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Conference Paper

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Beiträge zur Jahrestagung des Vereins für Socialpolitik 2024: Upcoming Labor Market Challenges

Provided in Cooperation with:

Verein für Socialpolitik / German Economic Association

Suggested Citation: Kiesl-Reiter, Sarah (2024) : Subjective Expectations about Joint Return Distributions, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2024: Upcoming Labor Market Challenges, ZBW - Leibniz Information Centre for Economics, Kiel, Hamburg

This Version is available at:

<https://hdl.handle.net/10419/302423>

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Subjective Expectations about Joint Return Distributions*

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Preliminary – please do not quote

February 29, 2024

Abstract

A large literature studies the formation and heterogeneity of subjective expectations of asset returns and their role in individual economic decision-making. Yet, most of the existing work focuses on subjective return expectations of single assets. In this paper, I use data from a unique survey module to study the formation of subjective expectations with respect to the joint return distribution of a “mixed” asset. This task requires individuals to not only form expectations about asset returns, but to also incorporate expectations regarding the correlation of asset returns—a key aspect of portfolio diversification. I find that a non-negligible share of individuals takes into account basic diversification properties only partially or not at all in their expectation formation. More generally, I find that assessing outcomes in terms of probabilities is challenging for many individuals, particularly for those with low financial sophistication and low socio-economic status.

*I benefited from comments and suggestions made by Helmut Elsinger, Melanie Lührmann, Panu Poutvaara, and Joachim Winter.

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1 Introduction

A large literature studies the determinants of subjective expectations and their role in household financial decision-making (Bachmann et al., 2023). Yet, most of the existing work focuses on the measurement of subjective expectations about *univariate* outcomes. A natural next step is to extend the literature by measuring subjective expectations about *joint* outcomes. This is particularly relevant in the context of investment behavior, where considering investment options simultaneously rather than in isolation – taking into account correlations of different investments – is essential for better diversification and risk management. Exploring subjective expectations about joint return distributions can contribute to understanding the widely documented lack of diversification in household portfolios (see e.g., Badarinza et al., 2016; Blume and Friend, 1975; Goetzmann and Kumar, 2008; Gomes et al., 2021).

In this paper, I analyze data from a unique survey module that asks individuals to report their subjective expectations about the joint return distribution of an investment in a portfolio which consists of two broad asset classes, housing and stocks. This task requires individuals to not only form expectations about asset returns, but to also incorporate expectations regarding the correlation of asset returns. In addition, the survey elicits individuals’ subjective expectations about the return distributions of the assets underlying the portfolio, i.e., separately for an investment in housing and for an investment in stocks. The expectation questions included in the survey are designed in a way such that they elicit the whole return distribution using subjective probabilities, similar to Giglio et al. (2021) or Laudenbach et al. (2021). From the subjective return distributions, I can obtain estimates of the mean and standard deviation (for each of the three investments), which is crucial for my analysis.

Drawing on this survey data, I investigate how well individuals’ subjective expectations regarding the return (as measured by the mean of the subjective return distribution) and risk (as measured by the standard deviation of the subjective return distribution) of the three different investments¹ align with two basic diversification properties: (1) The expected return of a two-asset portfolio lying within the range of the expected returns of its individual underlying assets, and (2) the risk of a two-asset portfolio being lower than or equal to the maximum risk associated with its individual underlying assets. Individuals forming subjective expectations

¹Housing, stocks, and two-asset portfolio including housing and stocks.

in line with the first (second) property are referred to as *satisfying the return (risk) constraint*. Individuals may form subjective expectations satisfying either one, both, or neither of the two constraints.

My results show that a non-negligible share of respondents (every fourth) does *not* provide a response to the probabilistic expectation questions about asset returns.² Further, respondents who provide responses take into account basic diversification properties only partially or not at all in their expectation formation: 50% of respondents satisfy the return constraint, 79% satisfy the risk constraint, and only 41% satisfy both, the return and the risk constraint. The respondent’s socio-economic status and overall financial literacy are strong predictors for participating in the expectation-elicitation task and satisfying the return and risk constraint.

I analyze data from a survey module integrated in the 2020 wave of the Financial Lives survey—a nationally representative survey of the UK adult population, conducted by the Financial Conduct Authority (FCA) between August 2019 and February 2020. The survey module was presented to a randomly selected subset of 3,843 individuals, among which 2,926 completed the whole module. In addition to measuring individuals’ subjective expected return distributions over the 12-month horizon for three different investments, the survey module elicits individuals’ general understanding of different financial investments and their risk and growth potential.

My paper makes two main contributions. First, my findings contribute to the literature on the elicitation and formation of subjective expectations about asset returns using survey data. There is a large literature studying individuals’ subjective expectations about *stock market returns* (see e.g., Amromin and Sharpe, 2014; Dominitz and Manski, 2007, 2011; Drerup et al., 2017; Giglio et al., 2021; Heiss et al., 2022; Hudomiet et al., 2011; Hurd et al., 2011; Kézdi and Willis, 2011; Merkle and Weber, 2014; Vissing-Jorgensen, 2003). More recently, researchers also show increasing interest in individuals’ subjective expectations about *house price changes* (see e.g., Armona et al., 2019; Bailey et al., 2018a; Bottan and Perez-Truglia, 2020; Chopra et al., 2023; De Stefani, 2021; Kiesl-Reiter et al., 2024; Kindermann et al., 2021; Kuchler et al., 2022; Kuchler and Zafar, 2019).

²Possible reasons for item non-response are discussed in Section 4.1.

While the methodology of eliciting subjective expectations about return distributions in surveys has been applied to single assets in several studies, I am not aware of research that measures expectations with respect to the *joint* return distribution for more than one asset in surveys.³ When forming expectations about joint return distributions, survey participants not only have to take into account the return and risk of one single asset, but also the *correlation of asset returns*. I extend the existing literature by studying subjective expectations about the joint return distribution for an investment in a “mixed asset,” including both, stocks and real estate. I use survey data from the UK, a country in which stocks and real estate make up a significant proportion (39.4%) of the total wealth held by households, with real estate being by far the most important component in UK household’s portfolios (Badarinza et al., 2016).⁴ More generally, my paper also contributes to the literature on the methodology and response behavior in the elicitation of subjective expectations (Binswanger and Salm, 2017; Hurd, 2009; Manski, 2004, 2017).

Second, my paper contributes to the large literature on individual financial literacy. Studying individuals’ understanding of the concept of risk diversification has been in the focus of many research papers (see e.g., Lusardi and Mitchell, 2014; van Rooij et al., 2011). Most of this research relies on knowledge-based questions integrated in surveys to directly test people’s understanding of the concept of risk diversification. My paper adds to the existing literature by studying how well individuals take into account basic diversification properties in their expectation formation. My findings show that men, individuals with higher education, higher household income, and higher overall financial literacy are more likely to participate in the expectation-elicitation task and to take into account basic diversification properties in their expectation formation. These findings are consistent with well-established patterns in the literature on the correlates of individual financial literacy (see Klapper and Lusardi, 2020; Lusardi and Mitchell, 2014).

The paper proceeds as follows. Section 2 provides theoretical background. Section 3 introduces the data and expectation measures, and the estimation approach used in deriving the moments of the subjective return distributions. Section 4 presents information on (non-)participation in

³An important exception is the work by Drerup (2019) who investigates the elicitation of subjective expectations about joint return distributions in a laboratory experiment.

⁴Figures (as of 2012) include the main residence, other real estate, directly held stocks, mutual funds, and bonds.

the expectation-elicitation task, and summary statistics. Section 5 presents my main results of how well individuals' subjective expectations regarding the return and risk of three different investments align with basic diversification properties. Section 6 discusses limitations and implications for future survey design. Section 7 concludes.

2 Theoretical Background

Let us consider an investment of a sum I in two risky assets S (for stock) and H (for housing), forming a portfolio P . Let w_S and w_H be the proportions ("weights") of I invested in assets S and H , respectively. Weights are assumed (i) to take on values that are between 0 and 1, i.e., w_S and $w_H \in [0, 1]$ ⁵ and (ii) to sum up to 1, i.e., $w_S + w_H = 1$. The investment horizon is one period. The investor only cares about the expected return and risk (as measured by the variance) of the portfolio.

2.1 Expected Return and Risk

Let R_S and R_H denote the returns on assets S and H ,⁶ respectively, with:

$$\mu_S = E[R_S], \sigma_S^2 = \text{var}(R_S), \mu_H = E[R_H], \sigma_H^2 = \text{var}(R_H)$$

$$\sigma_{SH} = \text{cov}(R_S, R_H), \rho_{SH} = \text{corr}(R_S, R_H)$$

The return of the portfolio R_P is given by the weighted average of the returns of the individual assets:

$$R_P = w_S * R_S + w_H * R_H$$

From the assumptions above, it follows that:

$$\mu_P = E[R_P] = w_S \mu_S + w_H \mu_H$$

$$\sigma_P^2 = \text{var}(R_P) = w_S^2 \sigma_S^2 + w_H^2 \sigma_H^2 + 2w_S w_H \sigma_{SH}$$

⁵Short positions exempted.

⁶Returns can follow any continuous distribution with a well-defined mean and variance.

2.2 Implication for Expected Return

Since μ_P is a linear combination of μ_S and μ_H , and from our assumptions on the weights w_S and w_H , it follows that⁷

$$\min(\mu_S, \mu_H) \leq \mu_P \leq \max(\mu_S, \mu_H) \quad (1)$$

Essentially, Equation 1 establishes that the expected return of a portfolio is higher than or equal to the minimum expected return of its individual assets and smaller than or equal to the maximum expected return of its individual assets.

2.3 Implication for Risk

Recall that the risk of the portfolio is measured by its variance:

$$\sigma_P^2 = \text{var}(R_P) = w_S^2 \sigma_S^2 + w_H^2 \sigma_H^2 + 2w_S w_H \sigma_{SH} \quad (2)$$

where σ_P^2 depends on the variance of the returns of the two individual assets, σ_S^2 and σ_H^2 , and on the covariance between the returns of the two assets, σ_{SH} .

We can rewrite Equation 2 in terms of standard deviation and correlation:

$$\sigma_P^2 = \text{var}(R_P) = w_S^2 \sigma_S^2 + w_H^2 \sigma_H^2 + 2w_S w_H \sigma_S \sigma_H \rho_{SH} \quad (3)$$

where ρ_{SH} is the correlation between the returns of the two individual assets, varying between -1 and $+1$. The more negative the correlation between the returns of assets S and H , the higher the benefits from diversification, and consequently, the lower the variance of the portfolio (i.e., the lower the risk associated with the investment), and vice versa.

Now let us consider two scenarios, (i) one where $\text{Corr}(R_S, R_H) = +1$, and (ii) one where $\text{Corr}(R_S, R_H) = -1$. Let's start with the first one. If we assume that the returns between S

⁷By definition, $\mu_P = w_S \mu_S + w_H \mu_H = w_S \mu_S + (1 - w_S) \mu_H$. Since w_S and $w_H \in [0, 1]$, $\mu_P \leq w_S \max(\mu_S, \mu_H) + (1 - w_S) \max(\mu_S, \mu_H)$, and thus $\mu_P \leq \max(\mu_S, \mu_H)$. Analogously for $\min(\mu_S, \mu_H) \leq \mu_P$.

and H are perfectly positively correlated, i.e., $Corr(R_S, R_H) = +1$, Equation 3 simplifies to:⁸

$$\sigma_P = w_S\sigma_S + w_H\sigma_H \quad (4)$$

Using the same argument as outlined in Footnote 7, it follows that

$$\sigma_P \leq \max(\sigma_S, \sigma_H) \quad (5)$$

Now, let us consider the second scenario where we assume that the returns between S and H are perfectly negatively correlated, i.e., $Corr(R_S, R_H) = -1$.

In this scenario, Equation 3 simplifies to:⁹

$$\sigma_P = \text{abs}(w_S\sigma_S - w_H\sigma_H) \quad (6)$$

Again, it follows that:

$$\sigma_P \leq \max(\sigma_S, \sigma_H) \quad (7)$$

In the two (most extreme) scenarios, where $Corr(R_S, R_H) = -1$ and $Corr(R_S, R_H) = +1$, the standard deviation of the portfolio is at most as high as the maximum standard deviation of its individual assets. For correlation values that lie between -1 and $+1$, the corresponding values for σ_P will be between σ_P where $Corr(R_S, R_H) = -1$ and σ_P where $Corr(R_S, R_H) = +1$. From Equation 5 and Equation 7, it follows that for all values of $Corr(R_S, R_H)$, it holds that:

$$\sigma_P \leq \max(\sigma_S, \sigma_H) \quad (8)$$

Essentially, Equation 8 establishes that the risk of a portfolio is always lower than or equal to the maximum risk associated with its individual assets.

⁸Using factoring, $\sigma_P^2 = w_S^2\sigma_S^2 + w_H^2\sigma_H^2 + 2w_Sw_H\sigma_S\sigma_H\rho_{SH}$ simplifies to $\sigma_P^2 = (w_S\sigma_S + w_H\sigma_H)^2$.

⁹Using factoring, $\sigma_P^2 = w_S^2\sigma_S^2 + w_H^2\sigma_H^2 + 2w_Sw_H\sigma_S\sigma_H\rho_{SH}$ simplifies to $\sigma_P^2 = (w_S\sigma_S - w_H\sigma_H)^2$.

3 Data and Estimation

3.1 Financial Lives Survey

For my analysis, I use data from a unique survey module on asset return and risk. In the module, individuals are asked detailed probabilistic questions about their subjective expectations of the one year-ahead returns associated with an investment in the housing market, and another one in the stock market. What is unique about the module is that it asks a similar question about the probability of a joint (pair-wise) outcome, i.e., it elicits individuals' subjective expectations of the return associated with a portfolio investment in the housing *and* stock market. Additionally, the module includes questions measuring individuals' general understanding of different financial investments and their risk and growth potential.

