# Low Interest Rates and Risk Taking: Evidence from Individual Investment Decisions*

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**Abstract**

We study the impact of low interest rates on risk taking. We demonstrate that individuals "reach for yield," that is, have a greater appetite for risk taking when interest rates are low. Using randomized investment experiments holding fixed risk premia and risks, we show that low interest rates lead to significantly higher allocations to risky assets, among MTurk subjects and HBS MBAs. This effect also displays non-linearity, and becomes increasingly pronounced as interest rates decrease below historical norms. The behavior is not easily explained by conventional portfolio choice theory or by institutional frictions. We then propose and provide evidence for mechanisms related to investor psychology, including reference dependence and salience. We also present results using historical data on household investment decisions.

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# 1 Introduction

Since the global financial crisis, central banks in major developed countries have set benchmark interest rates to historic lows. A widely discussed question is whether such low interest rates increase investors' appetite for risk taking, a phenomenon often referred to as "reaching for yield."[1] Increased risk taking may help stimulate the economy, but may also pose challenges for financial stability. Policy makers and investors have highlighted the importance of reaching for yield (Bernanke, 2013; Stein, 2013; Rajan, 2013; Fink, 2016). Researchers also posit the "risk-taking channel" of monetary policy (Borio and Zhu, 2012; Bruno and Shin, 2015; Brunnermeier and Schnabel, 2016).

What drives reaching for yield? Recent work offers insights based on institutional frictions, including agency problems (Feroli, Kashyap, Schoenholtz, and Shin, 2014; Morris and Shin, 2015; Acharya and Naqvi, 2015) and financial intermediaries' funding conditions (Diamond and Rajan, 2012; Drechsler, Savov, and Schnabl, 2015). A number of studies also provide empirical evidence that banks, money market mutual funds, and corporate bond mutual funds invest in riskier assets when interest rates are low (Maddaloni and Peydró, 2011; Jiménez, Ongena, Peydró, and Saurina, 2014; Chodorow-Reich, 2014; Hanson and Stein, 2015; Choi and Kronlund, 2016; Di Maggio and Kacperczyk, 2017).

In this paper, we present evidence that reaching for yield is not confined to institutions. Rather, it can be driven by preferences and psychology, and arise from the way people perceive and evaluate return and risk trade-offs in different interest rate environments.

Specifically, we show that individuals demonstrate a stronger preference for risky assets when the risk-free rate is low. We first document this phenomenon in a simple randomized experiment. In Treatment Group 1, participants consider investing between a risk-free asset with 5% returns and a risky asset with 10% average returns (the risky payoffs are approximately normally distributed with 18% volatility). In Treatment Group 2, participants consider investing between a risk-free asset with 1% returns and a risky asset with 6% average returns (the risky payoffs are again approximately normally distributed with 18% volatility). In other words, across the two treatment conditions, we keep the risk pre-

[1] The term "reaching for yield" is sometimes used in different ways. For instance, Becker and Ivashina (2015) document that insurance companies have a general propensity to buy riskier assets, and refer to this behavior as "reaching for yield." In recent discussions of monetary policy and financial markets, "reaching for yield" refers more specifically to the notion that investors may have a higher propensity to take risks *when interest rates are low*, which is what we focus on. The "reaching for yield" behavior we study in this paper, most precisely, is that people invest more in risky assets when interest rates are low, holding fixed the risks and excess returns of risky assets.

mium (i.e. average excess returns) and the risks of the risky asset fixed, and only make a downward shift in the risk-free interest rate. Participants are randomly assigned to one of the two conditions. The investment decision in each condition represents the simplest mean-variance analysis problem, where the solution should not be affected by the risk-free rate based on the textbook mean-variance benchmark (Markowitz, 1952; Sharpe, 1964).

We find robust evidence that people in the low interest rate condition (Treatment Group 2) invest significantly more in the risky asset than people in the high interest rate condition (Treatment Group 1). The average investment share in the risky asset increases by about 8 percentage points. This finding holds among large and diverse groups of participants (several thousand participants from the US general population through Amazon's Mechanical Turk platform as well as four hundred Harvard Business School MBA students), and across different settings (hypothetical questions as well as incentivized experiments). Such behavior by individuals is not explained by institutional frictions. It is also hard to square with standard portfolio choice theory under fairly general conditions (specifically, absolute risk aversion is weakly decreasing in wealth).

We conjecture two categories of mechanisms that may contribute to reaching for yield in individual investment decisions. The first category captures the observation that people may form reference points of investment returns. When interest rates fall below the reference level, people experience discomfort, and become more willing to invest in risky assets to seek higher returns. This observation connects to the popular view among investors that 1% interest rates are "too low," in comparison to what they have become used to over past experiences. Reference dependence is a well recognized feature of decision making (Kahneman and Tversky, 1979), and increasing research points to the importance of history-dependent reference points (Kahneman and Miller, 1986; Bordalo, Gennaioli, and Shleifer, 2017). The observation also suggests a novel implication that the degree of reaching for yield when interest rates are low may depend on the previous economic environment.

The second category of mechanisms postulates that reaching for yield could be affected by the salience of the higher average returns on the risky asset in different interest rate environments. Specifically, 6% average returns relative to 1% risk-free returns may be more salient than 10% average returns relative to 5% risk-free returns. This intuition can be formalized by a version of the Salience Theory (Bordalo, Gennaioli, and Shleifer, 2013a). It also connects to the well documented phenomenon, often referred to as Weber's law, that people tend to evaluate stimuli by proportions (i.e. 6/1 is much larger than 10/5) rather than by differences.

We design a set of additional tests to investigate these potential mechanisms, and find support for both. First, we document considerable non-linearity in how investment decisions respond to interest rates. We examine allocations across a wider range of interest rate conditions, from -1% to up to 15% (holding fixed the excess returns of the risky asset as before), and randomly assign participants to one of these conditions. We find that reaching for yield is particularly pronounced as interest rates decrease below historical norms prior to the Great Recession, and dissipates when interest rates are sufficiently high. The non-linear response to interest rates further suggests the psychological foundations of reaching for yield. The patterns are consistent with history-dependent reference points. They are also broadly consistent with salience, as the proportions change more with interest rates when rates are low.

Second, as further evidence for history-dependent reference points, we find that investment history has a significant impact on investment decisions. For instance, when participants first make investment decisions in the high interest rate condition and then make decisions in the low interest rate condition, they invest substantially more in the risky asset in the low rate condition.

Third, as further evidence for salience, risk taking decreases and reaching for yield is dampened if investment payoffs are presented using gross returns (e.g. instead of saying 6%, we say that one gets 1.06 units for every unit invested). In this case, the proportion of average returns shrinks (from 6/1 and 10/5, to 1.06/1.01 and 1.1/1.05), especially in the low interest rate condition, and becomes similar across the two conditions. As the higher average returns of the risky asset become much less salient, risk-taking in the low interest rate condition diminishes.

Our study uses an experimental approach as experiments allow us to cleanly isolate the effect of changes in the risk-free rate, and hold fixed the excess returns and risks of the risky asset. It is otherwise challenging to find large exogenous variations in interest rates (Ramey, 2016). It can also be difficult to measure investors' beliefs about returns and risks of assets in capital markets (Greenwood and Shleifer, 2014), which further complicates the analysis. In addition, experiments help us test the underlying mechanisms in detail, and better understand what drives the reaching for yield behavior we observe.

We supplement our experimental results with suggestive evidence from observational data. We use data from several sources and find consistent results. We start with monthly portfolio allocations data reported by members of the American Association of Individual Investors (AAII) since late 1987. We find that allocations to stocks decrease with interest rates and allocations to safe interest-bearing assets increase with interest rates, controlling for proxies of returns and risks in the stock market and general economic conditions. The magnitude is close to what we find in the benchmark experiment. We also use data on flows into equity and high yield corporate bond mutual funds, and find higher inflows when interest rates fall.

Our study contributes to several strands of research. First, it provides new insights for understanding reaching for yield and the potential "risk-taking channel" of low interest rates. We present novel evidence from individual investment decisions, and reveal two psychological mechanisms at play. The results complement prior work that studies institutional frictions. The individual-level behavior we document can affect financial markets in several ways. It can influence the investments of households, who are important end investors that allocate savings between safe and risky assets (Campbell, 2006; Frazzini and Lamont, 2008; Lou, 2012; Célérier and Vallée, 2016). Households' preferences can also shift investment decisions by financial institutions, which often cater to clients' tastes. In addition, the preferences and psychology we document may affect professional investors. Reaching for yield is significant among financially well-educated individuals like HBS MBAs, and it does not appear to diminish with wealth, investment experience, or work experience in finance.

Second, we demonstrate an important application of insights from behavioral economics. We draw upon several mechanisms to study the impact of low interest rates on investor risk taking, including reference dependence (Kahneman and Tversky, 1979), salience (Bordalo, Gennaioli, and Shleifer, 2013a), and history dependence (Kahneman and Miller, 1986; Bordalo, Gennaioli, and Shleifer, 2017; Simonsohn and Loewenstein, 2006; Malmendier and Nagel, 2011). These mechanisms have been previously applied to a variety of issues, such as the equity premium puzzle (Benartzi and Thaler, 1995; Barberis, Huang, and Santos, 2001), income targeting in labor supply (Camerer, Babcock, Loewenstein, and Thaler, 1997; Thakral and Tô, 2017), consumer choice (Hastings and Shapiro, 2013; Pagel, 2017), professional sports (Pope and Schweitzer, 2011), among others. Our work joins a growing literature that illustrates the relevance of behavioral frictions to questions in macro-finance (Fuster, Hebert, and Laibson, 2011; Simsek, 2013; Cheng, Raina, and Xiong, 2014; García-Schmidt and Woodford, 2015; Gennaioli, Ma, and Shleifer, 2015; Gabaix, 2016; Malmendier, Nagel, and Yan, 2017; Farhi and Werning, 2017).

Third, our paper relates to experimental studies on decision under risk and uncertainty. A number of experiments test elements that affect risk taking (Holt and Laury, 2002; Gneezy and Potters, 1997; Cohn, Engelmann, Fehr, and Maréchal, 2015; Kuhnen, 2015; Beshears, Choi, Laibson, and Madrian, 2016). We focus on interest rates, which are an essential component in most monetary risk decisions in practice (e.g. investment decisions of households and firms), and show its key impact. In a contemporaneous experiment with hypothetical questions, Ganzach and Wohl (2017) also find increased risk taking when interest rates are low. We provide a large set of evidence across many different settings, isolate behavior that departs from standard benchmarks, and test the underlying mechanisms in detail.

The remainder of the paper is organized as follows. Section 2 presents results of the benchmark experiment. Section 3 discusses possible explanations for the reaching for yield behavior we observe, and Section 4 tests these mechanisms. Section 5 provides results using historical data on household investment decisions. Section 6 concludes.

# 2 Benchmark Experiment

This section describes our benchmark experiment that tests low interest rates and risk taking. We conduct this experiment in different settings and with different groups of participants, which yield similar results. In the benchmark experiment, participants consider investing between a risk-free asset and a risky asset. Half of the participants are randomly assigned to the high interest rate condition and half to the low interest rate condition. In the high interest rate condition, the risk-free asset offers 5% annual returns and the risky asset offers 10% average annual returns. In the low interest rate condition, the risk-free asset offers 1% annual returns and the risky asset offers 6% average annual returns. In both conditions, the risky asset's excess returns are the same and approximately normally distributed. We truncate a normal distribution into nine outcomes to help participants understand the distribution more easily; the volatility of the risky asset's returns is 18% (about the same as the volatility of the US stock market). In other words, across the two conditions, we keep the excess returns of the risky asset fixed and make a downward shift of the risk-free rate. We document that participants invest significantly more in the risky asset in the low interest rate condition, and the result is robust to experimental setting, payment structure, and participant group.

## 2.1 Experiment Design and Sample Description

Our experiment takes the form of an online survey that participants complete using their own electronic devices (e.g. computers and tablets). The survey has two sections: Section 1 presents the investment decision, and Section 2 includes a set of demographic questions. Each experiment has 400 participants, who are randomly assigned to the two treatment conditions (high vs. low interest rates).

We conduct the benchmark experiment among two groups of participants. The first group consists of adults in the US from Amazon's Mechanical Turk (MTurk) platform. MTurk is an online platform for surveys and experiments, which is increasingly used in economic research (Kuziemko, Norton, Saez, and Stantcheva, 2015; Ambuehl, Niederle, and Roth, 2015; D'Acunto, 2015; Cavallo, Cruces, and Perez-Truglia, 2016; DellaVigna and Pope, 2017a,b). It allows access to a diverse group of participants from across the US, completes large-scale enrollment in a short amount of time, and provides response quality similar to that of lab experiments (Casler, Bickel, and Hackett, 2013). These features are very helpful for our study. As we show later, our MTurk participants have similar demographics as the US general population, with fewer elderlies and a higher level of education. Figure 1 shows the geographic location of participants in the benchmark experiments, which is representative of the US population. Our experiments on MTurk provide relatively high payments compared to the MTurk average to ensure quality response.

We also conduct the benchmark experiment with Harvard Business School MBA students. HBS MBA students are a valuable group of participants who are financially well-educated, and who are likely to become high net worth individuals that are the most important end investors in financial markets. A significant fraction of HBS MBAs also pursue finance careers, and some may become key figures in financial institutions. Their participation helps us study whether reaching for yield exists among these important financial decision-makers. Payments in our experiment with HBS MBAs are comparable to previous financial investing experiments with finance professionals (Cohn, Engelmann, Fehr, and Maréchal, 2015; Charness and Gneezy, 2010).

Below we provide detailed descriptions of the benchmark experiment in three different settings and the sample characteristics.

**Experiment B1: MTurk, Hypothetical**

In Experiment B1, participants consider a question about investing total savings of

$100,000 between the risk-free asset and the risky asset, and report their most preferred allocation. The investment horizon is one year. Participants are recruited on MTurk in June 2016. They receive a fixed participation payment of $1. The experiment takes about 15 minutes to complete, and we allow a maximum duration of 60 minutes for all of our MTurk experiments. The survey form for Experiment B1 is presented in the Survey Appendix.

Table 1 Panel A shows the summary statistics of participant demographics in Experiment B1. Roughly half of the participants are male. About 75% of participants report they have college or graduate degrees; the level of education is higher than the US general population (Ryan and Bauman, 2015). The majority of participants are between 20 to 40 years old. Their attitudes toward risk taking, as measured by choices among simple binary gambles, are relatively conservative: the majority prefer safe lotteries with lower expected payoffs to risky lotteries with higher expected payoffs.[2] In the demographic section, we also ask participants' subjective evaluation of risk tolerance, and the majority select they are "somewhat risk averse but willing to hold some risky assets." About 60% of participants have financial wealth (excluding housing) above $10,000; roughly 10% to 15% of participants are in debt, while 5% to 10% have financial wealth more than $200,000. The wealth distribution is largely in line with the US population (the 2016 Survey of Consumer Finances shows median household financial assets of $23,500). Most participants have some amount of investment experience; 56.5% own stocks, slightly higher than the stock ownership rate of 51.9% from the 2016 Survey of Consumer Finances.

**Experiment B2: MTurk, Incentivized**

In Experiment B2, participants consider allocating an experimental endowment of 100,000 Francs between the risk-free asset and the risky asset. The investment horizon is one year. Participants are recruited on MTurk in February 2016. They receive a participation payment of $0.7, and could earn a bonus payment proportional to their investment outcomes, with every 8,950 Francs converted to one dollar of bonus payment.[3] The bonus payment is on the scale of $12, which is very high on MTurk. After the experiment is completed, par-

[2]Specifically, at the end of the demographics section, we ask a question where participants report their favorite lottery among six options: a) 50% chance receive $22 and 50% chance receive $22; b) 50% chance receive $30 and 50% chance receive $18; c) 50% chance receive $38 and 50% chance receive $14; d) 50% chance receive $46 and 50% chance receive $10; e) 50% chance receive $54 and 50% chance receive $6; f) 50% chance receive $60 and 50% chance receive $0. We categorize risk tolerance as low if participants choose option a) or b), medium if they choose option c) or d), and high if they choose option e) or f).

[3]We use an experimental currency called Francs (and then convert final payoffs to dollars) following prior experimental studies on investment decisions (Camerer, 1987; Lei, Noussair, and Plott, 2001; Bossaerts, Plott, and Zame, 2007; Smith, Lohrenz, King, Montague, and Camerer, 2014). Francs in larger scales helps to make the investment problem easier to think about.

ticipants see the investment outcome (the return of the safe asset is fixed and the return of the risky asset is randomly drawn based on the distribution). We follow prior experiments on investment decision-making and implement the decision of 10% randomly selected participants, who will receive the bonus payment. The payment structure is clearly explained throughout the experiment. Cohn, Engelmann, Fehr, and Maréchal (2015) review payment schemes with random implementation and argue "there is solid evidence showing that these schemes do not change behavior."[4] We verify that results are unchanged whether the bonus payment is provided to all participants or a random subset of participants. Internet Appendix Table A10 shows comparison experiments we run to test robustness to payment structure. Given the one year investment horizon, in our baseline specification the bonus payment is delivered a year after participation. In Table A10, we also verify that behavior is not affected by the delayed bonus. The survey form for Experiment B2 is presented in the Survey Appendix.

Table 1 Panel B shows the demographics of participants in Experiment B2. Experiment B2 has slightly more male participants; participants are also slightly wealthier, and have a higher stock ownership rate (64% in Experiment B2, compared to 56.5% in Experiment B1 and 51.9% in 2016 SCF). Overall the demographics are similar to those in Experiment B1.

**Experiment B3: HBS MBA, Incentivized**

In Experiment B3, participants consider allocating an experimental endowment of 1,000,000 Francs to the risk-free asset and the risky asset. The investment horizon is one year. Participants are recruited via email from all enrolled MBA students at HBS in April 2016. They receive a $12 dining hall lunch voucher in appreciation for their participation, and could earn a bonus payment proportional to their investment outcome, with every 4,950 Francs converted to one dollar of bonus payment. Thus the bonus payment is on the scale of $210. Similar to Experiment B2, we implement the decision of 10% randomly selected participants and they receive the bonus payment. Financial offices at Harvard process the bonus payment, scheduled for approximately a year after the experiment to adhere to the one year investment horizon. The survey form for Experiment B3 is presented in the Survey Appendix.

Table 1 Panel C shows that about 60% of participants are male, roughly 70% are from the US (and 30% are international students), and roughly 70% have primary educational back-

[4]From an ex ante perspective, participants should make their optimal decisions, in case they are chosen and their choices are implemented.

ground in social science or science and engineering. The MBA participants have a higher level of risk tolerance than MTurk participants, according to both lottery choice-based assessment and subjective assessment. More than 40% report having some or extensive investment experience; 80% own stocks, and 40% have worked in finance.

## 2.2 Results

Table 2 reports results of the benchmark experiment. The first four columns in Table 2 Panel A show mean allocations to the risky asset in the high and low interest rate conditions for Experiments B1 to B3, the difference between the two conditions, and the $t$-stat that the difference is significantly different from zero. In all three settings, the mean allocation to the risky asset is about 7 to 9 percentage points higher in the low interest rate condition. Specifically, the mean allocation to the risky asset increases from 48.15% in the high rate condition to 55.32% in the low rate condition in Experiment B1 (difference is 7.17%), from 58.58% to 66.64% in Experiment B2 (difference is 8.06%), and from 66.79% to 75.61% in Experiment B3 (difference is 8.83%). It is natural that the general level of risk tolerance can vary across these experiments depending on the subject pool and the setting (e.g. HBS MBAs are more risk tolerant than MTurk participants; MTurk participants are more risk tolerant investing experimental endowments than investing a significant amount of savings), so the *level* of mean allocations is different in Experiments B1 to B3. However, these differences in risk tolerance do not seem to affect the pattern of reaching for yield.

Panel A columns (5) to (9) report additional tests. Column (5) shows $p$-values from non-parametric Mann-Whitney-Wilcoxon tests. The remaining columns report mean differences in allocations controlling for individual characteristics, through OLS regressions as well as propensity score matching (estimates of average treatment effects are reported). The covariates include gender, education, age, risk tolerance, wealth, investment experience in the MTurk samples; and gender, risk tolerance, investment experience, and work experience in finance in the HBS MBA sample. The results are very similar. Figure 2 plots the distribution of allocations to the risky asset in the high and low interest rate conditions for Experiments B1 to B3. The distributions are fairly smooth, with an upward shift in allocations in the low rate condition relative to the high rate condition.[5]

[5]In the experiment, participants make decisions about investing a fixed amount of money. In practice, interest rates may also affect the consumption/saving decision and therefore the amount of money people decide to invest in the first place. Prior empirical studies, however, often do not find significant responses of consumption and savings to interest rates (Mankiw, Rotemberg, and Summers, 1985; Hall, 1988; Campbell

Table 2 Panel B presents the regression results for each sample, with coefficients on control variables:

$$Y_i = \alpha + \beta Low_i + X_i'\gamma + \epsilon_i \tag{1}$$

where $Y_i$ is individual $i$'s allocation to the risky asset, $Low_i$ is a dummy variable that takes value one if individual $i$ is in the low interest rate condition, and $X_i$ is a set of demographic controls. The treatment effect of the low interest rate conditions, $\beta$, is the same as results in Panel A column (6). Among the demographic controls, males tend to invest more in the risky assets in most samples, while education, age, and wealth do not show a significant impact. Investment experience and work experience in finance have some positive effects on overall risk taking, though not statistically significant. Participants' risk tolerance is significantly positively correlated with risk taking (here risk tolerance is measured through choices among simple lotteries; results are similar using subjective evaluations of risk preferences). In terms of magnitude, the treatment effect of the low interest rate condition (allocations to the risky asset higher by 8 percentage points) is roughly the same as risk tolerance increasing by one category, or by about a tercile of individuals in each sample.

The increase of mean allocations to the risky asset of around 8 percentage points is economically meaningful. It is a roughly 15% increase on the base of about 60% allocations to the risky asset. To make the magnitude easier to assess, we also translate the differences in portfolio shares to equivalents in terms of changes in the effective risk premium. Specifically, we calculate, for a given coefficient of relative risk aversion $\gamma$, how much the risk premium (i.e. average excess returns) on the risky asset, $\mu$, needs to change to induce this much shift in portfolio allocations, $\phi$, in a conventional mean-variance analysis problem if we apply the formula $\phi = \mu/\gamma\sigma^2$. For $\gamma = 3$,[6] for instance, the treatment effect is equivalent to $\mu$ changing by about 0.7 percentage points (on a base of about 5 percentage point risk premium).

Our results on reaching for yield are consistent in different settings and subject pools. Some previous studies find the influence of psychological forces and certain biases may diminish with education and experience (List and Haigh, 2005; Cipriani and Guarino, 2009; Kuchler and Zafar, 2017), while others do not find such an effect or find the opposite (Haigh and List, 2005; Abbink and Rockenbach, 2006; Cohn, Engelmann, Fehr, and Maréchal, 2015). In our data, HBS MBAs and MTurks reach for yield by a similar degree. Nor do

and Mankiw, 1989). In Section 5, we also present suggestive evidence that lower interest rates appear to be associated with both higher portfolio shares and higher dollar amounts invested in risky assets.

[6] $\gamma = 3$ is roughly consistent with the average level of allocation in the risky asset in Experiment B1.

we find that reaching for yield declines with wealth, investment experience, or education among MTurks, or with investment and work experience in finance among MBAs, as shown in Internet Appendix Table A9. If anything, participants with more wealth, investment experience, and work experience in finance appear to reach for yield slightly more, but our sample size of 400 generally does not have enough power to detect significant differences in subsample comparisons.

*Stake Size in Incentivized Experiments*

One constraint of incentivized investment experiments is the stakes are modest compared to participants' wealth. Experimental research emphasizes monetary incentives, but researchers have budget limits. With respect to the typical stake size in incentivized experiments, participants should be risk neutral and put everything in investments with the highest average returns. In our data, only about 25% of participants in Experiment B2 (MTurk) and about 30% of participants in Experiment B3 (MBA) invested everything in the risky asset, in line with previous studies which show that participants are typically risk averse with respect to small stakes.

In our setting, we make three observations in light of the concern about modest stake size. First, this issue does not affect the hypothetical experiment. The treatment effect of the interest rate condition is consistent across hypothetical and incentivized tests, which suggests the robustness of the result. Second, to the extent that small stakes make participants more risk neutral and decreases variations in investment decisions, it works against us finding significant differences between different interest rate conditions. Third, experimental research finds that risk preferences with respect to small stakes are meaningful and are consistent with participants' risk preferences in other settings (e.g. larger stakes, hypothetical decisions) (Holt and Laury, 2002). Previous studies find informative results using experimental stakes to calibrate parameters associated with curvatures in utility functions (Andersen, Harrison, Lau, and Rutström, 2008; Andreoni and Sprenger, 2012; Charness, Gneezy, and Imas, 2013) or test portfolio choice decisions (Bossaerts, Plott, and Zame, 2007; Cohn, Engelmann, Fehr, and Maréchal, 2015), and we use stake size in line with prior work. We also find that participants' risk tolerance with respect to experimental stakes lines up with their risk preferences in financial investing in general. For example, Table A11 in the Internet Appendix shows that allocations in the experiment are significantly correlated with allocations of participants' household financial wealth.

In sum, we find investments in the risky asset increase significantly in the low interest rate condition. Such reaching for yield behavior is remarkably stable in different settings and populations. In the next section, we discuss potential explanations of this result.

# 3 Potential Mechanisms

In this section, we discuss potential explanations of our findings in Section 2. We first show that conventional portfolio choice theories may not easily explain the reaching for yield behavior we document. We then suggest two categories of possible explanations, reference dependence and salience, which we test in Section 4.

## 3.1 Can Conventional Portfolio Choice Theory Generate "Reaching For Yield"?

The investment decision in our benchmark experiment corresponds to a standard static portfolio choice problem with one risk-free asset and one risky asset. An investor considers allocating wealth $w$ between a safe asset with returns $r_f$, and a risky asset with returns $r_f + x$, where $x$ is the excess returns with mean $\mu = \mathbb{E}x > 0$. Let $\phi$ denote the proportion of wealth allocated to the risky asset, and $1 + r_p = 1 + r_f + \phi x$ the portfolio returns. The investor chooses optimal $\phi^* \in [0,1]$ to maximize expected utility:

$$\phi^* = \arg\max_{\phi \in [0,1]} \mathbb{E}u\left(w\left(1 + r_p\right)\right) \tag{2}$$

We start with the case of mean-variance analysis, the widely used approximation to the general portfolio choice problem, and then discuss the general case.

**Mean-Variance Analysis.** Conventional portfolio choice analysis often uses the mean-variance approximation, in which case the investor trades off the average returns and variance of the portfolio, and obtains

$$\phi^*_{mv} \triangleq \arg\max_{\phi \in [0,1]} \ \mathbb{E}r_p - \frac{\gamma}{2} Var\left(r_p\right) = \min\left(\frac{\mathbb{E}x}{\gamma Var\left(x\right)}, 1\right), \tag{3}$$

where $\gamma = \frac{-wu''(w)}{u'(w)}$ denotes the coefficient of relative risk aversion.

