Expectations-Based Reference-Dependent Consumption and Portfolio Choice: Evidence from the Lab*

Michaela Pagel† Christopher Zeppenfeld‡

October 28, 2013

!!!Preliminary & Incomplete - Comments Welcome!!!

Abstract

In a lab experiment, we test standard consumption and portfolio choice predictions against those of expectations-based reference-dependent and hyperbolic-discounting preferences. The experiment consists of four periods. In the first period, subjects are endowed with experimental wealth. Then, subjects decide how much of their experimental wealth to "consume" by surfing the internet instead of performing an alternative monotone task. To consume in future periods, they either store their wealth safely or invest it into a risky lottery. The main predictions of reference-dependent preferences, which stand in contrast to those of standard and hyperbolic-discounting preferences are: First, the consumption share is decreasing in the investment outcome. Intuitively, the agent delays painful cuts in consumption to let his expectations-based reference point decrease. Second, the portfolio share is decreasing in the outcome. The agent increases his risk exposure in bad states to not realize too many loss feelings about future consumption. Third, the agent's behavior is not time consistent. The agent likes to increase his consumption and risky asset holdings above expectations today, but considers his expectations when making plans about tomorrow. However, preliminary results indicate that subjects behave according to the standard model.

JEL: C91, D91, G11.

*We thank David Gill, Stefano DellaVigna, Ulrike Malmendier, Matthew Rabin, Muriel Niederle, Nava Ashraf, Dirk Sliwka, Achim Wambach, and Arne Weiss for valuable suggestions and insightful comments. We also thank seminar participants at the University of Cologne and the University of California at Berkeley, and conference participants of the Economic Science Association 2012 North America Meeting.

†Graduate School in Economics; University of California, Berkeley; mpagel@econ.berkeley.edu.

‡Cologne Graduate School in Management, Economics and Social Sciences; University of Cologne; zeppenfeld@wiso.uni-koeln.de.

1 Introduction

Individual preferences determine how people allocate wealth between consumption and investment over different states of the world and between different points in time. However, standard preferences are inconsistent with several empirical facts about consumption and portfolio choice, such as stickiness in consumption, hump-shaped consumption patterns, stock market non-participation, and decreasing portfolio shares over the life-cycle.[1] We design a stylized laboratory experiment to analyze consumption allocation and portfolio choice and test the predictions of an alternative preference-based explanation, namely expectations-based reference dependence.

Expectations-based reference-dependent preferences have been developed by Koszegi and Rabin (2006, 2007, 2009) and have since been shown to be consistent with real-world behavior in a variety of domains, including taxicab drivers labor supply, expectations-driven endowment effects, and real-effort experiments. The preferences consist of two components, consumption utility and gain-loss utility. Consumption utility is based on the level of consumption, as in standard theory. Gain-loss utility is based on a comparison of consumption with a reference point, as in prospect theory, and the agent is loss averse, i.e., losses hurt more than gains please. Hereby, the agent's reference point is stochastic and corresponds to the rational beliefs formed in the previous period about the entire stream of future consumption. Then, the agent compares his previous and updated beliefs about present and future consumption experiencing gain-loss utility over what he has learned; thus, the preferences can be referred to as "news utility".

Reference-dependent preferences make predictions in a dynamic consumption and portfolio choice problem that stand in contrast to standard and hyperbolic-discounting preferences. First, the consumption share is decreasing in the investment outcome. Cutting consumption below expectations today hurts more than cutting consumption tomorrow when the reference point will be lower because expectations have adjusted. Second, the portfolio share is decreasing in the investment outcome. To not realize too many loss feelings about prospective consumption, the agent increases his risky holdings in the event of a bad return realization. Third, the agent is behaving time-inconsistently. The agent wants to increase both consumption and risk exposure

[1] See for example Jappelli and Pistaferri (2010), Fernandez-Villaverde and Krueger (2007), Gomes et al. (2005), Samuelson (1969), and Merton (1969).

above the levels he expected, which he takes as given in that period. In contrast, in previous periods, he considered the fact that such a choice would have increased his expectations. As increasing consumption and risk above expectations is more pleasurable than increasing both, the agent overconsumes and overinvests relative to an optimal pre-committed path that maximizes expected utility.