The survey module on asset return and risk was implemented in the 2020 wave of the *Financial Lives survey*—a nationally representative survey, conducted by the Financial Conduct Authority (FCA), covering 16,000 adults aged 18 and older living in the UK. The module was presented to a randomized subset of 3,843 participants, with the vast majority (94%) conducting the survey online.¹⁰ The interview process spanned from August 2019 to February 2020, with over half of the participants being interviewed in January 2020.

The Financial Lives survey includes a broad range of information on individuals' socio-demographic and economic background characteristics and attitudes. It also elicits rich information on individuals' use of financial products, their investment behavior, their experiences in dealing with financial products and services, and their financial sophistication.

3.2 Measuring Subjective Expectations

The Financial Lives survey measures individuals' subjective expectations of the year-ahead returns associated with three types of investments:

- (1) Investment of £100,000 in a house in the respondent's local area (H),
- (2) Investment of £100,000 in the FTSE-100 UK stock-market index (S), and

¹⁰The Financial Lives 2020 survey used a mixed-mode approach in its data collection, combining online and face-to-face interviews. This approach was specifically designed to include individuals with no or infrequent internet access, and those aged 70 or older (Financial Conduct Authority, 2021).

- (3) Investment of £100,000 in a portfolio (P), with 50% invested in a house in the respondent’s local area (H) and 50% invested in the FTSE-100 UK stock-market index (S).

For all three investments, the survey elicits the subjective return expectations in probabilistic form. This means that respondents are asked to assign subjective probabilities to a range of possible future return brackets in a way such that the probabilities add up to 100%.¹¹ In a first survey question, respondents are asked to imagine that they received an unexpected inheritance of £100,000 which they put towards buying a house in their local area, and to subjectively assess the percentage chances that—in 12 months’ time—the house will have *decreased in value* by (i) 10% or more, (ii) 9.9% to 5%, or (iii) 4.9% to 0%; or *increased in value* by (iv) 0.1% to 5%, (v) 5.1% to 10%, (vi) 10.1% to 15%, or (vii) 15.1% or more. A similar expectation question (with the same return brackets and investment amount) was asked for investing in the FTSE-100 UK stock-market index.¹²

Most importantly, the survey also elicits the subjective distribution of expected returns for an investment in a portfolio, where respondents are asked to imagine to split the investment and put £50,000 (i.e., half of the total investment amount) towards buying a house in their local area, and another £50,000 in the FTSE-100 UK stock-market index. The return brackets for the portfolio investment are identical to those for the housing and stock market investment.

The probabilistic expectation questions for the three types of investments (H , S , and P) were shown on different screens, but respondents could revisit previous survey questions to review and potentially modify their responses. Before respondents were asked the expectation questions on asset return, they were shown two examples to familiarize them with the probabilistic question format. The examples were about the *number of days of rain in July* in (i) Edinburgh and in (ii) Barcelona (where it is usually way less rainy than in Edinburgh). For the exact wording of the survey questions and the introductory examples, see Figure A1 in the Appendix.¹³

¹¹While the majority of respondents assigned integer values to the different brackets, they could generally input decimal values up to two decimal places. Respondents could only move on with the next survey question if the probabilities assigned to the different brackets added up to 100%.

¹²The design of the survey questions is similar to the one by Giglio et al. (2021) or Laudenbach et al. (2021) who study subjective expectations of stock market returns. The SCE Housing Survey fielded by the Federal Reserve Bank of New York adopts a similar question design to elicit subjective expectations of future house price changes (see e.g., Armona et al., 2019; Kuchler and Zafar, 2019).

¹³For the whole survey questionnaire, see <https://www.fca.org.uk/publication/research/financial-lives-survey-2020-questionnaire.pdf>.

3.3 Estimating Moments of the Subjective Return Distribution

I derive estimates of the first two moments of the subjective return distribution (the mean and the standard deviation) for each of the three different investment types. To do so, the literature distinguishes non-parametric and parametric estimation approaches. In my main specification, I adopt the non-parametric estimation approach suggested in Hurd et al. (2011)—an approach heavily used in the recent literature (see e.g., Giglio et al., 2021 or Laudenbach et al., 2021).¹⁴ They construct non-parametric estimates of the mean of the expected rate of return distribution for stock market investments. The model is given by

$$E(\pi) = \sum_j P(\pi \in B_j) E(\pi | \pi \in B_j) \quad (9)$$

where, $P(\pi \in B_j)$, is the subjective probability assigned to bracket j , and, $E(\pi | \pi \in B_j)$, is the historical average of one-year rates of return conditional on the return being in bracket j .

The non-parametric estimate of the standard deviation of the expected rates of return is given by

$$SD(\pi) = \sqrt{E(\pi^2) - E(\pi)^2} \quad (10)$$

where

$$E(\pi^2) = \sum_j P(\pi \in B_j) E(\pi^2 | \pi \in B_j) \quad (11)$$

I use the same methodology to obtain estimates of the mean of the subjective expected return distribution for the three investments described in Section 3.2. In the computation of the standard deviation, I further follow Bailey et al. (2018b) and assign a standard deviation of zero to respondents who enter probabilities in one bracket only.

¹⁴In robustness analyses in Section 5.1.3, I review alternative approaches of estimating the moments of the subjective return distribution. Among others, I consider an alternative non-parametric estimation approach, considering midpoints of the return brackets (similar to Bailey et al., 2018b; Kuchler and Zafar, 2019). Further, I consider a parametric estimation approach, fitting a log-normal distribution to the cumulative distribution function of expectations (similar to Drerup et al., 2017; Zimpelmann, 2021). As pointed out by Armona et al. (2019), we do not know individuals’ “mental model” when forming their return expectations. Given that the different estimation approaches cover a wide range of assumptions about how individuals form subjective expectations, my results are fairly stable.

In my analysis, $P(r_x \in B_j)$ denotes a respondent’s subjective probability assigned to bracket j for investment x with $x \in \{H, S, P\}$. Data on $P(r_x \in B_j)$ comes from the Financial Lives survey; for each of the three investments in the survey, there are seven return brackets B_j .

For investment H , I compute $E(r_H|r_H \in B_j)$ based on historical UK-wide year-on-year house price changes r_H for each month from the *UK House Price Index (UK HPI)*;¹⁵ for investment S , I compute $E(r_S|r_S \in B_j)$ based on historical year-on-year returns for each month from the *Financial Times Stock Exchange (FTSE) 100 Index* using *yahoo!Finance* data on adjusted close prices;¹⁶ and for investment P (50/50 investment in H and S), I first compute historical year-on-year portfolio returns, $r_P = 0.5 * r_H + 0.5 * r_S$, for each month, which then I use to compute $E(r_P|r_P \in B_j)$. For all three investments, I consider historical returns from May 2003 to July 2019—I consider the period before the survey was conducted, and I look back in time just long enough to ensure that for each investment type and each return bracket, there is at least one historical return belonging to the bracket.¹⁷

Table 1 reports the bracket points, $E(r|r \in B_j)$, derived from the historical returns data.¹⁸ Historically, the FTSE-100 UK stock market index took on more extreme positive and negative return values than the UK HPI, which explains that the derived points for the open-ended brackets are higher (in absolute terms) for the stock market investment than for the housing market investment. Note that for a given return bracket, derived points for the portfolio investment are not necessarily between the derived points for the stock and housing market investment.¹⁹

¹⁵For more information, see <https://landregistry.data.gov.uk/app/ukhpi>.

¹⁶Close prices are adjusted for dividends and splits.

¹⁷The choice to stick to the shortest possible lookback period is motivated by the literature that highlights that individuals’ investment decisions, beliefs, and risk attitudes are particularly influenced by *recent* experiences of returns (“recency bias”) (Malmendier, 2021a,b; Malmendier and Nagel, 2011). In robustness analyses in Section 5.1, I also consider alternative time spans.

¹⁸For more information on the historical returns used in the computation of $E(r|r \in B_j)$, see Figure B1 in the Appendix.

¹⁹If in the historical returns data, for each month, the annual return of the FTSE-100 UK stock market index and the UK HPI were in the same return bracket, the derived bracket points for the portfolio would be between the derived points for the stock and housing market investment in each bracket; however, historical returns data shows that this is not the case.

Table 1: Bracket points, $E(r|r \in B_j)$

Bracket	Housing	Stock	Portfolio
B1: -10% or less	-14.21	-20.91	-21.05
B2: -9.9% to -5%	-8.36	-7.28	-7.97
B3: -4.9% to 0%	-1.54	-2.54	-1.78
B4: 0.1% to 5%	2.61	2.89	2.84
B5: 5.1% to 10%	7.28	7.50	7.51
B6: 10.1% to 15%	11.81	12.45	11.54
B7: 15.1% or more	17.84	20.67	19.35

Notes: The table shows bracket points for the three different investments, derived from historical returns data (from 5/2003–7/2019) conditional on the return being in the bracket (following the non-parametric estimation approach by Hurd et al., 2011). *Data Source:* Historical values from the UK HPI and the FTSE-100 UK stock-market index.

3.4 Additional Survey Data

Risk aversion. The Financial Lives survey contains a measure of risk aversion. More specifically, it asks individuals to assess their willingness to take risks on a scale of 0 to 10, where 0 is “not at all willing to take risks” and 10 is “very willing to take risks.” I define individuals to be “risk averse” if they answer 4 or less.

Financial sophistication. The survey elicits a range of different measures of individuals’ financial sophistication. First, it includes the standard financial literacy questions following Lusardi and Mitchell (2011, 2014) testing individuals’ knowledge about (i) interest rates, (ii) interest compounding, (iii) inflation, and (iv) risk diversification. I consider respondents to have “high financial literacy” if they have an understanding of all four financial concepts. Second, the survey measures individuals’ knowledge about the relative riskiness of different assets; I consider individuals to “understand relative asset risk” if they believe that keeping their money in a savings account is less risky than investing in the stock market or in their local housing market. Third, the survey elicits individuals’ confidence working with numbers.²⁰

²⁰For the exact wording of the underlying survey questions, see Table A1 in the Appendix; for the description of the variables used in the analyses, see Table A2.

4 Descriptive Analysis

4.1 (Non-)Response to Probabilistic Expectation Questions

The survey module on asset return and risk includes 3,843 respondents in total. However, not all of the respondents in the survey module provided a response to the probabilistic expectation questions.²¹ Table 2 shows that only 76% were able to do so. Even though respondents were shown two introductory examples (about the number of days of rain in July in Edinburgh and in Barcelona) that should help clarify the probabilistic question format, almost one third had difficulties with the format and consequently dropped out of the survey module altogether.²²

In Table 2, I report regression results from a linear probability model with *providing a response to the probabilistic expectation questions* as the dependent variable. I find that women are less likely than men to provide answers to the probabilistic expectation questions. Compared to individuals aged 35–50, those relatively younger are less likely to answer the expectation questions. Consistent with findings from Kleinjans and Soest (2014) and Binswanger and Salm (2017) who find individuals with higher education and cognitive ability to be less likely to not provide answers to probabilistic expectation questions, I find a negative association between education and non-response. Further, I find that self-employed individuals (as compared to employed ones) are more likely to select themselves into answering the expectation questions. The chance of providing a response also increases with a person’s household income. These findings consistently align with well-established patterns in the literature on the correlates of individuals’ financial literacy (see Klapper and Lusardi, 2020; Lusardi and Mitchell, 2014).

I consider two alternative regression specifications, including indicator variables reflecting individuals’ financial sophistication (column 2) and their financial behavior (column 3). Individuals’ financial sophistication is highly predictive of providing a response to the probabilistic expectation questions—individuals who are knowledgeable about the concepts of interest compounding, inflation, risk diversification, and relative asset risk, as well as those who consider themselves confident working with numbers are significantly more likely to provide answers to

²¹Table A3 in the Appendix reports summary statistics.

²²In the survey module on asset return and risk, individuals were asked to report expectations in probabilistic form for different investment types (a savings account, the local housing market, the FTSE-100 UK stock-market index, and a portfolio). If a respondent indicated an inability to answer the probabilistic expectation question for one investment type, they dropped out from the survey module, i.e., they were not asked to report expectations for any of the other investment types.

Table 2: Correlates of responding to probabilistic expectation questions

Dependent variable	Response to probabilistic expectation questions		
	(1)	(2)	(3)
Gender (ref: Male)			
Female	-0.083*** (0.013)	-0.050*** (0.013)	-0.050*** (0.013)
Other	-0.066 (0.060)	-0.069 (0.066)	-0.062 (0.065)
Age (ref: 35–50)			
18 to 34	-0.094*** (0.017)	-0.075*** (0.017)	-0.058*** (0.017)
51 to 64	0.036* (0.019)	0.008 (0.018)	-0.006 (0.019)
65 or older	0.005 (0.030)	-0.014 (0.030)	-0.026 (0.030)
Education (ref: Higher)			
Lower or medium	-0.092*** (0.014)	-0.059*** (0.014)	-0.054*** (0.014)
None	-0.331*** (0.025)	-0.271*** (0.025)	-0.256*** (0.025)
Info missing	-0.332*** (0.031)	-0.263*** (0.032)	-0.257*** (0.032)
Employment status (ref: Employed)			
Self-employed	0.079*** (0.026)	0.070*** (0.026)	0.063** (0.026)
Retired	0.061** (0.027)	0.053** (0.027)	0.043 (0.027)
Other	0.001 (0.020)	0.009 (0.020)	0.023 (0.020)
Annual HH income (ref: £20k - <£40k)			
Less than £20k	-0.056*** (0.021)	-0.036* (0.021)	-0.023 (0.021)
£40k - <£70k	0.058*** (0.019)	0.037* (0.019)	0.032* (0.019)
£70k or more	0.080*** (0.021)	0.045** (0.020)	0.038* (0.020)
Info missing	-0.144*** (0.019)	-0.120*** (0.019)	-0.117*** (0.019)
Risk averse		-0.010 (0.013)	-0.008 (0.013)
High financial literacy		0.163*** (0.014)	0.153*** (0.015)
Understands relative asset risk		0.062*** (0.014)	0.060*** (0.014)
Confident working with numbers		0.032** (0.013)	0.030** (0.013)
Holding shares/equities			0.046*** (0.016)
Homeowner			0.058*** (0.015)
Constant	0.906*** (0.048)	0.768*** (0.049)	0.726*** (0.050)
Mean DepVar	0.76	0.77	0.77
Adj. R-squared	0.18	0.21	0.21
N	3,843	3,806	3,806
Month Fixed Effects	✓	✓	✓

Notes: The table shows estimates from a linear probability model. The dependent variable is equal to 1 if an individual provides a response to the probabilistic expectation questions on asset return, and 0 otherwise. ‘ref.’ indicates the omitted category. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. *Data Source:* Financial Lives 2020 survey.

the probabilistic expectation questions. This is also true for individuals owning their homes or participating in the stock market.

