {\sigma_t^i}^2 h_g^i \lambda^i(\lambda^i - \rho^i) > \mu_t^i - \frac{1}{2}\gamma^i {\sigma_t^i}^2 + \gamma^i {\sigma_t^i}^2 h_g^i(\rho^i\lambda^i - 1). \tag{11}$$

Intuitively, if beliefs are such that mean-variance efficient portfolios favor traditional equity, the hedging motive must be strong enough (h_g^i large enough) to justify the observed choice of green. For a household who chooses traditional, the inequality flips. Appendix C.2 derives these results.

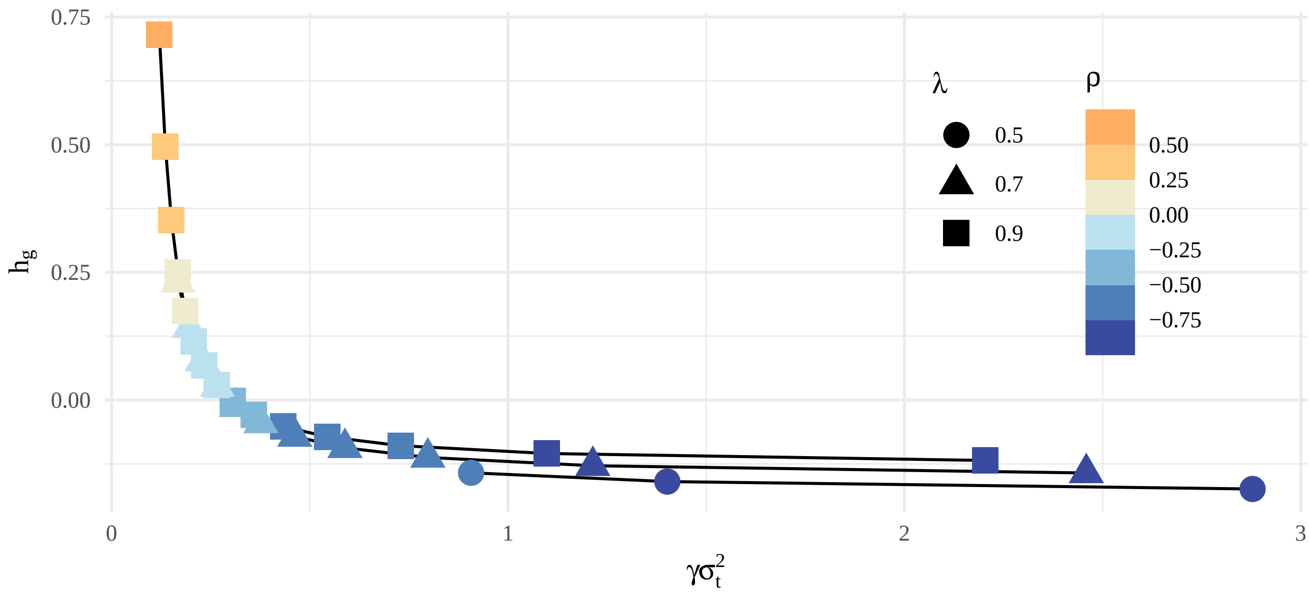
The first two steps of the procedure result in a set of possible parameter values for each household. Our third step chooses a particular vector of parameter values from this set by shrinking parameters towards homogeneity. More specifically, we select parameter values that minimize an objective function that penalizes deviations of the parameters from a common baseline set of values. The idea here is to start from a baseline of homogeneity, motivated by historical parameter values, and allow for heterogeneity only if the data demand it. As baseline values for hedging demand and the risk ranking, we choose zero and one, respectively. These values would apply in a world where households do not distinguish green and traditional assets. For the correlation coefficient, we choose a high baseline value of 90% that reflects the close historical comovement of traditional and green equity fund returns estimated by Berk and van Binsbergen (2021). Formally, given data on portfolio weights, expected returns and convenience yields, we choose the risk parameters for every household to minimize

$$\left(h_g^i\right)^2 + \left(\rho^i - 0.90\right) + \left(\lambda^i - 1\right)^2 \tag{12}$$

subject to two portfolio formulas (for the overall risky portfolio share and the portfolio share on green equity funds) and two inequality constraints (a bound for the relative green risk λ^i and a bound for hedging demand (11).)

Intuition for identification. Steps one and two of the procedure result in a set of possible parameter values for each household. Figure 5 illustrates this set for a particular household. The household holds both green and traditional equity funds (with portfolio weights described in equations (10)), chooses green in the hypothetical choice question (implying that inequality (11) holds), and believes the green equity fund is dominated (i.e., the household expects lower returns and more risk from the green fund.)

Figure 5: Illustrating the role of individual parameter values



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

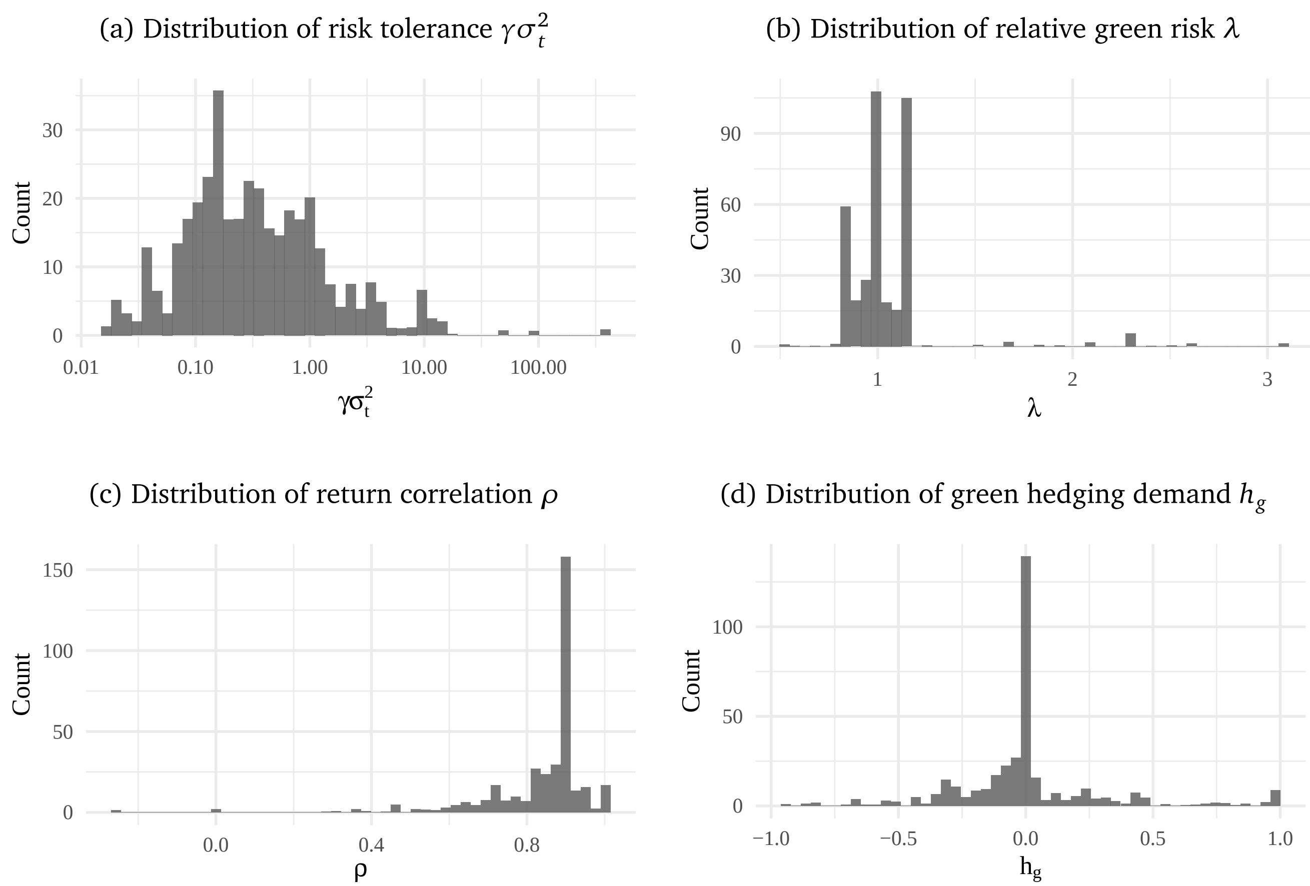
The household's perceived correlation ρ^i of returns is crucial for portfolio choice because it governs the degree of substitutability between green and traditional equity funds. When the correlation is low, traditional equity funds cannot be easily substituted for green equity funds. When the correlation is negative (as in the blue circles, triangles, and squares in Figure 5), diversification provides a strong motive for holding both equity funds, even if one of them is dominated. In the equation that determines the green portfolio weight (10), the negative correlation pushes up the green expected return. The diversification motive is strengthened further when the household has high risk sensitivity, measured on the horizontal axis. At the same time, low correlation and high risk sensitivity lower the household's hedging demand h_g^i for green equity in equation (7) along the vertical axis. When the correlation is positive (as in the orange squares), diversification is a weaker motive for holding both assets. To explain why the household chooses a dominated fund, hedging demand must be strong (high on the vertical axis), which requires low risk sensitivity.

By shrinking the parameter values towards homogeneity, the algorithm chooses among these various explanations for the household's observed choices. In particular, the algorithm finds it more plausible that the household views the green and traditional equity funds as quite substitutable, as they have been in historical data. A positive correlation coefficient ρ^i weakens the diversification motive and thereby pushes the estimation towards a positive hedging demand h_g^i for green equity funds and lower risk sensitivity $\gamma^i {\sigma^i_t}^2$.

Distribution of estimated household parameters. The estimation reveals that substantial heterogeneity is necessary to explain the observed household choices. Figure 6 shows the cross-sectional distribution of risk tolerance, relative green risk, correlation coefficients, and green hedging demands. While there is substantial heterogeneity in these parameters across households, the range of values is quite reasonable and in line with standard estimates. Risk sensitivity, defined as the product of risk aversion and the variance of the traditional fund, mostly sits between .1 and 1. For a coefficient of risk aversion of 10, a typical number in quantitative models with portfolio choice, the corresponding range of standard deviations for annual returns is between 10% and 32%, hence bracketing typical historical estimates. Typical estimates of relative green risk λ^i range between .8 and 1.2, so the perceived volatility of green funds is within 20% of that for traditional funds.