The first hypothesis predicts that the consumption share decreases in the return realization and time horizon. In contrast, standard and hyperbolic-discounting preferences predict that the consumption share only depends on the remaining time horizon. In the event of a bad investment outcome, cutting consumption is particularly painful; thus, the agent wishes to delay this cut to let his reference point decrease. Such a delayed response in consumption is also predicted for positive outcomes. Good realizations yield gain feelings today lowering marginal gain-loss utility, while the reference point tomorrow will be higher again. Therefore, the agent shifts some of the consumption to the future thereby delaying adjustments in consumption. Thus, current shocks predict future changes in consumption, which makes consumption sticky or excessively smooth.[2]

The second hypothesis predicts that the portfolio share decreases in the return realization and time horizon. In contrast, standard and hyperbolic-discounting preferences imply that the optimal portfolio share is constant. A bad investment outcome implies that the agent experiences loss feelings about future consumption that, however, can be counterbalanced by an increase in his investment share. The agent is happy to bear the associated increase in volatility, as his portfolio share is generally lower than in the standard model. Such a reaction reminds of a disposition effect (Shefrin and Statman, 1985; Odean, 1998), i.e., the tendency to sell winning stocks too early and to stick to losing stocks too long; but, it originates from loss feelings about future consumption considerations rather than from comparisons with past purchase prices. Similarly, such a reaction reminds of risk-lovingness in the loss domain, as in prospect theory; but, it originates from loss feelings about future consumption rather than convexities in the utility function.

The third hypothesis predicts that the agent overconsumes compared to a pre-committed path that maximizes expected utility, whereas standard preferences imply time-consistent behavior. Un-

[2]Excess smoothness or stickiness in consumption refer to the empirical observation that consumption initially underresponds to income shocks and then adjusts with a delay. See, e.g., Flavin (1985), Campbell and Deaton (1989), and Jappelli and Pistaferri (2010).

der pre-commitment the agent optimizes jointly over consumption and beliefs about consumption. Similarly, he considers his beliefs when planning future consumption. However, if he is not pre-committed to a consumption plan, then he takes his beliefs as given in any period and is inclined to increase consumption above his beliefs and thus overconsumes relative to the pre-committed plan. Analogously, the news-utility agent is inclined to increase risk exposure above his beliefs. Hereby, he enjoys the gain sensations of higher consumption prospects, which outweigh the increase in consumption volatility as his initial risk exposure is rather low. Moreover, the amount of overconsumption and overinvestment relative to the pre-committed path is reference dependent and increasing in the return realization. In contrast, hyperbolic-discounting preferences predict a constant overweighting with respect to consumption utility only. The third hypothesis is thus aimed to differentiate reference-dependent time inconsistency from hyperbolic discounting.

The experiment consists of four periods each of which is 19 minutes long. In the first period, subjects are endowed with initial experimental wealth. Consumption corresponds to the purchase of internet time. While subjects surf the web, they do not have to perform an alternative task which corresponds to monotone window-clicking; i.e., the closing of pop-up windows that appear randomly over time and at random positions on their computer screen. However, subjects need to start doing this dull task once they have consumed the internet time they purchased in the current period. Moreover, subjects decide how much experimental wealth to store safely or invest in a risky lottery for consumption, i.e., internet time, in future periods. In the last period, subjects consume all remaining wealth. That the experiment features real consumption rather than monetary payoffs in a portfolio-choice framework is a key contribution of this paper.

Subjects first face a "pre-commitment" stage and subsequently an "allocation-and-consumption" stage. In the pre-commitment stage, subjects have to make a consumption and portfolio plan for every possible contingency. Then, we randomly determine whether this initial plan is binding for each subject in the second stage. If it is binding, a subject has to follow his or her plan. If it is not binding, subjects have to allocate their initial wealth anew in every period of the second stage.

Our preliminary results indicate support for the standard model. The consumption and investment shares are not significantly negatively correlated with the investment outcome and subjects do not seem to overconsume or overinvest relative to their pre-committed plan. However, when we control for the severity of the shock, subjects tend to increase their investment share in the event of bad outcomes. That is, the higher a subject has been invested and therewith the higher the subject is affected by the outcome, the more he invests to counterbalance the effect. Moreover, under non-pre-commitment they are more willing to increase their risk exposure after bad shocks, which they do not plan under pre-commitment.

The rest of the paper is organized as follows. In the next section, we discuss related experimental literature. Section 3, presents the model, derives theoretical predictions, and states testable hypotheses. Subsequently, we present our experiment design. Section 5 presents the results which we discuss in section 6. Section 7 concludes.

2 Related Experiments

This section presents consumption and portfolio-choice experiments followed by experiments on KR preferences and related methodology. To the best of our knowledge, there exists no experiment that tests actual-consumption (instead of monetary payoffs) and portfolio decisions simultaneously.

Sippel (1997) analyzes consumer choice under different budget constraints by letting subjects choose from a variety of real consumption bundles to be consumed in the laboratory as an alternative to sit around and do nothing. Subjects frequently violate revealed-preference axioms, hence contradicting standard utility maximization under budget constraints.

Brown, Chua, and Camerer (2009) investigate whether bounded rationality or time inconsistency explains undersaving in a habit-forming life-cycle context. Regarding bounded rationality, they use monetary incentives and find that personal experience and social learning, i.e., observing others' choices, facilitate subjects' convergence to optimal saving levels. Regarding time inconsistency, Brown, Chua, and Camerer use beverages as real consumption goods and report that subjects have a preference for immediate gratification consistent with quasi-hyperbolic preferences.