When we hold fixed the distribution of the excess returns $x$, the risk-return trade-off stays the same in mean-variance analysis, and investment decisions should not change with the level of the risk-free rate $r_f$.[7]

**General Case.** The optimal mean-variance portfolio allocation $\phi^*_{mv}$ in Equation (3) is a second-order approximation to the optimal allocation to the risky asset $\phi^*$ defined in Equation (2).[8] Now we analyze the general case which also takes into account the potential impact of higher order terms. We consider how the optimal allocation to the risky asset $\phi^*$ changes with the risk-free rate $r_f$ for a given distribution of the excess returns $x$.

**Proposition 1.** *We assume the investor's utility function $u$ is twice differentiable and strictly concave, with (weakly) decreasing absolute risk aversion. Then, for a given distribution of the excess returns $x$, the optimal allocation to the risky asset $\phi^*$ is (weakly) increasing in $r_f$.*

The intuition for this result is that, for a given distribution of $x$, when $r_f$ increases the investor effectively becomes wealthier. If absolute risk aversion is decreasing in wealth, the investor would be less risk averse and more willing to invest in the risky asset. In other words, the investor would "reach against yield," which is the opposite of what we document in Section 2. This wealth effect, however, is not first order and it drops out in the mean-variance approximation.[9]

Proposition 1 assumes weakly decreasing absolute risk aversion, a property shared by commonly used utility functions (e.g. CRRA). The prediction of Proposition 1 would be reversed if investors instead have increasing absolute risk aversion. Is this a possible explanation for the reaching for yield phenomenon we document? In studies of choice under

[7] For our incentivized experiments, would wealth outside the experiment affect predictions of the conventional portfolio choice analysis? We make three observations. First, if the investor's outside wealth $w_o$ has a non-stochastic return $r_o$, we can just redefine the utility function $\tilde{u}(w(1+r_p)) = u(w_o(1+r_o) + w(1+r_p))$ and the same analysis applies. Second, even if the return on outside wealth is stochastic, as long as it is independent of the returns in the experiment, we can show that the optimal allocation based on mean-variance analysis (a second-order approximation to the problem in (2)) still should not change with respect to the interest rate. Finally, as Barberis, Huang, and Thaler (2006) point out, narrow framing (which refers to investors' tendency to consider investment problems in isolation, rather than mingling them with other risks) is key to explaining many phenomena, including the lack of risk neutrality to modest risks which holds in our experiments. To the extent that investors frame narrowly, the analysis here also applies directly.

[8] The approximation is exact with constant absolute risk aversion (i.e. $\frac{-u''(w)}{u'(w)}$ is constant) and $x$ having a normal distribution. Note that the approximation is not exact with constant relative risk aversion and $x$ having a log normal distribution. This is because while $x$ has a log normal distribution, the portfolio returns $1 + r_p = 1 + r + \phi x$ are not necessarily log normally distributed.

[9] Why do we only need decreasing *absolute* risk aversion, instead of decreasing *relative* risk aversion, for $\phi^*$ to be increasing in $r_f$? Note that the investor's final wealth is given by $w(1 + r_f + \phi x)$. An increase of $r_f$, for a given $\phi$, increases the absolute level of his final wealth but does not change the absolute amount of risk he is taking. In contrast, an increase in $w$, for a given $\phi$, would increase the absolute amount of risk the investor is taking. Accordingly, for $\phi^*$ to increase with $r_f$, decreasing *absolute* risk aversion is sufficient (whereas for $\phi^*$ to increase with $w$, decreasing *relative* risk aversion is required).

uncertainty, increasing relative risk aversion is sometimes observed, but (weakly) decreasing absolute risk aversion appears to be a consensus (Holt and Laury, 2002). Moreover, increasing absolute risk aversion is hard to square with additional experimental results we present in Section 4 to test mechanisms.

In sum, the conventional portfolio choice framework does not seem to naturally generate predictions in line with the reaching for yield phenomenon we find in Section 2.

### 3.2 Reference Dependence

In the following, we discuss two categories of mechanisms that can lead to reaching for yield in personal investment decisions.

The first category of mechanisms comes from the observation that people may form reference points of investment returns, and strive to achieve the reference returns. When the risk-free rate falls below the reference level, people experience discomfort and become more willing to invest in risky assets to seek higher returns. This connects to the popular view among investors that 1% interest rates are "too low" (where the notion "too low" suggests comparison to some reference level and discomfort in light of that).

One way to specify reference dependence is through a framework of loss aversion around reference points, as formulated in the Prospect Theory (Kahneman and Tversky, 1979). In the following, we first use this type of framework to analyze the investment decision problem and predictions for reaching for yield. We then discuss reference point formation in our setting, as well as alternative ways of modeling reference-dependent investment decisions. Finally we discuss additional empirical predictions and implications.

We use the same set-up as before, but now we assume the utility function $u$ features loss aversion captured by a kink around the reference point:

**Assumption 1.**

$$u\left(w\left(1+r_p\right)\right)=\begin{cases} w\left(r_p-r_r\right) & r_p \geq r_r \\ -\lambda w\left(r_r-r_p\right) & r_p < r_r \end{cases} \tag{4}$$

*where $r_r$ is the reference point (in returns) and $\lambda > 1$ reflects the degree of loss aversion below the reference point.*

Here we only include the reference point component, without adding additional features of the Prospect Theory such as diminishing sensitivity and probability reweighting, as the gist of our observation relates to the reference point and loss aversion around the reference point. We discuss the case with diminishing sensitivity later. Probability reweighting does not affect our key result in Proposition 2 about responses to changes in the risk-free rate; see He and Zhou (2011) for a more detailed discussion.

**Proposition 2.** *Under Assumption 1, for a given distribution of the excess returns $x$:*

*i. The optimal allocation to the risky asset $\phi^*$ is (weakly) decreasing in $r_f$ if $r_f < r_r$.*

*ii. The optimal allocation to the risky asset $\phi^*$ is (weakly) increasing in $r_f$ if $r_f > r_r$.*

Proposition 2 shows that when the risk-free rate $r_f$ is below the reference point $r_r$, the investor invests more in the risky asset as interest rates fall. The intuition is that when interest rates are below the reference point and drop further, investing in the safe asset will make the investor bear the entire increase in the first-order loss (i.e. utility loss from loss aversion). The risky asset, however, provides some chance to avoid the increase in the first-order loss. As a result, the lower the interest rates, the higher the incentive to invest in the risky asset. This result suggests a potential explanation for the evidence we document in Section 2 that participants in the low interest rate condition invest more in the risky asset.

On the other hand, when the risk-free rate $r_f$ is above the reference point $r_r$, the optimal allocation to the risky asset $\phi^*$ is (weakly) increasing in $r_f$. The intuition is that when the risk-free rate is above the reference point, investing in the safe asset can avoid the first-order loss with certainty. If interest rates fall but stay above the reference point, the safe asset still does not generate any first-order loss, but there is a higher chance that the risky investment gets into the region with the first-order loss. Accordingly, the incentive to invest in the risky asset increases with interest rates. In other words, the investor would "reach against yield" in this case with $r_f > r_r$.

Proposition 2 focuses on how investment decisions change as we shift the risk-free rate $r_f$ while fixing the reference point $r_r$. Reference dependence also generates predictions about how decisions are affected by the reference point $r_r$ for a given level of interest rate $r_f$.

**Corollary 1.** *Under Assumption 1, for a given level of excess returns $x$, we have:*

*i. The optimal allocation to the risky asset $\phi^*$ is (weakly) increasing in $r_r$ if $r_f < r_r$.*

*ii. The optimal allocation to the risky asset $\phi^*$ is (weakly) decreasing in $r_r$ if $r_f > r_r$.*

Corollary 1 shows that if the risk-free rate $r_f$ is below the reference point $r_r$, the higher the reference point, the higher the allocation to the risky asset. The intuition is similar to that of Proposition 2. For example, when the risk-free rate is below the reference point, an investor with a higher reference point bears the full increase in the first-order loss if he invests in the safe asset. However, he only bears a partial increase in the first-order loss if he invests in the risky asset which has some chance of escaping the loss region. As a result, higher reference points are associated with stronger incentives to invest in the risky asset.

*Reference Point Formation*

One natural question is where investors' reference points come from. In the following, we discuss the leading theories of reference points, and explain why people's past experiences may be the main contributor to the type of reference dependence that generates reaching for yield behavior. We provide formal proofs and more discussions in Internet Appendix Section B.1.

In the framework of Kahneman and Tversky (1979), the reference point is the status quo wealth level ($r_r = 0$). However, as long as the interest rate is non-negative, it would be higher than the status quo reference level $r_f \geq r_r = 0$. This falls into the second case of Proposition 2, and does not explain the reaching for yield behavior in our benchmark experiment.[10]

In later work, Barberis, Huang, and Santos (2001) propose reference points which are equal to the risk-free rate ($r_r = r_f$), and Kőszegi and Rabin (2006) propose reference points that are rational expectations of asset returns in the investor's investment choice set. In both cases, when the risk-free rate changes while the distribution of excess returns is held fixed, returns on the safe asset, returns on the risky asset, and the reference point move in parallel. Accordingly, the trade-offs in the investment decision are essentially unchanged. As a result, the optimal allocation to the risky asset stays the same, and investment decisions should not be different across the treatment conditions in our benchmark experiment.[11]

Another line of work suggests that people's past experiences have a significant impact on preferences and behavior (Kahneman and Miller, 1986; Simonsohn and Loewenstein, 2006; Malmendier and Nagel, 2011; Bordalo, Gennaioli, and Shleifer, 2017). In our setting, one intuition is that people adapt to or anchor on some level of investment returns based on past experiences. When the risk-free rate drops below the level they are used to, people

[10]That said, we do not suggest that loss aversion at zero does not matter. It could be important for many behavior (e.g. aversion to small risks), but it does not appear to be the key driver of reaching for yield, if not partially offsetting it.

[11]For expectations-based reference points, this result applies when the reference point is entirely determined by forward-looking rational expectations, which is the emphasis of Kőszegi and Rabin (2006). It is also possible that expectations-based reference points are influenced by past experiences and have a backward looking component. This alternative case is analogous to the final category of history-dependent reference points we discuss below.

experience discomfort and become more willing to invest in risky assets.[12] This falls in the first case of Proposition 2, which predicts reaching for yield. Given the economic environment in the decades prior to the Great Recession, reference points from past experiences appear in line with investors' view that 1% or 0% interest rates are "too low."[13]

Together with Corollary 1, history-dependent reference points suggest a novel implication: the degree of reaching for yield may depend on prior economic conditions. How much investors shift to risky assets when interest rates are low may be different if they used to live in an environment of high interest rates compared to if they used to live in an environment of modest interest rates.

*Functional Forms for Modeling Reference Dependence*

The functional form we use to model reference dependence in the above follows the traditional Prospect Theory formulation. Our emphasis is that *reference dependence* can generate reaching for yield behavior, but we do not stick to a particular functional form of modeling reference dependence in investment decisions. We provide two additional formulations of reference dependence in Internet Appendix Sections A.4 and A.5.

First, we present a model of reference dependence where investors experience discomfort/loss aversion when the expected returns of the portfolio are below the reference point. (In contrast, in the traditional Prospect Theory formulation discussed above, investors suffer from loss aversion for each state where the realized returns are below the reference point.) This alternative formulation predicts reaching for yield when interest rates are low, but does not predict reaching against yield when interest rates are high.

Second, we also consider the traditional Prospect Theory formulation with diminishing sensitivity. We show that the theoretical prediction of whether diminishing sensitivity contributes to reaching for yield is ambiguous (the Internet Appendix gives a detailed explanation). We provide a few special conditions under which diminishing sensitivity yields unambiguous predictions. We then evaluate the general case numerically, based on standard parameter values (Tversky and Kahneman, 1992; Barberis, Huang, and Thaler, 2006)

[12]The reference point could also come from saving targets that people aim for to cover certain expenses, which are likely formed based on past experiences and leads to a similar reduced form formulation.

[13]In the incentivized experiments, if participants mingle the experimental returns with other returns and monetary payoffs in their lives, one question is whether they compare the experimental returns or the sum of all monetary payoffs with respect to their reference points. As Barberis, Huang, and Thaler (2006) highlight, narrow framing—the tendency to consider an investment problem in isolation as opposed to mingling it with other risks (e.g. labor income risks, other investments)—appears to be a robust element of investor behavior. To the extent that participants are inclined to frame narrowly and evaluate the investment problem on its own, we can directly apply the predictions of the reference dependence mechanisms studied in this section. The same holds for the salience and proportional thinking mechanism in Section 3.3.

together with investment payoffs in our experiment. We find that diminishing sensitivity generally contributes to reaching for yield in our setting, but the magnitude of the effect is relatively small. Overall, it seems hard for diminishing sensitivity *alone* to account for the evidence in Section 2 without the loss aversion component discussed above.[14]

*Nominal Illusion*

One may wonder whether a form of "nominal illusion" can explain the behavior we document in Section 2. "Nominal illusion" *alone*—that is, investors may confuse real and nominal returns (Modigliani and Cohn, 1979; Campbell and Vuolteenaho, 2004; Cohen, Polk, and Vuolteenaho, 2005)—does not make a difference in our setting: the excess returns and risks of the risky asset are not affected by whether people think about the investment payoffs in nominal or real terms. Nonetheless, nominal illusion may interact with reference dependence: investors' reference points could be more about nominal returns, so low nominal interest rates may affect behavior differently than low real interest rates. We provide brief discussions later that nominal reference points appear more important in our data.

## 3.3 Salience and Proportional Thinking

The second category of mechanisms is that investment decisions could be affected by the salience of the higher average returns of the risky asset, which may vary with the interest rate environment. Specifically, 6% average returns might appear to be more salient compared to 1% risk-free returns than 10% average returns compared to 5% risk-free returns. This intuition can be formalized by a version of the Salience Theory of Bordalo, Gennaioli, and Shleifer (2013a). It also connects to the well documented phenomenon that people tend to evaluate stimuli by proportions (i.e. 6/1 is much larger than 10/5) rather than by differences (Weber's law; Tversky and Kahneman (1981); Kőszegi and Szeidl (2013); Cunningham (2013); Bushong, Rabin, and Schwartzstein (2016)).

Equation (5) outlines a representation of this idea, which uses a variant of the mean-variance analysis in Equation (3). The investor still trades off a portfolio's expected returns and risks. The relative weight between these two dimensions, however, depends not only

[14]Some recent research questions diminishing sensitivity, especially convexity of the utility function in the loss domain, in the investment context (Bracha, 2016). We also find that diminishing sensitivity alone does not seem to account for the evidence in Section 2.

on the investor's relative risk aversion, but also on the ratio of the assets' average returns:

$$\phi_s^* \triangleq \arg\max_{\phi\in[0,1]} \ \delta \mathbb{E} r_p - \frac{\gamma}{2} Var\left(r_p\right), \tag{5}$$

where $\delta$ is a function of the properties of the two assets, and is increasing in the ratio of the average returns of the two assets $(r_f + \mathbb{E}x)/r_f$.

Equation (5) embeds the idea that investors' perception of the risky asset's compensation for risk is not exactly the risk premium defined as the *difference* between the average returns on the risky asset and the risk-free rate. Instead, it is also affected by the *proportion* of the average returns of the two assets. When the proportion is large, investors perceive compensation for risk taking to be better, and behave as if the return dimension in Equation (5) gets a higher weight.

In the language of the Salience Theory of Bordalo, Gennaioli, and Shleifer (2013a), $\delta$ captures the salience of the expected return dimension relative to the risk dimension. When the proportion of the average returns of the two assets is larger, the expected return dimension becomes more salient, and gets a higher weight in portfolio decisions.[15] We adopt a specification of $\delta$ following Bordalo, Gennaioli, and Shleifer (2013a).

**Assumption 2.** *We require the risk-free rate $r_f > 0$ throughout this subsection. Following Bordalo, Gennaioli, and Shleifer (2013a), define*

$$\delta(r_f + \mathbb{E}x, r_f, Var\left(x\right), 0) = f\left(\left|\frac{(r_f + \mathbb{E}x) - r_f}{(r_f + \mathbb{E}x) + r_f}\right| - \left|\frac{Var\left(x\right) - 0}{Var\left(x\right) + 0}\right|\right), \tag{6}$$

*where $f : [-1, 1] \to R^+$ is an increasing function.*

This definition is a generalization of the original formulation in Bordalo, Gennaioli, and Shleifer (2013a), which is also applied in Bordalo, Gennaioli, and Shleifer (2016).[16] In this

[15] In our context, the Salience Theory and proportional thinking are broadly the same. In the Internet Appendix Section B.3, we discuss a subtle difference between the way "salience" is defined in Bordalo, Gennaioli, and Shleifer (2013a) and proportional thinking, which is not important in our application. We also explain the relationship between our framework and other models related to salience/proportional thinking such as Bordalo, Gennaioli, and Shleifer (2012), Bordalo, Gennaioli, and Shleifer (2013b), and Bushong, Rabin, and Schwartzstein (2016).

[16] In the original set-up, either the risk dimension is more salient or the return dimension is more salient, and the more salient dimension receives a fixed weight. When there is a risk-free asset, the risk dimension is always more salient, by a fixed amount. Accordingly, returns of the risk-free asset do not change the salience of the return dimension relative to the risk dimension. We generalize Bordalo, Gennaioli, and Shleifer (2013a) to a continuous salience function that allows salience to move even when there is a risk-free asset. Our formulation nests the original salience function as a special case $f\left(t\right) = \begin{cases} \beta & t > 0 \\ \frac{1}{\beta} & t < 0 \end{cases}$, where $\beta > 1$.

framework, $\delta$ depends on both the ratio of the average returns between the two assets and the ratio of their variance: the first part in the parenthesis can be rewritten as $\left|\frac{(r_f+\mathbb{E}x)/r_f-1}{(r_f+\mathbb{E}x)/r_f+1}\right|$, which is increasing in the ratio of the average returns $(r_f + \mathbb{E}x)/r_f$; analogously, $\delta$ is decreasing in the ratio of the assets' variance. In our setting, the focus is how changes in the average returns of the assets affect investment decisions, and we keep the risk properties of the two assets fixed (so the second term in the parenthesis is always one, as the variance of the risky asset is held fixed and the variance of the safe asset is zero).

**Proposition 3.** *Under Assumption 2, for a given distribution of the excess returns $x$, the optimal allocation to the risky asset, $\phi_s^*$, is (weakly) decreasing in the risk-free rate $r_f$.*

The intuition of Proposition 3 is straightforward. Holding average excess returns $\mathbb{E}x$ constant, the proportion of the average returns $(r_f + \mathbb{E}x)/r_f$ increases as $r_f$ decreases. Accordingly, $\delta$ is larger and the investor is more willing to invest in the risky asset.

# 4 Testing Mechanisms

In this section, we perform three additional experiments to test possible explanations for the reaching for yield behavior discussed in Section 3. We find evidence supportive of both reference dependence and salience.

## 4.1 Experiment T1 (Non-Linearity)

In Experiment T1, we extend the benchmark experiment and test investment allocations across a wider spectrum of interest rate conditions. We study seven interest rate conditions, with the risk-free rate ranging from -1% to 15%. The excess returns of the risky asset are the same as those in the benchmark experiment, and the average excess returns is 5%. We randomly assign participants to one of these conditions.

Through this experiment, we would like to examine two main questions. The first question is whether reaching for yield exhibits non-linearity, and is most pronounced when interest rates are below a certain range. Both reference dependence and salience/proportional thinking predict such non-linearity. For example, in the model of reference point and loss aversion specified in Section 3.2, allocations to the risky asset would increase as interest rates

In addition, the decision problem in Bordalo, Gennaioli, and Shleifer (2013a) and Bordalo, Gennaioli, and Shleifer (2016) is a discrete choice problem. We generalize it to settings where the decision is continuous, which applies to the portfolio choice problem here. See Internet Appendix Section B.3 for more discussions.

fall when interest rates are below the reference point. In the model of salience/proportional thinking discussed in Section 3.3, allocations to the risky asset would be more sensitive to interest rates when interest rates are low, where the ratio of the average returns $(r_f + \mathbb{E}x)/r_f$ changes more with the risk-free rate $r_f$. On the other hand, conventional portfolio choice theory with increasing absolute risk aversion, for instance, does not predict strong non-linearity. The non-linearity in risk taking may also have policy implications. The second question is whether we observe "reaching against yield" (i.e. less allocations to the risky asset as the risk-free rate increases) when interest rates are sufficiently high, as predicted by the traditional Prospect Theory formulation discussed in Section 3.2 Proposition 2.

We conduct Experiment T1 in June 2016. Participants are recruited on MTurk. As in the benchmark experiments, each interest rate condition has 200 participants. Similar to Experiment B2 (Benchmark Incentivized, MTurk), participants consider allocating experimental endowment of 100,000 Francs to the risk-free asset and the risky asset. The payment structure follows Experiment B2. The participation payment is \$0.7. Participants may also receive a bonus payment proportional to their investment outcomes, with every 8,950 Francs converted to one dollar (so the bonus payment is on the scale of \$12). We implement the decision of 10% randomly chosen participants and they receive the bonus payment. Table A14 in the Internet Appendix shows the demographics of participants in Experiment T1, which are similar to those in the benchmark experiments. In all of our experiments, we use participants who did not participate in any of our previous experiments.[17]

Table 3 presents the results of Experiment T1. The mean allocation to the risky asset is 78% when the risk-free rate is -1%, 70% when the risk-free rate is 0%, 65% when the risk-free rate is 1%, and 58% when the risk-free rate is 3%. As interest rates rise further, allocations change more slowly. The mean allocation to the risky asset is 57% when the risk-free rate moves to 5%, which is roughly the same as when the risk-free rate is 3%. It declines to 50% when the risk-free rate is 10%, and stays about the same when the risk-free rate is 15%. Mean allocations across different interest rate conditions are also plotted in Figure 3.

Results in Experiment T1 suggest notable non-linearity in how investment decisions respond to interest rates. Reaching for yield is particularly pronounced when interest rates

[17] For incentivized experiments in Section 4, participants receive their bonus payments shortly after participation. Delaying the bonus by one year requires us to collect MTurk participants' contact information, in case they no longer work on MTurk in one year's time. In Section 2 and Internet Appendix Table A10, we have tested that the results are robust to payment timing. Therefore, in the additional experiments we pay the bonus within one week to simplify the logistics.

are low, roughly below 3%. Statistical tests can reject linearity with high significance.[18] The shape of the non-linear response is in line with reasonable reference points based on the average level of interest rates and investment returns most participants were used to prior to the Great Recession. The pattern is also generally consistent with salience/proportional thinking, as the ratio of the average returns $(r_f + \mathbb{E}x)/r_f$ becomes significantly less sensitive to $r_f$ when $r_f$ is high.[19] On the other hand, conventional portfolio choice theory with increasing absolute risk aversion does not easily square with the strong non-linearity.

In addition, while we see clear patterns of reaching for yield when interest rates get into the low range, we do not observe reaching against yield when interest rates approach the high end. In Section 3 Proposition 2, we show the baseline Prospect Theory formulation does predict reaching against yield when the risk-free rate is higher than the reference point. One possibility is that reaching against yield is modest in magnitude, and our sample size of 200 per condition does not have enough power to detect it; this effect could be further dampened by salience/proportional thinking. Another possibility is that the reaching against yield prediction is not very robust, and is specific to the functional form in the baseline Prospect Theory formulation. As mentioned in Section 3.2, an alternative formulation of reference dependence predicts reaching for yield when interest rates are low, but no reaching against yield when interest rates are high. We present this alternative formulation in Internet Appendix Section A.5.[20]

## 4.2 Experiment T2 (History Dependence)

In Experiment T2, we examine how investment history and reference dependence affect investment decisions. Specifically, participants in this experiment make two rounds of

[18]For instance, in a quadratic specification of $Y_i = \alpha + \beta r_{f,i} + \gamma r_{f,i}^2 + \epsilon_i$, where $Y_i$ is individual $i$'s allocation to the risky asset and $r_{f,i}$ is the risk-free rate in individual $i$'s assigned condition, the $t$-stat on $\gamma$ not equal to zero is 5.67 ($p$-value $< 0.001$). We can also test the null that the piece-wise slopes between all the adjacent interest rate conditions are the same, and the null can be rejected with $p$-value $< 0.001$.

[19]While intuitively it may seem that negative interest rates are quite "salient," existing models do not provide a clear way to deal with negative quantities. The salience function we use in Assumption 2 can work with $r_f$ that is modestly negative, as long as $(r_f + \mathbb{E}x) + r_f > 0$, which is satisfied when the risk-free rate $r_f$ is -1% and the average excess returns $\mathbb{E}x$ is 5%. But more generally, how to generalize this class of models to negative quantities is still an open question.

[20]One may want to use the experimental results to formally estimate what investors' reference returns are. This analysis faces several challenges. For instance, as we discuss above, how the reference point influences the optimal allocation's response to interest rates is sensitive to the functional form. Reference points may also be heterogeneous among investors. In addition, the existence of salience/proportional thinking may complicate the analysis. Even though reference dependence may predict, as Proposition 2 shows, that investors reach against yield when interest rates are above the reference return, salience/proportional thinking still predicts reaching for yield, which adds difficulties to estimating the reference point.

investment decisions: half of the participants (Group 1) first make decisions in the high interest rate condition (5% safe returns and 10% average risky returns, same as the benchmark experiment), and then make decisions in the low interest rate condition (1% safe returns and 6% average risky returns); the other half of the participants (Group 2) do the reverse. Group 1 mimics the situation where people move from a high interest rate environment to a low interest rate environment, which is a particularly relevant case for the recent discussions about investor reactions to low interest rates. After being placed in the high interest rate condition, participants in Group 1 are likely to carry a relatively high reference point when they move to the low interest rate condition. As Section 3.2 suggests, allocations to the risky asset in a low rate environment would increase when people have higher reference points. Accordingly, participants in Group 1 may invest more aggressively in the risky asset in the low interest rate condition.

We conduct two versions of Experiment T2. In the incentivized version, in each round participants consider allocating experimental endowment of 100,000 Francs to the safe asset and the risky asset (the outcomes of the risky asset in the two rounds are uncorrelated). Participants are recruited on MTurk in June 2016. They receive a participation payment of $1.2. They may also receive a bonus payment proportional to their investment outcome in one randomly chosen round, with every 8,950 Francs converted to one dollar (so the bonus payment is on the sale of $12). Investment outcomes for both rounds are displayed after the entire experiment is completed. Participants are then informed which round the bonus payment would depend on, and whether they are among the 10% randomly selected participants to receive the bonus payment. Making payments based on randomly chosen outcomes is standard in prior experimental work (e.g. Holt and Laury (2002); Frydman and Mormann (2016)).[21] To check the robustness of this result, we also report results from a hypothetical version. In the hypothetical version, in each round participants consider hypothetical questions about investing total savings of $10,000 between the safe asset and the risky asset. Participants are recruited from MTurk in August 2015. They receive $0.5 for participation. In both versions, there are 200 participants in Group 1 and 200 participants in Group 2. Internet Appendix Table A15 shows the demographics of participants in Experiment T2.