The distribution of hedging demands in Figure 6(d) has a wide support ranging from -100% to

Figure 6: Cross Sectional Distribution of Household Parameters



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

(b) Distribution of relative green risk λ

(c) Distribution of return correlation ρ

(d) Distribution of green hedging demand h_g

100%, with a mass at zero. These estimates are mostly guided by households' answers to the hypothetical investment question. We have already seen that the distribution of green convenience yields in Figure 2 also has a wide support. These estimates were taken directly from the hypothetical green bank account question. Together, these distributions of preference parameters will imply that households choose optimal individual portfolio holdings that differ from the mean-variance benchmark.

When considering the full set of estimates in Table 3 and other household characteristics, a few key values are correlated with each other. Households for whom climate is a top concern have a 60 bp green convenience yield, while other households have a −44 bp convenience yield. Households with a higher green convenience yield are more optimistic about green equity funds; the correlation between $\theta^i - 1$ and their perceived greenium is −36%. Households with higher green hedging demand tend to have lower expected green returns and tend to perceive green equity to be riskier; the correlation between h_g^i and their perceived greenium is 25%, while the correlation between h_g^i and λ^i is 56%.[16] There are no other significant correlations between our estimated parameters. Table 4 below shows how parameters vary across household groups with different market participation patterns and portfolio strategies.

6.3 Equilibrium

We now add a supply side, define equilibrium, and explain how we perform counterfactuals. We are particularly interested in how shifts in asset demand, for example, driven by changes in taste parameters or beliefs, alter equilibrium asset prices and aggregate investment. Equilibrium responses to demand shifts depend on the elasticity of supply: typically, prices move less and quantities move more when supply is more elastic. We consider two scenarios that we use below to understand different counterfactuals: perfectly elastic supply and fixed supply.

Equilibrium with elastic equity supply. For our elastic supply scenario, we assume that the supply of equity and the riskfree asset is perfectly elastic at current prices. Consider an economy with linear technology and no adjustment costs to capital. In such an economy, the value of the stock market equals the quantity of capital (which trades at a price of one), and beliefs about returns correspond to beliefs about the marginal product of capital. Any counterfactual change in aggregate demand modifies the financing conditions of firms and the financial industry, which respond by offering more or less green capital. The demand changes thus affect aggregate investment and the quantity of assets in the counterfactual. This perspective captures the medium-term response of asset markets to demand shifters and provides an upper bound on the near-term quantity impact.

[16] This last correlation is informed by households' survey answers to the hypothetical investment question. From Figure 4 we know that hypothetical choices that deviate from the mean-variance benchmark and thus reflect hedging demand are often for the equity fund that households perceive as riskier.

Formally, we can study equilibrium with elastic supply by computing how households' portfolio weights respond to changes in demand parameters. Elastic supply pins down equity prices at one in the counterfactual. Our model further takes as given the initial distribution of wealth across households. Since we have assumed an intertemporal substitution elasticity of one that makes the savings rate independent of beliefs, savings are proportional to initial wealth. Since utility is homothetic, we can normalize aggregate savings or initial wealth. For convenience, we set aggregate savings to one and denote the share of household i's savings by s^i. An *asset market equilibrium with elastic equity supply* then consists of an allocation of savings to the riskfree asset and the two equity funds.

In equilibrium, aggregate investment is given by the wealth-weighted sum of portfolio weights. To clarify the contribution of different features of individual behavior, we start from the decomposition (4) of individual weights and find the aggregate portfolio weights

$$\bar{\omega} = \sum \frac{s^i}{\bar{s}} T^i \mu^i + \sum \frac{s^i}{\bar{s}} T^i \log \theta^i e_2 + \sum \frac{s^i}{\bar{s}} h^i, \tag{13}$$

where e_2 is the second unit vector. With fixed asset prices, the counterfactual changes in aggregate demand (for example, the absence of convenience yields θ^i or hedging demands h^i, or higher expected excess returns on green equity μ_g^i) represent changes in expected asset payoffs. Given the same distribution of savings, we recompute aggregate investment with the newly expected asset payoffs. Importantly, we recompute the households' optimal portfolios not only on the intensive margin but also along the extensive margin. This is critical because the counterfactual parameters may affect households' decisions to participate in certain asset markets.

For the baseline equilibrium, we evaluate the various components of aggregate demand (13). The aggregate portfolio weights are 26.4% for traditional equity and 6.9% for green equity. The biggest contribution to aggregate demand is from its mean-variance component: 24.9% for traditional and 7.7% for green equity. While deviations from the mean-variance benchmark are small on aggregate, they are large at the individual level. To understand the substantial heterogeneity across households, Table 4 reports wealth-weighted averages of household parameters for equity holders. Equity holders represent 43% of households and own the majority of aggregate household wealth. Their average green convenience yield is positive but tiny (1bp), and their green hedging demand is −3 pp. The small deviation of aggregate demand from the mean-variance benchmark can be traced to this *negative green hedging demand*. Their average expected return on traditional equity is roughly 1pp higher than on green equity, reflecting a positive greenium.

Only a tiny group of households, 4% of the population with not much wealth, have an all-green equity portfolio and are more concerned about climate change. All characteristics of this group support green equity investments: a high convenience yield, positive hedging demand, and a negative greenium. Roughly half of equity holders hold some green equity. This group includes households with all-green equity portfolios. Equity holders who hold some green equity are slightly wealthier than households who only hold traditional equity. Moreover, green equity holders are, on average, more concerned about climate change than traditional equity holders but less so than households with all-green equity portfolios. Green equity holders have a positive green convenience yield, while traditional equity holders have a negative convenience yield (24bp versus −24bp). The magnitude of the average green convenience yield in the all-green subgroup is more than twice as large compared to green equity holders. Among green equity holders, there is large heterogeneity in hedging demands and expected returns. Their average green hedging demand is negative, −5pp, but the all-green subgroup has a strong positive hedging demand. Their average greenium is negative but tiny. Traditional equity holders are the most pessimistic about green equity.[17]

Table 4: Household Heterogeneity by Portfolio Choice

	Equity Holders	All Green	Green Holders	Traditional Holders
Population Share	0.43	0.04	0.21	0.22
Wealth Share	0.74	0.06	0.38	0.36
Climate Top Concern	0.43	0.62	0.51	0.34
Green Convenience Yield	0.0001	0.0058	0.0024	−0.0024
Green Hedging Demand	−0.0316	0.0853	−0.0532	−0.0087
Greenium	0.0114	−0.0152	−0.0003	0.0237

Equilibrium with fixed equity supply. Our other scenario holds the supply of equity shares fixed, as in a Lucas tree economy. Consider an economy with two types of trees that each promise some fixed payoffs. In such an economy, the price of the tree is the present value of payoffs. Fixed supply, by definition, means that payoffs do not respond to changes in demand. With constant quantities of trees, all adjustments in tree values are due to price changes. This perspective helps distinguish the role of different demand parameters for the pricing of green and traditional assets.

Formally, computing equilibrium in this scenario finds market-clearing prices given payoff expectations, as in the quantitative temporary equilibrium approach in Landvoigt, Piazzesi and Schneider (2015) and Leombroni, Piazzesi, Rogers and Schneider (2021). While we fix equity supply, we continue to assume that the safe asset is supplied elastically at the interest rate r^f. This assumption is motivated by Germany's integration into the world market for safe assets. We also continue to

[17] Since convenience and hedging will lead to deviations from mean-variance efficient portfolios, these findings are consistent with those in Giglio, Maggiori, Stroebel, Tan, Utkus and Xu (2023) who document that investors' expected returns cannot explain their portfolio choices. Moreover, the wide range of hedging demands is consistent with the survey results in Stroebel and Wurgler (2021) which indicate strong disagreement among professional investors about whether green investments have high payoffs in good or bad states of the world. Their findings suggest that more investors believe that green investments have high payoffs in good states, consistent with negative hedging demand on average.

work with a fixed distribution of savings. In a tree economy, where prices adjust, this assumption is restrictive: it is accurate only if initial wealth is entirely price inelastic, for example, because it consists only of labor income or safe assets. In principle, demand might respond to prices because of wealth redistribution. Robustness checks suggest that such effects are relatively small in our context compared to the direct effects of prices on return expectations.[18]

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

To write an intuitive formula for equilibrium prices, it is helpful to define $\bar{T} = \sum_i T^i s^i / \bar{s}$ as the wealth-weighted average of household risk tolerance matrices T^i. We note that while individual T^is are singular when a household invests in only one risky asset, average risk tolerance $\bar{T}$ is invertible as long as one household invests in both risky assets (which is true in all scenarios we consider.) Rearranging the equation for aggregate investment (13) and using the definition of the expected excess return (8), the vector of equilibrium log equity prices is then

$$\log P = -r_t^f \iota + \sum \frac{s^i}{\bar{s}} \bar{T}^{-1} \left(T^i \left(E^i [\log D] + \frac{1}{2} \operatorname{diag} \Sigma + \log \theta^i e_2 \right) + h^i \right) - \bar{T}^{-1} \bar{\omega}, \tag{14}$$

where ι is a vector of ones.

Equilibrium prices reflect weighted averages of individual households' expected payoffs as well as their compensation for risk and taste. The interest rate expression $-r_t^f \iota$ discounts the expected payoffs $E^i[\log D]$ (including a Jensen's inequality term) weighted by households' relative wealth $s^i / \bar{s}$ and risk sensitivity $\bar{T}^{-1} T^i$. If all households have the same risk sensitivity (e.g., they have the same risk aversion coefficient and covariance matrix), we get the identity matrix, $\bar{T}^{-1} T^i = I$, and equilibrium prices reflect a wealth-weighted average of discounted expected payoffs. The expected payoffs are shifted by convenience yields θ^i and hedging demands.