Augenblick et al. (2013) analyze time inconsistency by comparing monetary and real-effort choices in a longitudinal experiment. Subjects show few time inconsistency under monetary incentives but a considerable present bias under real effort by allocating unpleasant consumption (work) to the future instead of doing it today.[3]

Karle et al. (2013) analyze static consumer choice under price uncertainty and Koszegi and Rabin (2006) preferences. Subjects report their taste for two sandwiches without knowing the specific prices. Subsequently, prices were determined randomly and subjects choose one sandwich. Karle et al. find a significant share of choice reversals, i.e., subjects who liked the (ex-post) more-expensive sandwich better, actually chose the cheaper one.

Generally, portfolio choice experiments investigate the risk-taking decisions of subjects who invest their experimental cash in lotteries. Though subjects may revise their portfolio composition between periods, they only derive utility from terminal wealth. Hence, these experiments neglect the intertemporal consumption decisions and their interplay with portfolio choices we are interested in. For example, much work has been done on testing the portfolio-choice assumptions underlying asset pricing models (Kroll et al. 988a; 988b; Kroll and Levy, 1992; Bossaerts, Plott, and Zame, 2007), analyzing the effects of ambiguity aversion on portfolio composition (Bossaerts, Ghirardato, Guarnaschelli, and Zame, 2010; Charness and Gneezy, 2010; Ahn, Choi, Gale, and Kariv, 2011), or introducing background risk (Klos and Weber, 2006).[4]

Ploner (2003) analyzes the effect of stock ownership on intertemporal wealth allocation. Subjects are endowed with stocks and cash and have to divest their portfolio across periods to stay above a minimum spending level.[5] Ploner finds that subjects overspend in early periods and that the initial stock value acts as a reference level for the selling decision.

Testing predictions derived from Koszegi and Rabin (2006), Ericson and Fuster (2011) endow subjects with either a pen or a mug and show that the expectation to be able to trade the endowed item in later rounds weakens the famous endowment effect. However, in two similar experiments, Smith (2008) obtains only mixed results while Heffetz and List (2011) do not confirm the findings of Ericson and Fuster.

[3]Further experiments on (monetary) consumption choices include Kotlikoff, Samuelson, and Johnson (1988); Anderhub, Güth, Müller, and Strobel (2000); Mattei (2000); Février and Visser (2004) and Luhan, Roos, and Scharler (2011).

[4]Interestingly, a first indication of our hypothesis on the risky asset share to decrease in the the return realization is given in footnote 11 in Gneezy and Potters (1997, p. 639) in which they state that: "Although this finding is statistically insignificant, bets are larger after a loss than after a gain."

[5]Thus, subjects could only reduce an exogenously determined risk exposure and did not face an actual portfolio choice to determine their desired risk position. Therefore, they were not able to react appropriately to the realization of risk by rebalancing their holdings accordingly.

Sprenger (2011) provides evidence for reference dependence in individual risk attitudes. He finds that subjects have an endowment effect for gambles. When risk is expected, i.e., the reference level is stochastic, and subjects were offered a certain amount, they behave nearly risk-neutral. When risk came unexpected, i.e., the reference level was a certain amount, and subjects were offered a lottery, they act risk averse. This supports the theoretical results derived by Koszegi and Rabin (2007) and evidence against predictions derived by disappointment aversion.[6]

Methodologically, Houser et al. (2010) propose a design closely related to ours. They test whether subjects are willing to pay for a commitment device that excludes a tempting alternative from their choice set. Temptation consists of frequently offering subjects to abandon a boring task (counting numbers) and to surf the internet instead. When such a tempting choice screen appears, subjects can either continue counting, stop counting completely and surf the internet (and therewith forfeit the high payoff), or pay to get rid of the choice screen completely and therewith commit to the counting task. We also use the contrast between a boring real-effort task and surfing the internet as the pleasurable alternative. However, in our experiment, subjects switch back and forth between the boring task and consumption, depending on their allocation decision. Furthermore, in our experiment, subjects do not forgo payoffs while surfing the internet rather their aim is to maximize available internet time and to allocate it optimally. Our design gains additional reliability from the experiment of Houser et al.. Using the internet as a mean to simulate a pleasurable goods is a reasonable choice given the various opportunities it provides.

3 Model and Hypotheses

This section introduces the preferences and illustrates the model's predictions intuitively by taking a close look at the second-to-last period decision-making problem within the experimental set-up. Hypotheses 1 to 7 state the predictions we test experimentally. The formal derivation of the model

[6]Further evidence for KR preferences from real effort experiments is provided by Abeler, Falk, Goette, and Huffman (2011) and Gill and Prowse (2012). Mas (2006), Pope and Schweitzer (2011) and Card and Dahl (2011) provide field data evidence for adjustment of police performance after wage arbitration, expectation-based performance of golfers, and increase in domestic violence after unexpected football outcomes, respectively. Taxi drivers' daily income and work load targeting is shown to be accordant to a forward looking reference point by Doran (2010) and Crawford and Meng (2011).

environment, solution concept, and equilibrium notion is dedicated to appendix C.