[21] Consider for example the decision in the second round: there is a 1/2 chance that the first round will be chosen so the second round does not matter, and a 1/2 chance that the second round will be chosen so the first round does not matter. Thus the decision in the second round should not depend on what happens in the first round, and vice versa, for the purpose of maximizing expected utility as long as utility functions are additively separable across different states.

Table 4 and Figure 4 present results of Experiment T2, which show several findings. First, there is evidence of reaching for yield both within group and across groups. Within each of Group 1 and Group 2, allocations to the risky asset are higher in the low rate condition than in the high rate condition. Across Group 1 and Group 2, when making the first decision, the group facing the low rate condition (Group 2) has significantly higher allocations to the risky asset than the group facing the high rate condition (Group 1). This is analogous to the benchmark experiment.

Second and importantly, participants in Group 1—who consider the high rate condition first—have particularly high allocations to the risky asset in the low rate condition. On average, they invest roughly 10 percentage points more in the low rate condition than participants in Group 2. These results are in line with predictions of reference dependence laid out in Corollary 1 and the idea that reference points are history-dependent. Correspondingly, the reaching for yield behavior is also particularly pronounced in Group 1.[22]

Internet Appendix Section B.2 presents alternative designs to test history dependence, which produce similar findings. In these tests, all participants face the same interest rate environment in the final round, but prior to that, one group starts with an environment with higher interest rates, while another group starts with an environment with lower interest rates. Our discussant Cary Frydman performed a hypothetical experiment on MTurk. We performed an incentivized version with slightly different interest rate specifications. The results show a consistent pattern: when participants consider the final medium interest rate condition, those who start in a high interest rate setting invest more aggressively in the risky asset than those who start in a low interest rate setting.[23]

These findings point to potential path dependence of reaching for yield. Experiences

[22]In this experiment, we do not find that experiences of the low rate condition have a significant influence on allocations in the high rate condition. According to Corollary 1 of Section 3.2, with the traditional Prospect Theory formulation, a decrease in the reference point should increase risk taking when the reference point is lower than the risk-free rate. In this case, Group 2 would be expected to invest more in the risky asset in the high rate condition, which we do not observe in the data. Since Corollary 1 follows from Proposition 2, this prediction is equivalent to the reaching against yield prediction we discussed in Experiment T1. Thus it shares the same explanations for the lack of evidence in our data, as elaborated at the end of Section 4.1.

[23]Can salience/proportional thinking explain the results of the history dependence experiments? In Assumption 2 of Section 3.3, the salience function we introduce is static, and the optimal allocation $\phi_s^*$ defined in Equation (5) is independent of investment history. Bordalo, Gennaioli, and Shleifer (2017) explore combining history-dependent reference points with salience. In this framework, a higher reference point (e.g. due to past experiences) makes the low interest rates on the safe asset appear more pronounced. However, it also makes the returns on the risky asset appear less attractive. These two forces push in different directions and the relative strength depends on the functional form, which the literature does not yet provide guidance. Conceptually, this approach is broadly in line with the idea of history-dependent reference points we emphasize in Section 3.2. As mentioned in Section 3.2, the key of our observation is history-dependent reference points, and there can be multiple ways to model their role in investment decisions (e.g. combining them with different forms of loss aversion, salience, or other formulations).

of high interest rate environments, which likely increase people's reference points, may intensify reaching for yield behavior. With some extrapolation, the evidence hints at a novel implication that the degree of reaching for yield in a low interest rate setting may depend on the previous economic environment. It could be more pronounced if the prior environment had relatively high interest rates. This observation connects to recent research that highlights the importance of past experiences in economic decision making (Malmendier and Nagel, 2011, 2016; Bordalo, Gennaioli, and Shleifer, 2017).

Experiment T2 studies the history dependence mechanisms by exploiting differences in short-term experiences (reference points could be affected by both long-term and short-term experiences, e.g. reference points of weather[24]). In our data, we make two observations about the impact of reference points from long-term lifetime experiences. First, as discussed in Section 4.1, the non-linearity in Experiment T1 is in line with reference points from prior life experiences. Second, we also test whether heterogeneity in lifetime experiences, which may result in different reference points, can help explain differences in investment decisions. In our experiments, due to relative homogeneity in age, variations in lifetime experiences are limited (the interquartile difference is average experienced interest rates, for example, is about 1%). Moreover, given we only have one cross-section, we cannot separate experience effects from age effects. To shed further light on this issue, in Internet Appendix Section C.2.2 we use panel data from the Survey of Consumer Finances and apply the empirical strategy of Malmendier and Nagel (2011). We present suggestive evidence that, at each point in time, individuals who experienced higher interest rates over their lifetime appear less satisfied with safe assets and exhibit a higher propensity to invest in risky assets like stocks. While there are several caveats in the observational data (e.g. hard to fully control for potential differences in perceived risks and returns of risky assets), the overall pattern seems consistent with history-dependent reference points.

[24]As an analogy, a person's reference point for weather can be affected by long-term life experiences (whether $30°F$ is cold is different for a New Yorker versus a Floridian) as well as short-term experiences ($30°F$ may feel particularly cold if a New Yorker just returned from a vacation in Florida, which temporarily changes his reference points). Experiment T2 isolates the mechanism by creating different short-term experiences and temporary perturbations in reference points (e.g. New Yorkers randomly assigned to winter vacations in Florida vs Colorado, who will come back with different temporary reference points about weather).

## 4.3 Experiment T3 (Salience and Proportional Thinking)

In Experiment T3, we examine the influence of salience and proportional thinking. In particular, we study whether results vary when we present investment payoffs using net returns (Baseline Framing) versus gross returns (Gross Framing), as explained below.

Baseline Framing: The baseline framing is what we use in the benchmark experiments and in Experiments T1 and T2. Specifically, we first explain the (average) returns of the investments. The returns are presented as net returns (e.g. 1%, 5% etc.), which is most common in financial markets. In addition, for the risky investment, we approximate a normal distribution with nine truncated outcomes, and further explain the distribution of the risky asset using a plot and corresponding examples. In the plot and the examples, we describe the probability that one will get a certain number of Francs if one invests 100 or 1000 Francs. The investment descriptions read as follows:

> **Investment A**: Investment A's return is **5%** for sure.
>
> For example, suppose you put 100 Francs into this investment, you will get 105 Francs.
> ...
>
> **Investment B**: Investment B has nine possible outcomes. Its average return is **10%**. The volatility of the investment returns is 18%. The nine possible outcomes are shown by the chart below, where the number inside each bar indicates the probability of that particular outcome.
>
> For example, suppose you put 100 Francs into this investment, you will get 110 Francs on average. There is uncertainty about the exact amount of money you will get. The first row of the chart below describes the nine possible outcomes: there is a 19% chance that you will get 120 Francs, there is a 12% chance that you will get 90 Francs, etc.
> ...

Gross Framing: In the gross framing experiments, instead of using the commonly used net returns, we describe the investments' payoffs using gross returns. Instead of 5%, we say for every Franc invested one would get 1.05 Francs. We keep everything else the same. The investment descriptions read as follows:

> **Investment A**: For every Franc you put into Investment A, you will get **1.05** Francs for sure.
>
> For example, suppose you put 100 Francs into this investment, you will get 105 Francs.
> ...
>
> **Investment B**: Investment B has nine possible outcomes. For every Franc you put into Investment B, you will get **1.1** Francs on average. The volatility of the investment returns is 18%. The nine possible outcomes are shown by the chart below, where the number inside each bar indicates the probability of that particular outcome.
>
> For example, suppose you put 100 Francs into this investment, you will get 110 Francs on average. There is uncertainty about the exact amount of money you will get. The first row of the chart below describes the nine possible outcomes: there is a 19% chance that you will get 120 Francs, there is a 12% chance that you will get 90 Francs, etc.
> ...

The comparison between baseline framing and gross framing tests the influence of salience and proportional thinking. A corollary of Proposition 3 is that for any given interest rate, allocations to the risky asset would be higher with baseline framing than with gross framing, and this difference would be more pronounced in the low interest rate condition (see Internet Appendix Lemma A1). Intuitively, the ratio of average returns between the risky asset and the risk-free asset with gross framing (e.g. 1.06/1.01) is much smaller than its counterpart with baseline framing (e.g. 6/1). This change is larger for the low rate condition (i.e. 6/1 to 1.06/1.01) than for the high rate condition (i.e. 10/5 to 1.1/1.05). Correspondingly, salience and proportional thinking could lead to less reaching for yield with gross framing than with baseline framing, as the proportions of average returns become very similar across the two conditions with gross framing.[25] Additionally, the test helps further differentiate our findings from conventional portfolio choice theory with increasing absolute risk aversion, which does not predict variations based on framing.

In Experiment T3, we randomly assign participants to different framing conditions and different return conditions (i.e. baseline high, baseline low, gross high, gross low), with 200 participants in each condition. Participants are recruited on MTurk in June 2015. Experiment T3 and Experiment T1 are run together; all procedures and payment structures are the same. Internet Appendix Table A16 shows the demographics in Experiment T3.

Table 5 and Figure 5 present results of Experiment T3. With baseline framing, the mean allocation to the risky asset is 57.13% in the high interest rate condition, and 64.51% in the low interest rate condition. With gross framing, the mean allocation to the risky assets is 52.65% and 54.44% in the high and low interest rate conditions respectively. Allocations to the risky asset are lower with gross framing than with baseline framing, especially in the low rate condition. The mean allocation in the risky asset decreases by 4.47% from baseline framing to gross framing in the high interest rate condition, and by 10.06% in the low interest rate condition. This result is consistent with predictions of salience and proportional thinking. Correspondingly, the degree of reaching for yield is dampened with gross framing. With baseline framing, the mean allocation to the risky asset is 7.38% higher

[25] To understand how the reaching for yield behavior may change with framing, we also test another framing which we refer to as "net framing." In the net framing conditions, we explain the investments' headline returns in net returns, just like with the baseline framing. When we explain the distribution of the risky asset's returns through examples, instead of describing them as getting a certain amount of Francs for every 100 (or 1000) Francs invested, we describe them as gaining or losing a certain amount of Francs. For instance, the description of Investment A becomes: "Investment A's return is **5%** for sure. For example, suppose you put 100 Francs into this investment, you will earn 5 Francs." We find that the reaching for yield behavior is similar using net framing and baseline framing, shown in Internet Appendix Table A13.

in the low interest rate condition; with gross framing, this difference decreases to 1.79%.[26]

### 4.4 Discussion

Taken together, results in Experiments T1 to T3 suggest that both reference dependence and salience contribute to reaching for yield. The findings are also hard to square with conventional portfolio choice theory.

Specifically, we find significant non-linearity in how risk taking varies with interest rates: reaching for yield is particularly pronounced when interest rates are low. The non-linearity is consistent with reference dependence based on past experiences, and also broadly consistent with salience and proportional thinking. In addition, in line with predictions of reference dependence, the degree of risk taking is significantly affected by perturbations that may influence participants' reference points. In line with predictions of salience and proportional thinking, allocations to the risky asset decrease and reaching for yield is dampened when investment payoffs are described in gross returns. In the experiments, we ask participants to explain their investment decisions. The explanations also show that both categories of mechanisms affect investment behavior.

## 5 Suggestive Evidence from Observational Data

In this section, we complement the experimental evidence with suggestive evidence from observational data. Using data on household investment decisions from three different sources, we show that low interest rates are associated with increased investments in risky assets. The pattern and magnitude are in line with findings in our experiments.

There are two important challenges in this analysis using observational data. First, it is hard to assess investors' beliefs about the returns and risks of risky assets. Ideally, we would like to control for investors' expectations of excess returns and risks of the risky asset, and isolate the impact of shifts in the risk-free rate. Even if investors have rational expectations, it could be hard to find exact measures of asset properties. Moreover, recent

[26] What is the relationship between results in Experiment T3 and reference dependence? One observation is that since reference points from the natural environment are most likely about net returns, gross framing may dampen the influence of reference points. Specifically, when using net returns, 1% interest rates may appear particularly low relative to experience, but this comparison could be less instinctive when investment payoffs are described in gross returns. Thus results in Experiment T3 may not be inconsistent with reference dependence. Can reference dependence and the observation above fully *explain* results in Experiment T3? Probably not, given that allocations to the risky asset in the high interest rate condition are also higher with baseline framing than with gross framing.

research documents that households do not appear to have rational expectations about stock returns. Instead, subjective expectations of future stock returns tend to be negatively correlated with expected returns based on rational expectations models (Greenwood and Shleifer, 2014; Amromin and Sharpe, 2013). In light of this issue, we control for both model-based measures and subjective expectations from investor surveys.

Second, interest rate variations can be correlated with other drivers of household investment decisions, which may create omitted variable biases. One type of omitted variable problem arises if interest rates are correlated with investors' expectations of excess returns, and if expectations of excess returns are imperfectly measured. Since interest rates tend to be low in economic downturns, the bias may magnify our results if investors have rational expectations (given that rational expected returns tend to be high in recessions), and dampen our results if investors do not have rational expectations and are more pessimistic in recessions. Another type of omitted variable problem arises if interest rates are correlated with investors' risk aversion. If investors have higher risk aversion in recessions, the bias will again dampen our results. We include controls of economic conditions (e.g. GDP growth, credit spreads). In the data, these controls strengthen our results.[27]

**Main Variables.** We measure household investment decisions using data from three sources. The first data source is monthly portfolio allocations reported by members of the American Association of Individual Investors (AAII). We have time series data on the mean allocation to stocks (direct holdings and mutual funds) and "cash" (which in investor terminology refers to interest-bearing liquid assets, such as savings accounts, CDs, money market funds as explained in the AAII survey form), available since November 1987. A nice feature of this data is that it documents portfolio shares, which correspond to quantities in our experiment. The second data source is monthly flows into risky assets including equity mutual funds and high-yield corporate bond mutual funds since 1985, from the Investment Company Institute (ICI). The third data source is quarterly household sector

[27] One may also consider using monetary policy shocks to instrument for changes in the risk-free rate. In our sample period, monetary policy shocks by Romer and Romer (2004) and Gertler and Karadi (2015) are strong instruments for interest rate changes at the monthly frequency (our data on household investment allocations are at monthly or quarterly frequencies); other high frequency identification shocks are not (Bernanke and Kuttner, 2005; Hanson and Stein, 2015; Nakamura and Steinsson, 2017). We find results with slightly larger coefficients but less power using the Romer and Romer (2004) and Gertler and Karadi (2015) shocks, shown in Internet Appendix Table A18. A caveat is, to the extent that monetary policy shocks may affect stock market conditions (e.g. excess returns and risks), they are not perfect instruments unless we can find precise measures of expectations of stock returns and risks. In addition, it could also be hard to rule out that monetary policy shocks may affect investors' risk tolerance for other reasons. Thus the two omitted variable issues discussed above could still be relevant in analyses using monetary policy shocks.

flows into stocks and interest-bearing safe assets since 1985, from the Flow of Funds (FoF). Because interest rate variations occur over time, in this analysis we use long, relatively high frequency, time-series data on investment allocations (instead of panel data with limited time periods such as the SCF or brokerage accounts data from Barber and Odean (2001)).

For the risk-free rate, we use the three-month Treasury rate (results are similar using alternative measures such as the effective Fed Funds rate). For control variables, we use several measures of model-based expected stock returns. We start with Campbell-Shiller price-earnings ratio (P/E10). One caveat of the price-earnings ratio (or other valuation ratios like dividend yield, etc.) is it is in theory related to expected returns (Campbell and Shiller, 1988; Campbell, 1991), not expected *excess* returns.[28] To check robustness, we also use the surplus consumption ratio ($Surp$) of Campbell and Cochrane (1999), which is theoretically linked to expected excess returns and empirically shown as a strong predictor, as well as predicted next twelve-month excess stock returns (estimated using past twelve-month stock returns and surplus consumption). In addition, we control for proxies of subjective expectations using investor sentiment measured in the AAII survey, as in Greenwood and Shleifer (2014). Finally, we control for $VIX^2$ (the square of $VIX$, which measures expected variance of the S&P 500 index), as well as commonly used proxies for general economic conditions: past year real GDP growth, and the credit spread (Gilchrist and Zakrajšek, 2012). We lag all the right hand side variables by one period, as opposed to using contemporaneous ones, since allocation decisions may affect contemporaneous asset prices (so using contemporaneous controls could be problematic).

Internet Appendix Section D provides a summary of variable definitions and data sources. Table 6 presents summary statistics of the main variables used in this section.

**Results.** Table 7 presents results using portfolio allocations data from AAII. We find that lower interest rates are associated with higher allocations to stocks and lower allocations to "cash." A one percentage point decrease in interest rates is associated with a roughly 1.4 to 2 percentage points increase in allocations to stocks and a similar size fall in allocations

[28]For a given market risk premium, an increase in the risk-free rate can mechanically increase the expected return/discount rate. If we control for model-based expected returns, as opposed to expected *excess* returns, the coefficient on the risk-free rate could be biased, and the direction depends on how household investment allocations respond to model-based expected excess returns. If allocations to stocks are positively correlated with model-based expected excess returns, then the magnitude of the coefficient on the risk-free rate could be inflated (bias for us). If allocations to stock are negatively correlated with model-based expected excess, then the magnitude of the coefficient on the risk-free rate could be dampened (bias against us). The latter case appears to hold in the data: households invest more aggressively in stocks when valuations are high and model-based expected excess returns are low, consistent with findings in Greenwood and Shleifer (2014).

to "cash." In our benchmark experiments, the treatment is a 4 percentage points difference in the level of interest rates, which is associated with a roughly 8 percentage points change in the mean allocation to the risky asset. The magnitude of investment allocations' response to interest rates appears similar in the experiment and in the observational data. In Internet Appendix Table A17, we present regressions using changes in allocations and changes in interest rates, which show similar results. We also find that results are weaker using real interest rates, suggesting nominal interest rates may play a more important role.

Table 8 presents results using investment flows from ICI and Flow of Funds. As flows are analogous to changes in allocations, here we use changes in interest rates on the right hand side. Across different data sources, decreases in interest rates are consistently associated with flows into risky assets and out of safe interest-bearing assets.[29]

We also use standard structural VAR (sVAR) to study the impulse response of investment decisions to innovations in interest rates, presented in Internet Appendix Figure A8 and Figure A9. The sVAR analysis yields the same results. The impulse response suggests persistent impact in the medium run.

**Who takes the other side of households' investment flows?** In Internet Appendix Table A19, we use data from the Flow of Funds to study net flows into equities by households and other sectors, as well as net equity issuance by firms (net inflows are equal to net issuance by accounting identity). Table A19 shows that following a fall in interest rates, the financial sector tends to have higher inflows to equities, although the increase is not statistically significant. The inflows from US households and institutions are partly accommodated by investors in the rest of the world, who reduce their holdings of US equities. The main player on the other side of the inflows appears to be US corporate issuers, whose net equity issuance increases. We also examine changes in asset prices to verify that the flows are driven by higher demand for equities (as opposed to higher supply). Internet Appendix Figure A10 plots the response of *excess* stock returns to interest rate movements. Lower interest rates are associated with higher excess stock returns in the first few months, followed by lower excess returns in the long term, consistent with findings by Bernanke and Kuttner (2005) and Bianchi, Lettau, and Ludvigson (2017). Taken together, the results appear consistent

[29] In the past two decades, stock market participation rate declined secularly while interest rates fell. The falling stock market participation rate appears driven by a number of demographic issues (e.g. inequality, income and unemployment conditions) and most pronounced among young households based on the SCF data. Both among stock market participants and for the household sector in aggregate, however, investment in stocks does not seem to secularly decline; drops in interest rates do seem to prompt aggregate household inflows to risky assets such as high yield bonds and stocks.

with increased household demand for equities when interest rates fall, which generates a positive price impact in the near term (as inflows persist for a while). The rest of the world accommodates a portion of the inflows. Higher overall demand for equities also induces more issuance by firms. After equity prices and valuations go up, there are eventually lower excess returns going forward.

In sum, results using different types of historical data show consistent patterns of increased risk taking by households when interest rates fall. The findings are in line with our experimental evidence on investment decisions. Given the challenges and limitations discussed above, we hold results in the observational data as suggestive and complementary to our core experimental results.

# 6 Conclusion

In this paper, we document that individuals demonstrate a greater appetite for risk taking when interest rates are low. Using simple randomized experiments of investment decision making, we show that allocations to the risky asset are significantly higher when interest rates are low, holding fixed the excess returns of the risky asset. We find consistent results in different settings, and in diverse subject pools including MTurk workers and HBS MBAs. We propose two categories of explanations, reference dependence and salience, and provide evidence that both contribute to the reaching for yield behavior. Despite challenges and caveats, we find complementary evidence in observational data that risk taking in household investment decisions increases as interest rates fall.

Since the Great Recession, central banks in many countries adopted extraordinary policies to stimulate the economy. A large volume of research studies how these policies affect borrowers (Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru, and Yao, 2016a; Auclert, 2016; Greenwald, 2016; Wong, 2016; Di Maggio, Kermani, and Palmer, 2016b; Beraja, Fuster, Hurst, and Vavra, 2017). There has been less focus on responses by savers. Our findings, along with other recent research (Hartzmark and Solomon, 2017), suggest there is also much to be understood about savers' behavior. Indeed, many savers appear to have a deeply ingrained notion that saving is the preservation of wealth, and wealth should grow at a "decent" rate. Such mindset could lead to saver behavior that is at odds with predictions of canonical models when interest rates are low or negative, as our evidence illustrates. Savers' tendencies to take more risks in a low interest environment can also influence financial institutions' actions: institutions may invest in riskier assets to cater to clients' preferences, or they may design securities that highlight returns and shroud risks to further exploit these preferences (Célérier and Vallée, 2016).

Taken together, our findings provide new perspectives for understanding investor behavior in low interest rate environments, and the potential "risk-taking channel" of monetary policy. Besides monetary policy, low interest rates likely arise from a confluence of factors; our evidence may also be relevant to forces contributing to secular declines in interest rates, such as low productivity growth (Gordon, 2015), weak aggregate demand (Summers, 2015), or shortage of assets (Caballero, Farhi, and Gourinchas, 2008). Investors' reaching for yield behavior could have implications for the link between key macroeconomic issues and capital market dynamics and financial stability.

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# Main Figures and Tables

Figure 1: Geographic Distribution of MTurk Participants

This plot shows the geographic distribution of MTurk participants in the benchmark experiments (Experiments B1 and B2). The dots indicate participant locations. The background shade is colored based on log population density in each county.

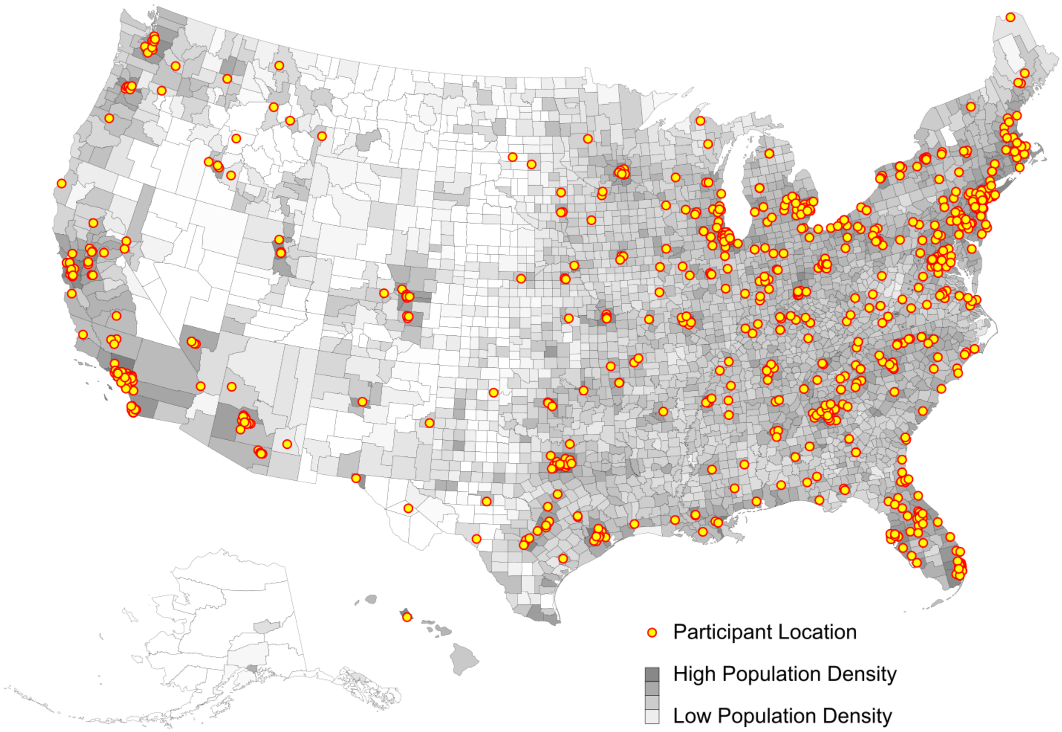
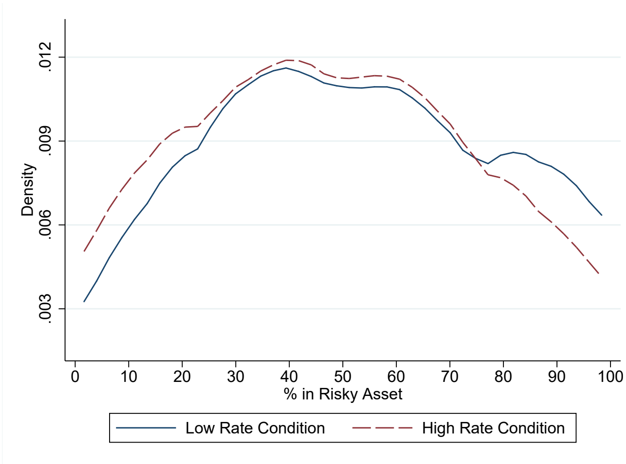


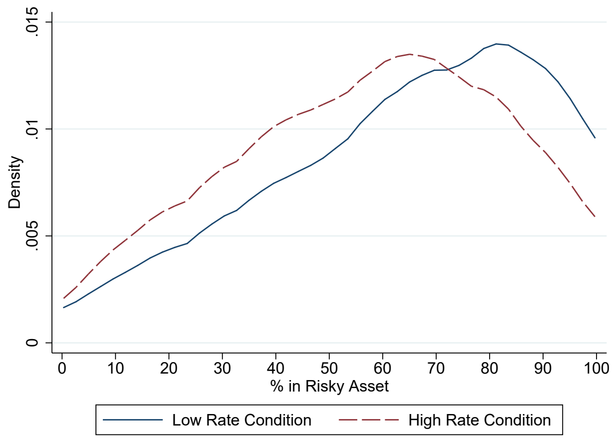
Figure 2: Distribution of Allocations to the Risky Asset in Benchmark Experiments

Density plots of allocations to the risky asset in the benchmark experiments. Panels A, B, and C present plots for Experiments B1, B2, and B3 respectively. The solid line is the distribution of allocations to the risky asset in the low interest rate condition, and the dashed line is that in the high interest rate condition.