[18] 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.

The risk premium, which is the last term in equation (14), reduces the price. If households have the same risk sensitivity, it takes the familiar form $\gamma\Sigma\bar{\omega}$: risk aversion multiplied by the covariance of the trees with the market portfolio $\bar{\omega}$. If all households are risk-neutral, the risk premium is zero. With heterogeneous risk tolerance, what matters is the wealth-weighted average risk tolerance, again giving more weight to richer households who take larger positions. We emphasize that it is important for the pricing equation that the utility function 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.

The role of relative risk sensitivity $\bar{T}^{-1}T^i$ is understood most easily in the special case when all households believe that payoffs are uncorrelated, so the matrices T^i and $\bar{T}$ are diagonal. In this case, the valuation of traditional equity is independent of the expected payoffs from green equity and vice versa. The weight on household i's expected traditional equity payoffs is simply the inverse ratio of household i's risk sensitivity $\gamma^i {\sigma_t^i}^2$ divided by the wealth-weighted harmonic mean of all households' risk sensitivities. Households expected payoffs thus carry greater weight if they tolerate more risk and take a bolder position in the equity market.

More generally, the valuation of the two assets is interdependent if households perceive payoffs to be correlated. For example, traditional equity is worth less if green equity offers a close substitute (a highly correlated risk) about which the household is more optimistic. This is why in general the matrix $\bar{T}T^i$ of weights is not diagonal: expected green payoffs also matter for the valuation of traditional equity and vice versa. Again, both households' relative wealth and their relative risk tolerance matter for the degree to which their views are incorporated into the price.

Consider now a change in the environment, such as a change in preferences or payoff expectations. The optimal policy derived from the objective function (3) delivers portfolio weights for any belief about returns. Given households' payoff expectations, we can derive these beliefs about returns $R_j = D_j/P_j$ for any candidate equity price vector P and obtain the optimal portfolio weights. To get the aggregate excess demand function for equity, we sum over all individual equity demands and subtract the value of aggregate equity supply $(P_t\bar{\omega}_t, P_g\bar{\omega}_g)^\top$. We can then find equilibrium equity prices that make investors willing to hold the fixed supply given their new demand parameters, including expectations of asset payoffs.

For changes in the environment that alter preference parameters and not expected payoffs, we can interpret any difference between equity prices in the counterfactual equilibrium and the baseline equilibrium as a change in the risk premium. Indeed, consider an econometrician who observes data from our model and measures the expected excess returns. The econometrician measures conditional expected log 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 payoffs, 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.

7 Counterfactuals: the Impact of Green Investing Today

How did the rise of sustainable investing affect asset prices and aggregate investment? We now perform a series of counterfactuals to answer this question. In particular, we compare the impact of two new market forces. Section 7.1 considers the importance of convenience yields and hedging demands. We shut each of these features down in counterfactuals, maintaining a setting in which households invest in two distinct equity funds given their return expectations measured from the survey. Section 7.2 takes into account that a distinction between green and traditional is itself a novel feature of investing. Until recently, households did not pay attention to that distinction. We therefore perform a counterfactual where households invest in a single type of equity given their return expectations. We analyze these changes in asset demand with different supply scenarios.

7.1 The Importance of Convenience and Hedging

Our first set of experiments studies the role of convenience yields θ^i and hedging motives h^i. We shut down each of these elements and recompute equilibrium. We do this for both supply scenarios introduced in the previous section. Table 5 summarizes the results. Panel A characterizes the initial equilibrium and hence provides a baseline for all counterfactuals. Panels B and C present results under elastic and fixed equity supply, respectively. The first two rows in Panel B and C show how asset markets would change absent convenience yields and hedging motives. The first two columns show percentage changes in the value of equity. The final three columns show how the population of green investors changes in these scenarios.

Consider first the elastic equity supply scenario. Absent green convenience yields (first row of Panel B), household demand for green equity is more than 10 percent higher, while demand for traditional equity is half a percent lower. Similarly, when households lack hedging motives, demand for green equity is more than 20 percent higher, while demand for traditional equity is 7.5 percent lower. The presence of convenience and hedging thus make green investment substantially *smaller* than it would be otherwise. Relating these changes to the initial equilibrium (in Panel A) implies that counterfactual aggregate investment in green equity *increases* by roughly 1pp of total household wealth without convenience yields and by 1.5pp of total household wealth without hedging motives.

Table 5: Counterfactual Results

	equity value/wealth		green investor population		
	traditional	green	wealth share	$E[\log D_g / D_t]$	weight ω_g
Panel A: Initial equilibrium	.26	.07	.38	.00	.18
Panel B: Elastic equity supply	% change in quantity				
no convenience yields	−0.5	+13.3	−.06	+.01	+.07
no hedging motives	−7.5	+21.9	0	+.01	+.05
info treatment	−21.9	+81.0	+.06	+.02	+.18
Panel C: Fixed equity supply	% change in price				
no convenience yields	0.1	+0.4	−.09	.00	+.06
no hedging motives	−0.2	+0.5	−.08	+.01	+.05
one tree	−0.7	−1.4		0	
info treatment	−0.1	+2.9	−.15	+.03	+.09
Panel D: Green safe asset	% change in equity		value/wealth		
(elastic equity supply)	traditional	green	green safe assets	all safe assets	green assets
$r_t^f - r_g^f = .01$	−0.5	−1.3	.15	.62	.23
$r_t^f - r_g^f = .005$	−1.1	−3.1	.29	.62	.37

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

Now turning to the scenario with fixed supply (first row of Panel C), shutting down either convenience or hedging increases the price (and hence decreases the premium) of green equity by roughly 40-50bp while lowering the price (and increasing the premium) of traditional equity by 10-20bp. These equity price changes push the return premium for green equity down by 40-50bp, while pushing the premium for traditional equity up by 10-20bp. Without convenience and hedging, the cost of capital of a green firm selling a marginal new equity tree is thus 70bp lower than that of a traditional firm.

Why do convenience and hedging *lower* the value of green equity? The broad theme that hedging demand holds back green investment already appeared in Table 4. The effect here is larger because portfolio demand is a nonlinear function of these parameters due to short-sale constraints. While the demand decomposition (13) shows how the intensive margin depends on θ^i and h^i for every household, the counterfactual in Table 5 recomputes the optimal portfolio, including along the *extensive margin* of whether or not the household chooses to participate in green equity. In this experiment, households who have positive convenience yields or hedging demands for green equity but who do not have high green return expectations reoptimize and exit the green market in the counterfactual. At the same time, households with negative convenience yields or hedging demands but who are quite optimistic about green equity choose to enter the green market in the counterfactual and may be willing to take on substantial stakes.

Columns 3-5 of Table 5 illustrate this effect. We consider the share of total savings by participants in green equity markets, the difference in (wealth-weighted) subjectively expected log payoffs $\log D_g/D_t$ by these participants, and finally their average portfolio weight on green equity. The top line shows levels in the initial equilibrium. For each exercise, we then report the change due to reoptimization. With fixed supply (Panel C), for example, shutting down convenience yields lowers the wealth share of green investors by 9pp, but green investors in the counterfactual have a 6pp higher portfolio weight on green equity. Eliminating hedging motives does not change the wealth share of green investors, but make the average (wealth-weighted) green investor perceive a 1pp higher payoff on green equity and hence choose a 5pp higher portfolio weight.

Qualitatively, the same effects occur with elastic supply. Higher optimism among green market participants is the key driver of higher green equity valuations in this counterfactual. As the price of green equity is bid up, the least optimistic households exit the green market. This results in an even more optimistic population of households who participate in the green market, so the price—and hence the value—of green equity in the counterfactual goes up.

7.2 The Role of Attention

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

In the counterfactual economy, households invest in only one tree that subsumes all stocks. We assume that household beliefs about returns on this single tree are given by their current beliefs about the traditional equity fund.[19] The idea is that households who do not distinguish between green and other equity treat all equity as traditional. We further shut down convenience yields and hedging demands, as in the previous exercises. The portfolio choice problem in the counterfactual economy is thus simpler than in our baseline: households now only choose the weight on a single risky tree, as opposed to a vector of weights for the two equity funds. We denote by P_1 the price of the single tree in the counterfactual equilibrium. Retaining the normalization from the previous section, the total number of shares of the single tree is $\bar{\omega}'\iota$, the sum of the green and traditional tree shares in the baseline. The value of the stock market in the counterfactual is $P_1\bar{\omega}'\iota$, so the effect of attention allocation on the aggregate market is given by $(1-P_1)\bar{\omega}'\iota$ as equity prices are normalized to one in the baseline.

Consider now the effect of attention allocation on relative prices. A key difference to the previous section is that investors in the counterfactual here treat green and traditional equity as perfect substitutes. Since the two funds are identical copies of each other, the demand for individual funds is indeterminate. The relative value of green funds in the counterfactual equilibrium follows from supply: it depends on the share of payoffs on the single tree paid by green firms. We denote the vector of the payoff shares by α^p and hold it fixed when moving from the initial to the counterfactual equilibrium. The interpretation is that the same firms issue the same claims to future payoffs—the only difference is that investors treat them just like traditional equity. In the counterfactual equilibrium, where all equity trades at the same price, the total value of green equity is therefore $\alpha^p_g\bar{\omega}'\iota$. We emphasize that the payoff share α^p_g of green equity is generally different from the market share of green equity in the initial equilibrium, defined by $\alpha^m_g = \bar{\omega}_g/\bar{\omega}'\iota$, because the market share is also determined by features that are not directly payoff-related, such as convenience yields.

We estimate the payoff shares α^p in the initial equilibrium from households' average expected payoffs. Here we use the fact that we know every household's expected payoffs for the two trees. Since we have normalized the price of trees in the initial equilibrium to one, the aggregate portfolio weights $\bar{\omega}$ represent the number of available trees. Multiplying by an individual household's expected return thus delivers the household's expected aggregate payoffs from traditional and green firms. For example, $E^i[R_g]\bar{\omega}_g$ is what household i expects the green sector of the economy to pay out. This expected payoff share can be high because either (i) green trees are a large part of the economy or (ii) the household is relatively more optimistic about green trees. While households can disagree in their optimism about green trees, we assume that the wealth-weighted average expected payoffs reflect the size of the green sector of the economy.