3.1 Expectations-Based Reference-Dependent Preferences

The static preferences. To understand reference-dependent preferences, it is helpful to first introduce the static preferences as specified in Koszegi and Rabin (2006). The agent experiences "consumption utility", $u(c)$, which corresponds to the traditional model of utility determined by the absolute value of consumption c only. Additionally, the agent experiences "gain-loss utility" $n(c, r) = \mu(u(c) - u(r))$. The gain-loss utility function $\mu(\cdot)$ corresponds to the prospect-theory model of utility determined by consumption c relative to the reference point r. $\mu(\cdot)$ is a piecewise linear value function with slope η and a coefficient of loss aversion λ, i.e. $\mu(x) = \eta x$ for $x > 0$ and $\mu(x) = \eta\lambda x$ for $x \leq 0$. The parameter $\eta > 0$ weighs the gain-loss utility component relative to the consumption utility component and $\lambda > 1$ implies that losses are weighed more heavily than gains, the agent is loss averse. Total utility is the sum of consumption and gain-loss utility and given by

$$U = u(c) + n(c, r) = u(c) + \mu(u(c) - u(r)). \tag{1}$$

Koszegi and Rabin (2006) preferences allow for stochastic outcomes distributed according to $F_c(c)$, as well as a stochastic reference point distributed according to $F_r(r)$. The agent experiences gain-loss utility by evaluating each possible outcome relative to all other possible outcomes

$$n(F_c, F_r) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \mu(u(c) - u(r)) dF_r(r) dF_c(c). \tag{2}$$

Koszegi and Rabin (2006) make an additional central assumption that the distribution of the reference point $F_r(r)$ equals the agent's fully probabilistic expectations, formed in the recent past, about consumption c.

The dynamic preferences. We use the dynamic version of these preferences as specified in Koszegi and Rabin (2009). In each period t, the agent's preferences are defined over both outcomes and beliefs and we explicitly define his probabilistic "beliefs" about each of the model's period t

variables from the perspective of any prior period as follows.

Notation Let $I_t = \{X_t, Z_t, s_t\}$ denote the agent's information set in some period $t \leq t+\tau$; then, the agent's probabilistic beliefs about any model variable $V_{t+\tau}$ conditional on period t information is denoted by $F^t_{V_{t+\tau}}(v) = Pr(V_{t+\tau} < v|I_t)$, and $F^{t+\tau}_{V_{t+\tau}}$ is degenerate.

Throughout the paper, we assume rational expectations, i.e., the agent's beliefs about any of the model's variables equal the objective probabilities determined by the economic environment.

Instantaneous utility in each period t is the sum of consumption utility, "contemporaneous" gain-loss utility about current consumption, and "prospective" gain-loss utility about the entire stream of future consumption

$$U_t = u(C_t) + n(C_t, F^{t-1}_{C_t}) + \gamma \sum_{\tau=1}^{\infty} \beta^{\tau} \boldsymbol{n}(F^{t,t-1}_{C_{t+\tau}}). \tag{3}$$

The first term in equation (3), $u(C_t)$, corresponds to consumption utility in period t, which relies on absolute consumption only

$$u(C_t) = \frac{C_t^{1-\theta}}{1-\theta}. \tag{4}$$

To understand the following terms in equation (3), first note that the reference point in period t is the conditional distribution of consumption in period t and all future periods $t+\tau$, given the information available in period $t-1$. The fully probabilistic rational beliefs formed in period $t-1$ about period $t+\tau$ consumption is denoted by the distribution $F^{t-1}_{C_{t+\tau}}$. Thus, the second term in equation (3), $n(C_t, F^{t-1}_{C_t})$, corresponds to gain-loss utility in period t over contemporaneous consumption. Because the agent compares actual contemporaneous consumption to the fully probabilistic beliefs he entered the period with, he experiences gain-loss utility over "news" about contemporaneous consumption as follows

$$n(C_t, F^{t-1}_{C_t}) = \eta \int_{-\infty}^{C_t} (u(C_t) - u(r)) dF^{t-1}_{C_t}(r) + \eta\lambda \int_{C_t}^{\infty} (u(C_t) - u(r)) dF^{t-1}_{C_t}(r).$$

The third term in equation (3), $\gamma \sum_{\tau=1}^{\infty} \beta^{\tau} \boldsymbol{n}(F^{t,t-1}_{C_{t+\tau}})$, corresponds to gain-loss utility, experienced in period t, over the entire stream of future consumption. Prospective gain-loss utility about period