Panel A. Experiment B1: MTurk, Hypothetical




Panel B. Experiment B2: MTurk, Incentivized




Panel C. Experiment B3: HBS MBA, Incentivized

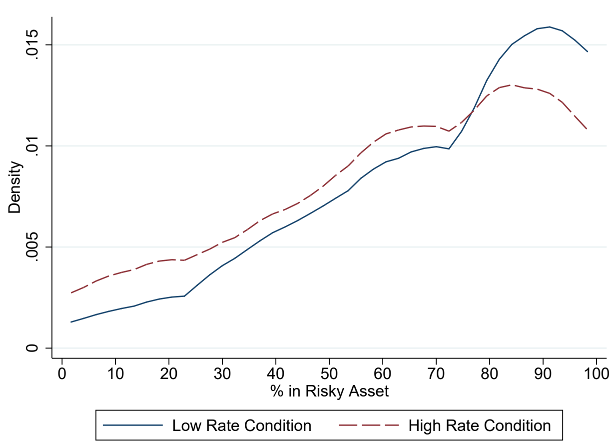


Figure 3: Mean Allocations Across Interest Rate Conditions

Mean allocations to the risky asset across various interest rate conditions in Experiment T1. Each condition has 200 participants. The x-axis shows the risk-free rate in each condition. The mean excess returns on the risky asset is 5% in all conditions. The y-axis is the mean allocation to the risky asset. The vertical bar shows the 95% confidence interval for the mean allocation.

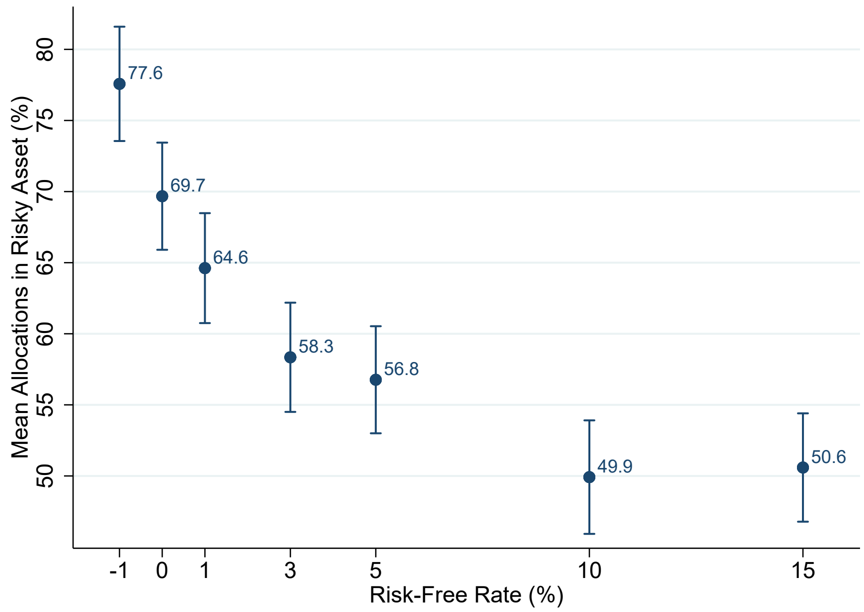


Figure 4: Path Dependence of Investment Decisions

This plot shows mean allocations in Experiment T2. In Group 1, participants first make investment decisions in the high interest rate condition (5% risk-free rate and 10% average risky returns), and then make decisions in the low interest rate condition (1% risk-free rate and 6% average risky returns). In Group 2, participants first make investment decisions in the low rate condition, and then make decisions in the high rate condition. The circles are mean allocations in the high interest rate condition; the diamonds are mean allocations in the low interest rate condition. The vertical bar shows the 95% confidence interval for the mean allocation. We perform this experiment using both hypothetical questions and incentivized tests.

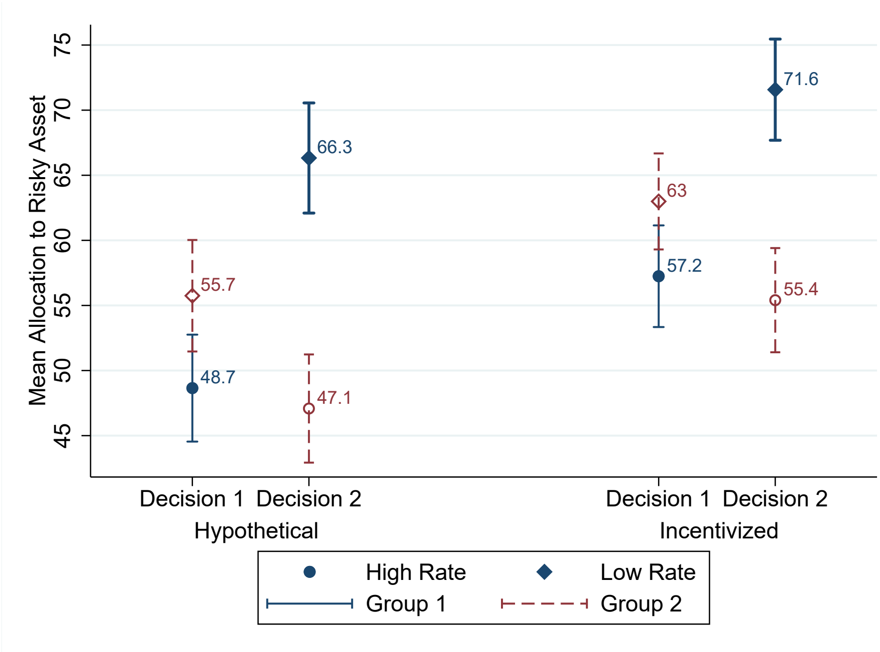



Figure 5: Mean Allocations with Baseline and Gross Framing

Mean allocations to the risky asset in Experiment T3. The circles are mean allocations in the high interest rate condition; the diamonds are mean allocations in the low interest rate condition. The vertical bar shows the 95% confidence interval for the mean allocation.

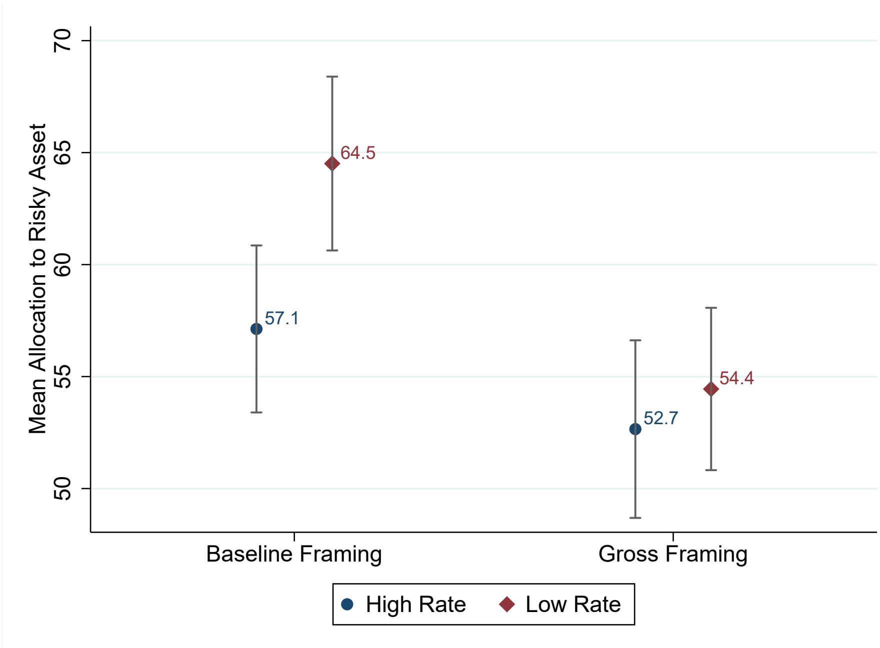


Table 1: Summary Statistics of Benchmark Experiment Samples

This table presents the demographics of benchmark experiment samples. Panels A, B, C tabulate information for Experiments B1, B2, B3 respectively. In the Low condition, the risk-free rate is 1%; in the High condition, the risk-free rate is 5%. The mean excess returns of the risky asset is 5% in both conditions. For the MBA sample, we do not collect age because of homogeneity, and do not collect wealth as it might be sensitive information. Risk tolerance is measured through a question that asks participants to choose their favorite lottery from six options increasing in risks and expected payoffs. We group risk tolerance into low, medium, and high based on the lottery chosen.

Panel A. Experiment B1: MTurk, Hypothetical

| | | Low | | High | |
|---|---|---|---|---|---|
| | | *N* | % | *N* | % |
| Gender | Male | 82 | 40.0 | 102 | 52.3 |
| | Female | 123 | 60.0 | 93 | 47.7 |
| Education | Graduate school | 38 | 18.5 | 30 | 15.4 |
| | College | 112 | 54.6 | 118 | 60.5 |
| | High school | 53 | 25.9 | 45 | 23.1 |
| Age | Below 30 | 103 | 50.2 | 98 | 50.3 |
| | 30–40 | 63 | 30.7 | 56 | 28.7 |
| | 40–50 | 16 | 7.8 | 25 | 12.8 |
| | Above 50 | 23 | 11.2 | 16 | 8.2 |
| Risk tolerance | High | 32 | 15.6 | 35 | 18.0 |
| | Medium | 67 | 32.7 | 64 | 32.8 |
| | Low | 106 | 51.7 | 96 | 49.2 |
| Financial wealth (ex. housing) | 200K+ | 10 | 4.9 | 17 | 8.7 |
| | 50K–200K | 56 | 27.3 | 56 | 28.7 |
| | 10K–50K | 57 | 27.8 | 43 | 22.1 |
| | 0–10K | 59 | 28.8 | 51 | 26.2 |
| | In debt | 23 | 11.2 | 28 | 14.4 |
| Investing experience | Extensive | 7 | 3.4 | 6 | 3.1 |
| | Some | 61 | 29.8 | 60 | 30.8 |
| | Limited | 88 | 42.9 | 75 | 38.5 |
| | No | 49 | 23.9 | 54 | 27.7 |
| Total | | 205 | | 195 | |

Panel B. Experiment B2: MTurk, Incentivized

| | | Low | | High | |
|---|---|---|---|---|---|
| | | *N* | % | *N* | % |
| Gender | Male | 116 | 56.6 | 111 | 56.9 |
| | Female | 89 | 43.4 | 84 | 43.1 |
| Education | Graduate school | 30 | 14.6 | 33 | 16.9 |
| | College | 122 | 59.5 | 125 | 64.1 |
| | High school | 52 | 25.4 | 35 | 17.9 |
| Age | Below 30 | 103 | 50.2 | 88 | 45.1 |
| | 30–40 | 54 | 26.3 | 66 | 33.9 |
| | 40–50 | 30 | 14.6 | 23 | 11.8 |
| | Above 50 | 18 | 8.8 | 18 | 9.2 |
| Risk tolerance | High | 33 | 16.1 | 27 | 13.9 |
| | Medium | 73 | 35.6 | 72 | 36.9 |
| | Low | 99 | 48.3 | 96 | 49.2 |
| Financial wealth (ex. housing) | 200K+ | 25 | 12.2 | 22 | 11.3 |
| | 50K–200K | 47 | 22.9 | 55 | 28.2 |
| | 10K–50K | 60 | 29.3 | 58 | 29.7 |
| | 0–10K | 42 | 20.5 | 35 | 17.9 |
| | In debt | 31 | 15.1 | 25 | 12.8 |
| Investing experience | Extensive | 6 | 2.9 | 6 | 3.1 |
| | Some | 68 | 33.2 | 66 | 33.8 |
| | Limited | 83 | 40.5 | 75 | 38.5 |
| | No | 48 | 23.4 | 48 | 24.6 |
| Total | | 205 | | 195 | |

Panel C. Experiment B3: HBS MBA, Incentivized

| | | Low | | High | |
|---|---|---|---|---|---|
| | | $N$ | % | $N$ | % |
| Gender | Male | 117 | 58.2 | 129 | 64.8 |
| | Female | 84 | 41.8 | 70 | 35.2 |
| Past 15 yrs of life | US | 140 | 69.7 | 133 | 66.8 |
| | Abroad | 61 | 30.3 | 66 | 33.2 |
| Primary educational field | Humanities | 26 | 12.9 | 23 | 11.6 |
| | Social Science | 64 | 31.8 | 43 | 21.6 |
| | Science & Engineering | 80 | 39.8 | 95 | 47.7 |
| | Other | 31 | 15.4 | 38 | 19.1 |
| Risk tolerance | High | 116 | 57.7 | 107 | 53.8 |
| | Medium | 48 | 23.9 | 56 | 28.1 |
| | Low | 37 | 18.4 | 36 | 18.1 |
| Investment experience | Extensive/professional | 22 | 10.9 | 25 | 12.6 |
| | Some | 71 | 35.3 | 60 | 30.2 |
| | Limited | 70 | 34.8 | 69 | 34.7 |
| | No | 38 | 18.9 | 45 | 22.6 |
| Worked in finance | Yes | 84 | 41.8 | 86 | 43.2 |
| | No | 117 | 58.2 | 113 | 56.8 |
| Total | | 201 | | 199 | |

Table 2: Low Interest Rates and Risk Taking: Benchmark Experiment Results

This table presents results of the benchmark experiments. In Panel A, the first four columns show mean allocations to the risky asset in the high and low interest rate conditions, the difference in mean allocations between the two conditions, and the corresponding $t$-statistics. Column (5) shows $p$-values from the Mann–Whitney–Wilcoxon test, against the null that allocations in the high and low interest rate conditions are the same. Columns (6) and (7) show the mean difference in allocations controlling for individual characteristics through OLS; columns (8) and (9) show the difference through propensity score matching (ATE). In the MTurk samples, covariates include dummies for gender, age group, education level, risk tolerance, investment experience, wealth level. In the HBS MBA sample, covariates include dummies for gender, risk aversion level, investment experience, and work experience in finance. Panel B presents the OLS regressions displaying coefficients on the controls. The absorbed groups are female, below 30, high school or below, low risk tolerance, in debt, no or limited investment experience, did not work in finance.

Panel A. Allocations to Risky Asset (%)

| | High (1) | Low (2) | **Dif** (Raw) (3) | [$t$] (4) | $U$ test ($p$) (5) | **Dif** (OLS) (6) | [$t$] (7) | **Dif** (Match) (8) | [$t$] (9) |
|---|---|---|---|---|---|---|---|---|---|
| B1: MTurk, Hypo. | 48.15 | 55.32 | 7.17 | [2.52] | (0.02) | 7.69 | [2.74] | 7.27 | [2.66] |
| B2: MTurk, Incen. | 58.58 | 66.64 | 8.06 | [3.06] | (0.00) | 8.14 | [3.23] | 8.66 | [2.81] |
| B3: HBS MBA, Incen. | 66.79 | 75.61 | 8.83 | [3.13] | (0.00) | 8.76 | [3.19] | 8.91 | [3.30] |

Panel B. Regressions with Individual Characteristics

| | % Allocated to Risky Asset | | |
|---|---|---|---|
| | B1 (MTurk) | B2 (MTurk) | B3 (HBS) |
| **Low Rate Condition** | **7.69** | **8.14** | **8.76** |
| | [2.74] | [3.23] | [3.19] |
| Male | -1.04 | 6.63 | 6.25 |
| | [-0.36] | [2.49] | [2.14] |
| College | -3.09 | 3.32 | |
| | [-0.92] | [1.00] | |
| Grad School | 0.51 | 1.31 | |
| | [0.11] | [0.29] | |
| Age (30—40) | 3.69 | 0.86 | |
| | [1.16] | [0.29] | |
| Age (40—50) | 7.51 | 1.87 | |
| | [1.48] | [0.47] | |
| Age (50+) | 1.26 | 6.63 | |
| | [0.22] | [1.35] | |
| Risk Tolerance Med | 12.30 | 10.15 | 5.56 |
| | [3.97] | [3.62] | [1.36] |
| Risk Tolerance High | 18.22 | 15.28 | 15.39 |
| | [4.46] | [4.25] | [4.01] |
| Wealth (0—10K) | -6.07 | -8.69 | |
| | [-1.41] | [-1.88] | |
| Wealth (10K—50K) | 0.27 | -4.87 | |
| | [0.06] | [-1.13] | |
| Wealth (50K—200K) | -5.29 | -2.85 | |
| | [-1.20] | [-0.63] | |
| Wealth (200K+) | 0.75 | 3.40 | |
| | [0.11] | [0.67] | |
| More Experience | 5.80 | 2.95 | 4.41 |
| | [1.71] | [1.05] | [1.28] |
| Worked in Finance | | | 3.34 |
| | | | [1.00] |
| Constant | 41.03 | 54.44 | 55.81 |
| | [8.91] | [9.82] | [14.27] |
| Obs | 400 | 400 | 400 |
| $R^2$ | 0.118 | 0.136 | 0.115 |

Robust $t$-statistics in brackets

Table 3: Allocations in Various Interest Rate Conditions

This table presents results of Experiment T1. It shows mean allocations to the risky asset in different interest rate conditions. Each condition has 200 participants. Each column presents results for one condition. The first two rows show the properties of the investments in a given condition: the first row is the returns on the safe asset; the second row is the mean returns on the risky asset. The excess returns of the risky asset are the same in all conditions. The third row shows mean allocations to the risky asset in each condition, and the fourth row shows the 95% confidence interval.

| **Risk-Free Rate** | -1% | 0% | 1% | 3% |
| --- | --- | --- | --- | --- |
| Mean Returns of Risky Asset | 4% | 5% | 6% | 8% |
| Mean Allocations to Risky Asset (%) | 77.58 | 69.67 | 64.62 | 58.34 |
| 95% CI | (73.53, 81.62) | (65.88, 73.46) | (60.72, 68.51) | (54.48, 62.21) |

| **Risk-Free Rate** | 5% | 10% | 15% | |
| --- | --- | --- | --- | --- |
| Mean Returns of Risky Asset | 10% | 15% | 20% | |
| Mean Allocations to Risky Asset (%) | 56.77 | 49.92 | 50.59 | |
| 95% CI | (52.98, 60.55) | (45.90, 53.93) | (46.76, 54.43) | |

Table 4: Path Dependence of Investment Decisions

This table presents results of Experiment T2. Half of the participants are randomly assigned to Group 1, and they first make investment decisions in the high interest rate condition (5% risk-free rate and 10% average risky returns), and then make decisions in the low interest rate condition (1% risk-free rate and 6% average risky returns). The other half of the participants are assigned to Group 2, and they first make investment decisions in the low rate condition, and then make decisions in the high rate condition. We perform this experiment using both hypothetical questions and incentivized tests.

| | | |
|---|---|---|
| G1 | High: 5—10 | Low: 1—6 |
| Mean Alloc. to Risky | 48.65 | **66.33** |
| G2 | Low: 1—6 | High: 5—10 |
| Mean Alloc. to Risky | 55.75 | 47.08 |
| G1 (Low) - G2 (Low) | Difference<br>10.58 | [$t$]<br>[3.44] |

(a) Hypothetical

| | | |
|---|---|---|
| G1 | High: 5—10 | Low: 1—6 |
| Mean Alloc. to Risky | 57.24 | **71.57** |
| G2 | Low: 1—6 | High: 5—10 |
| Mean Alloc. to Risky | 62.99 | 55.40 |
| G1 (Low) - G2 (Low) | Difference<br>8.58 | [$t$]<br>[3.14] |

(b) Incentivized

Table 5: Baseline and Gross Framing

This table presents results of Experiment T3. The first half of Panel A reports mean allocations to the risky asset in the high and low interest rate conditions, the difference in mean allocations between the two conditions, and the $t$-statistics associated with the test that the difference is different from zero. $p$-values from the Mann–Whitney–Wilcoxon test are also included. The bottom half of Panel A compares allocations with baseline framing to allocations with gross framing. Panel B presents differences in allocations controlling for individual characteristics, both through OLS and through propensity score matching (ATE). The individual characteristics include dummies for gender, education level, age group, risk tolerance, investment experience, and wealth level. The first half of Panel B compares allocations in the high and low interest rate conditions for a given framing. The second half of Panel B compares allocations with baseline and gross framing for a given interest rate condition.

Panel A. Mean Allocations to Risky Asset (%)

| | High: 5—10 | Low: 1—6 | Difference | [$t$] | $U$ test ($p$-val) |
|---|---|---|---|---|---|
| Baseline | 57.13 | 64.51 | 7.38 | [2.69] | (0.00) |
| Gross | 52.65 | 54.44 | 1.79 | [0.65] | (0.47) |
| Baseline - Gross | 4.47 | 10.06 | 5.59 | - | - |
| [$t$] | [1.61] | [3.72] | [1.44] | - | - |
| $U$ test ($p$-val) | (0.14) | (0.00) | - | - | - |

Panel B. Differences Controlling for Individual Characteristics

| | Dif (OLS) | [$t$] | Dif (ATE) | [$t$] |
|---|---|---|---|---|
| Baseline: Low − High | 5.90 | [2.25] | 6.75 | [2.47] |
| Gross: Low − High | 1.93 | [0.70] | 0.68 | [0.21] |
| High: Baseline − Gross | 5.08 | [1.94] | 5.43 | [1.97] |
| Low: Baseline − Gross | 9.65 | [3.61] | 11.37 | [4.30] |

## Table 6: Summary Statistics of Observational Data

Summary statistics for observational data. Mean, median, standard deviation, quartiles, and data time periods are presented. Variables include: allocations to stocks and "cash" (interest-bearing liquid assets, such as savings accounts, CDs, money market funds) using data from the American Association of Individual Investors (AAII); equity and high yield corporate bond mutual fund flows, normalized by respective net asset value, using data from the Investment Company Institute (ICI); household sector flows into stocks (both direct holdings and mutual fund holdings) and interest-bearing safe assets (include time and saving deposits, money market mutual funds, and commercial paper), normalized by household sector financial wealth, using data from the Flow of Funds; interest rates; stock market sentiment (% Bullish - % Bearish) from AAII, Campbell-Shiller P/E10, Campbell-Cochrane surplus consumption ratio, $VIX^2$, past four quarter GDP growth, and the credit spread (BAA - 10-year Treasury).

| | Mean | Std. Dev. | 25% | 50% | 75% | Start | End | $N$ |
|---|---|---|---|---|---|---|---|---|
| *Portfolio Share Data from AAII* | | | | | | | | |
| % in Stocks | 60.18 | 8.35 | 53.27 | 61.25 | 66.91 | 1987M11 | 2014M12 | 326M |
| % in "Cash" (AAII) | 23.96 | 6.32 | 19.00 | 22.69 | 28.00 | 1987M11 | 2014M12 | 326M |
| *Mutual Fund Flow Data from ICI* | | | | | | | | |
| Equity Fund Flows/NAV (%) | 0.39 | 0.77 | -0.12 | 0.28 | 0.90 | 1985M1 | 2014M12 | 360M |
| HY CB Fund Flows/NAV (%) | 0.65 | 1.90 | -0.58 | 0.75 | 1.77 | 1985M1 | 2014M12 | 360M |
| *Household Investment Flows Data from FoF* | | | | | | | | |
| Flows into Stocks/HH Fin. Ast. (%) | -0.19 | 0.82 | -0.72 | -0.22 | 0.27 | 1985Q1 | 2014Q4 | 120Q |
| Flows into Deposits/HH Fin. Ast. (%) | 0.71 | 0.87 | 0.15 | 0.75 | 1.36 | 1985Q1 | 2014Q4 | 120Q |
| *Interest Rates* | | | | | | | | |
| 3-Month Treasury Rate | 3.66 | 2.53 | 1.13 | 4.31 | 5.53 | 1985M1 | 2014M12 | 360M |
| *Controls* | | | | | | | | |
| Stock Market Sentiment (AAII) | 8.57 | 15.30 | -1.81 | 9.36 | 18.75 | 1987M8 | 2014M12 | 329M |
| P/E10 | 23.44 | 7.54 | 18.31 | 22.41 | 26.46 | 1985M1 | 2014M12 | 360M |
| $Surp$ | 0.113 | 0.098 | 0.081 | 0.157 | 0.185 | 1985M1 | 2014M12 | 360M |
| $VIX^2$ | 0.049 | 0.051 | 0.023 | 0.035 | 0.056 | 1986M1 | 2014M12 | 348M |
| Past 4Q GDP Growth | 2.70 | 1.68 | 1.80 | 3.02 | 3.96 | 1985Q1 | 2014Q4 | 360M |
| Credit Spread | 2.31 | 0.74 | 1.73 | 2.17 | 2.75 | 1985M1 | 2014M12 | 360M |

Table 7: Interest Rates and AAII Portfolio Allocations

Monthly time series regressions:

$$Y_t = \alpha + \beta r_{f,t-1} + X'_{t-1}\gamma + \epsilon_t$$

where $r_f$ is the 3-month Treasury rate; $X$ includes P/E10 in column (2), the surplus consumption ratio in column (3), and predicted next 12-month excess stock returns in column (4) (estimated using surplus consumption and past 12-month excess stock returns), as well as AAII stock market sentiment, $VIX^2$, real GDP growth in the past four quarters, and the credit spread (BAA - 10-year Treasury). $Y$ is mean allocations to stocks in Panel A and mean allocations to "cash" in Panel B. Monthly from November 1987 to December 2014. Standard errors are Newey-West, using the automatic bandwidth selection procedure of Newey and West (1994).