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

Formally, we measure the green payoff share

$$\alpha_g^p = \frac{E[R_g]\bar{\omega}_g}{E[R_g]\bar{\omega}_g + E[R_t]\bar{\omega}_t} = .2001, \tag{15}$$

where expectations are taken under the wealth-weighted average belief of equity investors. If average expected returns of the two trees were equal, we would obtain a payoff share equal to the market share in the initial equilibrium, $\alpha^p = \alpha^m$. In the survey data, however, average expected returns on green equity are below those on traditional equity, so its estimated payoff share is lower than its market share. Intuitively, green equity has a higher market share because optimistic households push up its equilibrium price and thereby lower its expected return.

Consider now the change in the value of the trees from the baseline to the counterfactual. In vector form, these changes are $P_1\alpha^p\bar{\omega}'\iota - \bar{\omega}$. Dividing by the values $\bar{\omega}$ in the baseline equilibrium, we can write the percentage changes in the values of green and traditional trees as $P_1\alpha_g^p/\alpha_g^m - 1$ and $P_1\alpha_t^p/\alpha_t^m - 1$, respectively. With fixed supply, these changes in value reflect price changes. If investors in the initial equilibrium treat the trees as identical, so $\alpha^m = \alpha^p$, then the prices of the two trees change by the same percentage, given by $P_1 - 1$. More generally, the percentage change in the price of green trees is smaller than that for traditional trees if and only if $\alpha^m > \alpha^p$. Intuitively, when the market share of green trees in the baseline equilibrium is higher than the payoff share, the price of green trees should drop relatively more once households stop paying attention to tree color and only value trees for their payoffs.

The third row of Panel C in Table 5 reports the difference between the value of equity in the counterfactual versus the initial equilibrium. The counterfactual price is $P_1 = .992$, which implies that both price changes are negative. In the counterfactual economy, the value of green equity is 1.4 percentage points lower, while the value of traditional equity is 70 basis points lower. Since this calculation holds expected payoffs fixed, we can conclude that sustainable investing reduced the premium of green equity relative to the safe interest rate by 1.4 percentage points. It has also reduced the premium of traditional equity but by a smaller amount. Sustainable investing has thus opened up a 70 basis point greenium. The table further shows that the rise of sustainable investing boosted the stock market overall. Indeed, the counterfactual equity market trades $0.70(1-\alpha) + 1.4\alpha = 84$ basis points below the baseline equilibrium, so the equity premium is 84bp higher.

As we have seen, these effects are not due to a shift in convenience yields or hedging demands, which actually hold down the value of the green fund.[20] Instead, the price movement reflects the fact

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

that investors have become aware of the distinction between green and other equity and now think they are imperfect substitutes. Relative to the counterfactual equilibrium, where the distinction is shut down, prices in the initial equilibrium reflect a clientele of enthusiastic investors who sort into holding green equity. This has two effects. On the one hand, demand for green equity drives up its price. On the other hand, as green investors invest less in traditional equity, they matter less for prices in that market, which increases traditional equity prices as well. Short sale constraints reinforce this effect as investors who strongly prefer green leave the traditional market altogether. The overall effect of attention is to increase the demand for green equity so much that it more than offsets the dampening effect of green taste.[21]

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 for the latter is an RCT from the survey that measures the effect of information on expected returns.

8.1 Introduction of a Green Safe Asset

As we have seen in Section 4, households are willing to give up substantial interest-rate spreads in order to invest in green bank accounts. Figure 3 already suggested that household demand for green deposits is strong. In our model, green and traditional safe assets may pay different interest rates. The introduction of a green safe asset can thus have a large effect on green investment overall. However, it is not clear from the earlier analysis whether the availability of green safe assets will adversely affect the green equity market. In the baseline equilibrium without a widely available green safe asset, households with high green convenience yields have an incentive to take risk and select into green equity, on which they effectively perceive higher expected excess returns. Once green safe assets are available, the green convenience yield applies to both safe and risky green assets and thereby lowers the effective expected excess returns on green equity, as we can see from the equation for risky asset demand (6).

We perform two exercises that vary the available quantity of green safe assets. Since safe assets are perfect substitutes, there is a 1-1 relationship between quantity and interest rate independently

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

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

The takeaway from this counterfactual 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 high green convenience yields 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 basis points are minor relative to the large equity premia most households expect. Overall, green investment, reported in the last column, increases with more green 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. In fact, there are already signs the market for green bank accounts is in transition, with major nationwide banks announcing plans to provide green bank accounts to a broad audience. For example, Deutsche Bank is offering a green bank account for corporate clients (per a press release on March 31, 2021). ING has announced plans to launch a green bank account for retail clients (per press conference on February 3, 2023).

8.2 Information about the Potential of Green Investing

Another consideration for the future of green finance is that many households may not be well-informed about green investment products. As climate change becomes more tangible, firms, governments, and international institutions are devoting more resources to address the challenges (see, e.g., Krueger, Sautner and Starks 2020; Stroebel and Wurgler 2021; van Benthem, Crooks, Giglio, Schwob and Stroebel 2022). Asset managers are increasingly promoting green financial products. To assess the likely impact of providing more information, we included an RCT in our survey designed to make the potential of sustainable investing for the green transition more salient to households. We used the RCT's results to design an additional counterfactual.

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

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

Since the treatment informs households of the potential for green investment to make a difference in the climate transition, it is plausible that the treatment effect differs depending on how concerned a household is about the climate transition. This motivates measuring not only an overall average treatment effect but also studying whether the effect depends on whether households care about climate change. The survey provides a measure of concern about climate change by asking respondents to rank the top issues facing Germany: climate change, the COVID-19 pandemic, the economy, and refugees. The questionnaire asks this question before the information treatment. We say that households are *concerned* if they rank climate as one of their number one issues in response to this question.

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 received the treatment and zero otherwise, as well as on the interaction of the treatment indicator with a concern indicator C_i equal to one if the household mentioned climate as a top issue facing Germany and zero otherwise:

$$Y_i^{post} = \alpha + \beta_1 X_i + \beta_2 X_i C_i + \phi W_i + \epsilon_i. \tag{16}$$

The coefficient β_1 thus measures the average treatment effect for respondents not concerned about the climate relative to the control group (α). The coefficient β_2 on the interaction term measures the effect for concerned respondents compared to unconcerned respondents in the same treatment group. We also include a vector of controls W_i that contains the concern for climate change indicator, C_i, a dummy indicating whether the respondent holds the asset in question, and other demographic, income, and wealth characteristics.[22]

Table 6 considers two post-treatment outcomes Y_i^{post}. The first two columns report results for the subjective expected excess return of green over traditional equity $E^i[R_g] - E^i[R_t]$ by household i. For the third and fourth columns, the outcome is the interest-rate spead that the household is willing to give up for a green deposit account. For each outcome, we first present the overall average treatment effects without interaction term, and then the treatment effects interacted with being concerned. We highlight two controls: i) individuals for whom climate is a top concern perceive higher green

[22] Due to the random assignment of the treatment groups, the control term $\phi \mathbf{W_i}$ is close to orthogonal to the treatments and mainly increases the estimates' precision.

expected excess returns and have a roughly 0.6 percent higher convenience yield, and ii) for each outcome, we show the effect of a dummy indicating that the household actually holds the asset in question. We find, reassuringly, that households who own green equity expect a more than two percent higher excess return on green equity. Moreover, households who own green deposits are willing to give up more than one percent for that account.

There are two main takeaways from the RCT. First, explaining the potential of green finance makes households relatively more optimistic about the returns on green equity. On average, treated respondents expect 1.6% more returns from green equity in column (1). Moreover, this effect is entirely driven by households most concerned about climate change who expect close to 4% more returns in column (2). Second, the information also tends to raise the convenience yield on green deposits. While the average effect in column (3) is small and insignificant, zooming in on the group of concerned households again reveals a significant effect of about 42bp in column (4). We conclude

Table 6: Information Treatment about Potential of Green Investing

	Dependent variable:			
	Expected Excess Green Returns		Green Convenience Yield	
	(1)	(2)	(3)	(4)
Potential of Green Investing	1.607**	−0.523	−0.083	−0.283***
	(0.624)	(0.927)	(0.062)	(0.086)
Climate Top Issue	2.182***	1.182*	0.565***	0.453***
	(0.576)	(0.658)	(0.058)	(0.067)
Potential of Green Investing × Climate Top Issue		3.876***		0.415***
		(1.252)		(0.124)
Green Equity Fund	2.330***	2.293***		
	(0.606)	(0.604)		
Green Deposit Account			0.296**	0.292**
			(0.130)	(0.130)
Demographic Controls	✓	✓	✓	✓
Income/Wealth Controls	✓	✓	✓	✓
Observations	1,289	1,289	2,484	2,484
R^2	0.083	0.089	0.159	0.163

Note: This table reports the effects of the information treatment about the Potential of Green Investing. 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 -20% and 20% which corresponds to the 10th and 90th percentile of the return distributions. *p<0.1, **p<0.05, ***p<0.01.

that more information makes concerned households more optimistic about green equity and willing to give up higher interest-rate spreads for green deposits.

What are the quantitative macro implications of these estimated effects of information? We now use the regression results from Table 6 to perform a counterfactual that increases expected returns on green equity for all concerned households in the population by 4%. We perform the exercise with both elastic and fixed supply of equity, reported in the third row of Panel B and the fourth row of Panel 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 asset payoffs.

The quantitative effect of making the potential of sustainable investing salient to concerned households is large because these households dramatically increase their demand for green equity. We obtain either large quantity effects, in the case of elastic equity supply, or large price effects, in the case of inelastic equity supply. The right-hand columns of Table 5 show the role of adjustment along the extensive and intensive margins of green equity. With elastic supply, both move in the same direction: the pool of participants in green equity markets now has a larger wealth share and also a larger green portfolio weight. As a result, the quantity of green equity almost doubles. With fixed supply, concerned households drive up the price of green stocks. As a result, there is significant exit from green investing, as indicated by a lower wealth share of green investors. However, the optimism of the newly informed investors more than makes up for these losses, as the price increases by almost 3%, a substantial drop in the equity premium on green stocks.