$t+\tau$ consumption $C_{t+\tau}$ depends on the agent's beliefs about period $t+\tau$ consumption he entered the period with $F^{t-1}_{C_{t+\tau}}$ and on his updated beliefs about period $t+\tau$ consumption $F^{t}_{C_{t+\tau}}$. The updated and prior beliefs about period $t+\tau$ consumption $F^{t-1}_{C_{t+\tau}}$ and $F^{t}_{C_{t+\tau}}$ are not independent as there are common future shocks. Thus, there exists a joint distribution which we denote by $F^{t,t-1}_{C_{t+\tau}} \neq F^{t}_{C_{t+\tau}} F^{t-1}_{C_{t+\tau}}$ of period $t+\tau$ consumption under the updated and prior fully probabilistic beliefs. Prospective gain-loss utility about period $t+\tau$ consumption is then given by $\boldsymbol{n}(F^{t,t-1}_{C_{t+\tau}})$. Because the agent compares his newly formed beliefs to the beliefs he entered the period with, he experiences gain-loss utility over "news" about future consumption

$$\boldsymbol{n}(F^{t,t-1}_{C_{t+\tau}}) = \int_{-\infty}^{\infty} \mu(u(c) - u(r)) dF^{t,t-1}_{C_{t+\tau}}(c, r).$$

This definition of prospective gain-loss utility is a modification of the state-wise definition, as specified in Koszegi and Rabin (2006, 2007) and stated in equation (2), that explicitly considers dependence of F_r and F_c.[7] The agent discounts prospective gain-loss utility exponentially by β the standard agent's consumption utility discount factor. Moreover, prospective gain-loss utility relative to contemporaneous gain-loss utility is subject to $\gamma \in [0, 1]$, so that the agent puts the weight $\gamma\beta^{\tau} < 1$ on prospective gain-loss utility about consumption in period $t+\tau$.

Because both contemporaneous and prospective gain-loss utility are experienced over news, the second and third terms in equation (3) are referred to as "news utility".

3.2 The Model's Predictions and Testable Hypotheses

After having introduced the preferences, we first describe the general model environment. Subsequently, we illustrate the news-utility agent's decision-making problem in the second-to-last period of the experiment in order to build intuition for the model's predictions.

[7]Koszegi and Rabin (2009) generalize the the state-wise definition to a percentile-wise comparison, because the agent would otherwise experience gain-loss disutility over priorly expected risk even if no update in information takes place. By explicitly noting the dependence of prior and new beliefs, the stated formulation circumvents this problem in a different way as prospective gain-loss utility is zero if prior and updated beliefs correspond exactly. While all comparisons are equivalent for contemporaneous gain-loss utility, the model's implications can be quantitatively slightly different for prospective gain-loss utility.

3.2.1 The model environment

We consider a simple partial-equilibrium model. The agent lives for $t = \{1, ..., T\}$ periods and is endowed with initial wealth W_1. Each period the agent optimally decides how much to consume C_t out of his wealth W_t and how to invest $W_t - C_t$. The agent has access to a risk-free investment with return R^f and a risky investment with i.i.d. return R_t. The risky investment's share is denoted by α_t such that the portfolio return in period t is given by $R_t^p = R^f + \alpha_{t-1}(R_t - R^f)$. Accordingly, the agent's maximization problem in each period t is given by

$$max_{C_t}\{u(C_t) + n(C_t, F_{C_t}^{t-1}) + \gamma \sum_{\tau=1}^{T-t} \beta^\tau \boldsymbol{n}(F_{C_{t+\tau}}^{t,t-1}) + E_t[\sum_{\tau=1}^{T-t} \beta^\tau U_{t+\tau}]\}. \quad (5)$$

subject to the budget constraint

$$W_t = (W_{t-1} - C_{t-1})R_t^p = (W_t - C_t)(R^f + \alpha_{t-1}(R_t - R^f)). \quad (6)$$

In the experiment, we set $T = 4$, $R_f = 1$, and R_t follows an i.i.d. process $F_R = \{R^l, R^h\}$ with equal probability to move up or down, respectively yielding a high gross return, R^h, or a low gross return, R^l.

3.2.2 The model's predictions

Now we take a closer look at the consumption and portfolio optimization problem in the second-to-last period of the experiment, period 3, in order to build intuition for the model's predictions.