Panel A. Interest Rates and Mean Allocations to Stocks

| | Mean Allocations to Stocks | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| L.$r_f$ | -0.38 | -1.47 | -1.92 | -2.00 |
| | [-0.51] | [-4.49] | [-2.46] | [-2.57] |
| L.P/E10 | | 0.84 | | |
| | | [9.16] | | |
| L.$Surp$ | | | 6.79 | |
| | | | [0.40] | |
| L.$E[rx^{12}_{stk}]$ | | | | -0.12 |
| | | | | [-0.60] |
| L.AAII Sentiment | | 0.04 | 0.17 | 0.16 |
| | | [1.66] | [4.01] | [3.67] |
| L.$VIX^2$ | | -6.34 | -14.45 | -5.73 |
| | | [-0.78] | [-0.96] | [-0.27] |
| L.Past 12M GDP Growth | | 0.34 | 2.11 | 2.17 |
| | | [0.85] | [2.61] | [2.77] |
| L.Credit Spread | | -3.87 | -2.64 | -3.37 |
| | | [-4.02] | [-1.34] | [-1.46] |
| Constant | 61.47 | 52.58 | 66.01 | 68.87 |
| | [19.30] | [14.59] | [10.88] | [9.03] |
| Observations | 326 | 326 | 326 | 326 |

Newey-West $t$-statistics in brackets

Panel B. Interest Rates and Mean Allocations to "Cash"

| | Mean Allocations to "Cash" | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| L.$r_f$ | 0.62 | 1.51 | 1.19 | 1.28 |
| | [1.21] | [3.85] | [2.26] | [1.99] |
| L.P/E10 | | -0.47 | | |
| | | [-4.22] | | |
| L.$Surp$ | | | 20.56 | |
| | | | [1.78] | |
| L.$E[rx^{12}_{stk}]$ | | | | -0.21 |
| | | | | [-1.27] |
| L.AAII Sentiment | | -0.02 | -0.13 | -0.13 |
| | | [-1.00] | [-4.29] | [-3.41] |
| L.$VIX^2$ | | 9.69 | 11.01 | 27.02 |
| | | [1.10] | [1.06] | [1.52] |
| L.Past 12M GDP Growth | | -0.01 | -1.33 | -1.10 |
| | | [-0.01] | [-2.45] | [-1.63] |
| L.Credit Spread | | 3.83 | 2.82 | 1.69 |
| | | [3.56] | [2.11] | [0.86] |
| Constant | 21.85 | 21.32 | 15.14 | 19.50 |
| | [9.99] | [4.97] | [3.69] | [3.02] |
| Observations | 326 | 326 | 326 | 326 |

Newey-West $t$-statistics in brackets

Table 8: Interest Rates and Household Investment Flows

Time series regressions:

$$F_t = \alpha + \beta \Delta r_{f,t-1} + X'_{t-1}\gamma + \epsilon_t$$

where $r_f$ is 3-month Treasury rate. In Panel A, $F$ is monthly flows into equity mutual funds (normalized by net asset value of equity mutual funds, i.e. $F$ is flows as a percentage of net asset value) using data from ICI; $X$ includes controls in Table 7. In Panel B, $F$ is monthly flows into high yield corporate bond mutual funds (normalized by net asset value of high yield corporate bond mutual funds) using data from ICI; $X$ includes past 12-month excess returns of high yield corporate bonds in column (2), past 12-month excess returns and high yield corporate default rates in column (3), and predicted next 12-month high yield corporate bond excess returns (estimated using past 12-month excess returns and corporate default rates) in column (4), as well as the credit spread and real GDP growth in the past four quarters. In Panel C, $F$ is quarterly household sector flows into stocks (including both direct holdings and mutual fund holdings, normalized by household financial assets) using data from Flow of Funds; $X$ includes controls in Table 7 (measured at the end of the previous quarter). In Panel D, $F$ is quarterly household sector flows into interest-bearing safe assets (time and saving deposits, money market mutual funds, commercial papers, normalized by household financial assets, i.e. $F$ is flows as a percentage of household financial wealth) using data from Flow of Funds; $X$ includes controls in Table 7 (measured at the end of the previous quarter). All regressions include four lags of $F$. Outcome variables are from the beginning of 1985 to the end of 2014, but AAII sentiment is only available starting August 1987. Standard errors are Newey-West, using the automatic bandwidth selection procedure of Newey and West (1994).

| | | | | |
|---|---|---|---|---|
| **Panel A. Equity Mutual Fund Flows (ICI)** | | | | |
| L.D.$r_f$ | -0.42 | -0.42 | -0.40 | -0.44 |
| | [-2.51] | [-2.50] | [-2.39] | [-2.13] |
| Controls | No | Yes | Yes | Yes |
| Observations | 360 | 328 | 328 | 328 |
| **Panel B. High Yield Corp. Bond Mutual Fund Flows (ICI)** | | | | |
| L.D.$r_f$ | -1.01 | -0.78 | -0.78 | -1.17 |
| | [-2.42] | [-1.69] | [-1.70] | [-2.65] |
| Controls | No | Yes | Yes | Yes |
| Observations | 360 | 360 | 360 | 360 |
| **Panel C. Household Flows into Stocks (FoF)** | | | | |
| L.D.$r_f$ | -0.37 | -0.47 | -0.40 | -0.74 |
| | [-2.63] | [-2.89] | [-2.39] | [-3.51] |
| Controls | No | Yes | Yes | Yes |
| Observations | 120 | 109 | 109 | 109 |
| **Panel D. Household Flows into Deposits (FoF)** | | | | |
| L.D.$r_f$ | 0.41 | 0.40 | 0.38 | 0.34 |
| | [3.11] | [2.51] | [2.41] | [1.60] |
| Controls | No | Yes | Yes | Yes |
| Observations | 120 | 109 | 109 | 109 |

Newey-West $t$-statistics in brackets

# Internet Appendix

# A Proofs

## A.1 Proof of Proposition 1

Consider first the problem without the constraint $0 \leq \phi \leq 1$. Let $h(\phi) = \mathbb{E}u(w(1+r_p))$. We have $\frac{\partial^2 h(\phi)}{\partial \phi^2} = \mathbb{E}\left[x^2 u''(\tilde{w})\right] < 0$ because $u$ is strictly concave. As a result, $h(\phi)$ is strictly concave and twice differentiable. Define $\phi_1^* = \arg\max_\phi \mathbb{E}u(w(1+r_p)) = \arg\max_\phi h(\phi)$, i.e. the optimal allocation to the risky asset in the unconstrained problem. Because $h(\phi)$ is strictly concave and twice differentiable, $\phi_1^*$ is fully characterized by the first order condition:

$$\mathbb{E}\left[xu'\left(w(1+r_f)+\phi_1^* wx\right)\right] = 0.$$

Therefore,

$$\frac{\partial \phi_1^*}{\partial r_f} = -\frac{\mathbb{E}\left[xu''\left(w(1+r_f)+\phi_1^* wx\right)\right]}{\mathbb{E}\left[x^2 u''\left(w(1+r_f)+\phi_1^* wx\right)\right]} = -\frac{\mathbb{E}\left[xu''(\tilde{w})\right]}{\mathbb{E}\left[x^2 u''(\tilde{w})\right]} = \frac{\mathbb{E}\left[xu'(\tilde{w})A(\tilde{w})\right]}{\mathbb{E}\left[x^2 u''(\tilde{w})\right]},$$

where $\tilde{w} = (1+r_f)w + \phi_1^* xw$ is the investor's final wealth, and $A(\tilde{w}) = \frac{-u''(\tilde{w})}{u'(\tilde{w})}$ denotes the coefficient of absolute risk aversion.

Since $u$ is strictly concave, $\frac{\mathbb{E}[xu'(\tilde{w})A(\tilde{w})]}{\mathbb{E}[x^2u''(\tilde{w})]}$ has the same sign as $-\mathbb{E}\left[xu'(\tilde{w})A(\tilde{w})\right]$. Note that

$$\begin{aligned}
\mathbb{E}\left[xu'(\tilde{w})A(\tilde{w})\right] &= \int_{x\geq 0} xu'(\tilde{w})A(\tilde{w})\,dx + \int_{x<0} xu'(\tilde{w})A(\tilde{w})\,dx \\
&\leq \int_{x\geq 0} xu'(\tilde{w})A(\tilde{w}(0))\,dx + \int_{x<0} xu'(\tilde{w})A(\tilde{w}(0))\,dx \\
&= A(\tilde{w}(0))\,\mathbb{E}\left[xu'(\tilde{w})\right] = 0
\end{aligned}$$

where $\tilde{w}(0) = w(1+r_f)$ denotes the final wealth level when the realized excess returns is $x = 0$ and we use the fact that $A(\tilde{w})$ is weakly decreasing in $\tilde{w}$. As a result, $\frac{\partial \phi_1^*}{\partial r} \geq 0$, that is, $\phi_1^*$ is (weakly) increasing in $r_f$.

We can now consider the constrained problem $\phi^* = \arg\max_{0\leq\phi\leq 1} \mathbb{E}u(w(1+r_p)) = \arg\max_{0\leq\phi\leq 1} h(\phi)$. Because $h(\phi)$ is strictly concave, $h(\phi)$ is increasing in $\phi$ when $\phi \leq \phi_1^*$ and decreasing in $\phi$ when $\phi > \phi_1^*$. Thus $\phi^* = \min\{\phi_1^*, 1\}$.[30] It is also (weakly) increasing in $r_f$.

## A.2 Proof of Proposition 2

Let $r_d = r_r - r_f$ denote the difference between the reference point and the risk-free rate. When $r_d = r_r - r_f > 0$, the reference point is larger than the risk-free rate, which falls into

[30] Because $\mathbb{E}x > 0$, by the Arrow-Pratt Theorem $\phi_1^* > 0$.

case 1 of Proposition 2. When $r_d = r_r - r_f < 0$, the reference point is smaller than the risk-free rate, which falls into case 2 of Proposition 2.

We can write function $u$ as

$$u\left(w\left(1+r_p\right)\right) = \begin{cases} w\left(\phi x - r_d\right) & \phi x \geq r_d \\ -\lambda w\left(r_d - \phi x\right) & \phi x < r_d \end{cases}.$$

Note that $u$ is linear in $w$, so without loss of generality, we can assume $w = 1$. We have

$$\mathbb{E}u\left(1+r_p\right) = \left(\phi \mathbb{E}x - r^d\right) - \int_{-\infty}^{\frac{r_d}{\phi}} \left(\lambda - 1\right)\left(r_d - \phi x\right) f\left(x\right) dx \triangleq h\left(\phi, r_d\right).$$

where $f$ is the probability density function of the distribution of excess returns $x$, the first term captures expected investment returns in excess of the reference point, and the second term captures the utility loss from loss aversion in the region below the reference point. Take derivatives with respect to $\phi$, we have

$$\frac{\partial h\left(\phi, r_d\right)}{\partial \phi} = \mathbb{E}x + \int_{-\infty}^{\frac{r_d}{\phi}} \left(\lambda - 1\right) x f\left(x\right) dx. \tag{A7}$$

Case 1: $\mathbb{E}x < -\int_{-\infty}^{0} \left(\lambda - 1\right) x f\left(x\right) dx$. In this case, there exists unique $\underline{b}, \overline{b} > 0$, such that

$$\mathbb{E}x + \int_{-\infty}^{-\underline{b}} \left(\lambda - 1\right) x f\left(x\right) dx = 0,$$

$$\mathbb{E}x + \int_{-\infty}^{\overline{b}} \left(\lambda - 1\right) x f\left(x\right) dx = 0.$$

When $r_d > 0$,

$$\phi^* = \min\left\{\frac{r_d}{\overline{b}}, 1\right\}. \tag{A8}$$

This is because when $0 \leq \phi < \frac{r_d}{\overline{b}}$, $\frac{\partial h(\phi, r_d)}{\partial \phi} > \mathbb{E}x + \int_{-\infty}^{\overline{b}} \left(\lambda - 1\right) x f\left(x\right) dx = 0$, and when $\phi > \frac{r_d}{\overline{b}}$, $\frac{\partial h(\phi, r_d)}{\partial \phi} < \mathbb{E}x + \int_{-\infty}^{\overline{b}} \left(\lambda - 1\right) x f\left(x\right) dx = 0$.

When $r_d < 0$,

$$\phi^* = \min\left\{-\frac{r_d}{\underline{b}}, 1\right\}. \tag{A9}$$

This is because when $0 \leq \phi < -\frac{r_d}{\underline{b}}$, $\frac{\partial h(\phi, r_d)}{\partial \phi} > \mathbb{E}x + \int_{-\infty}^{-\underline{b}} \left(\lambda - 1\right) x f\left(x\right) dx = 0$, and when $\phi > -\frac{r_d}{\underline{b}}$, $\frac{\partial h(\phi, r_d)}{\partial \phi} < \mathbb{E}x + \int_{-\infty}^{-\underline{b}} \left(\lambda - 1\right) x f\left(x\right) dx = 0$.

Based on Equations (A8) and (A9), we have that the optimal allocation to the risky asset $\phi^*$ is (weakly) increasing in $r_d$ (and (weakly) decreasing in $r_f$) if $r_r > r_f$, and (weakly) decreasing in $r_d$ (and (weakly) increasing in $r_f$) if $r_r < r_f$.

Case 2: $\mathbb{E}x \geq -\int_{-\infty}^{0} \left(\lambda - 1\right) x f\left(x\right) dx$. In this case $\frac{\partial h(\phi, r_d)}{\partial \phi} > 0$, $\phi^* = 1$. That is, the expected returns of the risky asset are so attractive that utility loss due to loss aversion from bad realizations of the risky asset's returns is dominated. Investors prefer to invest all of their wealth in the risky asset. In this case, it is still true that the optimal allocation to the risky asset $\phi^*$ is weakly decreasing in $r_f$ if $r_r > r_f$, and weakly increasing in $r_f$ if $r_r < r_f$.[31]

## A.3 Proof of Corollary 1

Note that the proof of Proposition 2 only depends on $r_d = r_r - r_f$. As a result, this proof follows from the proof of Proposition 2.

## A.4 Diminishing Sensitivity

Below we provide a discussion about how the diminishing sensitivity component of the Prospect Theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) may affect reaching for yield. Diminishing sensitivity refers to the idea that the investor's utility is concave above the reference point (i.e. marginal utility gain becomes smaller when the gain is larger) and convex below the reference point (i.e. marginal utility loss becomes smaller when the loss is larger).

We show that the theoretical prediction of whether diminishing sensitivity contributes to reaching for yield is ambiguous. Consider for instance the case where the reference point is above the risk-free rate. Diminishing sensitivity above the reference point unambiguously contributes to reaching for yield: if the portfolio returns are above the reference point, as the risk-free rate falls, the same excess returns on the risky asset generate a *higher* marginal utility gain. Diminishing sensitivity below the reference point, however, may either contribute to or work against reaching for yield: if the portfolio returns are below the reference point but the risky asset has positive excess returns, then as the risk-free rate falls, the same excess returns on the risky asset generate a *lower* marginal utility gain. This force works against reaching for yield. If the portfolio returns are below the reference point and the risky asset has negative excess returns, then diminishing sensitivity again unambiguously contributes to reaching for yield (as the risk-free rate falls, the same excess returns on the risky asset generate a *lower* marginal utility loss). We then evaluate the case

[31]Note that when $r_d = r_r - r_f = 0$, the loss aversion framework here predicts that the optimal allocation to the risky asset is either 0 (if loss aversion is large enough, that is, $\mathbb{E}x < -\int_{-\infty}^{0} (\lambda - 1)\, x f(x)\, dx$) or 1 (if loss aversion is not large enough, that is, $\mathbb{E}x > -\int_{-\infty}^{0} (\lambda - 1)\, x f(x)\, dx$). This prediction is an artifact of the piecewise linear framework we use in Assumption 1 in the main text. To avoid such an extreme prediction, we can study a utility function with both a component featuring diminishing marginal utility over wealth (such as a CARA or CRRA component) and a component featuring gain-loss utility like Assumption 1 (e.g. Kőszegi and Rabin (2006)). In this case, the comparative static of the optimal allocation with respect to the risk-free rate will be influenced by both the force in Proposition 1 (conventional portfolio choice) and the force in Proposition 2 (loss aversion). Accordingly, the comparative static will be a weighted average of these two forces. The analysis in Proposition 2 can be thought of as a version that focuses on studying how loss aversion around the reference point *alone* influences investment decisions' response to the risk-free rate. We use this version to highlight the key mechanism that can drive reaching for yield.

with diminishing sensitivity numerically, based on standard parameter values (Tversky and Kahneman, 1992; Barberis, Huang, and Thaler, 2006) together with investment payoffs in our experiment. We find that diminishing sensitivity generally contributes to reaching for yield, but the magnitude is relatively small.

We analyze a set-up that includes both loss aversion around the reference point as in Section 3.2 and diminishing sensitivity. The investor's optimization problem is the same as Equation (2) in the main text, except the utility function $u$ features both loss aversion around the reference point and diminishing sensitivity, specified as follows:

**Assumption A3.**

$$u\left(1+r_p\right)=\begin{cases}\frac{1}{\alpha}\left[\left(\left(r_p-r_r\right)+1\right)^{\alpha}-1\right] & r_p\geq r_r\\ -\frac{\lambda}{\beta}\left[\left(-\left(r_p-r_r\right)+1\right)^{\beta}-1\right] & r_p<r_r\end{cases}\tag{A10}$$

*where $r_r$ is the reference return, $0<\alpha\leq 1$ reflects the degree of diminishing sensitivity above the reference point, $0<\beta\leq 1$ reflects the degree of diminishing sensitivity below the reference point, and $\lambda\geq 1$ reflects the degree of loss aversion below the reference point. Lower $\alpha$ and $\beta$ correspond to a higher degree of diminishing sensitivity.*

Here we specify the gain loss utility as a function of investment returns instead of the wealth level. Effectively, we analyze the case where the gain loss utility scales linearly with initial wealth, as opposed to having additional curvature driven by initial wealth.[32] The curvature of utility driven by initial wealth can be separately captured by a CRRA component, as discussed in footnote 31 of Section A.2. In addition, our specification avoids the property in the Tversky and Kahneman (1992) specification that marginal utility at the reference point is infinity,[33] which complicates the analysis and is also somewhat counterfactual. Instead, Equation (A10) normalizes the curvature of the utility function just above the reference point to 1 and the curvature of the utility function just below the reference point to $\lambda$, consistent with the utility function in Assumption 1.

We now analyze how the optimal allocation to the risky asset $\phi^*$ moves with the risk-free rate $r_f$ (reference point $r_r$) under Assumption A3. We begin with a decomposition that illustrates how different channels influence the comparative statics of the optimal allocation $\phi^*$ with respect to the risk-free rate $r_f$ and the reference point $r_r$. As in the proof of Proposition 2, let $r_d=r_r-r_f$ denote the difference between the reference point and the

[32] This can be extended to the case where the utility function is homothetic with respect to initial wealth.

[33] The specification following Tversky and Kahneman (1992) would be

$$u\left(\left(1+r_p\right)\right)=\begin{cases}\frac{1}{\alpha}\left(\left(r_p-r_r\right)\right)^{\alpha} & r_p\geq r_r\\ -\frac{\lambda}{\beta}\left(-\left(r_p-r_r\right)\right)^{\beta} & r_p<r_r\end{cases}.$$

risk-free rate. We can rewrite the utility function $u$ as

$$u(1+r_p) = \begin{cases} \frac{1}{\alpha}\left[((\phi x - r_d)+1)^{\alpha} - 1\right] & \phi x \geq r_d \\ -\frac{\lambda}{\beta}\left[((r_d - \phi x)+1)^{\beta} - 1\right] & \phi x < r_d \end{cases}. \tag{A11}$$

Let

$$\begin{aligned} h(\phi, r_d) \triangleq \mathbb{E}\left[u(1+r_p)\right] = &\int_{\frac{r_d}{\phi}}^{+\infty} \frac{1}{\alpha}\left[((\phi x - r_d)+1)^{\alpha} - 1\right] f(x)\, dx \\ &- \frac{\lambda}{\beta}\int_{-\infty}^{\frac{r_d}{\phi}} \left[(1+(r_d-\phi x))^{\beta} - 1\right] f(x)\, dx \end{aligned}$$

where $f$ is the probability density function of the distribution of the excess returns $x$.[34] The first term captures the utility gain when investment returns are above the reference point, and the second term captures the utility loss when investment returns are below the reference point. By Topkin's Theorem, to study how $\arg\max_{0\leq\phi\leq 1} h(\phi, r_d)$ moves with respect to $r_d$, we only need to study the sign of $\frac{\partial^2}{\partial\phi\partial r_d} h(\phi, r_d)$, that is, how the marginal gain of investing in the risky asset changes with respect to $r_d$.

$$\frac{\partial}{\partial\phi} h(\phi, r_d) = \int_{\frac{r_d}{\phi}}^{+\infty} x\left((\phi x - r_d)+1\right)^{\alpha-1} f(x)\, dx + \lambda \int_{-\infty}^{\frac{r_d}{\phi}} x\left(1+(r_d-\phi x)\right)^{\beta-1} f(x)\, dx,$$

$$\begin{aligned} \frac{\partial^2}{\partial\phi\partial r_d} h(\phi, r_d) = &(1-\alpha)\int_{\frac{r_d}{\phi}}^{+\infty} x\left((\phi x - r_d)+1\right)^{\alpha-2} f(x)\, dx \\ &- \lambda(1-\beta)\int_{-\infty}^{\frac{r_d}{\phi}} x\left(1+(r_d-\phi x)\right)^{\beta-2} f(x)\, dx + (\lambda - 1)\frac{r_d}{\phi^2} f\left(\frac{r_d}{\phi}\right). \end{aligned} \tag{A12}$$

Let us consider two cases.

Case 1: $r_d > 0$, i.e. the reference point is higher than the risk-free rate.

The first term in (A12), $(1-\alpha)\int_{\frac{r_d}{\phi}}^{+\infty} x\left((\phi x - r_d)+1\right)^{\alpha-2} f(x)\, dx \geq 0$, since $\alpha \leq 1$. When the realized portfolio returns are above the reference point, the marginal gain of investing in the risky asset is higher as the risk-free rate decreases (the reference point increases), due to diminishing sensitivity. This force contributes to reaching for yield.

The second term in (A12), $-\lambda(1-\beta)\int_{-\infty}^{\frac{r_d}{\phi}} x\left(1+(r_d-\phi x)\right)^{\beta-2} f(x)\, dx$, can be further

[34] In this proof, for technical simplicity, we assume that the pdf $f$ has full support on the real line.

decomposed into

$$-\lambda(1-\beta)\int_{-\infty}^{\frac{r_d}{\phi}} x\left(1+(r_d-\phi x)\right)^{\beta-2} f(x)\,dx = -\lambda(1-\beta)\int_{0}^{\frac{r_d}{\phi}} x\left(1+(r_d-\phi x)\right)^{\beta-2} f(x)\,dx - \lambda(1-\beta)\int_{-\infty}^{0} x\left(1+(r_d-\phi x)\right)^{\beta-2} f(x)\,dx. \tag{A13}$$

The first term in (A13), $-\lambda(1-\beta)\int_0^{\frac{r_d}{\phi}} x\left(1+(r_d-\phi x)\right)^{\beta-2} f(x)\,dx \leq 0$, since $\beta \leq 1$. This term reflects the situation where the portfolio returns are below the reference point but the excess returns of the risky asset are positive. In this region, the marginal gain of investing in the risky asset is lower as the risk-free rate decreases (the reference point increases), due to diminishing sensitivity. This force works against reaching for yield.

The second term in (A13), $-\lambda(1-\beta)\int_{-\infty}^{0} x\left(1+(r_d-\phi x)\right)^{\beta-2} f(x)\,dx \geq 0$, since $\beta \leq 1$. This reflects the situation where the portfolio returns are below the reference point and the excess returns of the risky asset are negative. In this case, the marginal loss of investing in the risky asset is lower as the risk-free rate decreases (the reference point increases), due to diminishing sensitivity. This force contributes to reaching for yield.

The third term in (A12), $(\lambda-1)\frac{r_d}{\phi^2} f\left(\frac{r_d}{\phi}\right) \geq 0$, since $\lambda \geq 1$. This is exactly the term that reflects how loss aversion around the reference point affects reaching for yield, as in Proposition 2 in the main text. When $r_d > 0$, this force contributes to reaching for yield.

Case 2: $r_d < 0$. i.e. the reference point is lower than the risk-free rate.

The first term in (A12), $(1-\alpha)\int_{\frac{r_d}{\phi}}^{+\infty} x\left((\phi x - r_d)+1\right)^{\alpha-2} f(x)\,dx$, can be further decomposed into

$$(1-\alpha)\int_{\frac{r_d}{\phi}}^{+\infty} x\left((\phi x - r_d)+1\right)^{\alpha-2} f(x)\,dx = (1-\alpha)\int_{0}^{+\infty} x\left((\phi x - r_d)+1\right)^{\alpha-2} f(x)\,dx + (1-\alpha)\int_{\frac{r_d}{\phi}}^{0} x\left((\phi x - r_d)+1\right)^{\alpha-2} f(x)\,dx \tag{A14}$$

The first term in (A14), $(1-\alpha)\int_0^{+\infty} x\left((\phi x - r_d)+1\right)^{\alpha-2} f(x)\,dx \geq 0$, since $\alpha \leq 1$. This reflects the situation where the portfolio returns are above the reference point, and the excess returns of the risky asset are positive. In this case, the marginal gain of investing in the risky asset is higher as the risk-free rate decreases (the reference point increases), due to diminishing sensitivity. This force contributes to reaching for yield.

The second term in (A14), $(1-\alpha)\int_{\frac{r_d}{\phi}}^{0} x\left((\phi x - r_d)+1\right)^{\alpha-2} f(x)\,dx \leq 0$ since $\alpha \leq 1$. This reflects the situation where the portfolio returns are above the reference point, but the excess returns of the risky asset are negative. In this case, the marginal loss of investing in the risky asset is higher as the risk-free rate decreases (the reference point increases), due to diminishing sensitivity. This force works against reaching for yield.

The second term in (A12), $-\lambda(1-\beta)\int_{-\infty}^{\frac{r_d}{\phi}} x\,(1+(r_d-\phi x))^{\beta-2} f(x)\,dx \geq 0$ since $\beta \leq 1$. When the realized portfolio returns are below the reference point, the marginal loss of investing in the risky asset is lower as the risk-free rate decreases (the reference point increases), due to diminishing sensitivity. This force contributes to reaching for yield.

The third term in (A12), $(\lambda-1)\frac{r_d}{\phi^2} f\left(\frac{r_d}{\phi}\right) \leq 0$ since $\lambda \geq 1$. Again, this is exactly the term that reflects how loss aversion around the reference point affects reaching for yield, as in Proposition 2 in the main text. When $r_d < 0$, this force works against reaching for yield.