9 Conclusion

How does green investing affect household portfolios, security prices, and, ultimately, security issuers' cost of capital? We use household survey data to estimate a heterogeneous agents asset pricing model. We find that the net effect of green investing is to increase the price of green assets and lower the cost of capital for green firms. We decompose this effect into the contributions of several key theoretical mechanisms. Green convenience yields and hedging demand for green equity are actually holding back green investment. Without them, green equity demand would be roughly 30% larger than its current level. This result is due to two forces. First, while convenience yields are weakly positive for the majority of the population, there is a non-trivial fraction of households with negative convenience yields. Second, hedging demand is also not always a positive motive for holding green assets. Many households currently invest in traditional equity to hedge a slower-than-expected transition to a green economy.

Looking ahead, we show that widespread availability of green safe assets to households, in the form of green bank deposit 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 deposits could be offered at a 50 basis points lower interest rate than traditional deposit accounts, the overall share of green assets in the economy would grow from 8% to 37% of total financial wealth. This effect is entirely driven by a rise in the share of green safe assets. 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 more information about green investment opportunities changes households' attitudes towards green assets. We find that such information increases the expected excess return on green equity for households who are already concerned about climate change. Using this shift in beliefs as a counterfactual in our model, we show that more information about green finance leads to a dramatic rise in the demand for green equity. The main driving force behind this effect is mean-variance portfolio demand, which is proportional to the expected excess return per unit of risk. While convenience yields and hedging demands are important for individual portfolio choices, they wash out in the aggregate since they have offsetting effects for different parts of the population of investors. By contrast, the aggregate effect of beliefs is substantial. Hence, measuring actual beliefs and demand for green assets, as we do in our survey, is key for understanding who holds green assets and why, and for quantifying the asset pricing implications of green investing. In sum, we provide fundamental empirical and theoretical building blocks for household climate finance, which could be built upon by other researchers in this area.

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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 Bundesbank Online Panel – Households (BOP-HH) with the actual population age distribution as measured by the German Federal Statistical Office (Statistisches Bundesamt). Unlike many online surveys, the BOB-HH 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 weights for this survey sample are designed 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 Statistisches 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 the BOP-HH survey closely match German household's financial portfolios from the European Central Bank's Household Finance and Consumption Survey (HFCS). [23] 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.

[23] 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.

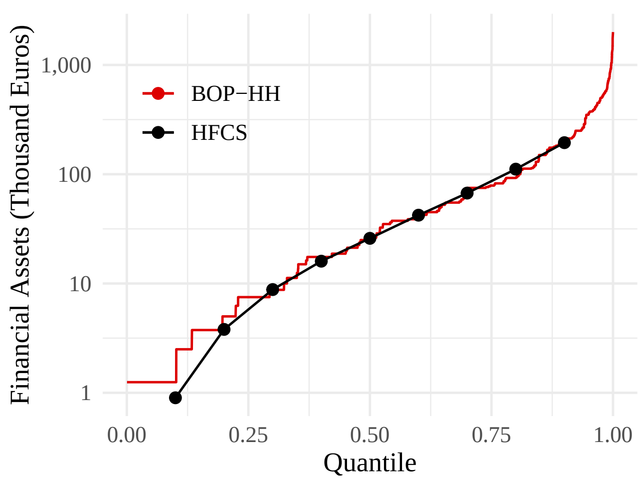
Financial asset participation rates are comparable between the two surveys. However, there is no direct mapping between all variables across the two surveys. 58.5% of households in the Bundesbank survey report holding securities, defined as shares, bonds including funds, and ETFs. In the HFCS, 20.6% of households report holding mutual funds, 3.1% bonds, 15.4% publicly traded shares, and 42% hold voluntary pensions or life insurance policies. Respondents to the Bundesbank survey are also 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.

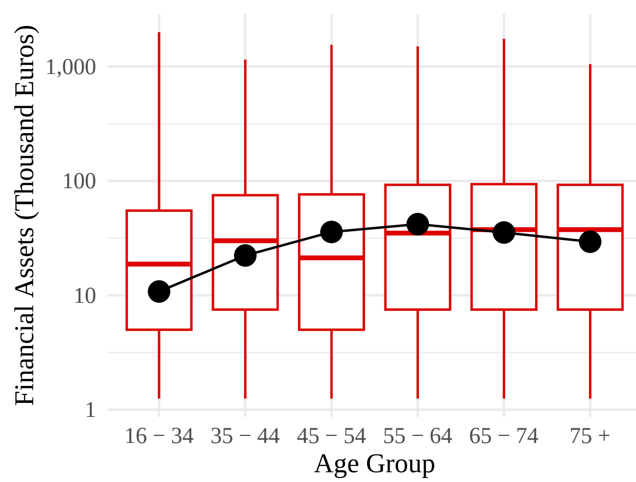
The age profile of financial assets holdings is also broadly similar. Figure A.2b shows a box plot of the financial asset holdings by age group compared to the median financial asset holdings reports in the HFCS. While the medians of the BOP-HH sample do not line up exactly with the HFCS sample, they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

Figure A.2: Comparison with HFCS

(a) Distribution of Financial Assets



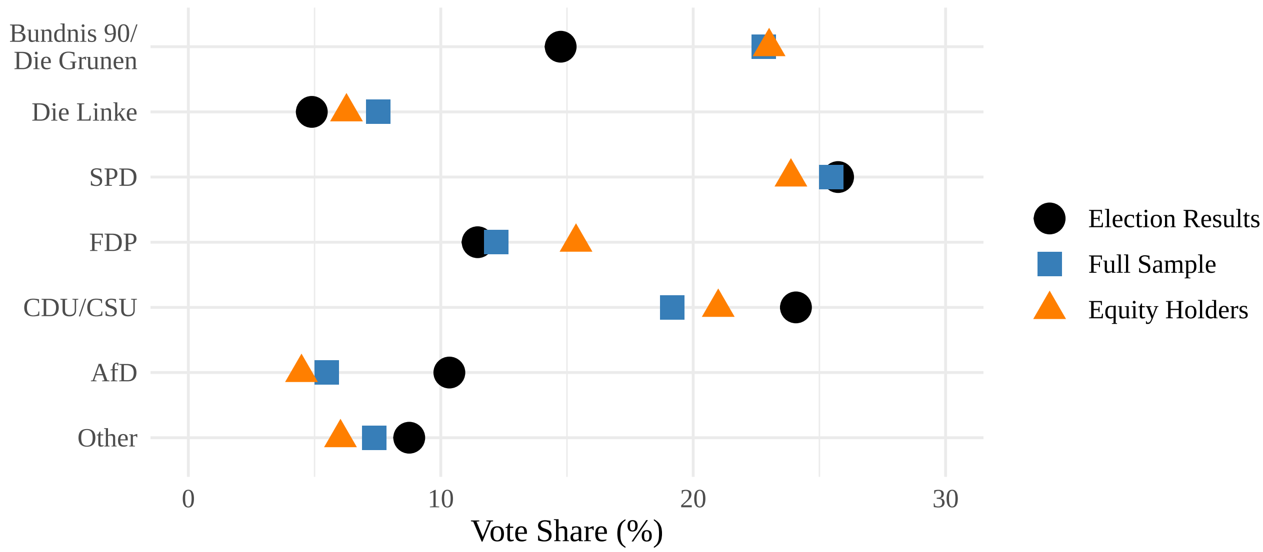
(b) Age - Financial Asset Profile



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, which include private non-self-employment businesses, assets in managed accounts and other types of financial assets. The medians and deciles are computed among households owning any sort of financial asset.

Comparison to Election Results. The BOP-HH 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. Over results are robust to re-weighting 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.

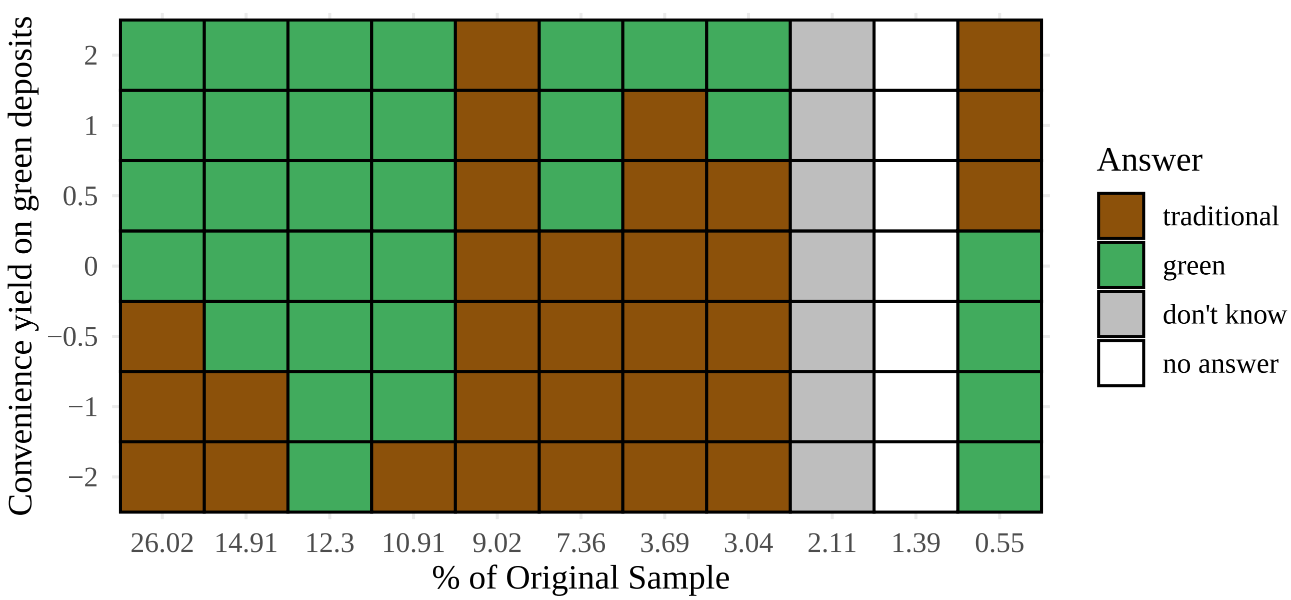
A.2 Response Rates

Green Deposit Account. Most respondents understood the sequence of green deposit spread questions and responded consistently. A consistent set of responses is a set of responses where if respondents choose the green deposit account at a cost of x percent, they then choose the green deposit account at any cost higher than x percent. 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% cost of the green deposit account over the traditional deposit account. Each column shows the response pattern 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 or higher interest rate than 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 misinterpreted 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 interest-rate spread questions on bank deposits. Each tile shows the choice of account going from a 2% to -2% spread between the traditional and the green deposit accounts. Each column shows the response pattern for a fraction of respondents in decreasing frequency going from left to right.