Variation in the optimal consumption-wealth ratio. In order to build intuition for the model's first prediction, variation in the consumption share, we neglecting portfolio choice for now. In period 3, the agent allocates his wealth W_3 between contemporaneous consumption C_3 and future consumption C_4. In period 4, he will consume whatever is left $C_4 = W_4$. Taking as given the fully probabilistic beliefs about contemporaneous and future consumption he entered the period with, i.e., $F^2_{C_3}$ and $F^2_{C_4}$, the agent maximizes

$$u(C_3) + n(C_3, F^2_{C_3}) + \gamma\beta\boldsymbol{n}(F^{3,2}_{C_4}) + \beta E_3[u(C_4) + n(C_4, F^3_{C_4})].$$

We assume for now that the low and high outcome of the return realization are sufficiently different so that the agent's optimal consumption plan is characterized by a low and a high consumption level, which has to be verified. Thus, the agent's beliefs about consumption in period 3 are binomial $F^2_{C_3} = \{C^l_3, C^h_3\}$. Moreover, the agent's beliefs about period 4 consumption formed in period 3 are binomial $F^3_{C_4} = \{C^l_4, C^h_4\}$. In contrast, the agent's beliefs about period 4 consumption formed in period 2 have four possible outcomes with equal probabilities $F^2_{C_4} = \{C^{ll}_4, C^{lh}_4, C^{hl}_4, C^{hh}_4\}$. Suppose the low outcome realizes in period 3, in this setting the agent's maximization problem can be rewritten as

$$\begin{aligned} u(C^l_3) + \frac{1}{2}\eta\lambda(u(C^l_3) - u(C^h_3)) + \gamma\beta(\frac{1}{4}\eta\lambda(u(C^{ll}_4) - u(C^{hl}_4)) \\ + \frac{1}{4}\eta\lambda(u(C^{lh}_4) - u(C^{hh}_4)) + \beta(\frac{1}{2}u(C^{ll}_4) + \frac{1}{2}u(C^{lh}_4) + \frac{1}{4}\eta(\lambda - 1)(u(C^{ll}_4) - u(C^{lh}_4))). \quad (7) \end{aligned}$$

To gain intuition, we go through the derivation of it's first derivative with respect to consumption

$$\begin{aligned} u'(C^l_3)(1 + \frac{1}{2}\eta\lambda) = \gamma\beta(\frac{1}{4}\eta\lambda R^l u'(C^{ll}_4) + \frac{1}{4}\eta\lambda R^h u'(C^{lh}_4)) \\ + \beta(\frac{1}{2}R^l u'(C^{ll}_4) + \frac{1}{2}R^h u'(C^{lh}_4) + \frac{1}{4}\eta(\lambda - 1)(R^l u'(C^{ll}_4) - R^h u'(C^{lh}_4))). \quad (8) \end{aligned}$$

The two terms on the left hand in the agent's maximization problem (7) represent consumption utility and gain-loss utility over contemporaneous consumption in period 3. Whereas the first term on the right hand in equation (7) represents prospective gain-loss utility over future consumption C_4 experienced in period 3. The agent takes his beliefs, i.e., $F^2_{C_3}$ and $F^2_{C_4}$, as given in the optimization. As the realization of uncertainty has been low the agent experiences high marginal gain-loss utility about period 3 as well as period 4 consumption. As assumed consumption is increasing in the return realization so that $C^{ll}_4 < C^{lh}_4$ and $C^{hl}_4 < C^{hh}_4$. Therefore, the first and second part in equation (8) correspond to marginal contemporaneous consumption and gain-loss utility over period 3 and prospective gain-loss utility over period 4 consumption.

The last term in equation (7) represents consumption and gain-loss utility over period 4 consumption in period 4. Note that expected marginal gain-loss utility $\frac{1}{4}\eta(\lambda-1)(R^l u'(C_4^{ll})-R^h u'(C_4^{lh}))$ is positive if $\theta > 1$

$$\Psi_3^l = \beta(\frac{1}{2}R^l u'(C_4^{ll}) + \frac{1}{2}R^h u'(C_4^{lh}) + \frac{1}{4}\eta(\lambda - 1)(R^l u'(C_4^{ll}) - R^h u'(C_4^{lh})))$$
$$> \beta(\frac{1}{2}R^l u'(C_4^{ll}) + \frac{1}{2}R^h u'(C_4^{lh})) = \Phi_3^l.$$

Now the first-order condition for the low realization can be rewritten as

$$u'(C_3^l) = \frac{\Psi_3^l + \gamma\Phi_3^l \frac{1}{2}\eta\lambda}{1 + \frac{1}{2}\eta\lambda}.$$

And the first-order condition for the high realization analogously

$$u'(C_3^h) = \frac{\Psi_3^h + \gamma\Phi_3^h \frac{1}{2}\eta}{1 + \frac{1}{2}\eta}.$$

Whereas the standard agent's first-order condition is given by

$$u'(C_3^l) = \Phi_3^l \text{ and } u'(C_3^h) = \Phi_3^h.$$

In addition to $\Psi_3^l > \Phi_3^l$ and $\Psi_3^h > \Phi_3^h$ if $\theta > 1$ it holds that $\frac{\Psi_3^l}{\Phi_3^l} > \frac{\Psi_3^h}{\Phi_3^h}$ as $u(\cdot)$ is concave which implies that

$$\frac{\frac{\Psi_3^l}{\Phi_3^l} + \gamma\frac{1}{2}\eta\lambda}{1 + \frac{1}{2}\eta\lambda} > \frac{\frac{\Psi_3^h}{\Phi_3^h} + \gamma\frac{1}{2}\eta}{1 + \frac{1}{2}\eta} > 1$$

for γ high enough such that the news-utility agent consumes less than the standard agent if he does not discount prospective gain-loss utility very highly. There are two effects at work: If the agent discounts news about the future, i.e. $\gamma < 1$, he has an additional reason to consume more today, since positive news about contemporaneous consumption are overweighted compared to news about prospective consumption. On the other hand, the agent expects marginal gain-loss disutility in the future which could be buffered by less consumption today. The underlying intuition is that gain-loss disutility is proportional to consumption utility. Thus fluctuations are less painful on a less steep part of the utility function and the agent has an additional incentive to increase savings.