The proposition below summarizes predictions in two special cases:

**Proposition A4.** *Under Assumption A3, for a given distribution of the excess returns $x$, if*

$$\text{(i) } r_f < r_r \text{ and } \beta = 1, \qquad \text{or} \qquad \text{(ii) } r_f > r_r \text{ and } \alpha = 1,\ \lambda = 1,$$

*the optimal allocation to the risky asset $\phi^*$ is (weakly) decreasing in $r_f$ and (weakly) increasing in $r_r$ in the following sense: suppose*

$$r_d < r_d', \quad \phi^* \in \arg\max\nolimits_{0\leq\phi\leq 1} h(\phi, r_d), \quad \text{and} \quad \phi^{*'} \in \arg\max\nolimits_{0\leq\phi\leq 1} h(\phi, r_d'),$$

*then we have $\phi^{*'} \geq \phi^*$.*[35]

*Proof.* Consider the case that either

$$\text{(i) } r_f < r_r,\ \alpha < 1, \text{ and } \beta = 1, \qquad \text{or} \qquad \text{(ii) } r_f > r_r,\ \alpha = 1,\ \beta < 1,\ \lambda = 1$$

(otherwise we can directly apply Propostion 2 in the main text). From the decomposition in (A12) and Topkin's Theorem, we know that either

$$\phi^* \leq \phi^{*'},$$

which proves the Proposition, or

$$\phi^* > \phi^{*'} \quad \text{and} \quad \left\{\phi^*, \phi^{*'}\right\} \subseteq \arg\max\nolimits_{0\leq\phi\leq 1} h(\phi, r_d) \cap \arg\max\nolimits_{0\leq\phi\leq 1} h(\phi, r_d').$$

However, if either

$$\text{(i) } r_f < r_r,\ \alpha < 1, \text{ and } \beta = 1, \qquad \text{or} \qquad \text{(ii) } r_f > r_r,\ \alpha = 1,\ \beta < 1,\ \lambda = 1,$$

we have $\frac{\partial^2}{\partial\phi\partial r_d} h(\phi, r_d) > 0$ according to the decomposition in (A12). As a result, it is impossible that

$$h(\phi^*, r_d) = h\left(\phi^{*'}, r_d\right) \quad \text{and} \quad h(\phi^*, r_d') = h\left(\phi^{*'}, r_d'\right).$$

The proposition is thus proved. □

The first part of Proposition A4 shows that if the reference point is above the interest rate and we shut down diminishing sensitivity in the loss region, the framework introduced in Assumption A3 unambiguously contributes to reaching for yield. The second part of Proposition A4 shows that if the reference point is below the interest rate and we shut down diminishing sensitivity in the gain region as well as loss aversion, the framework introduced in Assumption A3 also unambiguously contributes to reaching for yield.

[35] $\arg\max_{0\leq\phi\leq 1} h(\phi, r_d)$ could be a set due to the convex part of the utility function under diminishing sensitivity.

Unfortunately, without these further restrictions, analytically it is not clear whether diminishing sensitivity contributes to or works against the reaching for yield behavior documented in Section 2, as discussed above. Therefore, we perform a numerical exercise to evaluate the relative importance of the different terms in Equation (A12) in our setting.

We use the canonical Prospect Theory parameter values (Tversky and Kahneman, 1992; Barberis, Huang, and Thaler, 2006) to specify the degree of diminishing sensitivity. Specifically, we set $\alpha = \beta = 0.88$ and $\lambda = 2.25$. We start by examining how the diminishing sensitivity component in Assumption A3 influences the response of investment decisions to a small perturbation of the risk-free rate in the low interest rate condition in the benchmark experiment in Section 2 of the main text. In other words, we evaluate the influence of the first two terms in Equation (A12). We assume the mean excess returns $\mathbb{E}x = 5\%$, the volatility of the excess returns $\sqrt{Var\,(x)} = 18\%$, and the risk-free rate $r_f = 1\%$, as in our benchmark experiment in Section 2. We use $\phi = 60\%$, roughly matching the level of allocations to the risky assets in the low interest rate condition in the experiment. In Figure A6, we plot the first two terms in Equation (A12) as a function of the reference point $r_r$, ranging from $-10\%$ to 10%. We find that the terms are both positive, that is, diminishing sensitivity above and below the reference point both contribute to reaching for yield for all levels of the reference point.

We also find the loss aversion component in Assumption A3 influences the optimal allocation more than the diminishing sensitivity component. In Figure A7, we consider the same exercise and same parameter values as those in Figure A6. Here we plot the effect of diminishing sensitivity (the sum of the first two terms in Equation (A12)) and the effect of loss aversion (the last term in Equation (A12)), as a function of the reference point $r_r$. Figure A7 suggests that the loss aversion component has a much larger influence than the diminishing sensitivity component. The comparative static of how allocations to the risky asset move with the risk-free rate is dominated by the loss aversion component. In addition, if we shut down the loss aversion component (i.e. setting $\lambda = 1$ in Assumption A3) and keep the other parameter values the same as in Figures A6 and A7, investors would invest 100% in risky assets.

Taken together, diminishing sensitivity may contribute to reaching for yield in our setting, but diminishing sensitivity *alone* may not fully explain the reaching for yield behavior documented in Section 2.

## A.5 Reference Point in Expected Returns

Here we provide an alternative formulation of reference dependence. In this formulation, investors experience discomfort when the expected returns of the portfolio are below the reference point. In contrast, in the conventional Prospect Theory formulation discussed in Section 3.2, investors suffer from loss aversion in each state where the realized return is below the reference point. This alternative formulation of reference dependent loss aversion would modify Proposition 2, keeping predictions of reaching for yield, and eliminating predictions

Figure A6: Impact of Diminishing Sensitivity in Equation (A12), $r_f = 1\%$

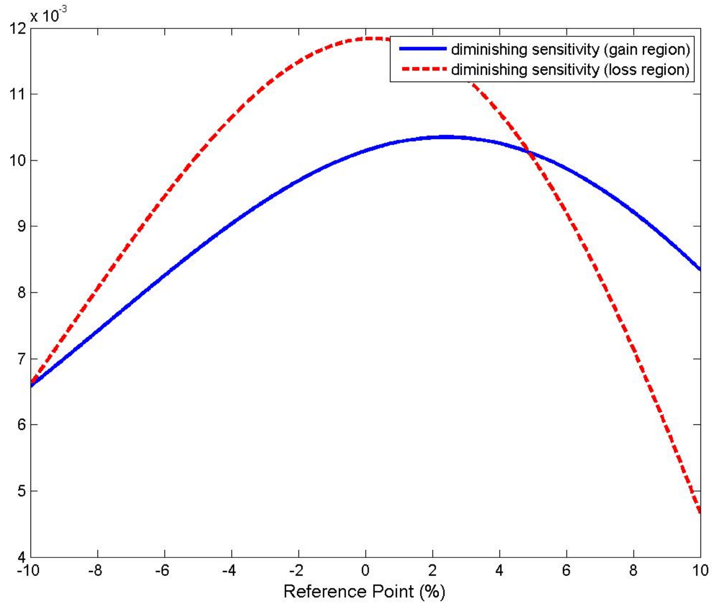
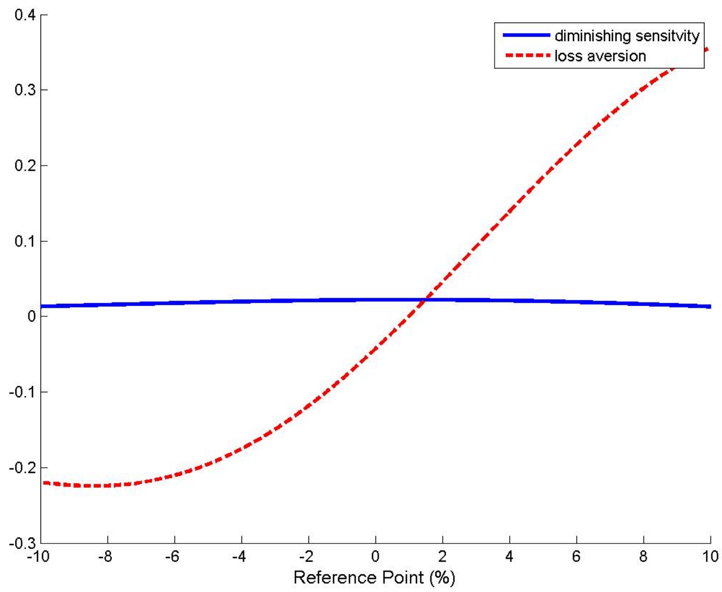



Figure A7: Impact of Diminishing Sensitivity and Loss Aversion in Equation (A12), $r_f = 1\%$



of reaching against yield when interest rates are sufficiently high.

Specifically, the investor trades off the expected returns and the variance of the portfolio, like in the mean variance case. The difference with traditional mean variance analysis is here the investor has a reference point about expected returns, and experience discomfort when the expected returns of his portfolio are below the reference point:

$$\phi^*_{mv,r} \triangleq \arg\max_{0\leq\phi\leq 1} v\left(\mathbb{E}r_p, r_r\right) - \frac{\gamma}{2} Var\left(r_p\right), \tag{A15}$$

where

$$v\left(\mathbb{E}r_p, r_r\right) = \begin{cases} \mathbb{E}r_p - r_r & \mathbb{E}r_p \geq r_r \\ -\lambda\left(r_r - \mathbb{E}r_p\right) & \mathbb{E}r_p < r_r \end{cases},$$

$r_r$ is the reference point and $\lambda > 1$ captures the degree of loss aversion.

**Proposition A5.** *For a given distribution of the excess returns $x$, the optimal allocation to the risky asset, $\phi^*_{mv,r}$ is (weakly) decreasing in $r_f$.*

*Proof.* Let $h(\phi) = v\left(\mathbb{E}r_p, r_r\right) - \frac{\gamma}{2} Var\left(r_p\right)$. We have

$$\frac{\partial h(\phi)}{\partial \phi} = \begin{cases} \mathbb{E}x - \gamma\phi Var(x) & \mathbb{E}r_p > r_r \\ \lambda\mathbb{E}x - \gamma\phi Var(x) & \mathbb{E}r_p < r_r \end{cases}.$$

As a result,

$$\phi^*_{mv,r} = \begin{cases} \frac{\mathbb{E}x}{\gamma Var(x)} & \frac{(\mathbb{E}x)^2}{\gamma Var(x)} + r_f > r_r \\ \frac{r_r - r_f}{\mathbb{E}x} & \frac{\lambda(\mathbb{E}x)^2}{\gamma Var(x)} + r_f \geq r_r \geq \frac{(\mathbb{E}x)^2}{\gamma Var(x)} + r_f \\ \frac{\lambda\mathbb{E}x}{\gamma Var(x)} & \frac{\lambda(\mathbb{E}x)^2}{\gamma Var(x)} + r_f < r_r \end{cases}.$$

$\phi^*_{mv,r}$ is (weakly) decreasing in $r_f$. □

## A.6 Proof of Proposition 3

Notice that when $r_f > 0$, $\left|\frac{(r_f+\mathbb{E}x)-r_f}{(r_f+\mathbb{E}x)+r_f}\right|$ is decreasing in $r_f$. As a result, $\delta(r_f+\mathbb{E}x, r_f, Var(x), 0)$ is decreasing in $r_f$. Therefore, $\phi^*_s = \min\left\{\frac{\delta\mathbb{E}x}{\gamma Var(x)}, 1\right\}$ is (weakly) decreasing in $r_f$.

## A.7 Influence of Gross Framing

Let $\phi^*_s$ denote a salient investor's optimal allocation in the risky asset with baseline framing in Experiment T3, according to Equation (5) in the paper. Define $\phi^*_{s,gross}$ as a salient investor's optimal allocation in the risky asset with gross framing in Experiment T3, according to:

$$\phi^*_{s,gross} \triangleq \arg\max_{\phi\in[0,1]} \delta_{gross}\mathbb{E}r_p - \frac{\gamma}{2} Var\left(r_p\right),$$

where $\delta_{gross} = \delta(1 + r_f + \mathbb{E}x, 1 + r_f, Var(x), 0)$ characterizes the salience of the return dimension relative to the risk dimension with gross framing. Note that the salience function here depends on gross interest rates instead of net interest rates, in contrast to the salience function with baseline framing.

**Lemma A1.** *For a given distribution of the excess returns $x$ and a given risk-free rate $r_f > 0$, the optimal allocation to the risky asset with baseline framing is always (weakly) larger than that with gross framing, i.e. $\phi^*_{s,gross} \leq \phi^*_s$.*

*Proof.* Notice that when $r_f > 0$, $\left|\frac{(r_f+\mathbb{E}x)-r_f}{(r_f+\mathbb{E}x)+r_f}\right| > \left|\frac{(1+r_f+\mathbb{E}x)-(1+r_f)}{(1+r_f+\mathbb{E}x)+(1+r_f)}\right|$. As a result, $\delta = \delta(r_f + \mathbb{E}x, r_f, Var(x), 0) > \delta(1 + r_f + \mathbb{E}x, 1 + r_f, Var(x), 0) = \delta_{gross}$. Therefore, $\phi^*_s = \min\left\{\frac{\delta \mathbb{E}x}{\gamma Var(x)}, 1\right\} \geq \min\left\{\frac{\delta_{gross}\mathbb{E}x}{\gamma Var(x)}, 1\right\} = \phi^*_{s,gross}$. $\square$

# B Additional Discussions

## B.1 Reference Point Formation

In the following, we discuss in detail the leading theories of reference point formation. We explain why investors' past interest rate experiences appear to be the main contributor to the type of reference dependence that generates reaching for yield under the framework of Section 3.2 and Assumption 1.

1. The reference point is the status quo wealth level (Kahneman and Tversky, 1979), or $r_r = 0$. This captures the notion that people experience "loss" when their final wealth falls below their original wealth level. It turns out that loss aversion around zero *alone* cannot explain the reaching for yield behavior documented in Section 2. This is because when $r_r = 0$, the reference point is below a positive risk-free rate, which falls into the second case of Proposition 2. As a result, loss aversion around zero *alone* can only generate "reaching against yield" in the setting of the benchmark experiment, contrary to the empirical evidence. That said, we are not suggesting that loss aversion at zero does not matter. It is perhaps important for many behavior (e.g. aversion to small risks), but it does not appear to be the key driver of reaching for yield, if not partially offsetting it.

2. The reference point is the risk-free rate (Barberis, Huang, and Santos, 2001), or $r_r = r_f$. This suggests that people are disappointed when their final wealth is below the wealth level they would have if they had invested everything in the risk-free assets. This set-up, however, also would not be able to generate reaching for yield behavior.

   **Lemma A2.** *Under Assumption 1, if $r_r = r_f$, for a given distribution of the excess returns $x$, the optimal allocation to the risky asset $\phi^*$ is independent of $r_f$.*

   *Proof.* Note that

$$u\left(w\left(1+r_p\right)\right)=\begin{cases} w\left(r_p-r_r\right)=w\phi x & x\geq 0 \\ -\lambda w\left(r_r-r_p\right)=\lambda w\phi x & x<0 \end{cases}$$

   is independent of $r_f$. As a result $\phi^* = \arg\max_{\phi\in[0,1]} \mathbb{E}u\left(w\left(1+r_p\right)\right)$ is independent or the risk-free rate $r_f$. □

   The intuition behind Lemma A2 is that as the risk-free rate $r_f$ changes, returns on the safe asset, returns on the risky asset, and the reference point move in parallel. Accordingly, the trade-offs in the investment decision are essentially unchanged. As a result, the optimal allocation to the risky asset $\phi^*$ is independent of $r_f$.

3. The reference point is rational expectations of asset returns in the investment choice set (Kőszegi and Rabin, 2006). In our setting, there are two ways to formalize this type of reference points.

   a). The reference point is given by a weighted average of the risk-free rate and the expected returns of the risky asset. That is, $r_r = (1-\omega) r_f + \omega (r_f + \mathbb{E}x)$, where $\omega$ is an *exogenous* weight. This leads to:

   **Lemma A3.** *Under Assumption 1, if $r_r = (1-\omega) r_f + \omega (r_f + \mathbb{E}x)$, for a given distribution of the excess returns $x$, the optimal allocation to the risky asset $\phi^*$ is independent of the risk-free rate $r_f$.*

   *Proof.* Note that

$$u(w(1+r_p)) = \begin{cases} w(r_p - r_r) = w(\phi x - \omega \mathbb{E}x) & \phi x \geq \omega \mathbb{E}x \\ -\lambda w(r_r - r_p) = \lambda w(\phi x - \omega \mathbb{E}x) & \phi x < \omega \mathbb{E}x \end{cases}$$

   is independent of $r_f$. As a result $\phi^* = \arg\max_{\phi \in [0,1]} \mathbb{E}u(w(1+r_p))$ is independent or $r_f$. □

   The intuition of Lemma A3 is similar to that of Lemma A2: when the risk-free rate $r_f$ changes, returns on the safe asset, returns on the risky asset, and the reference point move in parallel.

   b). The reference point is the expected returns of the *optimal* portfolio. That is, $r_r = (1-\phi^*) r_f + \phi^* (r_f + \mathbb{E}x)$, where $\phi^*$ is the *endogenous* optimal allocation defined in Equation (2). At the same time, the investor's utility in turn depends on $r_r$ (based on Assumption 1). This follows the concept of the personal equilibrium in Kőszegi and Rabin (2006). In other words, the investor's reference point is determined by the optimal allocation, while the optimal allocation in turn depends on the reference point.

   **Lemma A4.** *Under Assumption 1, if $r_r = (1-\phi^*) r_f + \phi^* (r_f + \mathbb{E}x)$, for a given distribution of the excess returns $x$, the optimal allocation to the risky asset $\phi^*$ is independent of the risk-free rate $r_f$.*

   *Proof.* Note that

$$u(w(1+r_p)) = \begin{cases} w(r_p - r_r) = w(\phi x - \phi^* \mathbb{E}x) & \phi x \geq \phi^* \mathbb{E}x \\ -\lambda w(r_r - r_p) = \lambda w(\phi x - \phi^* \mathbb{E}x) & \phi x < \phi^* \mathbb{E}x \end{cases} \tag{A16}$$

   where $\phi^*$ solves

$$\phi^* = \arg\max_{\phi \in [0,1]} \mathbb{E}u(w(1+r_p)). \tag{A17}$$

Because $u$ in Equation (A16) is independent of $r_f$, the $\phi^*$ jointly determined by Equations (A16) and (A17) is independent of $r_f$. □

The intuition here is similar to the intuition of Lemma A2 and Lemma A3: when the risk-free rate $r_f$ changes, returns on the safe asset, returns on the risky asset, and the reference point move in parallel. This leaves the investment decision unchanged.

4. The reference point is influenced by individuals' past experiences (Kahneman and Miller, 1986; Simonsohn and Loewenstein, 2006; Malmendier and Nagel, 2011; Bordalo, Gennaioli, and Shleifer, 2017). In our setting, one intuition is that people adapt to or anchor on some level of investment returns based on past experiences. When the risk-free rate falls below the level they are used to, people experience discomfort and become more willing to invest in risky assets. Formally, the reference point is given by a weighted average of the risk-free rate and realized returns of risky assets in the past. That is, $r_r = (1-\omega)\, r_{f,past} + \omega\,(r_{f,past} + x_{past})$, where $\omega$ can be either an exogenous weight or a weight that depends on investors' past portfolio choices.[36] Note that $\omega$, $r_{f,past}$, and $x_{past}$ are all predetermined. As a result, this case can be analyzed with Proposition 2. Given the economic environment in the decades prior to the Great Recession, reference points from past experiences appear in line with the popular view among investors that 1% or 0% interest rates are "too low," which predicts reaching for yield behavior.

## B.2 Additional Experiments on History Dependence

As mentioned in Section 4.2 of the main text, there are alternative research designs to test the history dependence of reaching for yield. Below we present a design where all participants face the same interest rate environment in the final round, but prior to that, one group starts with an environment with higher interest rates, while another group starts with an environment with lower interest rates.[37] We show results from two settings that follow this design.[38]

[36] Past returns are calculated as a weighted average of returns over a given horizon; the length of the horizon does not change the mechanism about how past reference point can contribute to the reaching for yield behavior.

[37] One possible concern with the design of Experiment T2 in Section 4.2 is that we find substantially higher risk taking in the low interest rate condition if participants first consider the high interest rate condition, but this could be driven by an order issue: for some reasons, participants take more risks in the second round of investment decision in general. We do not find evidence for this concern in the data. Results in Section 4.2 in the main text and in this section show that risk taking does not increase in general after the first round. It only increases if interest rates fall significantly. The alternative design also verifies that the concern does not affect our results.

[38] In the alternative design, since all participants end in a "medium" interest rate environment, the range of interest rates in the initial round may need to be wider. If we stay within the baseline range of interest rates (e.g. between 1% and 5%), the power could be lower for a given sample size, since the change from the high rate condition in the first round to the medium rate condition in the second round needs to be smaller in order to have everything stay within the range.

The first setting is a hypothetical experiment with three rounds of investment decisions: participants in Group 1 first consider a very high interest rate environment (15% safe returns and 20% average risky returns), then consider a high interest rate environment (13% safe returns and 18% average risky returns), and finally consider a medium interest rate environment (3% safe returns and 8% average risky returns); participants in Group 2 first consider a very low interest rate environment (0% safe returns and 5% average risky returns), then consider a low interest rate environment (1% safe returns and 6% average risky returns), and finally consider a medium interest rate environment (3% safe returns and 8% average risky returns). Our discussant Cary Frydman conducted this experiment on MTurk in November 2016 using our experimental protocol. There are 200 participants in Group 1 and 200 participants in Group 2.

The second setting is an incentivized experiment with two rounds of investment decisions: participants in Group 1 first consider a high interest rate environment (5% safe returns and 10% average risky returns), and then consider a medium interest rate environment (2% safe returns and 7% average risky returns); participants in Group 2 first consider a low interest rate environment (1% safe returns and 6% average risky returns), and then consider a medium interest rate environment (2% safe returns and 7% average risky returns). We performed this experiment on MTurk in December 2016. There are again 200 participants in Group 1 and 200 participants in Group 2. We do not perform a hypothetical experiment with the same investment pay-offs, since by this time our previous experiments have used more than 6,000 MTurk workers and our additional experiments are experiencing capacity constraints and lower data quality (Stewart, Ungemach, Harris, Bartels, Newell, Paolacci, and Chandler, 2015).

Table A12 presents the results. In both settings, participants in Group 1 invest more aggressively in the final round than participants in Group 2. The results are consistent with history-based reference dependence discussed in Section 3.2.[39]

## B.3 Salience and Related Models

In this section, we first discuss the relationship between the salience theory applied in Section 3.2 (which follows Bordalo, Gennaioli, and Shleifer (2013a, 2016) and adapts this framework to portfolio allocations), and several related ways of modeling salience. Specifically, we discuss the relationship between our formulation and Bordalo, Gennaioli, and Shleifer (2012) and Bordalo, Gennaioli, and Shleifer (2013b), which use a different formulation of the salience theory in the context of choice under risk.

The key difference between these two seemingly similar approaches is the following. In the first approach (Bordalo, Gennaioli, and Shleifer, 2013a, 2016), the investor's optimization problem represents the optimal portfolio problem based on the portfolio's average returns and variance (like in the case of conventional mean variance analysis), and he over-

[39] In addition, we also see verification of the baseline reaching for yield phenomenon: participants allocate less to the risky asset when interest rates are high, both within and across treatment groups.

weights the dimension (average returns or variance) that is salient. In the second approach (Bordalo, Gennaioli, and Shleifer, 2012, 2013b), the investor considers the pay-off of an asset *state by state*, and overweights the states in which the pay-offs of different assets differ by more (these are salient states). Similarly, when Bushong, Rabin, and Schwartzstein (2016) apply their relative thinking theory to choice under risk, they also focus on a state by state representation and provide a theory about why some states are overweighted while others are underweighted.

It seems plausible that the first approach is a better approximation of investor behavior, as investors do not necessarily have a clear mental representation of all possible economic states when making investment decisions. In fact, the second approach generates predictions of reaching against yield, which is contrary to the findings we document in Section 2. The intuition is that people focus on downside risks more than upside risks. As interest rates fall, holding the distribution of the excess returns fixed, there is a downward shift in the returns of all assets in all states, which makes the downside risk more salient.[40] Our findings provide some evidence for the way salience operates in the context of investment decisions and choice under risk, and may help to guide related models.

We also note that in the models of Bordalo, Gennaioli, and Shleifer (2013a) and Bordalo, Gennaioli, and Shleifer (2016), the decision problem is a discrete choice problem. In the portfolio choice problem we consider in Section 3.3, however, the decision is continuous. Our set-up makes the following departure from Bordalo, Gennaioli, and Shleifer (2013a) to streamline the investor's decision problem. In Bordalo, Gennaioli, and Shleifer (2013a), the salience of an attribute is choice-specific. Accordingly, the relative salience of the return dimension will be different for different portfolios. In other words, a strict adherence to such a choice-specific salience function requires the relative salience of the return dimension in Equation (5), $\delta$, to be a function of the asset allocation in the portfolio, $\phi$. When the choice variable is continuous, this approach could become quite cumbersome. Instead, in our formulation (Assumption 2) $\delta$ is a function of the properties of assets in the underlying choice set, independent of portfolio allocation $\phi$. We use this formulation as a parsimonious way to capture the idea that when interest rates are low and the ratio of the expected returns of the two assets is high, the expected return dimension becomes more salient. Fernandes (2016) also shows that the salience function should depend on the properties of the available assets and be independent of the portfolio allocation.

Finally, we discuss the subtle difference between the notion of salience defined in Bordalo, Gennaioli, and Shleifer (2013a) and the intuition of proportional thinking in our setting. Bordalo, Gennaioli, and Shleifer (2013a) emphasize that choices have different attributes/dimensions (return vs. risk, price vs. quality); one dimension could be more salient than another (depending on which dimension has larger proportional difference) and decision makers pay more attention to the salient dimension. Specifically, the *expected return dimension* of the *portfolio*, $\mathbb{E}r_p$, is more salient when interest rates are lower, be-

[40]For example, in Equation (3) of Bordalo, Gennaioli, and Shleifer (2013b), a decrease in the risk-free rate tends to make the state in which the risky asset performs poorly more salient.

cause low interest rates make the proportional difference in the expected return dimension larger. The intuition of proportional thinking, in its simplest form, does not depend on the relative importance of the two dimensions in a decision-maker's mind. Rather, investors' evaluation of the attractiveness of the risky asset is influenced by the ratio of average returns: investors perceive the risky asset to be better when the ratio is high. 6% average (risky) returns jump out as a more preferable alternative compared to 1% safe returns; 10% average (risky) returns appear as a less preferable alternative compared to 5% safe returns. When the intuition is framed this way, it is not that the dimension of the average portfolio returns is more salient, but that the risky asset's pay-offs are more salient/attractive.

In application, this distinction seems quite subtle and not very important. Because the relative importance of the return dimension according to the salience function a la Bordalo, Gennaioli, and Shleifer (2013a) is essentially driven by the ratio of the average returns (and the ratio of the risks, which are kept fixed in our experiments), the investor's optimal portfolio choice problem is essentially the same with both interpretations. Equation (5) in the main text nests both interpretations. $\delta$ in Equation (5) can be interpreted both as the salience of the return dimension (relative to the risk dimension), and as a way to effectively link the attractiveness of the risky asset to the ratio of average returns. In the main text, we use the most straightforward explanations to explain the intuition behind investor behavior, and do not draw distinctions between the notion of salience and proportional thinking.

# C Additional Tables and Figures

## C.1 Additional Experimental Results

Table A9: Subsample Results in Benchmark Experiments

This table shows the regression coefficient $\beta$ in

$$Y_i = \alpha + \beta Low_i + X_i'\gamma + \epsilon_i$$

for subsamples in the benchmark experiments, where $Y_i$ is the allocation to the risky asset, and $Low_i$ is an indicator variable that takes value one if the participant is in the low interest rate condition. The regression is estimated for each subsample; $\beta$, the associated $t$-statistics, and the number of participants in the subsample are reported. Controls are the same as in Table 2 in the paper, except that variables are dropped from the controls when they are used to split the sample. We did not include wealth in the MBA survey because it could be a sensitive question.