Equity Expectations. The response rate to our equity questions module was lower. We asked respondents to write in their expectations for annual returns for traditional and green equity funds and to rank the relative risk of the two accounts. We also asked respondents to make a hypothetical investment decision in which they chose one account in which to invest extra savings. 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
Hypothetical Investment Decision	0.74
Qualitative Questions	0.65
All Questions	0.40

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

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

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

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

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

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

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

B Additional Tables and Figures

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

B.1 Current Household Holdings of Green Assets

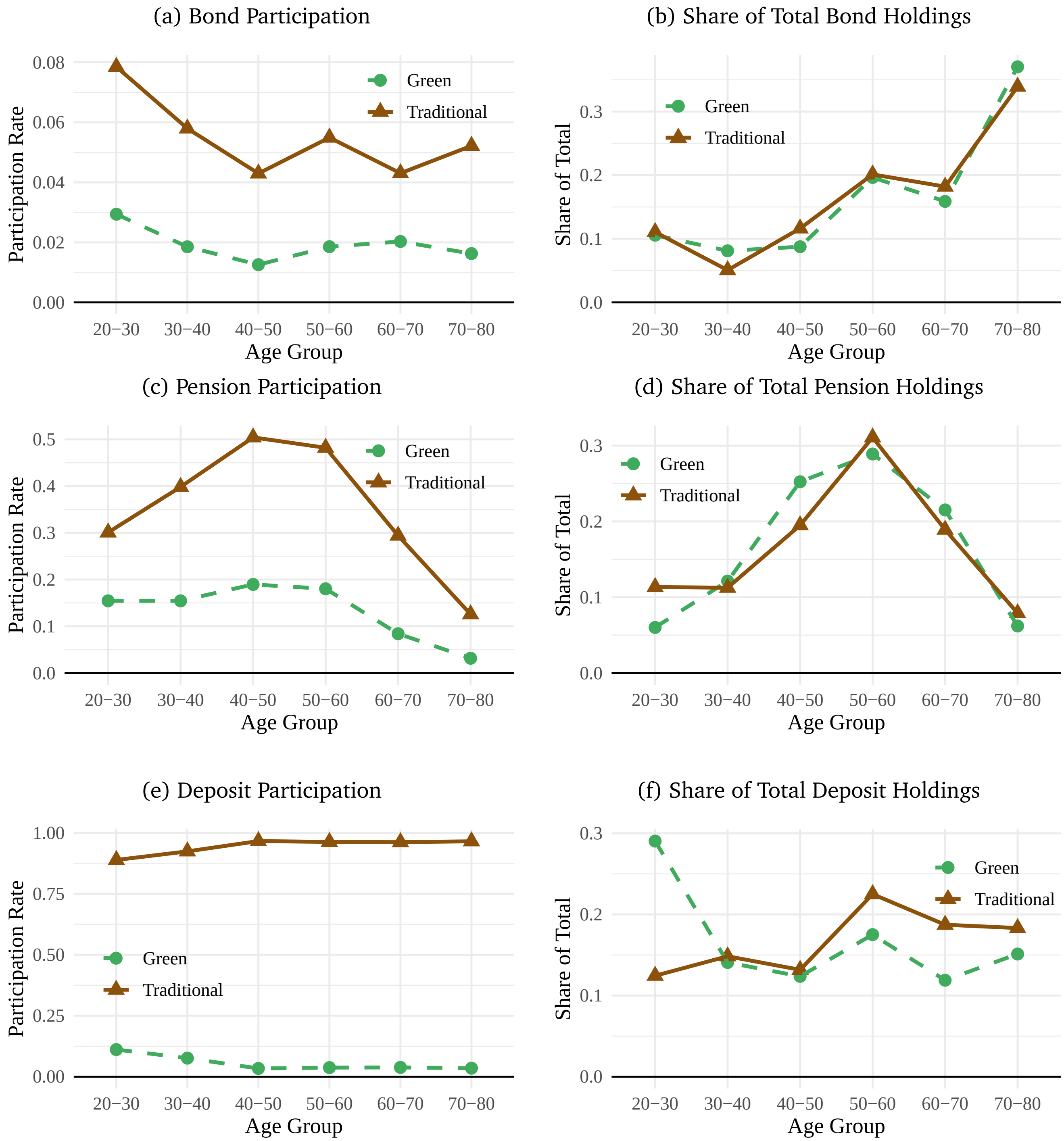
Many of the cross-sectional patterns for green equity holders are similar for other financial assets such as bonds, pensions, and deposits (Figure B.1). The age patterns for bond holdings are nearly identical to those for equity where younger households are more likely to participate in the green asset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

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

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

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

Figure B.1: Fixed Income Participation and Holdings by Age



Note: Households classify their holdings as “green" versus traditional assets. The left panels show the participation rate in green and traditional assets by age group. The right panels show the share of total assets held by an age group. Pensions include savings in private pension funds and life insurance contracts. The sample for bonds and pensions includes all respondents in the November 2021 wave of the Bundesbank Survey of Household Expectations. The sample for deposits includes all respondents in the May 2022 wave.

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

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

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

B.2 Demand for a Green Safe Asset

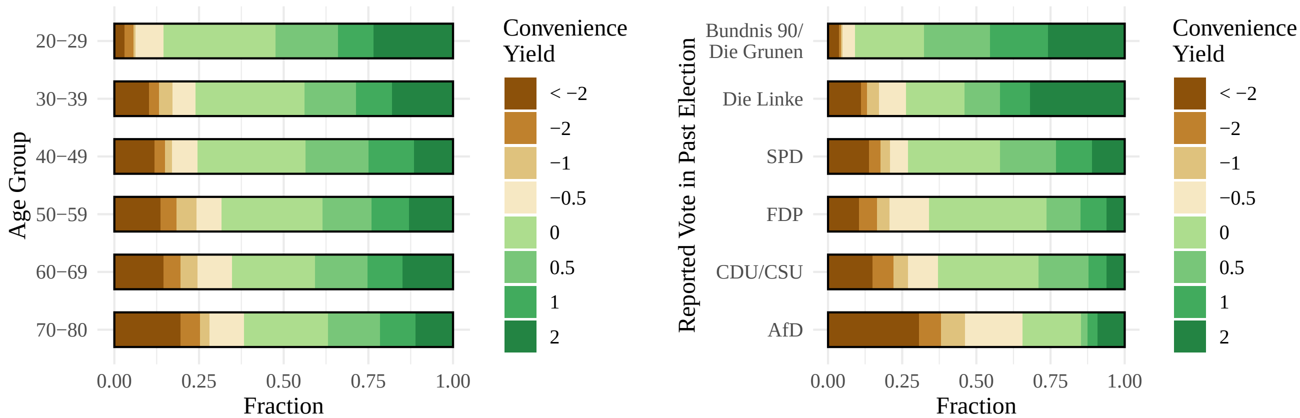
In the survey, we ask people to report their vote in the 2021 Bundestag election, which took place shortly before our survey. We give people the choice of one of the seven major political parties, another party, or that they did not vote in the election. While political parties differ across many dimensions, their perceived ranking on climate issues during the election campaign was (ordered from most to least advocacy for action to mitigate climate change): Alliance 90/ the Greens (Bündis 90/ Die Grünen), The Left (Die Linke), Social Democratic Party (SPD), Free Democratic Party (FDP), Christian Democratic Union of Germany/Christian Social Union in Bavaria (CDU/CSU), Alternative for Germany (AfD). Figure B.2(b) plots the distribution of convenience yields by reported vote. The ordering of parties based on the share of respondents with negative convenience yields 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 actions, have negative convenience yields on green deposit accounts, close to 10% choose green deposits even when they pay 2% less than traditional deposits. Similarly, a very small but non-zero fraction of Bündis 90/ Die Grünen voters and other left-leaning parties want to be paid 2% to hold green deposits. It is not unreasonable to think that these voters may believe that market solutions to climate issues are fraudulent or prevent effective government action. Households with this view might not want green deposits regardless of their interest rate and would be classified as having a greater than 2% convenience yield.

While party votes are a potential measure of households' tastes for green financial products, they are usually driven by consideration of more than a single issue. In the survey, respondents are asked to rate the importance of four issues facing Germany on a 1-10 scale: climate change, the COVID-19 pandemic, the economy, and refugees. To be consistent across respondents, we look at their relative ranking of issues instead of absolute numbers. Figure B.3 plots, for each convenience yield, the fraction of households who rank each of the four issues as Germany's top problem. These numbers do not sum to one since households may give their highest ratings to multiple issues. Of households with a 2% convenience yield on green deposits, 76% rank climate change as the most important issue. Concern for climate change is an imprecise measure, however, since 38% of households with a −2% convenience yield also rank climate as the most important issue. Another pattern that emerges is that more than 50% of households with negative convenience yields rank refugees as a top problem. Among households with 2% convenience yields, only 27% view refugees as among the most pressing issues.