In summary, I find that a non-negligible share of respondents has difficulty dealing with the assessment of different outcomes in terms of probabilities. The sample of respondents that ultimately provides answers to the probabilistic expectation questions is a selected one, characterized by higher socio-economic status (as defined by higher educational attainment, higher income and wealth, and higher financial sophistication).

4.2 Subjective Expectations about Univariate and Joint Return Distributions

4.2.1 Summary Statistics

In Figure 1, I report summary statistics of the survey responses on return expectations for the investments in the local housing market, the FTSE-100 UK stock-market index, and the portfolio (see Panels a, c, and e).²³ I compare subjective return distributions with historical return frequencies, separately for each investment (see Panels b, d, and f).

At the time of interview (end of 2019 and early 2020), respondents were more likely to expect *positive* returns on an investment in the local housing market than in the national stock market (77.3% vs. 64.7%, when adding up the dark blue bars). For both, modest positive returns (between 0.1% and 5%) were deemed most likely. Extreme gains (of 15.1% or more) or extreme losses (of -10% or less) were stated as almost equally likely in the stock market, with average probabilities around 5–6%. In contrast, in the local housing market, the average probability of extreme gains is—at around 6%—twice as large as that of extreme losses. For the portfolio investment it holds true that for each return bracket, the assigned probabilities lie between the probabilities assigned to the respective brackets of the housing and stock market investment. Table A4 in the Appendix shows that this pattern is also present for the median respondent.

Historically, annual house price changes in the UK have predominantly been positive, with the most frequent occurrences falling within the two middle brackets (0.1% to 5%, and 5.1%

²³The figure shows subjective probabilities assigned by the average respondent; detailed summary statistics are shown in Table A4 in the Appendix.

to 10%). This pattern is also reflected in people’s house price expectations. Historical annual returns of the FTSE-100 UK stock market index in each month are more evenly distributed across the different return brackets. Here, the subjective return distribution differs considerably from the historical return distribution. Compared to historical patterns, respondents assign too much probability mass to the middle brackets and too little to the tails (particularly to the one representing high positive returns) when forming subjective expectations about the return distribution of the FTSE-100. Historical annual returns of the portfolio investment mostly take on positive values. This pattern is also reflected in the expectation formation where respondents assign most of the probability mass to the positive return brackets, however, the distribution of subjective probabilities across the return brackets is quite different from the distribution observed in the historical return data.

4.2.2 Estimated Moments of the Subjective Return Distributions

In Table 3, I report summary statistics of the estimated mean and standard deviation of the subjective return distributions for the three different investments (following the non-parametric estimation approach by Hurd et al., 2011 outlined in Section 3.3). In 12 months’ time, respondents expect a higher mean change for the housing market investment than for the stock market investment, with estimated standard deviations being markedly lower for the housing market investment than for the stock market investment. The mean and standard deviation of the subjective return distribution of the portfolio investment are between the corresponding values of the single investments on average, but not across all moments. For all three investments, I find that the estimated mean is roughly normally distributed, while the distribution of the estimated standard deviation is right skewed (see Figure C1 in the Appendix).

5 Subjective Expectations and Consistency with Basic Diversification Properties

The primary goal of this paper is to analyze the formation of individuals’ subjective expectations about the return and risk of different investments and its consistency with basic

Table 3: Summary statistics of the mean and standard deviation of the subjective return distribution

	N	Mean	Std Dev	P10	P50	P90
$E(r_H)$	2,926	3.48	4.04	0.08	2.63	8.15
$E(r_S)$	2,926	2.14	4.91	-1.99	1.76	7.50
$E(r_P)$	2,926	2.94	4.36	-0.15	2.71	7.51
$SD(r_H)$	2,926	3.96	2.79	0.00	3.35	8.07
$SD(r_S)$	2,926	6.08	4.23	0.00	5.15	11.85
$SD(r_P)$	2,926	5.06	3.75	0.00	4.01	10.77

Notes: The table shows summary statistics of the mean and standard deviation of the subjective return distribution (following the non-parametric estimation approach by Hurd et al. (2011)) for different investments. *Data Source:* UK HPI, FTSE-100 UK stock-market index, and Financial Lives 2020 survey, $N=2,926$.

diversification properties. First, I study whether individuals form expectations about univariate and joint return distributions in a manner such that the expected return of a two-asset portfolio lies within the range of the expected returns of its individual underlying assets (see Equation 1)—I refer to these individuals as “satisfying the return constraint.” Second, I study whether individuals form expectations about univariate and joint return distributions in a manner such that the risk of a two-asset portfolio is always lower than or equal to the maximum risk associated with its individual underlying assets (see Equation 8)—I refer to these individuals as “satisfying the risk constraint.” Ultimately, I am interested in whether individuals form expectations in a manner such that they satisfy both, the return constraint *and* the risk constraint.

I first investigate whether, in theory, there exists (at least) one set of probabilities that can be assigned to the brackets of the portfolio investment such that both, the return and the risk constraint can be satisfied, considering as given (i) the respondents’ set of probabilities assigned to the housing market and stock market investment (taken from the Financial Lives survey), as well as (ii) the bracket points for all three investments (derived from historical returns data, see Table 1). I do so for all observations in my sample using the Z3 satisfiability-modulo-theories (SMT) solver developed by De Moura and Bjørner (2008).²⁴ For 2,888 of the total 2,926 observations who provide an answer to the probabilistic expectation questions, there exists a set of probabilities for the portfolio investment such that both constraints can

²⁴The Z3 SMT solver allows me to efficiently check satisfiability of both, the return and the risk constraint, for all 2,926 observations in my sample.

be satisfied; however, for 38 observations, no such set of probabilities exists.²⁵ This means that given my assumptions (in the estimation of the mean and standard deviation of the return distributions),²⁶ it is not possible for both constraints to be satisfied in the case of these 38 observations; as a consequence, I exclude them from my analysis.

Table 4 (columns 1–3) reports regression results from a linear probability model with *satisfying the return constraint* as the dependent variable. It shows that only half of the respondents satisfy the return constraint. Even though the sample of individuals who provide a response to the probabilistic expectation questions is already a selected one—characterized by higher income, education, and financial sophistication (see Section 4.1), the regression results show that among this selected sample, there are still certain characteristics that predict whether or not an individual satisfies the return constraint: The higher an individual's household income, the higher their chances of satisfying the return constraint. Similarly, home owners are more likely to satisfy the return constraint. Also, individuals with high financial literacy and those who consider themselves confident working with numbers are more likely to provide subjective probabilities that are consistent with the return constraint.²⁷ From these results it follows that among the group of individuals that is already characterized by higher socio-economic status there is yet another subgroup of individuals that particularly stands out in terms of financial knowledge about asset-related concepts—those owning real estate and having high household income.

Still, the adjusted R-squared reported in Table 4 is small, indicating a low overall fit of the model. One likely reason for that is the lack of variability in the regressors (as individuals with certain background characteristics have been more likely to provide answers to the probabilistic expectation questions in the first place, see Section 4.1). Due to the resulting sample being very homogeneous in its composition, it is not surprising that the regression performs rather

²⁵The majority of these cases refer to respondents who show bunching in their response behavior around the value of 100. If a respondent assigns 100 to one return bracket for the housing and stock market investment, the respondent would also have to assign 100 to one return bracket for the portfolio investment in order to satisfy the risk constraint. However, since the derived bracket points of the portfolio investment are not necessarily between the respective bracket points of the housing and stock market investment, assigning 100 to one bracket for the portfolio investment can result in not satisfy the return constraint.

²⁶In Section 5.1, I discuss the robustness of my results considering alternative ways of estimating the mean and standard deviation of the subjective return distribution.

²⁷Regarding the employment status, individuals in the category “other” (comprising unemployed and sick ones, those looking after the home, but also students) are significantly less likely to satisfy the return constraint than employed ones.

poorly at explaining variation in satisfying the return constraint. Measurement error in the elicitation of expectations and in the computation of the mean and standard deviation of the subjective return distributions might also contribute to explaining the low model fit.

The return constraint is satisfied by 50% of respondents, indicating violation by the remaining half. Violation of the return constraint can occur because respondents either underestimate or overestimate the expected return of the portfolio investment. My results show that 21% of respondents *underestimate* the expected portfolio return (i.e., they expect the return of the two-asset portfolio to be *lower than the minimum* expected return of the two individual underlying assets), whereas 29% of respondents *overestimate* the expected portfolio return (i.e., they expect the return of the two-asset portfolio to be *higher than the maximum* expected return of the two individual underlying assets). It is reasonable to assume that respondents who expect the return of a portfolio to be below the return of its individual underlying assets, have no incentive to spread their investments across different assets (cet.par.)—potentially resulting in portfolio underdiversification. The tendency to overestimate the expected portfolio return, can equally result in investment mistakes. When individuals expect higher returns for a portfolio than are realistically attainable, it can have detrimental financial consequences, especially in the context of long-term investments and retirement planning. Furthermore, when realized portfolio returns fail to meet unrealistic expectations, investors may start to question the benefits of diversification.

Table 4 (columns 4–6) reports regression results with *satisfying the risk constraint* as the dependent variable. It shows that three out of four respondents satisfy the risk constraint, i.e., they form expectations about three different investments in a way such that Equation 8 about asset risk holds. Self-employed individuals (as compared to employed ones) and home owners are more likely to satisfy the risk constraint in their expectations formation. Again, we see that individuals who have a good grasp of different financial concepts are also more likely to form subjective expectations in line with the risk constraint.²⁸

Interestingly, the share of respondents who meet the risk constraint is higher than the share of respondents who meet the return constraint. This might be due to the fact that Equation 8 only tests a rather loose condition—the risk of a portfolio being always *smaller than or equal* to the maximum risk associated with its individual underlying assets. In fact, diversification

²⁸The arguments regarding the low model fit raised above also apply here.

Table 4: Correlates of satisfying the return/risk constraint

Dependent variable	Satisfying the return constraint			Satisfying the risk constraint		
	(1)	(2)	(3)	(4)	(5)	(6)
Gender (ref: Male)						
Female	0.001 (0.019)	0.016 (0.020)	0.012 (0.020)	-0.003 (0.016)	0.009 (0.016)	0.008 (0.016)
Other	-0.069 (0.104)	-0.125 (0.113)	-0.125 (0.113)	0.108 (0.085)	0.088 (0.092)	0.085 (0.092)
Age (ref: 35–50)						
18 to 34	0.024 (0.026)	0.028 (0.026)	0.040 (0.027)	-0.023 (0.021)	-0.021 (0.021)	-0.004 (0.022)
51 to 64	0.051* (0.027)	0.041 (0.027)	0.038 (0.028)	0.040* (0.022)	0.030 (0.022)	0.019 (0.023)
65 or older	0.014 (0.043)	0.011 (0.043)	0.009 (0.043)	0.009 (0.035)	0.002 (0.035)	-0.008 (0.035)
Education (ref: Higher)						
Lower or medium	0.002 (0.021)	0.012 (0.021)	0.013 (0.021)	-0.010 (0.017)	0.001 (0.017)	0.004 (0.017)
None	0.021 (0.045)	0.039 (0.045)	0.042 (0.045)	0.024 (0.036)	0.046 (0.037)	0.056 (0.037)
Info missing	-0.017 (0.063)	-0.017 (0.066)	-0.017 (0.066)	-0.028 (0.052)	-0.024 (0.054)	-0.020 (0.054)
Employment status (ref: Employed)						
Self-employed	0.062* (0.037)	0.053 (0.037)	0.054 (0.037)	0.072** (0.030)	0.067** (0.030)	0.065** (0.030)
Retired	0.045 (0.038)	0.034 (0.038)	0.031 (0.038)	0.004 (0.031)	0.002 (0.031)	-0.004 (0.031)
Other	-0.078** (0.033)	-0.078** (0.033)	-0.067** (0.033)	-0.004 (0.027)	-0.003 (0.027)	0.011 (0.027)
Annual HH income (ref: £20k - <£40k)						
Less than £20k	0.013 (0.032)	0.022 (0.032)	0.032 (0.032)	-0.030 (0.026)	-0.022 (0.026)	-0.010 (0.026)
£40k - <£70k	0.058** (0.028)	0.053* (0.028)	0.052* (0.028)	0.019 (0.022)	0.015 (0.022)	0.011 (0.022)
£70k or more	0.073** (0.029)	0.057* (0.029)	0.056* (0.029)	0.036 (0.024)	0.025 (0.024)	0.019 (0.024)
Info missing	0.051* (0.030)	0.056* (0.030)	0.061** (0.030)	-0.043* (0.024)	-0.038 (0.024)	-0.034 (0.024)
Risk averse		-0.023 (0.019)	-0.026 (0.019)		-0.012 (0.016)	-0.013 (0.016)
High financial literacy		0.045** (0.021)	0.044** (0.021)		0.045** (0.017)	0.039** (0.017)
Understands relative asset risk		0.004 (0.022)	0.005 (0.022)		0.030* (0.018)	0.030 (0.018)
Confident working with numbers		0.045** (0.020)	0.044** (0.020)		0.018 (0.016)	0.017 (0.016)
Holding shares/equities			-0.027 (0.023)			0.016 (0.019)
Homeowner			0.055** (0.024)			0.064*** (0.020)
Constant	0.353*** (0.069)	0.309*** (0.073)	0.277*** (0.075)	0.758*** (0.057)	0.707*** (0.060)	0.662*** (0.061)
Mean DepVar	0.50	0.50	0.50	0.79	0.79	0.79
Adj. R-squared	0.01	0.01	0.01	0.01	0.01	0.01
N	2,888	2,878	2,878	2,888	2,878	2,878
Month Fixed Effects	✓	✓	✓	✓	✓	✓

Notes: The table shows estimates from a linear probability model. In columns 1–3, the dependent variable is equal to 1 if an individual is “satisfying the return constraint.” In columns 4–6, the dependent variable is equal to 1 if an individual is “satisfying the risk constraint.” ‘ref.’ indicates the omitted category. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data Source: Financial Lives 2020 survey.

can considerably reduce the risk of an investment (with the risk of a portfolio being *strictly smaller* than the maximum risk of its underlying assets), in particular when the returns of the underlying assets are negatively or only poorly positively correlated. Since respondents' beliefs about the correlation of returns of the two individual assets underlying the portfolio are not explicitly elicited in the Financial Lives survey, Equation 8 is the only condition that I can reliably test.