Panel A. Experiment B1: MTurk, Hypothetical

| | Wealth | | | Investment Experience | | Education | |
|---|---|---|---|---|---|---|---|
| | Below 10K | 10K to 100K | 100K+ | Some or Extensive | No or Limited | College or above | High School |
| $\beta$ | 3.43 | 8.40 | 12.90 | 12.54 | 5.27 | 5.79 | 13.48 |
| $[t]$ | [0.79] | [1.92] | [1.87] | [2.47] | [1.53] | [1.80] | [2.23] |
| $N$ | 161 | 170 | 69 | 134 | 266 | 298 | 102 |

Panel B. Experiment B2: MTurk, Incentivized

| | Wealth | | | Investment Experience | | Education | |
|---|---|---|---|---|---|---|---|
| | Below 10K | 10K to 100K | 100K+ | Some or Extensive | No or Limited | College or above | High School |
| $\beta$ | 5.55 | 7.55 | 13.90 | 5.78 | 8.66 | 8.89 | 3.66 |
| $[t]$ | [1.22] | [2.04] | [2.47] | [1.36] | [2.70] | [3.11] | [0.65] |
| $N$ | 133 | 175 | 92 | 146 | 254 | 310 | 90 |

Panel C. Experiment B3: MBA, Incentivized

| | Investment Experience | | Worked in Finance | |
|---|---|---|---|---|
| | Some or Extensive | No or Limited | Yes | No |
| $\beta$ | 10.56 | 7.31 | 10.02 | 7.66 |
| $[t]$ | [2.57] | [1.96] | [2.47] | [2.06] |
| $N$ | 178 | 222 | 170 | 230 |

## Table A10: Robustness Checks of Benchmark Experiments

This table presents results in the benchmark incentivized experiment with different payment methods. This set of experiments are conducted on MTurk together and participants are randomly assigned to different payment methods and different interest rate conditions. In all cases, participants consider allocating experimental endowment of 100,000 Francs to the risk-free asset and the risky asset. "Proportional" refers to the setting where all participants receive a bonus payment proportional to their investment outcomes, with every 89,500 Francs converted to one dollar (so the bonus payment is on the scale of \$1.2). "Randomized" refers to the setting where 10% randomly chosen participants receive a bonus payment proportional to their investment outcomes, with every 8,950 Francs converted to one dollar (so the bonus payment is on the scale of \$12). In the "immediate" payment conditions, the bonus payment is delivered within one week of the experiment. In the "one year" payment conditions, the bonus payment is delivered one year after the experiment. Panel A shows mean allocations to the risky asset in the high and low interest rate conditions, the difference in mean allocations across the two conditions, and the $t$-statistics associated with the test that the difference is different from zero. The final column also shows the $p$-value from the Mann-Whitney-Wilcoxon test, against the null that allocations in the high and low interest rate conditions are the same. Panel B presents the mean difference in allocations controlling for individual characteristics, both through OLS and through propensity score matching (ATE). The individual characteristics include dummies for gender, education level, age group, risk tolerance, investment experience, and wealth level.

### Panel A. Mean Allocations to Risky Asset (%)

| | High: 5—10 | Low: 1—6 | **Dif** (Raw) | [$t$] | $U$ test ($p$) |
|---|---|---|---|---|---|
| Proportional, immediate | 59.20 | 66.68 | 7.48 | [2.64] | (0.00) |
| Proportional, one year | 60.63 | 67.79 | 7.16 | [2.43] | (0.01) |
| Randomized, immediate | 58.07 | 66.80 | 8.73 | [3.13] | (0.00) |
| Randomized, one year | 58.58 | 66.64 | 8.06 | [3.06] | (0.00) |

### Panel B. Differences Controlling for Individual Characteristics

| Payment scheme | **Dif** (OLS) | [$t$] | **Dif** (Match) | [$t$] |
|---|---|---|---|---|
| Proportional, immediate | 6.75 | [2.43] | 7.94 | [2.79] |
| Proportional, one year | 7.27 | [2.56] | 6.22 | [1.99] |
| Randomized, immediate | 8.40 | [3.12] | 9.00 | [3.18] |
| Randomized, one year | 8.14 | [3.23] | 8.66 | [2.81] |

## Table A11: Experimental Decisions and Household Portfolio Allocations

Cross-sectional regression:

$$y_i = \alpha + \beta x_i + \epsilon_t$$

where $y_i$ is the allocation to the risky asset in the incentivized experimental decision, and $x_i$ is the fraction of the participant's household financial wealth in bank deposits (the stock market), as reported by the participant. Columns (1) and (2) present results in the sample of Experiment B2 (MTurk, Incentivized), and columns (3) and (4) present results in the sample of Experiment B3 (MBA, Incentivized).

| | % in Risky (Experimental Decision) | | | |
|---|---|---|---|---|
| | MTurk | | MBA | |
| % Asset in bank deposits | -0.12 | | -0.13 | |
| | [-3.02] | | [-3.29] | |
| % Asset in stocks | | 0.12 | | 0.10 |
| | | [2.69] | | [2.52] |

Robust $t$-statistics in brackets

Table A12: Additional Results on History Dependence

This table presents results of additional experiments on history dependence. Panel A shows results from a hypothetical experiment: half of the participants are randomly assigned to Group 1, where they first consider a very high interest rate environment (15% safe returns and 20% average risky returns), then consider a high interest rate environment (13% safe returns and 18% average risky returns), and finally consider a medium interest rate environment (3% safe returns and 8% average risky returns); the other half of the participants are assigned to Group 2, where they first consider a very low interest rate environment (0% safe returns and 5% average risky returns), then consider a low interest rate environment (1% safe returns and 6% average risky returns), and finally consider a medium interest rate environment (3% safe returns and 8% average risky returns). Panel B shows results from a hypothetical experiment: half of the participants are randomly assigned to Group 1, where they first consider a high interest rate environment (5% safe returns and 10% average risky returns), and then consider a medium interest rate environment (2% safe returns and 7% average risky returns); the other half of the participants are assigned to Group 2, where they first consider a low interest rate environment (1% safe returns and 6% average risky returns), and then consider a medium interest rate environment (2% safe returns and 7% average risky returns).

Panel A. Setting 1 (Hypothetical Experiment)

| | | | |
|---|---|---|---|
| G1 | Very High: 15—20 | High: 13—18 | Medium: 3—8 |
| Mean Alloc. to Risky | 37.74 | 38.43 | 60.29 |
| G2 | Very Low: 0—5 | Low: 1—6 | Medium: 3—8 |
| Mean Alloc. to Risky | 61.57 | 57.41 | 49.80 |
| G1 (Med) - G2 (Med) | Difference | [$t$] | |
| | 10.49 | [3.35] | |

Panel B. Setting 2 (Incentivized Experiment)

| | | |
|---|---|---|
| G1 | High: 5—10 | Medium: 2—7 |
| Mean Alloc. to Risky | 59.73 | 66.68 |
| G2 | Low: 1—6 | Medium: 2—7 |
| Mean Alloc. to Risky | 64.68 | 62.14 |
| G1 (Med) - G2 (Med) | Difference | [$t$] |
| | 4.54 | [1.66] |

Table A13: Baseline and Net Framing

This table examines the robustness of reaching for yield with net framing. Panel A shows mean allocations to the risky asset in the high and low interest rate conditions, the difference in mean allocations between the two conditions, and the $t$-statistics associated with the test that the difference is different from zero. Panel B presents the coefficient and $t$-statistics on the dummy of low returns condition, controlling for individual characteristics. The individual characteristics include dummies for gender, education level, age group, risk aversion, and household financial wealth.

Panel A. Mean Allocations to Risky Asset (%)

| | High: 5—10 | Low: 1—6 | Difference | $[t]$ | $U$ test $(p)$ |
|---|---|---|---|---|---|
| Baseline | 57.13 | 64.51 | 7.38 | [2.69] | (0.00) |
| Net | 51.46 | 58.55 | 7.08 | [2.53] | (0.01) |

Panel B. Differences Controlling for Individual Characteristics

| | Dif (OLS) | $[t]$ | Dif (Match) | $[t]$ |
|---|---|---|---|---|
| Baseline | 5.90 | [2.62] | 6.76 | [2.47] |
| Net | 6.35 | [2.22] | 5.71 | [1.98] |

Discussion of Table A13: In our data, the degree of reaching for yield is about the same with baseline framing and with net framing. The level of allocations to the risky asset is lower with net framing. This could be because net framing makes losing money more salient and decreases the general risk taking propensity.

Table A14: Demographic Information of Experiment T1 (Mapping Gradient) Sample

This table presents the demographics of Experiment T1. The first row denotes the risk-free rate in different conditions; the mean excess returns of the risky asset is 5% in all conditions. The statistics are the same as those in Table 1.

| | Condition: $r_f$ = | -1% | | 0% | | 1% | | 3% | | 5% | | 10% | | 15% | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $N$ | % | $N$ | % | $N$ | % | $N$ | % | $N$ | % | $N$ | % | $N$ | % |
| Gender | Male | 99 | 49.5 | 84 | 42.0 | 89 | 45.6 | 97 | 48.5 | 92 | 46.0 | 95 | 47.7 | 101 | 50.5 |
| | Female | 101 | 50.5 | 116 | 58.0 | 106 | 54.4 | 103 | 51.5 | 108 | 54.0 | 104 | 52.3 | 99 | 49.5 |
| Education | Graduate school | 32 | 16.0 | 37 | 18.5 | 30 | 15.4 | 37 | 18.5 | 34 | 17.0 | 36 | 18.1 | 32 | 16.0 |
| | College | 111 | 55.5 | 118 | 59.0 | 119 | 61.0 | 119 | 59.5 | 111 | 55.5 | 114 | 57.3 | 121 | 60.5 |
| | High school | 50 | 25.0 | 40 | 20.0 | 43 | 22.1 | 41 | 20.5 | 52 | 26.0 | 42 | 21.1 | 45 | 22.5 |
| Age | Below 30 | 85 | 42.5 | 82 | 41.0 | 87 | 44.6 | 80 | 40.0 | 96 | 48.0 | 85 | 42.7 | 98 | 49.0 |
| | 30—40 | 59 | 29.5 | 69 | 34.5 | 66 | 33.9 | 64 | 32.0 | 51 | 25.5 | 53 | 26.6 | 57 | 28.5 |
| | 40—50 | 25 | 12.5 | 26 | 13.0 | 25 | 12.8 | 36 | 18.0 | 27 | 13.5 | 34 | 17.1 | 26 | 13.0 |
| | Above 50 | 31 | 15.5 | 23 | 11.5 | 17 | 8.7 | 20 | 10.0 | 26 | 13.0 | 27 | 13.6 | 19 | 9.5 |
| Risk tolerance | Low | 115 | 57.5 | 91 | 45.5 | 98 | 50.3 | 89 | 44.5 | 101 | 50.5 | 109 | 54.8 | 97 | 48.5 |
| | Medium | 49 | 24.5 | 76 | 38.0 | 58 | 29.7 | 71 | 35.5 | 67 | 33.5 | 61 | 30.7 | 64 | 32.0 |
| | High | 36 | 18.0 | 33 | 16.5 | 39 | 20.0 | 40 | 20.0 | 32 | 16.0 | 29 | 14.6 | 39 | 19.5 |
| Fin. wealth (ex. housing) | 200K+ | 17 | 8.5 | 19 | 9.5 | 17 | 8.7 | 17 | 8.5 | 16 | 8.0 | 24 | 12.1 | 18 | 9.0 |
| | 50K–200K | 43 | 21.5 | 52 | 26.0 | 45 | 23.1 | 59 | 29.5 | 35 | 17.5 | 50 | 25.1 | 40 | 20.0 |
| | 10K–50K | 59 | 29.5 | 56 | 28.0 | 68 | 34.9 | 55 | 27.5 | 49 | 24.5 | 47 | 23.6 | 59 | 29.5 |
| | 0–10K | 51 | 25.5 | 40 | 20.0 | 43 | 22.1 | 48 | 24.0 | 69 | 34.5 | 52 | 26.1 | 54 | 27.0 |
| | In debt | 30 | 15.0 | 33 | 16.5 | 22 | 11.3 | 21 | 10.5 | 31 | 15.5 | 26 | 13.1 | 30 | 15.0 |
| Investing experience | Extensive | 11 | 5.5 | 6 | 3.0 | 6 | 3.1 | 9 | 4.5 | 4 | 2.0 | 9 | 4.5 | 9 | 4.5 |
| | Some | 52 | 26.0 | 66 | 33.0 | 48 | 24.6 | 62 | 31.0 | 61 | 30.5 | 72 | 36.2 | 48 | 24.0 |
| | Limited | 84 | 42.0 | 92 | 46.0 | 90 | 46.2 | 82 | 41.0 | 85 | 42.5 | 83 | 41.7 | 86 | 43.0 |
| | No | 53 | 26.5 | 36 | 18.0 | 51 | 26.2 | 47 | 23.5 | 50 | 25.0 | 35 | 17.6 | 57 | 28.5 |
| Total | | 200 | | 200 | | 195 | | 200 | | 200 | | 199 | | 200 | |

Table A15: Demographic Information of Experiment T2 (History Dependence) Sample

This table presents the demographics of Experiment T2. Participants in Group 1 first make investment decisions in the high interest rate condition (5% risk-free rate and 10% average returns on the risky asset), and then make decisions in the low interest rate condition (1% risk-free rate and 6% average returns on the risky asset). Participants in Group 2 first make investment decisions in the low rate condition, and then make decisions in the high rate condition. The statistics are the same as those in Table 1.

Panel A. Hypothetical

| | | Group 1 | | Group 2 | |
|---|---|---|---|---|---|
| | | *N* | % | *N* | % |
| Gender | Male | 105 | 51.7 | 95 | 48.2 |
| | Female | 98 | 48.3 | 102 | 51.8 |
| Education | Graduate school | 31 | 15.4 | 40 | 20.5 |
| | College | 114 | 56.7 | 107 | 54.9 |
| | High school | 56 | 27.9 | 48 | 24.6 |
| Age | Below 30 | 85 | 41.9 | 77 | 39.1 |
| | 30—40 | 54 | 26.6 | 51 | 25.9 |
| | 40—50 | 18 | 8.9 | 27 | 13.7 |
| | Above 50 | 46 | 22.7 | 42 | 21.3 |
| Risk tolerance | Low | 106 | 52.2 | 121 | 61.4 |
| | Medium | 68 | 33.5 | 50 | 25.4 |
| | High | 29 | 14.3 | 26 | 13.2 |
| Fin. wealth (ex. housing) | 200K+ | 16 | 7.9 | 17 | 8.6 |
| | 50K–200K | 31 | 15.3 | 74 | 37.6 |
| | 10K–50K | 66 | 32.5 | 46 | 23.4 |
| | 0–10K | 51 | 25.1 | 36 | 18.3 |
| | In debt | 39 | 19.2 | 24 | 12.2 |
| Investing experience | Extensive | 8 | 3.9 | 4 | 3.6 |
| | Some | 52 | 25.6 | 52 | 26.4 |
| | Limited | 77 | 37.9 | 73 | 37.1 |
| | No | 66 | 32.5 | 65 | 33.0 |
| Total | | 203 | | 197 | |

Panel B. Incentivized

| | | Group 1 | | Group 2 | |
|---|---|---|---|---|---|
| | | *N* | % | *N* | % |
| Gender | Male | 107 | 53.5 | 89 | 45.6 |
| | Female | 93 | 46.5 | 106 | 54.4 |
| Education | Graduate school | 30 | 15.0 | 34 | 17.4 |
| | College | 102 | 51.0 | 108 | 55.4 |
| | High school | 61 | 30.5 | 50 | 25.6 |
| Age | Below 30 | 95 | 47.5 | 79 | 40.5 |
| | 30—40 | 60 | 30.0 | 69 | 35.4 |
| | 40—50 | 27 | 13.5 | 26 | 13.3 |
| | Above 50 | 18 | 9.0 | 21 | 10.8 |
| Risk tolerance | Low | 106 | 53.0 | 112 | 57.4 |
| | Medium | 54 | 27.0 | 52 | 26.7 |
| | High | 40 | 20.0 | 31 | 15.9 |
| Fin. wealth (ex. housing) | 200K+ | 12 | 6.0 | 14 | 7.2 |
| | 50K–200K | 61 | 30.5 | 54 | 27.7 |
| | 10K–50K | 45 | 22.5 | 52 | 26.7 |
| | 0–10K | 45 | 22.5 | 42 | 21.5 |
| | In debt | 37 | 18.5 | 33 | 16.9 |
| Investing experience | Extensive | 9 | 4.5 | 2 | 1.0 |
| | Some | 44 | 22.0 | 61 | 31.3 |
| | Limited | 91 | 45.5 | 76 | 39.0 |
| | No | 56 | 28.0 | 56 | 28.7 |
| Total | | 200 | | 195 | |

Table A16: Demographic Information of Experiment T3 (Salience and Proportional Thinking) Sample

This table presents the demographics of Experiment T3. In the Low condition, the risk-free rate is 1%; in the High condition, the risk-free rate is 5%. The mean excess returns of the risky asset is 5% in both conditions. The statistics are the same as those in Table 1.

| | | Baseline | | | | Gross | | | | Net | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | | High | | Low | | High | | Low | | High | |
| | | $N$ | % | $N$ | % | $N$ | % | $N$ | % | $N$ | % | $N$ | % |
| Gender | Male | 89 | 45.6 | 92 | 46.0 | 88 | 43.6 | 94 | 47.5 | 85 | 42.1 | 84 | 43.5 |
| | Female | 106 | 54.4 | 108 | 54.0 | 114 | 56.4 | 104 | 52.5 | 117 | 57.9 | 109 | 56.5 |
| Education | Graduate school | 30 | 15.4 | 34 | 17.0 | 40 | 19.8 | 28 | 14.1 | 31 | 15.3 | 33 | 17.1 |
| | College | 119 | 61.0 | 111 | 55.5 | 115 | 56.9 | 122 | 61.6 | 114 | 56.4 | 112 | 58.0 |
| | High school | 43 | 22.1 | 52 | 26.0 | 43 | 21.3 | 45 | 22.7 | 54 | 26.7 | 42 | 21.8 |
| Age | Below 30 | 87 | 44.6 | 96 | 48.0 | 93 | 46.0 | 89 | 45.0 | 72 | 35.6 | 92 | 47.7 |
| | 30—40 | 66 | 33.9 | 51 | 25.5 | 52 | 25.7 | 62 | 31.3 | 69 | 34.2 | 61 | 31.6 |
| | 40—50 | 25 | 12.8 | 27 | 13.5 | 28 | 13.9 | 27 | 13.6 | 30 | 14.9 | 22 | 11.4 |
| | Above 50 | 17 | 8.7 | 26 | 13.0 | 29 | 14.4 | 20 | 10.1 | 31 | 15.4 | 18 | 9.3 |
| Risk tolerance | Low | 98 | 50.3 | 101 | 50.5 | 98 | 48.5 | 100 | 50.5 | 109 | 54.0 | 112 | 58.0 |
| | Medium | 58 | 29.7 | 67 | 33.5 | 75 | 37.1 | 58 | 29.3 | 56 | 27.7 | 47 | 24.4 |
| | High | 39 | 20.0 | 32 | 16.0 | 29 | 14.4 | 40 | 20.2 | 37 | 18.3 | 34 | 17.6 |
| Fin. wealth (ex. housing) | 200K+ | 17 | 8.7 | 16 | 8.0 | 26 | 12.9 | 16 | 8.1 | 15 | 7.4 | 17 | 8.8 |
| | 50K–200K | 45 | 23.1 | 35 | 17.5 | 53 | 26.2 | 46 | 23.2 | 57 | 28.2 | 36 | 18.7 |
| | 10K–50K | 68 | 34.9 | 49 | 24.5 | 55 | 27.2 | 56 | 28.3 | 50 | 24.8 | 53 | 27.5 |
| | 0–10K | 43 | 22.1 | 69 | 34.5 | 46 | 22.8 | 52 | 26.3 | 47 | 23.3 | 57 | 29.5 |
| | In debt | 22 | 11.3 | 31 | 15.5 | 22 | 10.9 | 28 | 14.1 | 33 | 16.3 | 30 | 15.5 |
| Investing experience | Extensive | 6 | 3.1 | 4 | 2.0 | 5 | 2.5 | 4 | 2.0 | 6 | 3.0 | 8 | 4.1 |
| | Some | 48 | 24.6 | 61 | 30.5 | 79 | 39.1 | 83 | 41.9 | 53 | 26.2 | 55 | 28.5 |
| | Limited | 90 | 46.2 | 85 | 42.5 | 77 | 38.1 | 57 | 28.8 | 95 | 47.0 | 73 | 37.8 |
| | No | 51 | 26.2 | 50 | 25.0 | 41 | 20.3 | 54 | 27.3 | 48 | 23.8 | 57 | 29.5 |
| Total | | 195 | | 200 | | 202 | | 198 | | 202 | | 193 | |

## C.2 Additional Results in Observational Data

### C.2.1 Interest Rates and Household Investment Allocations

Table A17: Interest Rates and AAII Portfolio Allocations: Specification in Changes

Monthly time series regressions:

$$\Delta Y_t = \alpha + \beta \Delta r_{f,t-1} + X'_{t-1}\gamma + \epsilon_t$$

where $r_f$ is 3-month Treasury rate; $X$ includes P/E10 in column (2), the surplus consumption ratio in column (3), and predicted next 12-month excess stock returns in column (4) (estimated using the surplus consumption ratio and past 12-month excess stock returns), as well as AAII stock market sentiment, $VIX^2$, real GDP growth in the past four quarters, and the credit spread. $Y$ is mean allocations to stocks in Panel A and mean allocations to "cash" in Panel B. All regressions include four lags of the outcome variable. Monthly from November 1987 to December 2014. Standard errors are Newey-West, using the automatic bandwidth selection procedure of Newey and West (1994).

Panel A. Interest Rates and Mean Allocations to Stocks

| | Change in Mean Allocations to Stocks | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| L.D.$r_f$ | -1.48 | -1.36 | -1.32 | -1.87 |
| | [-1.74] | [-1.46] | [-1.43] | [-1.92] |
| Controls | No | Yes | Yes | Yes |
| Observations | 320 | 320 | 320 | 320 |

Newey-West $t$-statistics in brackets

Panel B. Interest Rates and Mean Allocations to "Cash"

| | Change in Mean Allocations to "Cash" | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| L.D.$r_f$ | 1.64 | 1.48 | 1.43 | 1.66 |
| | [2.12] | [1.72] | [1.38] | [1.73] |
| Controls | No | Yes | Yes | Yes |
| Observations | 320 | 320 | 320 | 320 |

Newey-West $t$-statistics in brackets

Table A18: Interest Rates and Investment Allocations: Results with Monetary Policy Shocks

Time series regressions:

$$\Delta Y_t = \alpha + \beta r_{s,t} + X'_{t-1}\gamma + \epsilon_t$$

where $r_s$ is a measure of monetary policy shock, following Romer and Romer (2004) and Gertler and Karadi (2015) (current month Fed Funds futures). In Panels A to D, the regressions are monthly, and the outcome variables are respectively changes in mean allocations to stocks and cash from AAII, and flows into equity and high yield corporate bond mutual funds (normalized by net asset value) respectively. In Panels E and F, the regressions are quarterly, and the outcome variables are respectively household sector flows into stocks and interest-bearing safe assets (normalized by household financial assets). The outcome variables are the same as those in Table A17 and Table 8, and the same controls $X$ are used in each case. The Romer-Romer shocks end in December 2007; the Gertler-Karadi shocks end in June 2012. Standard errors are Newey-West, using the automatic bandwidth selection procedure of Newey and West (1994).

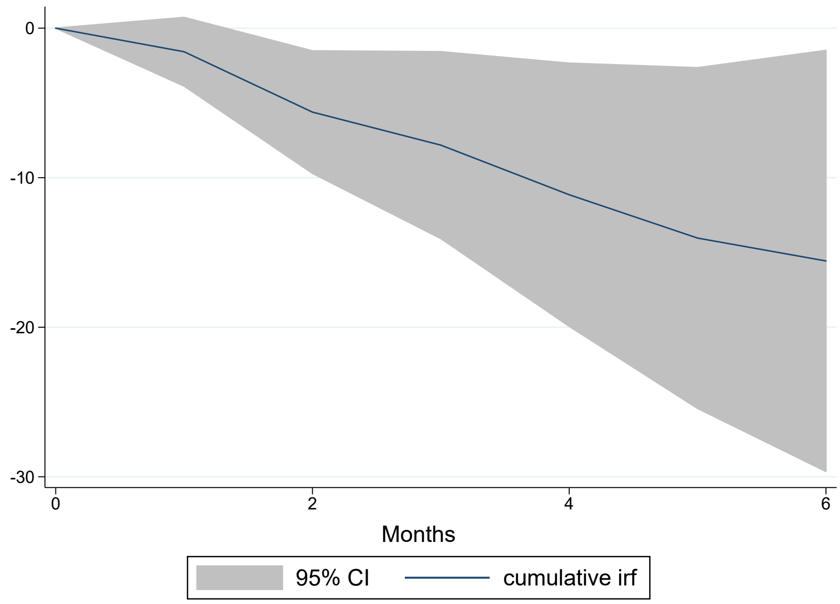
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Panel A. Change in Mean Allocations to Stocks (AAII)** | | | | | | | | |
| Romer-Romer | -3.89 | -4.48 | -4.24 | -5.05 | | | | |
| | [-2.82] | [-2.89] | [-2.77] | [-3.12] | | | | |
| Gertler-Karadi | | | | | -3.52 | -2.73 | -2.87 | -3.66 |
| | | | | | [-1.06] | [-0.80] | [-0.83] | [-1.03] |
| Controls | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Observations | 235 | 235 | 235 | 235 | 284 | 284 | 284 | 284 |
| **Panel B. Change in Mean Allocations to “Cash” (AAII)** | | | | | | | | |
| Romer-Romer | 2.89 | 3.26 | 3.11 | 3.64 | | | | |
| | [2.30] | [2.34] | [2.22] | [2.52] | | | | |
| Gertler-Karadi | | | | | 1.40 | 0.80 | 0.87 | 1.35 |
| | | | | | [0.45] | [0.25] | [0.27] | [0.40] |
| Controls | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Observations | 235 | 235 | 235 | 235 | 284 | 284 | 284 | 284 |
| **Panel C. Equity Mutual Fund Flows (ICI)** | | | | | | | | |
| Romer-Romer | -0.05 | -0.13 | -0.25 | -0.56 | | | | |
| | [-0.22] | [-0.56] | [-1.18] | [-1.60] | | | | |
| Gertler-Karadi | | | | | -1.29 | -1.30 | -1.32 | -1.52 |
| | | | | | [-2.71] | [-2.80] | [-2.75] | [-2.97] |
| Controls | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Observations | 276 | 244 | 244 | 244 | 284 | 284 | 284 | 284 |
| **Panel D. High Yield Corp. Bond Mutual Fund Flows (ICI)** | | | | | | | | |
| Romer-Romer | -1.40 | -1.22 | -1.19 | -1.34 | | | | |
| | [-2.25] | [-1.90] | [-1.83] | [-1.44] | | | | |
| Gertler-Karadi | | | | | -2.61 | -2.40 | -2.58 | -2.53 |
| | | | | | [-1.51] | [-1.40] | [-1.51] | [-1.52] |
| Controls | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Observations | 276 | 276 | 276 | 276 | 284 | 284 | 284 | 284 |
| **Panel E. Household Flows into Stocks (FoF)** | | | | | | | | |
| Romer-Romer | -0.23 | -0.32 | -0.02 | -0.61 | | | | |
| | [-0.84] | [-1.07] | [-0.09] | [-1.23] | | | | |
| Gertler-Karadi | | | | | -0.79 | -1.16 | -0.95 | -1.77 |
| | | | | | [-1.11] | [-1.80] | [-1.44] | [-2.35] |
| Controls | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Observations | 92 | 81 | 81 | 81 | 120 | 109 | 109 | 109 |
| **Panel F. Household Flows into Deposits (FoF)** | | | | | | | | |
| Romer-Romer | 0.03 | 0.08 | -0.07 | 0.49 | | | | |
| | [0.09] | [0.25] | [-0.23] | [0.90] | | | | |
| Gertler-Karadi | | | | | 0.12 | 0.08 | 0.06 | -0.15 |
| | | | | | [0.17] | [0.12] | [0.09] | [-0.20] |
| Controls | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Observations | 92 | 81 | 81 | 81 | 120 | 109 | 109 | 109 |

Newey-West $t$-statistics in brackets

Figure A8: Interest Rates and AAII Portfolio Allocations: sVAR Impulse Response

Impulse response plots of American Association of Individual Investors (AAII) member portfolio allocations to innovations in interest rates. Variables include (in VAR ordering sequence): monthly inflation and industrial production (standard inputs in macro VARs and slowest moving), allocations (stocks in Panel A and "cash" in Panel B), AAII Sentiment (% Bullish - % Bearish), $VIX^2$, P/E10, and the 3-month Treasury rate. We order the risk-free rate at the end to be conservative in our identification of interest rate innovations (results are similar if we drop some variables or use alternative orderings). Eight lags are used. Monthly from November 1987 to December 2014.