To clarify we take a look at the agent's normalized first-order condition. The first-order condition can be normalized by wealth, i.e., $\Phi_3^{l,h} = u'(W_3^{l,h} - C_3^{l,h})Q_3$ and $\Psi_3^{l,h} = u'(W_3^{l,h} - C_3^{l,h})\psi_3$, and thus rewritten in terms of the consumption-wealth ratio $\rho_3 = \frac{C_3}{W_3}$, such that

$$\rho_3^l = \frac{1}{1 + (\frac{\psi + \gamma Q_3 \frac{1}{2}\eta\lambda}{1 + \frac{1}{2}\eta\lambda})^{\frac{1}{\theta}}} > \rho_3^h = \frac{1}{1 + (\frac{\psi + \gamma Q_3 \frac{1}{2}\eta}{1 + \frac{1}{2}\eta})^{\frac{1}{\theta}}}.$$

Whereas the standard agent's consumption-wealth ratio is given by

$$\rho_3^s = \frac{1}{1 + Q_3^{\frac{1}{\theta}}} = \frac{1}{1 + (\psi_3^s)^{\frac{1}{\theta}}}$$

and the hyperbolic-discounting agent's consumption-wealth ratio is given by (taking γ as the quasi-hyperbolic discount factor usually denoted by β)

$$\rho_3^b = \frac{1}{1 + (\gamma Q_3)^{\frac{1}{\theta}}} = \frac{1}{1 + (\psi_3^b)^{\frac{1}{\theta}}}.$$

First, the news-utility agent's consumption-wealth ratio is lower if γ is high since $\psi_3 > Q_3$ for the same reason as above. Moreover, $\psi_3 > Q_3$ implies that the consumption-wealth ratio for the low realization is higher than for the high realization $\rho_3^l > \rho_3^h$ whereas it is constant in the standard and hyperbolic-discounting model. In the event of a bad shock the agent consumes relatively more out of his wealth. The underlying reasoning is very intuitive. If the agent encounters a bad shock then decreasing consumption below expectations today is more painful than decreasing consumption tomorrow when the reference point will have adjusted. If the agent encounters a good shock his marginal gain-loss utility today is relatively low in comparison to tomorrow when the reference point will have adjusted. Thus the agent finds it optimal to delay the consumption response to shocks. Putting it differently, the news-utility agent considers unexpected cuts in consumption as particularly painful. In the event of a bad shock the agent prefers to postpone cuts in consumption to let his reference point adjust. Moreover, positive shocks imply that contemporaneous gain-loss utility is low relative to future gain-loss utility since the agent's reference point will had adjusted in the future, which induces the agent to delay increases in consumption too. Thus the agent's consumption response to shocks is characterized by some degree of stickiness: The agent underreacts to shocks relative to the standard agent who adjusts consumption immediately. Therefore, the change in one-period ahead consumption ΔC_4 is predictable by the risky return realization determining ρ_3. If ρ_3 is low due to a negative shock the news-utility agent will consume relatively more out of his wealth and spreads the adjustment to his future. The following hypothesis summarizes the model's testable implication about consumption shares.

Hypothesis 1 *Variation in consumption shares*

$$\frac{d\frac{C_1}{W_1}}{dR_1} = \frac{d\rho_1}{dR_1} < 0, ..., \frac{d\rho_{T-1}}{dR_{T-1}} < 0.$$

Variation in the optimal portfolio share. Now we move on to additional portfolio choice. Suppose the low realization happens in period 3. Going back to the maximization problem (7) we derive the agent's first-order condition concerning α_3 as

$$\begin{aligned} 0 &= \gamma\beta(\frac{1}{4}\eta\lambda(R^l - R^f)u'(C_4^{ll}) + \frac{1}{4}\eta\lambda(R^h - R^f)u'(C_4^{lh}))+ \\ &+ \beta(\frac{1}{2}(R^l - R^f)u'(C_4^{ll}) + \frac{1}{2}(R^h - R^f)u'(C_4^{lh}) + \frac{1}{4}\eta(\lambda-1)((R^l - R^f)u'(C_4^{ll}) - (R^h - R^f)u'(C_4^{lh}))). \end{aligned} \tag{9}$$