In total, 21% of respondents do not satisfy the risk constraint, i.e., they expect the risk of a portfolio to exceed that of the individual underlying assets. These individuals clearly lack an understanding of the benefits of diversification for reducing investment risk, potentially translating into investment mistakes such as underdiversification.

To summarize, I find that 41% of respondents satisfy both constraints (see Table 5), 8.7% only satisfy the return constraint, 38% only satisfy the risk constraint, and 12.2% satisfy neither of the two constraints. Yet, there is substantial heterogeneity by socio-economic status. Notably, among the group of high socio-economic-status individuals who self-select into answering the probabilistic expectation questions, there is yet another subgroup of individuals that stands out when it comes to forming subjective expectations about the return and risk of different investments consistent with basic diversification properties—those with higher household income and wealth (acquired through home ownership), self-employed ones, and individuals who possess a broad understanding of financial matters.

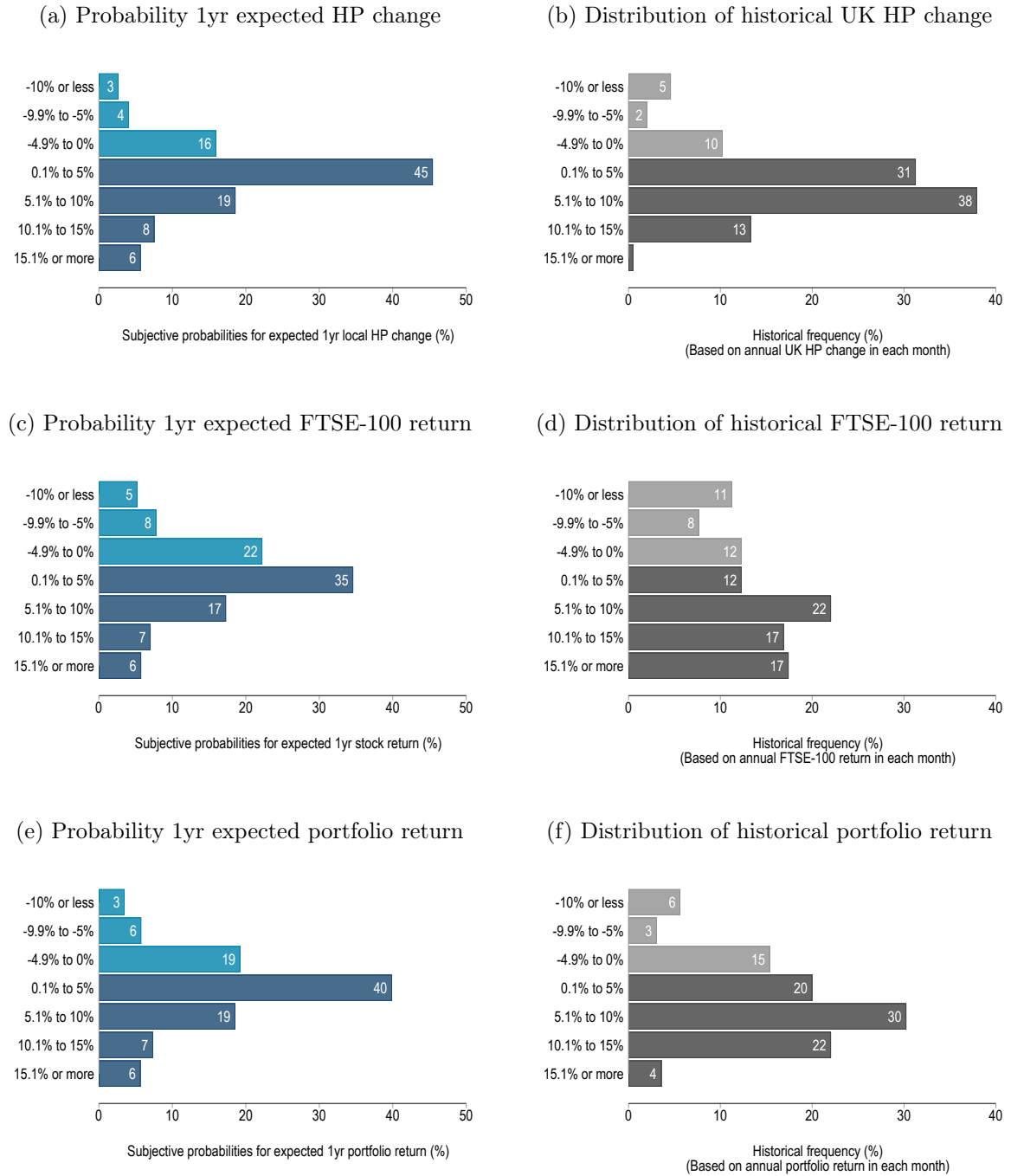
From the literature we know that individuals with low financial sophistication are more likely to make poor financial decisions (e.g., Bianchi, 2018; Disney and Gathergood, 2013; Gathergood and Weber, 2017; van Rooij et al., 2011) which in turn can adversely affect their financial well-being. In light of this evidence, my analysis reveals a concerning trend: a significant share of individuals struggles to take into account basic asset-related concepts in their expectation formation. This issue is especially pronounced among individuals with lower socio-economic status. It would be interesting to investigate further whether individuals who do not satisfy the return and risk constraint, in particular those who underestimate the expected return of a portfolio investment and those who overestimate the risk of such, are more likely to hold underdiversified portfolios, which can cause them to incur sizeable return losses (Gaudecker, 2015).

Table 5: Correlates of satisfying both constraints

Dependent variable	Satisfying the return and risk constraint		
	(1)	(2)	(3)
Gender (ref: Male)			
Female	-0.006 (0.019)	0.006 (0.020)	0.003 (0.020)
Other	0.030 (0.102)	-0.031 (0.111)	-0.033 (0.111)
Age (ref: 35-50)			
18 to 34	-0.007 (0.026)	-0.005 (0.026)	0.011 (0.026)
51 to 64	0.063** (0.027)	0.056** (0.027)	0.048* (0.027)
65 or older	0.033 (0.042)	0.032 (0.042)	0.026 (0.043)
Education (ref: Higher)			
Lower or medium	-0.004 (0.021)	0.003 (0.021)	0.006 (0.021)
None	0.039 (0.044)	0.052 (0.045)	0.059 (0.045)
Info missing	-0.037 (0.062)	-0.047 (0.065)	-0.045 (0.065)
Employment status (ref: Employed)			
Self-employed	0.075** (0.036)	0.069* (0.037)	0.068* (0.037)
Retired	0.015 (0.038)	0.005 (0.038)	0.000 (0.038)
Other	-0.064** (0.032)	-0.063** (0.032)	-0.049 (0.033)
Annual HH income (ref: £20k - <£40k)			
Less than £20k	0.010 (0.031)	0.016 (0.032)	0.028 (0.032)
£40k - <£70k	0.063** (0.027)	0.059** (0.027)	0.056** (0.027)
£70k or more	0.072** (0.028)	0.060** (0.029)	0.056** (0.029)
Info missing	0.021 (0.029)	0.024 (0.029)	0.030 (0.029)
Risk averse		-0.023 (0.019)	-0.025 (0.019)
High financial literacy		0.037* (0.020)	0.033 (0.021)
Understands relative asset risk		0.003 (0.022)	0.003 (0.022)
Confident working with numbers		0.027 (0.019)	0.026 (0.019)
Holding shares/equities			-0.009 (0.022)
Homeowner			0.068*** (0.024)
Constant	0.269*** (0.068)	0.239*** (0.072)	0.194*** (0.074)
Mean DepVar	0.41	0.41	0.41
Adj. R-squared	0.01	0.01	0.01
N	2,888	2,878	2,878
Month Fixed Effects	✓	✓	✓

Notes: The table shows estimates from a linear probability model. The dependent variable is equal to 1 if an individual is “satisfying the return and risk constraint,” i.e., forming subjective expectations about three different investments (two single assets and one two-asset portfolio) in a way consistent with Equation 1 and Equation 8. ‘ref.’ indicates the omitted category. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. *Data Source:* Financial Lives 2020 survey.

Figure 1: Subjective and historical return distributions



Notes: Panels (a/c/e) show the subjective probability distribution of expected 1-year local house-price changes/ FTSE-100 stock-market returns/ portfolio returns. Statistics are based on data from the Financial Lives 2020 survey. $N=2,926$. Panels (b/d/f) show the historical return frequencies based on monthly-computed annual UK HP changes/ FTSE-100 returns/ portfolio returns. Historical values from the UK HPI and the FTSE-100 UK stock-market index for the period from May 2003 to July 2019. Historical annual portfolio returns calculated for each month as: $r_P = 0.5 * r_H + 0.5 * r_S$.

5.1 Robustness

In this section, I study the robustness of my results. First, I take into account whether respondents finished the survey on the same day, and whether they participated in the survey online or face-to-face.²⁹ Second, I take a closer look at individuals' response behavior in the probabilistic expectation questions: I study how straightlining (i.e., respondents assigning identical probability distributions to the different investments) affects the chances of satisfying the return and/or risk constraint. In the literature on the elicitation of expectations using subjective probabilities, it has also been found that individuals show "bunching"³⁰ in their answers at the values of 0, 50, and 100 (Binswanger and Salm, 2017; Bruine de Bruin and Carman, 2012; Hurd, 2009; Kleinjans and Soest, 2014). In additional robustness checks, I therefore also study how bunching in the probabilistic expectation questions is associated with satisfying the two constraints.³¹ Finally, I study the sensitivity of my results with respect to using different approaches (both, other non-parametric as well as parametric ones) in the estimation of the mean and standard deviation of the subjective return distributions.

5.1.1 Survey Duration and Survey Mode

In Table 6, I report results from a regression analysis with *satisfying the return and risk constraint* as dependent variable, including additional covariates. I find that completing the survey within one day or over the course of various days plays no role in satisfying the return and risk constraint (see column 1); also, conducting the survey online or face-to-face does not seem to matter for satisfying the constraints (see column 2). Excluding respondents from the sample who did not finish the survey on the same day, Table 7 shows that the percentage of respondents satisfying the constraints is virtually unchanged (as compared to my baseline

²⁹In the Financial Lives survey, it was not recorded how long respondents spent on each survey question. Thus, it is unfortunately not possible to conduct robustness checks distinguishing between respondents who took more or less time to answer the probabilistic expectation questions.

³⁰Sometimes also referred to as "heaping" or "providing focal-point answers."

³¹It would be interesting to assess respondents' chances of satisfying the constraints by just randomly assigning probabilities to the return brackets of the portfolio investment. To do so, one would have to compute the number of different sets of probabilities that can be assigned to the return brackets of the portfolio investment satisfying the constraints (considering as given the probabilities assigned to the housing and stock investment, and the derived bracket points) as a share of the total number of all possible sets of probabilities. In total, there exist more than 1.7 billion possible different sets of probabilities that can be assigned to the return brackets of the portfolio investment (following the Stars-and-Bars theorem, assuming seven return brackets and respondents assigning integer values only). I refrain from this exercise as it is computationally very demanding.

results); the same is true when excluding respondents who conducted the survey face-to-face. Including control variables for the survey duration and survey mode in the regression analysis does neither cause the sign, the significance levels, nor the size of the previously included regressors to change.

5.1.2 Response Behavior

Straightlining

As outlined in Section 3.2, the Financial Lives 2020 survey elicits expectations of the subjective return distribution associated with three different investments using three separate, yet consecutive survey questions with identical return brackets. The literature on survey design highlights an increased risk of respondents providing similar or identical answers when being confronted with a block of survey questions that use the same response scale, potentially reducing data quality (Kim et al., 2019; Krosnick, 1991). This response strategy, which has come to be known as straightlining or non-differentiation, might also be employed by respondents in the Financial Lives survey when providing answers to the probabilistic expectation questions: I find that 6% of the survey participants report identical probability distributions across all three investments (“straightlining fully”); for 23%, the probability distribution associated with the portfolio investment is identical to either the probability distribution of the stock market investment, the probability distribution of the housing investment, or both (“straightlining partially”) (see Table A3 in the Appendix).