Panel A. Mean Allocations to Stocks




Panel B. Mean Allocations to "Cash"

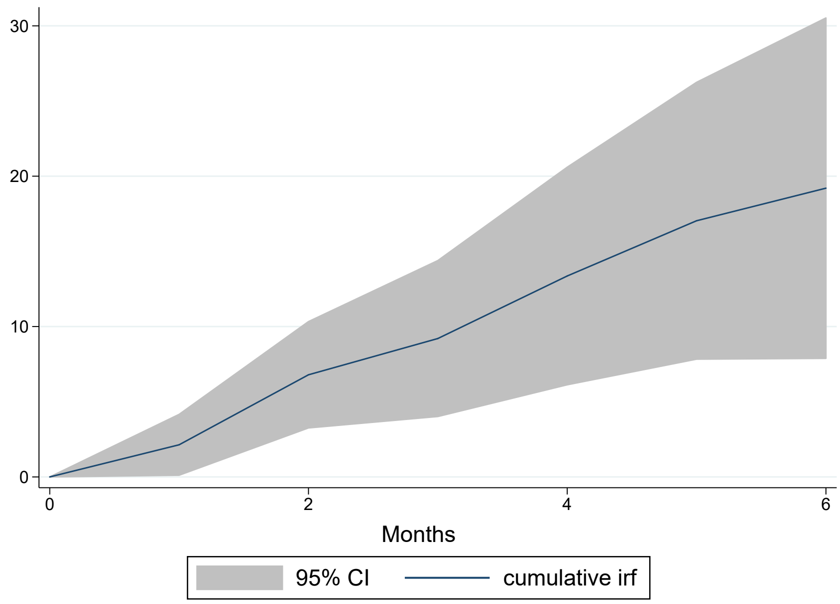
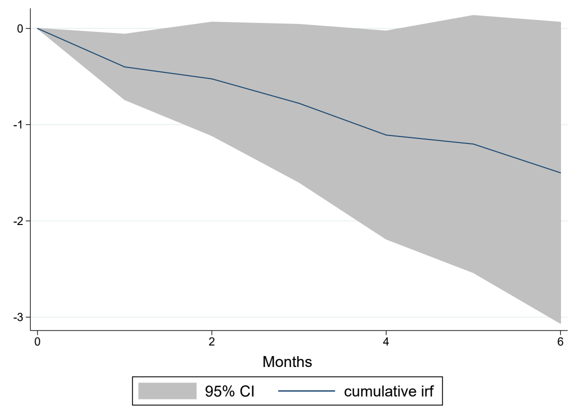
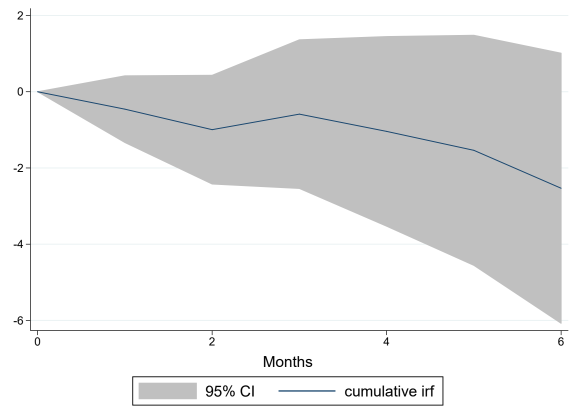


Figure A9: Interest Rates and Household Investment Flows: sVAR Impulse Response

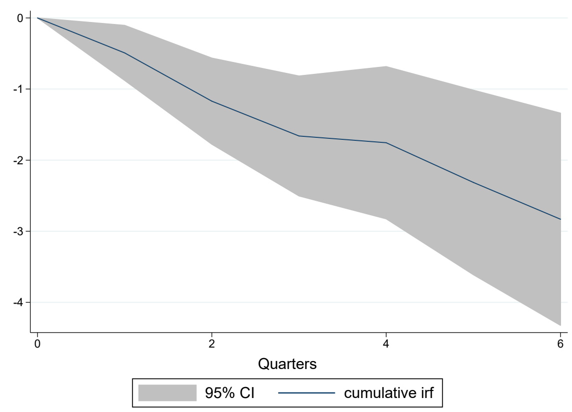
Impulse response plots of household investment flows to innovations in interest rates. Plot (a) shows monthly sVAR results of equity mutual fund flows (normalized by equity mutual fund net asset value) using data from the Investment Company Institute (ICI). Plot (b) shows monthly sVAR results of high yield corporate bond mutual fund flows (normalized by high yield corporate bond mutual fund net asset value) using data from ICI. Plot (c) shows quarterly household sector flows into stocks (including direct holdings and mutual fund holdings, normalized by household sector financial assets) using data from Flow of Funds. Panel (d) shows quarterly household sector flows into interest-bearing safe assets (including time and saving deposits, money market mutual fund, and commercial paper, normalized by household sector financial assets) using data from Flow of Funds. Variables include (in VAR ordering sequence): inflation rate, industrial production growth, allocations (stocks in Panel A and "cash" in Panel B), AAII Sentiment (% Bullish - % Bearish), P/E10, $VIX^2$, and the 3-month Treasury rate; AAII sentiment, P/E10, and $VIX^2$ are not included in plot (b). Eight lags are used.



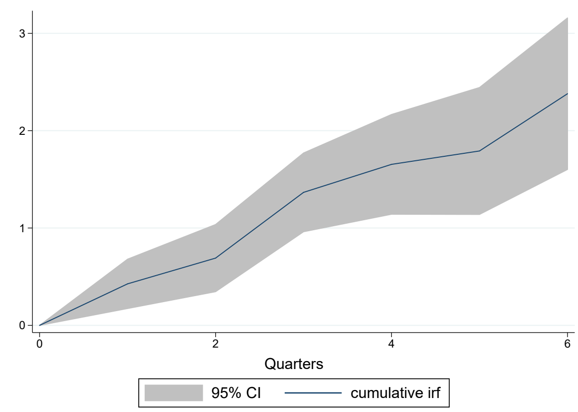

(a) Equity Mutual Fund Flows (ICI)




(b) High Yield Mutual Fund Flows (ICI)




(c) Household Flows into Stocks (FoF)




(d) Household Flows into Deposits (FoF)

Figure A10: Impulse Response of Excess Stock Returns to Interest Rate Innovations

Impulse response plots of monthly excess stock returns to innovations in interest rates. Variables include (in VAR ordering sequence): inflation rate, industrial production growth, monthly stock returns, and the 3-month Treasury rate. Eight lags are used. Monthly from January 1985 to December 2014.

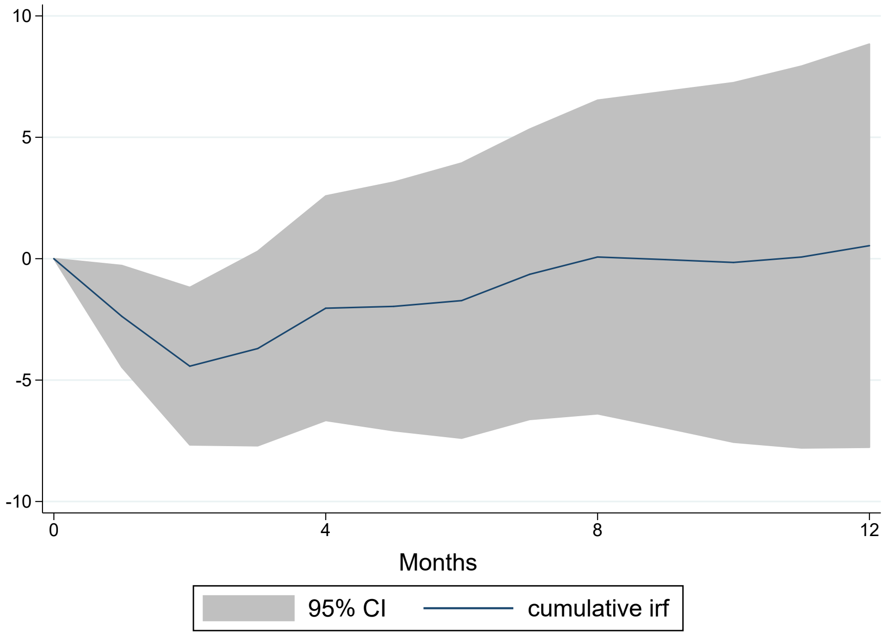


Table A19: Flows and Issuance by Sector

Time series regressions:

$$F_t = \alpha + \beta \Delta r_{f,t-1} + X'_{t-1}\gamma + \epsilon_t$$

where $r_f$ is 3-month Treasury rate; $F$ is quarterly net flows into corporate equities (normalized by US GDP) in columns (1) to (3), and quarterly net equity issuance of equities (normalized by US GDP) in columns (5) to (7); $X$ includes controls in Table 7: Spec 1 has the same controls as Table 7 column (2), Spec 2 has the same controls as Table 7 column (3), and Spec 3 has the same controls as Table 7 column (4). All regressions include four lags of $F$. Outcome variables are from the beginning of 1985 to the end of 2014, but AAII sentiment is only available starting August 1987. Standard errors are Newey-West, using the automatic bandwidth selection procedure of Newey and West (1994). Regression coefficient $\beta$ and the associated $t$-statistics are reported. Data on flows and issuance are from Flow of Funds, and they are in net terms. Flows from all sectors sum up to issuance by all sectors. On the flow side, all sectors include households, domestic financial sector, rest of the world, as well as a few other components such as government and non-financial corporations' holdings of mutual fund shares.

| | Net Flows into Stocks | | | | Net Issuance of Stocks | | |
|---|---|---|---|---|---|---|---|
| | Household (1) | Financials (2) | RoW (3) | All Sectors (4) | Non-Fin. (5) | Financials (6) | RoW (7) |
| No Control | -0.68 | -0.02 | 0.06 | -0.79 | -0.45 | -0.41 | 0.03 |
| | [-1.86] | [-0.07] | [0.51] | [-3.46] | [-2.31] | [-2.49] | [0.21] |
| w/ Control, Spec 1 | -0.72 | -0.28 | 0.09 | -1.27 | -0.63 | -0.54 | -0.05 |
| | [-1.69] | [-0.91] | [0.57] | [-4.51] | [-2.41] | [-2.14] | [-0.29] |
| w/ Control, Spec 2 | -0.61 | -0.34 | 0.04 | -1.24 | -0.55 | -0.53 | -0.12 |
| | [-1.33] | [-1.05] | [0.25] | [-4.39] | [-2.12] | [-2.09] | [-0.68] |
| w/ Control, Spec 3 | -1.13 | 0.08 | 0.19 | -1.30 | -0.40 | -0.47 | -0.33 |
| | [-1.67] | [0.17] | [0.77] | [-3.97] | [-1.13] | [-1.56] | [-1.72] |

### C.2.2 History-Dependent Reference Points: Results from the SCF

In the following, we present suggestive evidence of history-dependent reference points using data from the Survey of Consumer Finances (SCF). We follow the empirical strategy of Malmendier and Nagel (2011), and exploit differences in different individuals' lifetime interest rate experiences. We show that, at a given point in time, individuals who experienced high past interest rates appear less satisfied with safe assets and display a higher propensity of risk taking.

Figure A11 follows Figure 1 in Malmendier and Nagel (2011), and plots the differences in mean allocations to stocks (as well as deposits) between old and young against the differences in experienced past interest rates. It shows that in periods where old individuals' experienced interest rates are significantly higher than young individuals, old individuals' propensity to invest in stocks in also much higher.

Table A20 presents regressions following Malmendier and Nagel (2011):

$$Y_{it} = \alpha + \eta_t + \beta \bar{r}_{f,it} + \gamma \bar{r}_{x,it} + \xi' X_{it} + \epsilon_{it} \tag{A18}$$

where $Y_{it}$ captures investment decisions of household $i$ in year $t$. $\bar{r}_{f,it}$ is the main independent variable of interest, which measures average experienced past interest rates. We control for $\bar{r}_{x,it}$, which is average excess stock returns in household $i$'s previous lifetime experiences as of year $t$; it proxies for beliefs or preferences related to stocks due to prior experiences, as documented by Malmendier and Nagel (2011). $\bar{r}_{f,it}$ and $\bar{r}_{x,it}$ are calculated using the experience function in Malmendier and Nagel (2011), which is (exponentially-decaying) weighted averages of past experiences; we use the default decay parameter $\lambda = 1.5$ from Malmendier and Nagel (2011). We also control for a set of demographic characteristics, including dummies for education, age, race, marital status, employment status, income deciles, wealth (log financial assets). As in Malmendier and Nagel (2011), we include time dummies, and identify experience effects from cross-sectional heterogeneity among individuals.

Table A20 shows that, at a given point in time, individuals that experienced high interest rates in the past invest less in deposits and have a higher propensity of risk taking. For a one percentage point increase in average experienced past interest rates, portfolio shares in stocks (deposits) on average increase (decrease) by about 1.5 percentage points. The changes in portfolio shares are more pronounced among stock market participants. This pattern is consistent with the idea that these individuals are accustomed to higher levels of interest rates and are less satisfied with the current interest rates. Thus they invest less in deposits and are more likely to invest in risky assets.

There are, however, several caveats in this analysis using observational data. First, the SCF does not have data on beliefs about the risky asset's returns and risks. Thus it is challenging to adequately control for potential heterogeneity in beliefs. For instance, to the extent that interest rates tend to be higher in booms and lower in recessions, individuals who experienced higher past interest rates may have more experiences of booms and are thus more optimistic. Second, in the past half a century, interest rates experienced a secular decline, so the gap in interest rate experiences is correlated with the age gap: as can be seen in Figure A11, both differences in old and young individuals' experienced interest rates and differences their investment shares in stocks secularly increase. Thus it may be hard to rule out influences from systematic demographic shifts.

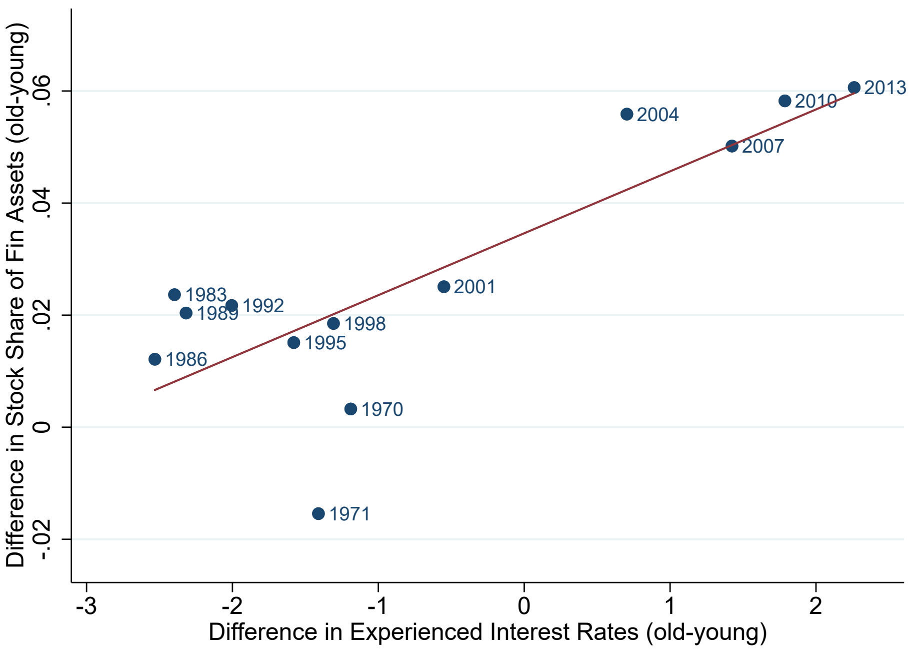
Finally, the reference points in the reference dependence model of Section 3.2 could be influenced by experiences of both past interest rates and past stock returns. In this case, in the SCF data, it is hard to tease apart experience effects that work through history-dependent reference points from experience effects that work through beliefs and other channels.

In sum, there are multiple challenges in observational data that make it significantly harder to cleanly isolate the underlying mechanisms. Nonetheless, the patterns in the observational data appear in line with our findings in the transparent randomized experiments. We hold the evidence of Figure A11 and Table A20 as suggestive of history-dependent reference points.

Figure A11: Differences in Mean Investment Shares between Old and Young

Differences in mean investment shares between old (household age > 60) and young (household age < 40). In Panel A, the $y$-axis is the difference in mean shares of stocks (directly held and through mutual funds) in financial assets between these two groups. In Panel B, the $y$-axis is the difference in mean shares of deposits (including checking, saving, CD, money market deposits) in financial assets between these two groups. The $x$-axis is the average short-term interest rates in the past 40 years minus the average in the past 20 years. Because SCF data is not very clear about investment of IRA and other retirement saving accounts before 2004, here we do not include retirement assets in financial assets.

Panel A. Differences in Mean Shares in Stocks




Panel B. Differences in Mean Shares in Deposits

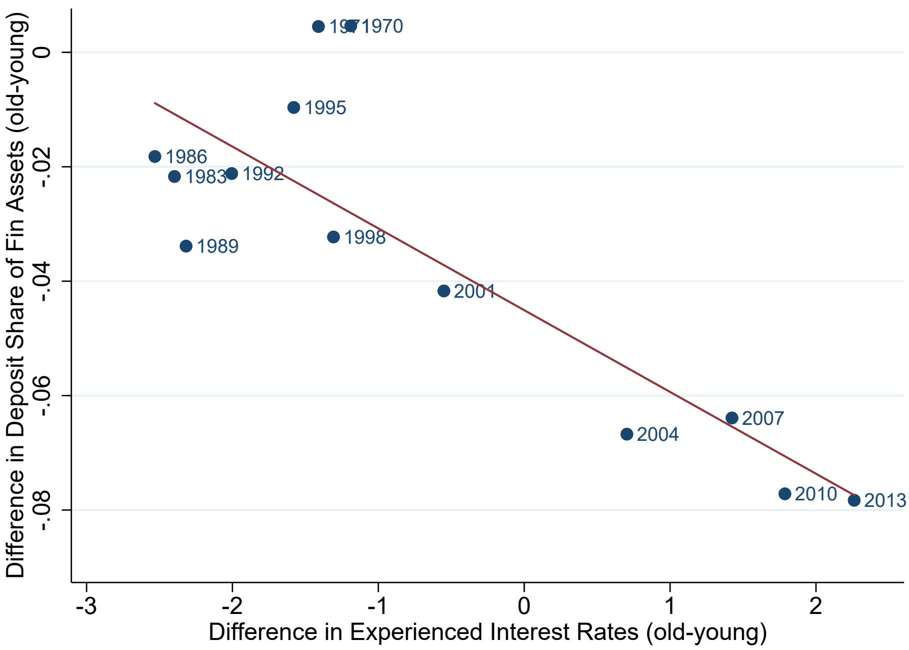


Table A20: Investment Decisions and Interest Rate Experiences

Panel regressions using Survey of Consumer Finance data:

$$Y_{it} = \alpha + \eta_t + \beta \bar{r}_{f,it} + \gamma \bar{r}_{x,it} + \xi' X_{it} + \epsilon_{it}$$

In column (1), the outcome variable is a categorical question about risk tolerance (1. not willing to take any financial risks; 2. take average financial risks expecting to earn average returns; 3. take above average financial risks expecting to earn above average returns; 4. take substantial financial risks expecting to earn substantial returns. The regression is estimated using ordered probit. In column (2), the outcome variable is a dummy variable that takes value one if household $i$ holds a positive amount of stocks at time $t$. In column (3), the outcome variable is the share of household $i$'s financial assets in stocks at time $t$. In column (4), the outcome variable is the share of household $i$'s financial assets in deposits at time $t$. The main dependent variable $\bar{r}_{f,it}$ is measures average experienced past interest rates. We also include $\bar{r}_{x,it}$, which is average experienced excess stock returns. $\bar{r}_{f,it}$ and $\bar{r}_{x,it}$ are calculated using the experience function in Malmendier and Nagel (2011), with default $\lambda = 1.5$. Controls include dummies for education, age, race, marital status, employment status, income deciles, and wealth (log financial assets). Because SCF data is not very clear about investment of IRA and other retirement saving accounts before 2004, here we do not include retirement assets in financial assets. Standard errors are corrected for multiple imputation.

| Outcome | Risk Tolerance<br>Ordered Probit<br>(1) | Holds Stocks<br>OLS<br>(2) | % in Stocks<br>OLS<br>(3) | % in Deposits<br>OLS<br>(4) |
|---|---|---|---|---|
| Experienced interest rates | 0.05 | 0.03 | 1.58 | -1.91 |
| | [3.94] | [6.78] | [6.40] | [-5.81] |
| Experienced excess stock returns | 0.03 | 0.01 | 0.36 | -0.13 |
| | [3.10] | [4.44] | [2.36] | [-0.74] |
| High School | 0.12 | 0.02 | 0.12 | -0.56 |
| | [6.47] | [4.15] | [0.34] | [-1.40] |
| College | 0.36 | 0.13 | 4.00 | -4.52 |
| | [18.13] | [18.90] | [9.72] | [-9.35] |
| Log financial assets | 0.10 | 0.08 | 4.68 | -6.01 |
| | [28.61] | [53.35] | [28.62] | [-28.80] |
| Age Dummies | Y | Y | Y | Y |
| Time Dummies | Y | Y | Y | Y |
| Other Controls | Y | Y | Y | Y |
| Obs | 41,260 | 43,947 | 43,941 | 43,932 |
| $R^2$ | | 0.335 | 0.252 | 0.286 |

$t$-statistics in brackets, corrected for multiple imputation

# D Data

## D.1 List of Experiments

| | Population | Setting | Test | $N$ | Time |
|---|---|---|---|---|---|
| 1 | Mturk | Hypothetical | Benchmark | 400 | Jun-16 |
| 2 | Mturk | Incentivized | Benchmark | 400 | Feb-16 |
| 3 | Mturk | Incentivized | Robustness checks (payment methods) | 1,200 | Feb-16 |
| 4 | HBS MBA | Incentivized | Benchmark | 400 | Apr-16 |
| 5 | Mturk | Incentivized | Experiment T1: gradient & non-linearity | 1,400 | Jun-16 |
| 6 | Mturk | Incentivized | Experiment T3: gross framing | 400 | Jun-16 |
| 7 | Mturk | Incentivized | Experiment T3: net framing robustness | 400 | Jun-16 |
| 8 | Mturk | Hypothetical | Experiment T2: history dependence | 400 | Aug-15 |
| 9 | Mturk | Incentivized | Experiment T2: history dependence | 400 | Jun-16 |
| 10 | Mturk | Hypothetical | Experiment T2: history dependence additional design (run by Cary Frydman) | 400 | Nov-16 |
| 11 | Mturk | Incentivized | Experiment T2: history dependence additional design | 400 | Dec-16 |
| 12 | Mturk | Incentivized | Robustness (binary distribution) | 400 | Jun-16 |
| 13 | Dutch households | Hypothetical | Experiment T1 (run by Dutch AFM) | 901 | Aug-17 |
| Total | | | | 7,501 | |

## D.2 Sources and Variable Definitions for Observational Data

| Variable | Construction | Source |
|---|---|---|
| Portfolio share in stocks and "cash" | Stocks include both direct holdings and stock mutual funds; "cash" refers to savings accounts, CDs, money market funds, etc. | American Association of Individual Investors |
| Flows into equity and high yield corporate bond mutual funds | | Investment Company Institute |
| Net asset value of equity and high yield corporate bond mutual funds | | Investment Company Institute |
| Household sector flows into stocks | FA153064105.Q+FA153064205.Q | Flow of Funds |
| Household sector flows into interest-bearing safe assets | FA153030005.Q+FA153034005.Q+FA163069103.Q | Flow of Funds |
| Household sector total financial wealth | FL154090005.Q | Flow of Funds |
| Stock market sentiment | % Bullish - % Bearish | American Association of Individual Investors |
| P/E10 | | Robert Shiller's website |
| Surplus consumption | Follows Campbell and Cochrane (1999) | |
| Real GDP | | Federal Reserve Economic Data (FRED) |
| $VIX$ | | CBOE |
| Credit spread | Baa bond yield - 10-year Treasury yield | FRED |
| High yield corporate bond excess returns | High yield corporate bond returns - risk-free returns | Bank of America Merrill Lynch |
| High yield corporate bond default rate | | Moody's |
| Inflation rate | CPI for all urban consumers | FRED |
| Industrial production | | FRED |

Note: Flow of Funds occasionally updates historical time series. The values used here are retrieved in May 2016.