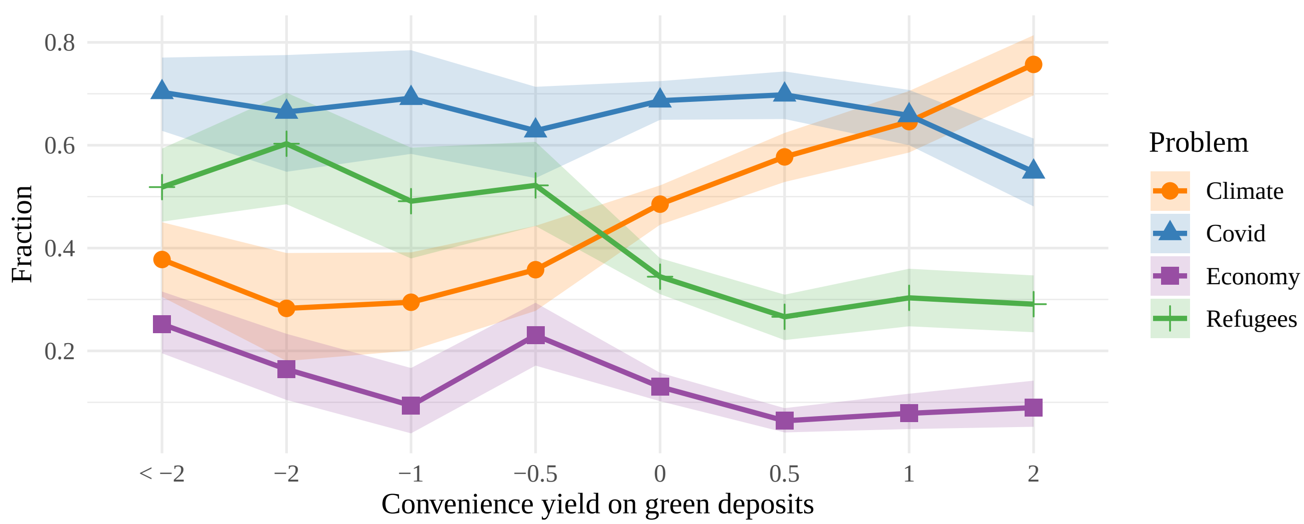
Figure B.2: Heterogeneity in Taste for a Green Safe Asset

(a) Convenience Yield by Age (b) Convenience Yield by Party Vote



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

Figure B.3: Correlation of Convenience Yields with Alternative Measures of Green Preferences



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

B.3 Information Treatment about Risk-Return Trade-offs

Table B.2 shows the effect of the information treatment about risk-return trade-offs on expected excess returns on green equity, the relative riskiness of green equity, and the fraction of households that have return expectations that are consistent with risk-return trade-offs. The treatment has no significant effects on any of these outcome variables.

Table B.2: Information Treatment about Risk-Return Trade-offs

	Dependent variable:		
	Expected Excess Green Returns	Green Account Riskier	Consistent Return Expectations
	(1)	(2)	(3)
Risk Return Treatment	0.715	−0.038	−0.005
	(0.587)	(0.028)	(0.022)
Demographic Controls	✓	✓	✓
Income/Wealth Controls	✓	✓	✓
Observations	1,349	2,430	2,088
R^2	0.060	0.035	0.019
Adjusted R^2	0.051	0.029	0.013
Note:			*p<0.1; **p<0.05; ***p<0.01

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

$$c_1 = R^w (w - c_0) \quad \text{with } R^w = \left(1 - \omega_t - \omega_g\right) R^f + \omega_t R_t + \omega_g \theta R_g, \tag{17}$$

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

$$\max_{\omega_t,\omega_g} \log\left(E\left[\left(R^w H\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}\right). \tag{18}$$

Lognormal returns. We now assume that the vector $R = \begin{pmatrix} R_t & R_g \end{pmatrix}^\top$ is lognormal. The vector of log returns is $r = \log R = E[r] + \varepsilon_r$, where ε_r is a normal vector with mean zero and variance Σ. Log mean returns are $\log E[R] = E[r] + \frac{1}{2}\text{diag}(\Sigma)$. While this makes individual returns lognormal, lognormality is not preserved when returns are added together, so the return on wealth R^w in equation (17) is not lognormal.

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

$$g(z) = \log\left(\omega^\top \exp(z) + \left(1 - \omega^\top \iota\right)\exp(k\iota)\right), \tag{19}$$

where ω is a vector of weights that sums to one, $\exp(z)$ is element-wise exponentiation, and ι is a vector of ones. We want to write $g(z) = \log f(z)$, where $f(z)$ is what is in the bracket in equation (19).

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

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

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

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

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

$$g\,(z) \approx k\iota + \omega^\top (z - k\iota) + \frac{1}{2}\omega^\top \mathrm{diag}\left((z-k\iota)(z-k\iota)^\top\right) - \frac{1}{2}\omega^\top (z-k\iota)(z-k\iota)^\top \omega. \tag{20}$$

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 (20) 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 (17) on wealth as

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

The risky part fits the above formalism (19) with $k = r^f$ and we can also expand the riskfree part to approximate

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

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

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

$$\log H = \eta_0 + \eta_g \begin{bmatrix} r_t & r_g \end{bmatrix} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

$$\mathrm{var}\,(\log H) = \eta_g^2 \begin{bmatrix} 1 & -1 \end{bmatrix} \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix}.$$

Moreover, we have the covariances

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

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

Substituting the moments into the objective function (18), and leaving out terms that do not depend on the portfolio ω, we obtain

$$\begin{aligned}
&\max_\omega \log\left(E\left[\left(R^w H\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}\right) \\
&= \max_\omega E\left[\exp\left((1-\gamma)\left(\log R^w + \log H\right)\right)\right] \\
&= \max_\omega \left\{E \log R^w + E \log H + \frac{1}{2}(1-\gamma) \operatorname{var}\left(\log R^w + \log H\right)\right\} \\
&= \max_\omega \left\{r^f + \omega^\top\left(\mu + \log\theta e_2\right) - \frac{1}{2}\omega^\top \Sigma \omega + \frac{1}{2}(1-\gamma)\left(\omega^\top \Sigma \omega + \operatorname{var}(\log H) + 2\omega^\top \eta_g \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix}\right)\right\} \\
&= \max_\omega \left\{\omega^\top\left(\mu + \log\theta e_2\right) - \frac{1}{2}\gamma \omega^\top \Sigma \omega + (1-\gamma)\,\omega^\top \eta_g \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix}\right\}. \qquad (21)
\end{aligned}$$

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

$$\mu + \log\theta e_2 - \gamma \Sigma \omega + (1-\gamma)\,\eta_g \Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix} + \nu = 0. \qquad (22)$$

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

$$\omega = T\left(\mu + \log\theta e_2\right) + h, \text{ where } h = \frac{1-\gamma}{\gamma}\eta_g \Sigma^{-1}\Sigma \begin{bmatrix} 1 \\ -1 \end{bmatrix} = \frac{\gamma-1}{\gamma}\begin{bmatrix} -\eta_g \\ \eta_g \end{bmatrix}, \text{ and } T = \frac{1}{\gamma}\Sigma^{-1}. \qquad (23)$$

We have thus derived equation (4).

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

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

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

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

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

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

The optimal portfolio is therefore

$$\omega = \frac{1}{\gamma} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} 1 & -\frac{\rho}{\lambda} \\ -\frac{\rho}{\lambda} & \frac{1}{\lambda^2} \end{bmatrix} \begin{bmatrix} \mu_t \\ \mu_g + \log\theta \end{bmatrix} + h \tag{24}$$

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

$$\begin{aligned} \omega_g + \omega_t &= \frac{1}{\gamma} \begin{bmatrix} 1 & 1 \end{bmatrix} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} 1 & -\frac{\rho}{\lambda} \\ -\frac{\rho}{\lambda} & \frac{1}{\lambda^2} \end{bmatrix} \begin{bmatrix} \mu_t \\ \mu_g + \log\theta \end{bmatrix} \\ &= \frac{1}{\gamma} \begin{bmatrix} 1 & 1 \end{bmatrix} \frac{1}{\sigma_t^2 (1-\rho^2)} \begin{bmatrix} \mu_t - \frac{\rho\left(\mu_g + \log\theta\right)}{\lambda} \\ \frac{(\mu_g + \log\theta)}{\lambda^2} - \frac{\rho\mu_t}{\lambda} \end{bmatrix} \\ &= \frac{1}{\gamma} \frac{1}{\sigma_t^2 (1-\rho^2)} \left(\frac{\left(\mu_t + (\mu_g + \log\theta\right)}{\lambda^2} - \frac{\rho\,(\mu_t + \mu_g + \log\theta)}{\lambda} \right). \end{aligned} \tag{25}$$

We have thus derived the expression (10) for the sum of the risky portfolio weights.

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

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

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

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

A household chooses green if and only the second component is larger than the first. Rearranging this expression delivers the bound (11) 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

$$\tilde{u}\left(\omega\right) = \omega^\top \left(\mu + \log\theta e_2 + \gamma\Sigma h\right) - \frac{1}{2}\gamma\omega^\top\Sigma\omega. \tag{26}$$

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

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

Multiplying by $1+x$, we have

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

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

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

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

Dividing by x, we can simplify the expression to obtain

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

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

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

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 (26), or

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

Substituting, the vector of payoffs becomes

$$
\begin{aligned}
\pi &=\mu+\log\theta e_2+\gamma\Sigma h-\frac{1}{1+x}\gamma\Sigma\omega-\frac{1}{2}\frac{x}{1+x}\gamma\mathrm{diag}(\Sigma) \\
&=\mu+\log\theta e_2+\gamma\Sigma h-\frac{1}{1+x}\left(\mu+\gamma\Sigma h\right)-\frac{1}{2}\frac{x}{1+x}\gamma\mathrm{diag}(\Sigma) \\
&=\frac{x}{1+x}\left(\mu+\log\theta e_2+\gamma\Sigma h-\frac{1}{2}\gamma\mathrm{diag}(\Sigma)\right). \qquad (27)
\end{aligned}
$$

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

The household chooses green if the first element of the vector in bracket of equation (27) is smaller than the second element

$$
\mu_g+\log\theta-\frac{1}{2}\gamma{\sigma_t}^2\lambda^2+\gamma{\sigma_t}^2h_g\lambda(\lambda-\rho)>\mu_t-\frac{1}{2}\gamma{\sigma_t}^2+\gamma{\sigma_t}^2h_g(\rho\lambda-1) \qquad (28)
$$

which derives the inequality (11).