I control for this type of response behavior in the regression analysis and find that straightlining, both fully and partially, is positively associated with satisfying the return and risk constraint (see columns 3 and 4 in Table 6). Given the existing empirical evidence that straightlining is usually applied by lower-educated individuals (Kim et al., 2019),³² it is not implausible to assume that individuals employing this strategy in the Financial Lives survey are classified as satisfying the constraints, but actually lacking a proper understanding of the underlying asset-related concepts. Table 7 shows that excluding straightliners from the sample, the percentage of respondents satisfying both constraints drops by 5%-points.

³²Similarly, in my survey data I find that straightlining is negatively associated with education and overall financial literacy.

Bunching

From the existing literature we know that respondents have a tendency to bunch responses at 0, 50, or 100 when being asked about their expectations using subjective probabilities (Binswanger and Salm, 2017; Bruine de Bruin and Carman, 2012; Hurd, 2009; Kleinjans and Soest, 2014). In a next step, I therefore study the role of bunching in the probabilistic expectation questions in satisfying the return and risk constraint. More specifically, I identify respondents who assign a percentage of (i) 100 (to any bracket, and 0 to the remaining ones) for all three investments (7% of respondents), or (ii) 50/50 (to any two brackets, and 0 to the remaining ones) for all three investments (3.5% of respondents).³³ Controlling for bunching in the regression analysis (see column 5 in Table 6), I find that “bunchers” (irrespective of the type) are significantly more likely to be classified as satisfying the return and risk constraint.³⁴

While for some respondents, reported probabilities at 0, 50, 100 might represent meaningful expectations, for others they can be an expression of uncertainty (Bruine de Bruin et al., 2000; Hudomiet and Willis, 2013; Hurd, 2009; Kleinjans and Soest, 2014), with the latter one being particularly pronounced among individuals with lower numeracy and lower education (Binswanger and Salm, 2017; Bruine de Bruin and Carman, 2012).³⁵ Unfortunately, the Financial Lives 2020 survey does not include any questions measuring respondents’ (un)certainty when reporting their probabilistic return expectations. Hence, it is difficult to assess whether or not bunchers who satisfy the return and risk constraint have a genuine understanding of the underlying asset-related concepts. Excluding observations characterized by bunching, the percentage of respondents satisfying both constraints drops by 3.4%-points to 37.6% (see Table 7).

Including control variables for straightlining and bunching in the regression analysis leads to an increase in the R-squared. Also, it becomes evident that controlling for response behavior is essential in order to avoid the introduction of omitted-variable bias: Once I control for straightlining and bunching in the regression analysis, the size of the effect of financial literacy

³³Across all three investments, bunching of 100 occurred most frequently in the bracket “0.1% to 5%,” and bunching of 50/50 occurred most frequently in the brackets “-4.9% to 0%” and “0.1% to 5%.”

³⁴This is also true when looking at satisfying the return and risk constraint separately (see Table D1 in the Appendix).

³⁵Similarly, in my survey data I find that bunching is negatively associated with education and overall financial literacy.

on satisfying the return and risk constraint considerably increases, with significance levels changing from 10% to 1% (see columns 3–5 in Table 6).³⁶

5.1.3 Alternative Estimation of Moments of Subjective Return Distribution

I further investigate the sensitivity of my results with respect to using alternative approaches in the estimation of the mean and standard deviation of the return distributions for the three different investments. In my baseline analysis, I use the non-parametric estimation approach proposed by Hurd et al. (2011), drawing on historical returns data from 5/2003 to 7/2019 in the derivation of the bracket points, which are then to be weighted with the respondents' probabilities assigned to the different brackets. To test the sensitivity of my results, I first repeat the approach by Hurd et al. (2011) assuming a different time horizon, taking into account all available historical returns data from 3/1985 to 7/2019.³⁷ Next, I consider bracket midpoints (instead of deriving bracket points using historical returns data); I make assumption about the points assigned to the open-ended brackets, following the literature (see e.g., Bailey et al., 2018b; Giglio et al., 2021; Kuchler and Zafar, 2019).³⁸ Finally, I employ a parametric estimation approach: similar to Hurd et al. (2011), Drerup et al. (2017), and Zimpelmann (2021), I fit a log-normal distribution to the cumulative distribution function of expectations to obtain the mean and standard deviation of the return distribution.

For the different estimation approaches, the corresponding results (i.e., the percentage of respondents either satisfying the return constraint, the risk constraint, or both) are summarized in Table 8. Three key findings emerge: First, the number of observations for which both of the constraints are unsatisfiable (i.e., for which there exists no set of probabilities that can be assigned to the portfolio investment such that both constraints are satisfied) varies with the estimation approach (see column “ N unsatisfiable”). Given the change in the bracket points for the different specifications, this is not surprising. For the specification using bracket midpoints, all observations are satisfiable, which is a direct consequence of having identical

³⁶This is due to financial literacy and straightlining/bunching being both positively associated with satisfying the return and risk constraints, but financial literacy and straightlining/bunching being negatively associated. Note that the patterns of an increased R-squared, and an increase in size and improvement in significance of the financial-literacy coefficient is also present when looking at satisfying the return and risk constraint separately (see Table D1 in the Appendix).

³⁷The corresponding bracket points are reported in Table D2 in the Appendix.

³⁸I report results for the points -20 and +30 in the open-ended brackets, respectively, in Table 8, specification (3); the points are held constant across all three investments.

Table 6: Satisfying both constraints – Role of survey duration, mode, and reporting behavior

Dependent variable	Satisfying the return and risk constraint				
	(1)	(2)	(3)	(4)	(5)
Gender (ref: Male)					
Female	0.006 (0.020)	0.007 (0.020)	0.011 (0.019)	0.004 (0.019)	0.009 (0.019)
Other	-0.032 (0.111)	-0.029 (0.111)	0.003 (0.109)	-0.019 (0.109)	-0.002 (0.108)
Age (ref: 35–50)					
18 to 34	-0.006 (0.026)	-0.005 (0.026)	-0.003 (0.025)	0.001 (0.025)	-0.003 (0.025)
51 to 64	0.056** (0.027)	0.056** (0.027)	0.041 (0.026)	0.044* (0.026)	0.049* (0.026)
65 or older	0.031 (0.043)	0.023 (0.043)	0.008 (0.042)	0.013 (0.042)	0.018 (0.042)
Education (ref: Higher)					
Lower or medium	0.004 (0.021)	0.003 (0.021)	0.006 (0.021)	0.001 (0.021)	0.005 (0.021)
None	0.053 (0.045)	0.043 (0.045)	0.042 (0.044)	0.050 (0.044)	0.029 (0.044)
Info missing	-0.047 (0.065)	-0.044 (0.065)	-0.067 (0.063)	-0.065 (0.064)	-0.068 (0.063)
Employment status (ref: Employed)					
Self-employed	0.069* (0.037)	0.069* (0.037)	0.065* (0.036)	0.063* (0.036)	0.067* (0.036)
Retired	0.005 (0.038)	0.003 (0.038)	0.013 (0.037)	0.003 (0.037)	0.013 (0.037)
Other	-0.063** (0.032)	-0.062* (0.032)	-0.059* (0.031)	-0.055* (0.032)	-0.044 (0.031)
Annual HH income (ref: £20k - <£40k)					
Less than £20k	0.015 (0.032)	0.013 (0.032)	0.020 (0.031)	0.019 (0.031)	0.006 (0.031)
£40k - <£70k	0.058** (0.027)	0.058** (0.027)	0.051* (0.027)	0.061** (0.027)	0.054** (0.026)
£70k or more	0.060** (0.029)	0.060** (0.029)	0.057** (0.028)	0.064** (0.028)	0.059** (0.028)
Info missing	0.025 (0.029)	0.022 (0.030)	0.020 (0.029)	0.019 (0.029)	0.002 (0.029)
Risk averse	-0.022 (0.019)	-0.023 (0.019)	-0.028 (0.019)	-0.018 (0.019)	-0.026 (0.019)
High financial literacy	0.036* (0.020)	0.037* (0.020)	0.053*** (0.020)	0.053*** (0.020)	0.060*** (0.020)
Understands relative asset risk	0.003 (0.022)	0.004 (0.022)	0.003 (0.022)	0.004 (0.022)	0.010 (0.021)
Confident working with numbers	0.027 (0.019)	0.027 (0.019)	0.028 (0.019)	0.033* (0.019)	0.023 (0.019)
Survey not finished on same day	0.018 (0.032)	0.020 (0.032)	0.018 (0.031)	0.006 (0.031)	0.026 (0.031)
Survey conducted face-to-face		0.080 (0.055)	0.044 (0.054)	0.040 (0.054)	0.031 (0.054)
Straightlining, fully			0.437*** (0.039)		
Straightlining, partially				0.238*** (0.022)	
Bunching 50%/50%					0.400*** (0.049)
Bunching 100%					0.372*** (0.039)
Constant	0.238*** (0.072)	0.240*** (0.072)	0.224*** (0.071)	0.193*** (0.071)	0.210*** (0.070)
Mean DepVar	0.41	0.41	0.41	0.41	0.41
Adj. R-squared	0.01	0.01	0.05	0.05	0.06
N	2,878	2,878	2,878	2,878	2,878
Month Fixed Effects	✓	✓	✓	✓	✓

Notes: The table shows estimates from a linear probability model. The dependent variable is equal to 1 if an individual is “satisfying the return and risk constraint,” i.e., forming subjective expectations about three different investments (two single assets and one two-asset portfolio) in a way consistent with Equation 1 and Equation 8. ‘ref.’ indicates the omitted category. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data Source: Financial Lives 2020 survey.

Table 7: Robustness – Survey duration, mode, and reporting behavior

	N	Percentage satisfying the		
		Return constraint	Risk constraint	Return and risk constraint
(1) Baseline	2,888	49.8	79.1	41.0
(2) Subsample excl. surveys not finished on same day	2,625	49.4	78.9	40.8
(3) Subsample excl. surveys conducted face-to-face	2,783	49.3	79.1	40.7
(4) Subsample excl. straightlining fully	2,721	47.6	78.0	38.5
(5) Subsample excl. straightlining partially	2,240	46.0	74.9	35.7
(6) Subsample excl. bunching 50%/50%	2,787	48.7	78.7	39.7
(7) Subsample excl. bunching 100%	2,724	48.3	77.8	39.1
(8) Subsample excl. bunching 50%/50% or 100%	2,623	47.1	77.3	37.6

Notes: The table shows, for different subsamples, the percentage of individuals satisfying the return constraint, the risk constraint, or both. *Data Source:* Financial Lives 2020 survey.

bracket points for all three investment types. In the parametric estimation approach, the 106 observations classified as unsatisfiable refer to respondents who put all the probability mass in one of the open-ended brackets for any of the three investments. Second, the percentage of respondents satisfying the risk constraint is robust across the different specifications, ranging between 78.4% and 80%. Third, and in contrast to the previous point, the percentage of respondents satisfying the return constraint shows high variability with respect to using different estimation approaches (percentages vary between 49.8% and 60.8%), also translating into high variability in the percentage of respondents satisfying both constraints.

Table 8: Robustness – Alternative estimation of the mean and standard deviation of the return distribution

	N unsatisfiable	N	Percentage satisfying the		
			Return constraint	Risk constraint	Return and risk constraint
(1) Bracket points from hist. data (5/2003-7/2019)	38	2,888	49.8	79.1	41.0
(2) Bracket points from hist. data (3/1985-7/2019)	24	2,902	50.9	78.4	41.6
(3) Bracket midpoints	0	2,926	60.8	79.0	51.3
(4) Fitting log-normal distribution	106	2,820	57.9	80.0	49.8

Notes: The table shows the robustness of results with respect to using alternative approaches to estimating the mean and standard deviation of the return distribution. The original number of observations, $N=2,926$. Specifications (1) and (2) refer to the non-parametric estimation approach by Hurd et al. (2011), with specification (1) corresponding to my baseline analysis. *Data Source:* Financial Lives 2020 survey.

In the specification using bracket midpoints, the high percentage of respondents satisfying the return constraint is driven by respondents applying “partial straightlining” in their response behavior, i.e., having a probability distribution for the portfolio investments that is identical to either the distribution for the housing or stock market investment, or both. Since bracket points are identical across all three investments, survey participants applying partial straightlining automatically satisfy both constraints. In Table D3 in the Appendix, I show results excluding respondents applying partial straightlining: variability across the different specifications in satisfying the return constraint considerably decreases, with values varying between 45.6% and 49%.

To summarize, the results that I obtain are to some extent sensitive to (i) the assumptions regarding the approach in the estimation of the mean and standard deviation of the subjective return distribution and (ii) the assumptions regarding the validity of certain response behavior in the probabilistic expectation questions. As pointed out by Armona et al. (2019), we do not know individuals’ “mental model” when forming their return expectations. From the series of sensitivity checks conducted in Section 5.1, I can conclude that the true percentage of respondents satisfying the return constraint lies in the range between [45.6% and 60.8%], the percentage satisfying the risk constraint lies between [72.7% and 80%], and the percentage satisfying both constraints lies between [35.2% and 51.3%]. Given that percentages at the upper end of the ranges are often driven by respondents showing response behavior such as straightlining or bunching, together with the empirical evidence that this kind of reporting behavior is particularly present among individuals with low education and low overall financial literacy, the percentage of respondents satisfying the constraints *and* having an actual understanding of the studied concepts of portfolio construction is likely closer to the lower end of the respective ranges.

6 Survey Design: Limitations and Implications

The survey module on asset return and risk included in the Financial Lives 2020 survey is unique in the sense that it is the first one to elicit subjective expectations about joint return distributions. However, the survey module also exhibits limitations, which I want to discuss here in more detail, as well as implications for future survey design.

Non-Response and Self Selection

As outlined in Section 4.1, there is a large share of survey participants that does not provide a response to the probabilistic expectation questions. Even though the Financial Lives survey includes a set of introductory examples to familiarize respondents with the probabilistic question type (see Figure A1 in the Appendix), every fourth respondent reports having difficulties forming return expectations using subjective probabilities, and consequently drops out of the survey module altogether.³⁹ Furthermore, the subsample of respondents that provides

³⁹Hudomiet et al. (2011)/Binswanger and Salm (2017) study survey data from three/five waves of the Health and Retirement Study and report a similar item non-response rate of 19%/18.1% to the main probabilistic expectation question about stock market returns. Hurd et al. (2011) use household survey data to study stock

answers to the probabilistic expectation questions is a highly selected one, characterized by high socio-economic status.

One question for future research that arises from these results is whether there is a way to reduce item non-response and to mitigate the introduction of selection effects. To address this, a potential approach might be to employ an alternative question format for eliciting subjective expectations. For instance, Delavande and Rohwedder (2008) propose a question format that incorporates visualizations—specifically designed for the elicitation of subjective probability distributions in internet surveys. The main idea behind their visual question format is to provide respondents with a certain number of balls that they then assign to different “containers,” which reflect different ranges of a certain variable of interest (in my context, different containers would reflect different ranges of asset returns). The more balls a respondent assigns to a specific container, the more likely they consider an outcome to materialize in the range represented by the container.

The main difference of the visual question format to the format in the Financial Lives survey is that instead of filling in the percent chances for each of the return brackets in a blank field, respondents are provided with a set of balls that they assign to different containers. Especially for individuals who have difficulties dealing with numerical expressions of probabilities, the visual question format might be easier to understand and less demanding. Another advantage of the visual question format is that the number of balls that are yet to be assigned to the different containers is explicitly visible, while in the question format used in the Financial Lives survey, respondents have to do mental calculations, i.e., they have to keep track of how much of the 100 they have already assigned (and how much are still to be assigned) to the different brackets. Since in the Financial Lives survey, non-response is particularly high among individuals with low education, low financial literacy, and low confidence working with numbers, changing the question format by incorporating visual tools might lead to an increase in response rates among individuals with lower socio-economic status, possibly mitigating the introduction of selection effects.⁴⁰ A variation of the visual question format developed by Delavande and Rohwedder (2008) was already successfully adopted in household surveys

market expectations eliciting subjective probabilities for different return thresholds, and find non-response rates varying between 13% and 21% (across the different waves and thresholds).

⁴⁰Delavande and Rohwedder (2008) measure expectations about social security benefits using both, the visual question format and the percent-chance format (eliciting cumulative probabilities), and find no significant difference in the (non-)response rates between the two formats. However, it is not clear to what extent these

eliciting individuals' subjective expectations about asset returns (Drerup et al., 2017, 2023; Zimpelmann, 2021).⁴¹

Another visualization tool that has been applied in the elicitation of asset return expectations involves displaying percent chances assigned by respondents to different return brackets in the form of a histogram (see e.g., Giglio et al., 2021). Thereby, when assigning probabilities to the different brackets, respondents immediately get a visual representation of their subjective probability distribution. However, whether or not this kind of visual aid is powerful enough to reduce non-response (particularly among individuals with lower socio-economic status) is unclear.

In the Financial Lives survey, respondents received a gift card worth £10 once they completed the whole survey. However, participation in the survey module on asset return and risk (including the probabilistic expectation questions) was not incentivized explicitly. Integrating such a financial incentive in the expectation-elicitation task could potentially also contribute to an increase in item response rates. This has been done, for instance, by Drerup et al. (2017) who provide payoffs to a randomized subset of respondents, with payoffs depending on the accuracy of respondents' expressed expectations about stock market returns.

To summarize, the incorporation of visual aids or financial incentives in the measurement of probabilistic return expectations might reduce non-response (and eventually also selection effects). However, it is important to note that individuals who do not provide answers to the probabilistic return expectation questions in the first place, might just not have "well-defined probability distributions in their mind" (Binswanger and Salm, 2017).

Straightlining and Bunching

Some respondents apply response strategies such as straightlining or bunching when being asked about their subjective expected return distributions (Section 5.1). In total, 0.06 (0.23) are characterized by full (partial) straightlining, and 0.03 (0.07) exhibit bunching around 50%/50% (100%). My results show that respondents who exhibit such response strategies are generally more likely to satisfy the return and risk constraint (see Table 6). However,

results can be generalized when eliciting expectations for a different outcome variable or when having a different question design in which percent chances refer to marginal rather than cumulative probabilities.

⁴¹In this particular household survey, responses to the expectation questions are financially incentivized (which is not the case in the Financial Lives survey data, upon which my analysis is based); hence, comparing item (non-)response rates between the two surveys would be misleading.

whether these respondents do indeed have a better understanding of the underlying asset-related concepts is unclear, as there can be various reasons for observing the above-described response strategies: It may be an expression of epistemic uncertainty, inability, or a lack of motivation (Bruine de Bruin et al., 2000; Hurd, 2009; Krosnick, 1991). For some respondents, however, the provided responses may be an accurate expression of their subjective expectations (Manski, 2017). Unfortunately, with the information available in the Financial Lives survey, it is difficult to differentiate between these types of respondents.

For a more in-depth analysis of my results, I would require additional information. For instance, to assess the precision of the elicited subjective expectations data, Drerup et al. (2017) propose a set of measures which involve asking respondents about how difficult they perceived the expectation-elicitation task, or how certain or confident they were about their answers to the expectations questions. Further, they study the consistency of respondents' expectations. To do so, they elicit and compare (i) point estimates of the expected returns and (ii) the full return distribution using probabilistic assessments.⁴² Similar measures are used by Giglio et al. (2021) who study subjective expectations about stock market returns among retail investors. Besides analyzing additional survey data, collecting metadata on the time that respondents spend on answering a probabilistic expectation question could give valuable insights into how much effort of thought they put into it.

7 Conclusions

In this paper, I draw on data from a newly designed survey module to study the formation of expectations about univariate and joint return distributions using subjective probabilities. I find that there is a large share of individuals that has difficulty dealing with the assessment of different outcomes in terms of probabilities. Furthermore, a non-negligible share takes into account basic diversification properties only partially or not at all when forming expectations about the return and risk of different investments. This is particularly the case for individuals with lower socio-economic status.

⁴²Eliciting point estimates in addition to the full distribution of returns in the Financial Lives survey would have allowed me to also directly test Equation 1 (i.e., whether or not someone satisfied the return constraint), and to check internal consistency.

Individuals who do not satisfy the return and risk constraint, especially those who underestimate the expected return of a portfolio investment and those who overestimate the risk of such, have not much incentive to diversify their portfolios, which can result in sizeable return losses, particularly for individuals with low financial literacy (Gaudecker, 2015). My results suggest that understanding of probabilities and basic concepts of diversification are important topics to be covered in financial-education programs and information campaigns, which should specifically be targeted towards individuals with lower financial literacy and lower socio-economic status.

In this paper, I analyze survey data from an initial effort to measure expectations about *joint* return distributions. While the formation of return distributions for single assets is already considered challenging by many individuals, the formation of joint return distribution adds additional complexity as it requires individuals to further take into account the correlation of assets. In my analyses, I find that many survey participants do not participate in the expectation-elicitation task in the first place, or they resort to simple response strategies, introducing measurement noise. Before definite conclusions can be reached, it is therefore important to refine and improve the measurement of joint return distributions. Providing an extensive training on probabilities before eliciting subjective expectations about joint return distributions could be an interesting next step for future research. Furthermore, extending this analysis by investigating the role of joint return distributions in determining stock market participation, portfolio choice, and portfolio diversification is another important avenue for future work.

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Appendix

A Survey Questions and Survey Data

Figure A1: Elicitation of subjective expectations in the *Financial Lives* survey

RISK_INTRO2_2 [STATE TO ALL]

This example shows what we think the chances are of different numbers of days of **rain in Edinburgh** next July.

We don't know for sure how much it will rain, but we can give our best estimate.

	0%		
	<i>Still to use</i>		
0 to 5 days	<input type="text" value="5"/>	% ←	5% chance of 0 to 5 days of rain
6 to 10 days	<input type="text" value="10"/>	% ←	10% chance of 6 to 10 days of rain
11 to 15 days	<input type="text" value="30"/>	% ←	30% chance of 11 to 15 days of rain
16 to 20 days	<input type="text" value="35"/>	%	and so on...
21 to 25 days	<input type="text" value="15"/>	%	
26 or more days	<input type="text" value="5"/>	%	
TOTAL	100	%	

Note all answers must total to 100%.

RISK_INTRO2B [STATE TO ALL]

Here is another weather example. Again, you just need to read this.

This shows what we think the chances are of different numbers of days of **rain in Barcelona** next July (usually less rainy than Edinburgh!)

	5%		
	<i>Still to use</i>		
0 to 5 days	<input type="text" value="80"/>	% ←	80% chance of 0 to 5 days of rain
6 to 10 days	<input type="text" value="10"/>	% ←	10% chance of 6 to 10 days of rain
11 to 15 days	<input type="text" value="5"/>	% ←	5% chance of 11 to 15 days of rain
16 to 20 days	<input type="text"/>	%	and so on...
21 to 25 days	<input type="text"/>	%	
26 or more days	<input type="text"/>	%	
TOTAL	95	%	

Note all answers need to total to 100%. In this example, 5% points are still to be used.

Figure A1: Elicitation of subjective expectations in the *Financial Lives* survey (cont.)

RISK4_INTRO [STATE TO ALL]

Now you've seen the examples of the chances of rain next July in Edinburgh and Barcelona, we want to ask you about the chances of different investments making money.

For the next few questions, imagine you receive an unexpected inheritance of £100,000.

RISK5

Imagine you put the £100,000 towards buying a house in your local area.

What do you think are the percentage chances that the house will have gone up or down in value by the amounts given below in 12 months' time?

Write a percentage chance in each box-to reflect how likely you think different outcomes are. Make sure your percentages add up to 100%.

		0%	
		<i>Still to use</i>	
Rise in house value		% chance of 15.1% or more rise in house value	
		% chance of 10.1% to 15% rise in house value	
		% chance of 5.1% to 10% rise in house value	
		% chance of 0.1% to 5% rise in house value	
<hr style="border: 0.5px solid black;"/>			
Fall in house value		% chance of 0% to 4.9% fall in house value	
		% chance of 5% to 9.9% fall in house value	
		% chance of 10% or more fall in house value	
Total		% Note all answers must total to 100%.	

RISK6

Imagine instead you invest the £100,000 in the **FTSE 100, which is the main UK stock market index.**

What do you think are the percentage chances that your stock market investment will have gone up or down in value by the amounts given below in 12 months' time?

Write a percentage chance in each box to reflect how likely you think different outcomes are. Make sure your percentages add up to 100%.

		0%	
		<i>Still to use</i>	
Rise in stock market value		% chance of 15.1% or more rise in stock market value	
		% chance of 10.1% to 15% rise in stock market value	
		% chance of 5.1% to 10% rise in stock market value	
		% chance of 0.1% to 5% rise in stock market value	
<hr style="border: 0.5px solid black;"/>			
Fall in stock market value		% chance of 0% to 4.9% fall in stock market value	
		% chance of 5% to 9.9% fall in stock market value	
		% chance of 10% or more fall in stock market value	
Total		% Note all answers must total to 100%.	

Figure A1: Elicitation of subjective expectations in the *Financial Lives* survey (cont.)

RISK7

Now imagine you decide to split your investment and put:

- £50,000 towards buying a house in your local area and
- £50,000 in the main UK stock market index, called the FTSE 100 index

What do you think are the percentage chances that this total investment will have gone up or down in value by the amounts given below in 12 months' time?

Write a percentage chance in each box to reflect how likely you think different outcomes are. Make sure your percentages add up to 100%.

	0%	
	<i>Still to use</i>	
Rise in investment value	<input style="width: 80px; height: 25px;" type="text"/>	% chance of 15.1% or more rise in investment value
	<input style="width: 80px; height: 25px;" type="text"/>	% chance of 10.1% to 15% rise in investment value
	<input style="width: 80px; height: 25px;" type="text"/>	% chance of 5.1% to 10% rise in investment value
	<input style="width: 80px; height: 25px;" type="text"/>	% chance of 0.1% to 5% rise in investment value
Fall in investment value	<input style="width: 80px; height: 25px;" type="text"/>	% chance of 0% to 4.9% fall in investment value
	<input style="width: 80px; height: 25px;" type="text"/>	% chance of 5% to 9.9% fall in investment value
	<input style="width: 80px; height: 25px;" type="text"/>	% chance of 10% or more fall in investment value
TOTAL		% Note all answers must total to 100%.

Data Source: Financial Lives 2020 survey.