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

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

Therefore, we get the following lower bound for h_g

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

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

C.3 Matching Portfolio Weights in the May Wave

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

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

1. The household's green portfolio weight must satisfy equation (24):

$$\omega_g^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2}\left(\frac{\mu_g^i + \log\theta^i}{{\lambda^i}^2} - \frac{\rho^i \mu_t^i}{\lambda^i}\right) + h_g^i > 0. \tag{30}$$

2. The household's optimal portfolio weights on risky assets must satisfy equation (25):

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

3. The household's parameter values must also satisfy their choice of hypothetical equity fund. We want to respect either the upper or lower bound (29) on h_g, given by:

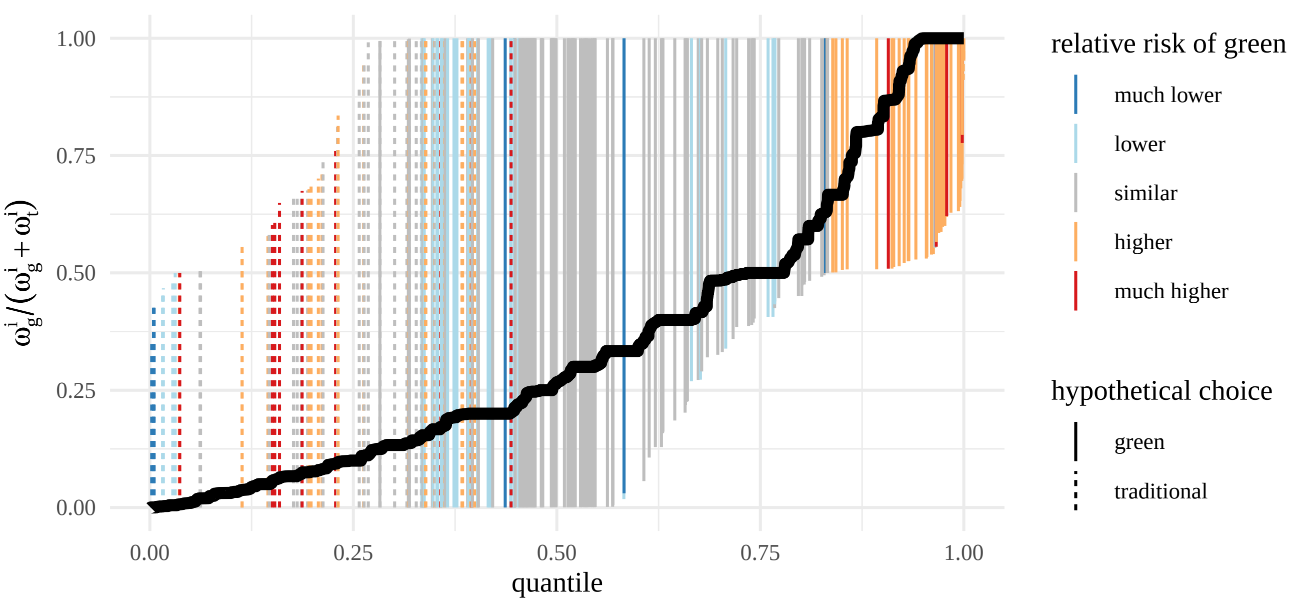
$$\frac{\mu_t^i - \mu_g^i - \log\theta^i + \frac{1}{2}\gamma^i {\sigma_t^i}^2({\lambda^i}^2 - 1)}{\gamma^i {\sigma_t^i}^2({\lambda^i}^2 - 2\rho^i\lambda^i + 1)}. \tag{32}$$

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

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

These bounds on households' green equity share are illustrated in Figure C.1. Each vertical line illustrates the possible values that are supported by households' expected returns on the two equity funds, their relative risk ranking, and hypothetical choice of green versus traditional equity funds. Some patterns emerge. For some households who choose the hypothetical traditional equity fund, there is a theoretical upper limit on the fraction of their green equity. The upper limit derives from the bound on hedging demand (32) implied by their hypothetical choice. Similarly, some households' hypothetical choice of the green account, together with their reported expectations, implies a binding lower bound on the share of their equity holdings that are green.

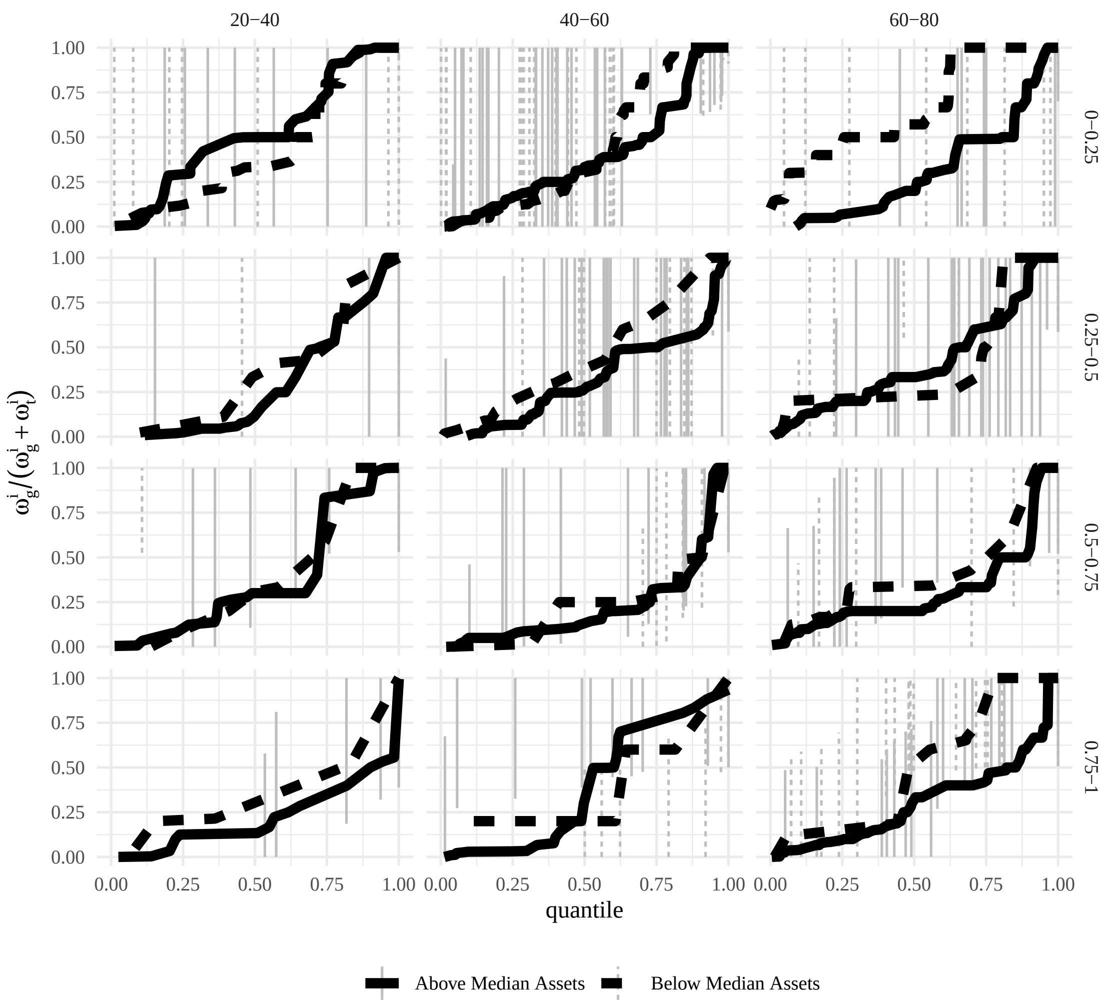
Figure C.1: Bounds on individual ω_g^i



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

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

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



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

C.4 Mapping Survey Responses to Model Primitives

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

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

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

$$\omega_t^i = \frac{\mu_t^i}{\gamma^i {\sigma_t^i}^2} - h_g^i. \tag{33}$$

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

$$\omega_g^i = \frac{1}{\gamma^i {\sigma_t^i}^2 (1-\rho^i)^2} \left(\frac{\mu_g^i + \log \theta^i}{\lambda^{i2}} - \frac{\rho^i \mu_t^i}{\lambda^i} \right) + h_g^i \leq 0. \tag{34}$$

3. The household's parameter values must also satisfy their choice of hypothetical equity fund. We want to respect either an upper or a lower bound (29) on h_g^i depending on their choice of hypothetical account, given by:

$$\frac{\mu_t^i - \mu_g^i - \log \theta^i + \frac{1}{2}\gamma^i {\sigma_t^i}^2 ({\lambda^i}^2 - 1)}{\gamma^i {\sigma_t^i}^2 (\lambda^{i2} - 2\rho^i \lambda^i + 1)} \tag{35}$$

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

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

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

$$\omega_g^i = \frac{\mu_g^i + \log\theta^i}{\lambda^{i2}\gamma^i{\sigma_t^i}^2} + h_g^i \tag{36}$$

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

$$\omega_t^i = \frac{1}{\gamma^i{\sigma_t^i}^2(1-\rho^i)^2}\left(\mu_t^i - \frac{\rho^i(\mu_g^i + \log\theta^i)}{\lambda^i}\right) - h_g^i \le 0 \tag{37}$$

3. The household's parameter values must also satisfy their choice of hypothetical equity fund. We want to respect either an upper or a lower bound (29) on h_g^i, given by:

$$\frac{\mu_t^i - \mu_g^i - \log\theta^i + \frac{1}{2}\gamma^i{\sigma_t^i}^2(\lambda^{i2}-1)}{\gamma^i{\sigma_t^i}^2(\lambda^{i2} - 2\rho^i\lambda^i + 1)} \tag{38}$$

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. 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.