Table A1: Elicitation of financial literacy in the *Financial Lives* Survey

Concept	Survey question
Interest rate	Suppose you put £100 into a savings account with a guaranteed interest rate of 2% per year. There are no fees or tax to pay. You don't make any further payments into this account and you don't withdraw any money. How much would be in the account at the end of the first year, once the interest payment is made? Please type in your answer to the nearest pound.
Interest compound	And how much would be in the account at the end of five years (remembering that there are no fees or tax deductions)? <ol style="list-style-type: none"> 1. More than £110 2. Exactly £110 3. Less than £110 4. It is impossible to tell from the information given 5. Do not know
Inflation	If the inflation rate is 5% and the interest rate you get on your savings is 3%, will your savings have more, less or the same amount of buying power in a year's time? <ol style="list-style-type: none"> 1. More 2. The same 3. Less 4. Do not know
Risk diversification	Is the following statement true or false? Buying shares in a single company usually provides a safer return than buying shares in a range of companies. <ol style="list-style-type: none"> 1. True 2. False 3. Do not know

Notes: The table shows the financial-literacy questions on interest rates, interest compound, inflation, and risk diversification included in the Financial Lives 2020 survey.

Table A2: Description of variables

Label	Description
<i>(a) Socio-demographic characteristics</i>	
	Dummy equal to 1 if ...
Gender: Female	Female.
Gender: Male	Male.
Gender: Other	Non-binary/gender-fluid, or gender not disclosed.
Age 18 to 34	Aged between 18 and 34.
Age 35 to 50	Aged between 35 and 50.
Age 51 to 64	Aged between 51 and 64.
Age 65 or older	Aged 65 or older.
Education: Higher	One of the following qualifications: (1) Higher degree, or (2) Degree or degree equivalent, or (3) Other Higher Education below degree level.
Education: Lower or medium	One of the following qualifications: (1) A level, vocational level 3 and equivalents, or (2) Trade Apprenticeships, or (3) O level/ GCSE Grades 4-9/A*-C, vocational level 2 and equivalents, or (4) Qualifications at level 1 and below, or (5) Other qualifications including overseas.

Continued on next page

Table A2 (Continued)

Label	Description
Education: None	No qualifications, or question about qualifications answered with “don’t know.”
Education: Info missing	No information on respondent’s education.
Employment status: Employed	Working for an employer (full-time or part-time) or agency work.
Employment status: Self-employed	Being self-employed (full-time or part-time).
Employment status: Retired	Being retired or semi-retired (drawing a pension or other income but still working).
Employment status: Other	Being unemployed, sick/disabled, student, carer, looking after the home, doing voluntary work, or answering “don’t know.”
Annual HH income: less than £20k	Total annual household income from all sources (including benefits) before taxes and other deductions less than £20,000 a year.
Annual HH income: £20k–<£40k	... £20,000 or more but less than £40,000 a year.
Annual HH income: £40k–<£70k	... £40,000 or more but less than £70,000 a year.
Annual HH income: £70k or more	... £70,000 or more a year.
Annual HH income: info missing	No information on respondents’ total annual household income.
Risk averse	Willingness to take risks ≤ 4 , when 0 is “not at all willing to take risks” and 10 is “very willing to take risks.”
High financial literacy	All four standard financial-literacy questions (about interest rates, interest compounding, inflation, and risk diversification) are answered correctly.
Understands relative asset risk	“Bank/savings account” ranked as least risky investment in a list together with two other investments such as “housing in local area” and “stock market.”
Confident working with numbers	Confidence working with numbers equal to 10, when 0 is “not at all confident” and 10 is “completely confident.”
Owens shares/equities	Owning shares or equities.
Homeowner	Owning the property currently living in (1) outright, or (2) with a mortgage (or a different kind of loan).
<i>(b) Survey duration and mode</i>	
Survey conducted face-to-face	Survey conducted face-to-face, and 0 if survey conducted online.
Survey not finished on same day	Survey questionnaire not finished on the same day.
<i>(c) Response behavior in probabilistic expectations questions</i>	
Straightlining, fully	Reported identical probability distributions to the probabilistic expectations questions on returns for all three investments (in the local housing market, the FTSE-100 stock-market index, and a portfolio).
Straightlining, partially	Reported probability distributions associated with the portfolio investment identical to either the probability distribution of the investment in the FTSE-100 stock-market index, the probability distribution of the investment in the local housing market, or both.
Bunching 50%/50%	Reported a probability of 100 in the probabilistic expectations questions to any return bracket, and 0 to the remaining ones for all three investments (in the local housing market, the FTSE-100 stock-market index, and a portfolio).
Bunching 100%	Reported probabilities of 50/50 in the probabilistic expectations questions to any two return brackets, and 0 to the remaining ones for all three investments (in the local housing market, the FTSE-100 stock-market index, and a portfolio).

Notes: The table shows a detailed description of the variables used in the analyses.

Table A3: Summary Statistics

	Observations total			Observations with answers to expectations questions			Observations with answers to expectations questions and constraints being satisfiable		
	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev
<i>(a) Socio-demographic characteristics</i>									
Gender: Male	3,843	0.48	0.50	2,926	0.52	0.50	2,888	0.52	0.50
Gender: Female	3,843	0.51	0.50	2,926	0.47	0.50	2,888	0.47	0.50
Gender: Other	3,843	0.01	0.11	2,926	0.01	0.09	2,888	0.01	0.09
Age 18 to 34	3,843	0.27	0.44	2,926	0.23	0.42	2,888	0.23	0.42
Age 35 to 50	3,843	0.29	0.45	2,926	0.30	0.46	2,888	0.30	0.46
Age 51 to 64	3,843	0.22	0.42	2,926	0.24	0.43	2,888	0.24	0.43
Age 65 or older	3,843	0.22	0.41	2,926	0.23	0.42	2,888	0.23	0.42
Higher education	3,843	0.56	0.50	2,926	0.63	0.48	2,888	0.63	0.48
Lower or medium education	3,843	0.31	0.46	2,926	0.30	0.46	2,888	0.30	0.46
No education	3,843	0.08	0.27	2,926	0.05	0.22	2,888	0.05	0.22
Education info missing	3,843	0.05	0.22	2,926	0.03	0.16	2,888	0.02	0.15
Employment status: Employed	3,843	0.54	0.50	2,926	0.55	0.50	2,888	0.55	0.50
Employment status: Self-employed	3,843	0.07	0.25	2,926	0.07	0.26	2,888	0.07	0.26
Employment status: Retired	3,843	0.25	0.43	2,926	0.27	0.44	2,888	0.26	0.44
Employment status: Other	3,843	0.14	0.35	2,926	0.11	0.32	2,888	0.11	0.31
Annual HH income: less than £20k	3,843	0.17	0.38	2,926	0.15	0.36	2,888	0.15	0.36
Annual HH income: £20k - <£40k	3,843	0.22	0.41	2,926	0.23	0.42	2,888	0.23	0.42
Annual HH income: £40k - <£70k	3,843	0.20	0.40	2,926	0.23	0.42	2,888	0.23	0.42
Annual HH income: £70k+	3,843	0.17	0.37	2,926	0.20	0.40	2,888	0.20	0.40
Annual HH income: info missing	3,843	0.24	0.43	2,926	0.18	0.39	2,888	0.18	0.39
Risk averse	3,806	0.44	0.50	2,916	0.42	0.49	2,878	0.42	0.49
High financial literacy	3,843	0.38	0.49	2,926	0.47	0.50	2,888	0.47	0.50
Understands relative asset risk	3,843	0.71	0.45	2,926	0.75	0.43	2,888	0.76	0.43
Confident working with numbers	3,843	0.38	0.49	2,926	0.42	0.49	2,888	0.42	0.49
Holding shares/equities	3,843	0.22	0.42	2,926	0.27	0.44	2,888	0.27	0.44
Homeowner	3,843	0.66	0.48	2,926	0.72	0.45	2,888	0.72	0.45
<i>(b) Survey duration and mode</i>									
Survey conducted face-to-face	3,843	0.06	0.23	2,926	0.04	0.19	2,888	0.04	0.19
Survey not finished on same day	3,843	0.08	0.27	2,926	0.09	0.29	2,888	0.09	0.29
<i>(c) Response behavior in probabilistic expectations questions</i>									
Straightlining, fully	2,926	0.06	0.24	2,926	0.06	0.24	2,888	0.06	0.23
Straightlining, partially	2,926	0.23	0.42	2,926	0.23	0.42	2,888	0.22	0.42
Bunching 50%/50%	2,926	0.03	0.18	2,926	0.03	0.18	2,888	0.03	0.18
Bunching 100%	2,926	0.07	0.25	2,926	0.07	0.25	2,888	0.06	0.23

Notes: The table shows summary statistics for the total sample of observations, the subsample of observations that provides answers to the probabilistic expectation questions, and the subsample of observations that provides answers to the probabilistic expectation questions and for which the return and risk constraints are satisfiable (for a discussion of satisfiability, see Section 5). *Data Source:* Financial Lives 2020 survey.

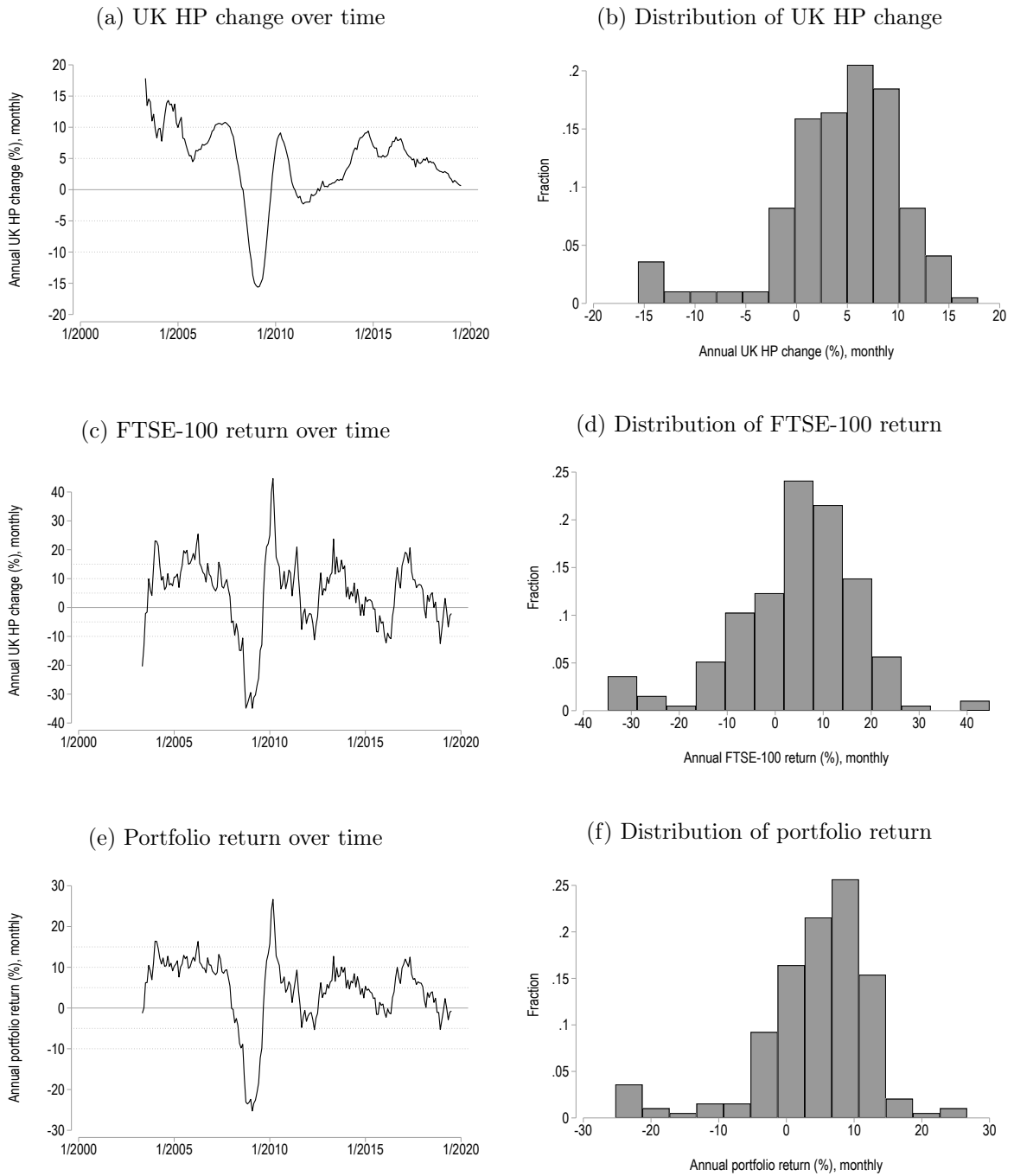
Table A4: Detailed summary statistics of survey responses on asset return expectations

	Mean	SD	P10	P25	P50	P75	P90
<i>(a) Probability 1yr local HP change in bracket (%)</i>							
B1: -10% or less	2.67	8.83	0	0	0	1	10
B2: -9.9% to -5%	4.09	8.45	0	0	0	5	10
B3: -4.9% to 0%	15.96	19.56	0	0	10	25	50
B4: 0.1% to 5%	45.46	31.76	0	20	48	70	95
B5: 5.1% to 10%	18.59	22.58	0	0	10	25	50
B6: 10.1% to 15%	7.54	14.50	0	0	0	10	20
B7: 15.1% or more	5.69	15.87	0	0	0	5	15
<i>(b) Probability 1yr stock return in bracket (%)</i>							
B1: -10% or less	5.24	12.36	0	0	0	5	15
B2: -9.9% to -5%	7.81	11.79	0	0	5	10	20
B3: -4.9% to 0%	22.24	20.24	0	5	20	30	50
B4: 0.1% to 5%	34.61	26.95	0	15	30	50	75
B5: 5.1% to 10%	17.32	20.74	0	0	10	20	45
B6: 10.1% to 15%	7.03	12.18	0	0	0	10	20
B7: 15.1% or more	5.75	15.07	0	0	0	5	15
<i>(c) Probability 1yr portfolio return in bracket (%)</i>							
B1: -10% or less	3.50	10.07	0	0	0	3	10
B2: -9.9% to -5%	5.77	9.94	0	0	0	10	15
B3: -4.9% to 0%	19.24	18.43	0	3	15	30	50
B4: 0.1% to 5%	39.90	29.03	0	20	40	50	85
B5: 5.1% to 10%	18.56	22.50	0	0	10	25	50
B6: 10.1% to 15%	7.37	14.18	0	0	0	10	20
B7: 15.1% or more	5.67	15.43	0	0	0	5	15

Notes: The table shows summary statistics of the probabilities assigned to the different return brackets for three different investments (housing, stocks, portfolio) in the expectation elicitation. *Data Source:* Financial Lives 2020 survey, $N=2,926$.

B Historical Asset Returns

Figure B1: Historical returns, 5/2003 to 7/2019

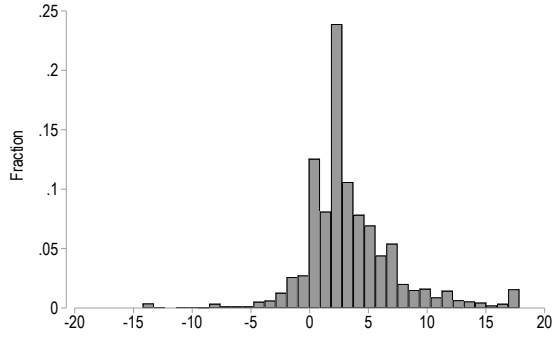


Notes: The figure shows the historical trends and the distribution of monthly-computed annual asset returns for the period from May 2003 to July 2019, used in the computation of $E(r|r \in B_j)$ in Section 3.3. In Panels (e) and (f), the “portfolio return” is computed for each month as the weighted average of the annual UK HP change (see Panels (a) and (b)) and the annual FTSE-100 return (see Panels (c) and (d)) with weights equal to 0.5. The horizontal lines in Panels (a), (c), and (e) correspond to the survey return brackets. *Data Source:* Historical values from the UK HPI and the FTSE-100 UK stock-market index.

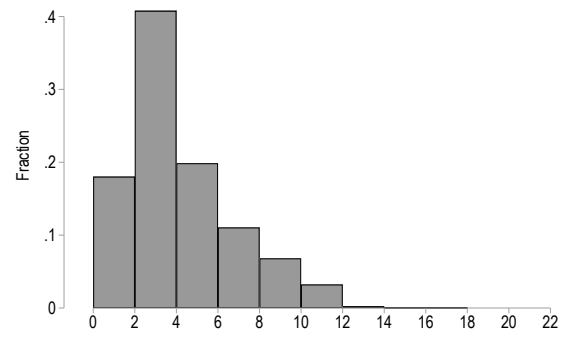
C Estimated Moments of the Subjective Return Distributions

Figure C1: Mean, $E(r)$, and standard deviation, $SD(r)$, of the expected return distributions

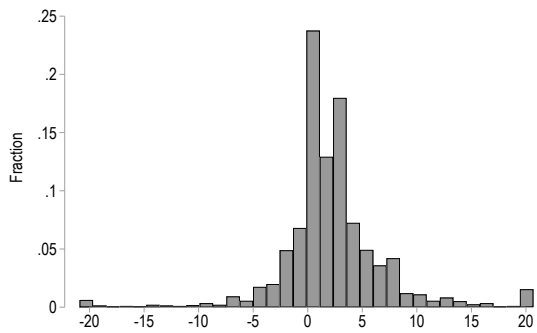
(a) Mean of the expected return distribution for the housing investment



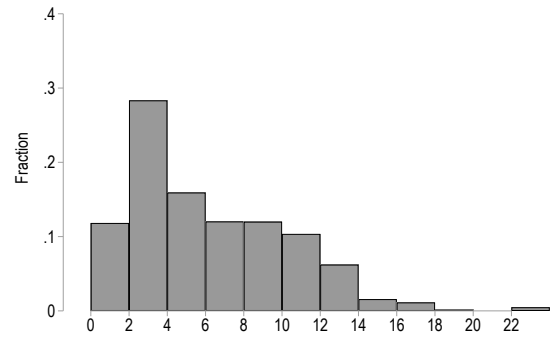
(b) Standard deviation of the expected return distribution for the housing investment



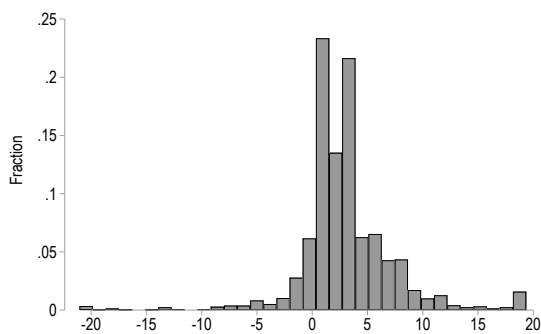
(c) Mean of the expected return distribution for the stock investment



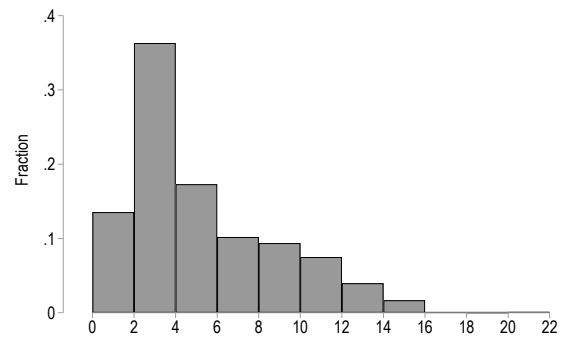
(d) Standard deviation of the expected return distribution for the stock investment



(e) Mean of the expected return distribution for the portfolio investment



(f) Standard deviation of the expected return distribution for the portfolio investment



Notes: The figures show histograms for the distribution of the mean and standard deviation (SD) of the expected return distribution (following the non-parametric estimation approach by Hurd et al., 2011) for different investments. *Data Source:* UK HPI, FTSE-100 UK stock-market index, and Financial Lives 2020 survey, $N=2,926$.

D Subjective Expectations and Consistency with Basic Diversification Properties

Table D1: Robustness – Survey mode, straightlining, bunching

Dependent variable	Satisfying the return constraint				Satisfying the risk constraint			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gender (ref: Male)								
Female	0.015 (0.020)	0.017 (0.020)	0.020 (0.020)	0.019 (0.020)	0.009 (0.016)	0.009 (0.016)	0.011 (0.016)	0.011 (0.016)
Other	-0.127 (0.113)	-0.123 (0.113)	-0.097 (0.111)	-0.104 (0.111)	0.088 (0.092)	0.088 (0.092)	0.102 (0.092)	0.109 (0.091)
Age (ref: 35–50)								
18 to 34	0.028 (0.026)	0.028 (0.026)	0.030 (0.026)	0.030 (0.026)	-0.021 (0.021)	-0.021 (0.021)	-0.020 (0.021)	-0.020 (0.021)
51 to 64	0.041 (0.027)	0.041 (0.027)	0.029 (0.027)	0.035 (0.027)	0.030 (0.022)	0.030 (0.022)	0.023 (0.022)	0.026 (0.022)
65 or older	0.009 (0.043)	-0.001 (0.043)	-0.014 (0.043)	-0.005 (0.043)	0.001 (0.035)	-0.001 (0.035)	-0.008 (0.035)	-0.004 (0.035)
Education (ref: Higher)								
Lower or medium	0.013 (0.021)	0.011 (0.021)	0.013 (0.021)	0.013 (0.021)	0.001 (0.017)	0.001 (0.017)	0.002 (0.017)	0.002 (0.017)
None	0.041 (0.045)	0.028 (0.046)	0.026 (0.045)	0.017 (0.045)	0.047 (0.037)	0.044 (0.037)	0.044 (0.037)	0.033 (0.037)
Info missing	-0.016 (0.066)	-0.012 (0.066)	-0.031 (0.065)	-0.028 (0.065)	-0.024 (0.054)	-0.023 (0.054)	-0.033 (0.053)	-0.044 (0.053)
Employment status (ref: Employed)								
Self-employed	0.053 (0.037)	0.054 (0.037)	0.051 (0.037)	0.052 (0.037)	0.067** (0.030)	0.067** (0.030)	0.066** (0.030)	0.066** (0.030)
Retired	0.033 (0.038)	0.030 (0.038)	0.038 (0.038)	0.038 (0.038)	0.002 (0.031)	0.002 (0.031)	0.006 (0.031)	0.009 (0.031)
Other	-0.078** (0.033)	-0.076** (0.033)	-0.074** (0.032)	-0.062* (0.032)	-0.003 (0.027)	-0.003 (0.027)	-0.002 (0.027)	0.006 (0.026)
Annual HH income (ref: £20k - <£40k)								
Less than £20k	0.021 (0.032)	0.017 (0.032)	0.024 (0.032)	0.012 (0.032)	-0.022 (0.026)	-0.023 (0.026)	-0.020 (0.026)	-0.027 (0.026)
£40k - <£70k	0.053* (0.028)	0.052* (0.028)	0.046* (0.027)	0.049* (0.027)	0.014 (0.022)	0.014 (0.022)	0.011 (0.022)	0.012 (0.022)
£70k or more	0.057** (0.029)	0.057* (0.029)	0.055* (0.029)	0.056* (0.029)	0.025 (0.024)	0.025 (0.024)	0.024 (0.024)	0.025 (0.023)
Info missing	0.057* (0.030)	0.052* (0.030)	0.051* (0.030)	0.038 (0.030)	-0.038 (0.024)	-0.038 (0.025)	-0.039 (0.024)	-0.049** (0.024)
Risk averse	-0.023 (0.019)	-0.023 (0.019)	-0.028 (0.019)	-0.026 (0.019)	-0.012 (0.016)	-0.013 (0.016)	-0.015 (0.016)	-0.013 (0.016)
High financial literacy	0.044** (0.021)	0.046** (0.021)	0.059*** (0.021)	0.063*** (0.021)	0.044*** (0.017)	0.045*** (0.017)	0.051*** (0.017)	0.057*** (0.017)
Understands relative asset risk	0.004 (0.022)	0.005 (0.022)	0.005 (0.022)	0.009 (0.022)	0.030* (0.018)	0.030* (0.018)	0.030* (0.018)	0.035* (0.018)
Confident working with numbers	0.045** (0.020)	0.044** (0.020)	0.045** (0.019)	0.042** (0.019)	0.018 (0.016)	0.018 (0.016)	0.018 (0.016)	0.016 (0.016)
Interview not finished on same day	0.035 (0.032)	0.037 (0.032)	0.036 (0.032)	0.042 (0.032)	0.013 (0.026)	0.014 (0.026)	0.013 (0.026)	0.017 (0.026)
Interview conducted face-to-face		0.112** (0.055)	0.083 (0.055)	0.078 (0.055)		0.019 (0.045)	0.003 (0.045)	-0.018 (0.045)
Straightlining			0.360*** (0.040)				0.193*** (0.033)	
Bunching 50%/50%				0.331*** (0.050)				0.138*** (0.041)
Bunching 100%				0.266*** (0.041)				0.258*** (0.033)
Constant	0.308*** (0.073)	0.311*** (0.073)	0.298*** (0.072)	0.289*** (0.072)	0.706*** (0.060)	0.707*** (0.060)	0.700*** (0.059)	0.691*** (0.059)
Mean DepVar	0.50	0.50	0.50	0.50	0.79	0.79	0.79	0.79
Adj. R-squared	0.01	0.01	0.04	0.04	0.01	0.01	0.02	0.03
N	2,878	2,878	2,878	2,878	2,878	2,878	2,878	2,878
Month Fixed Effects	✓	✓	✓	✓	✓	✓	✓	✓

Notes: The table shows estimates from a linear probability model. The dependent variable is equal to 1 if an individual is “satisfying the return and risk constraint,” i.e., forming subjective expectations about three different investments (two single assets and one two-asset portfolio) in a way consistent with Equation 1 and Equation 8. ‘ref.’ indicates the omitted category. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data Source: Financial Lives 2020 survey.

Table D2: Bracket points, $E(r|r \in B_j)$

Bracket	Housing	Stock	Portfolio
B1: -10% or less	-14.21	-19.10	-21.05
B2: -9.9% to -5%	-7.15	-7.24	-7.12
B3: -4.9% to 0%	-1.78	-2.39	-2.05
B4: 0.1% to 5%	2.51	2.87	2.70
B5: 5.1% to 10%	7.70	7.37	7.66
B6: 10.1% to 15%	12.03	12.65	11.92
B7: 15.1% or more	21.41	23.12	20.34

Notes: The table shows bracket points derived from historical returns data (from 3/1985–7/2019) conditional on the return being in the bracket (following the approach by Hurd et al., 2011). *Data Source:* Historical values from the UK HPI and the FTSE-100 UK stock-market index.

Table D3: Robustness – Alternative estimation of the mean and standard deviation of the return distribution, excluding partial straightliners

	N unsatisfiable	N	Percentage satisfying the		
			Return constraint	Risk constraint	Return and risk constraint
(1) Bracket points from hist. data (5/2003-7/2019)	11	2,240	46.0	74.9	35.7
(2) Bracket points from hist. data (3/1985-7/2019)	6	2,245	46.9	74.5	36.2
(3) Bracket midpoints	0	2,251	49.0	72.7	36.7
(4) Fitting log-normal distribution	69	2,182	45.6	74.2	35.2

Notes: The table shows the robustness of results with respect to using alternative approaches to estimating the mean and standard deviation of the return distribution. The original number of observations excluding partial straightliners, $N=2,251$. Specifications (1) and (2) refer to the non-parametric estimation approach by Hurd et al. (2011), with specification (1) corresponding to my baseline analysis. *Data Source:* Financial Lives 2020 survey.