The news-utility agent's first-order condition consists of two components. First, the optimal portfolio share affects the distribution of future consumption. Thus it shows up in prospective gain-loss experiences in period 3. Second, the agent's future indirect utility depends on the optimal portfolio share. In contrast, the standard and hyperbolic-discounting agent's first-order condition consists of the second aspect only and is given by

$$0 = \beta(\frac{1}{2}(R^l - R^f)u'(C_4^{ll}) + \frac{1}{2}(R^h - R^f)u'(C_4^{lh}))$$

which implies a constant portfolio share over time and states in an i.i.d. world. Now what are the implications of these differences? First, in comparison to the standard agent the last term in equation (9) contains future consumption as well as expected gain-loss disutility. Since the news-utility agent considers fluctuations in consumption as much more painful, he will optimally pick a lower portfolio share than the standard agent. Second, the news-utility agent experiences prospective gain-loss utility which depends on the distribution of period 4 consumption affected by the choice of α_3. Marginal gain-loss utility is either high, $\frac{1}{2}\eta\lambda$, in the event of a bad realization or low, $\frac{1}{2}\eta$, in the event of the good realization. Thus, the return realization affects today the optimal portfolio share. The agent experiences gain-loss feelings about the entire future stream of consumption. Thus, bad states of the world are particularly painful since plenty of adverse gain-loss feelings about the future have to be realized. Since the agent resides on a very low risk path in comparison to the standard agent, he can bear some additional volatility in his consumption prospects and thus finds it optimal to increase the portfolio share in these states. Thereby shifting the updated beliefs distribution to the right and closer to the original one which reduces gain-loss feelings. Thus, the agent chooses to increase the portfolio share in bad states in order to not encounter all of the loss feelings. The benefit of increasing the expected return to not realize as much loss feelings about the future outweighs the increase in volatility of future consumption.[8] The testable implication is summarized in the following hypothesis.

Hypothesis 2 *Variation in portfolio shares*

$$\frac{d\alpha_1}{dR_1} < 0, ..., \frac{d\alpha_{T-1}}{dR_{T-1}} < 0.$$

[8]In other words, the agent does not want to realize all the loss feelings associated with the bad return realization and thus holds on to the risky asset in absolute terms. The agent is "reluctant to realize the loss" and the psychological reasoning reminds us of the disposition effect. Furthermore, Barberis and Xiong (2009, pp. 751 f.) describe the disposition effect as follows: "Individual investors have a greater propensity to sell stocks trading at a paper gain rather than those trading at a paper loss." To some extent the optimal portfolio share reflects the agent's propensity to sell or probability to hold. Moreover, Barberis and Xiong (ming, pp. 2 f.) describe the implications of realization utility as follows: "A highly volatile stock offers the chance of a large gain which the investor can enjoy realizing. [...] historical highs will have a sharp effect on individual investors' propensity to sell." Again the underlying reasoning reminds us of the psychological mechanism driving variation in the optimal portfolio share in this model.

Moreover, the preferences predict that the portfolio share is decreasing in the agent's horizon. This is not the case for the standard model in which the optimal portfolio share is constant in the agent's horizon, as both the marginal benefit and the marginal cost of the risky investment increase linearly in the horizon. This result is difficult to show in the two-outcome model. The basic intuition is that the mean and variance of the news-utility agent's investment increases linearly in his horizon, whereas the expected loss is proportional to the investment's standard deviation rather than it's variance, thus the marginal cost increases with the square root in the horizon. Accordingly, the optimal risky investment increases with the news-utility agent's horizon.

Hypothesis 3 *Decreasing portfolio shares*

$$\alpha_1 >, ..., > \alpha_{T-1}.$$

Comparison to the optimal pre-committed path. In the following, we contrast the equilibrium we just described with the optimal pre-committed equilibrium that maximizes utility. In summary, the agent overconsumes and overinvests relative to the pre-committed equilibrium as stated in Hypotheses 4 and 6 and the variation in consumption and portfolio shares is more pronounced in the pre-committed equilibrium as stated in Hypotheses 5 and 7. We know explain the derivation of the pre-committed equilibrium in greater detail.

As can be seen easily from the simplified model, discounting prospective gain-loss utility more highly, i.e., decreasing γ, unambiguously shifts the consumption-wealth ratio and the portfolio share up. However, the standard model does not provide a meaningful benchmark to analyze present bias induced by news utility any more since experienced news utility has to be taken into account. Instead one needs to look at the expected-utility-maximizing consumption path the agent would like to pre-commit to. It turns out that news-utility introduce a conceptual taste for immediate consumption even if $\gamma = 1$, which we call beliefs-based present bias: Each period the agent wakes up and optimizes taking his beliefs as given. However, expected utility is higher on an optimal pre-committed consumption path, in which the agent simultaneously optimizes over consumption and beliefs in his investment and consumption choice in some period zero in which he does not experience gain-loss utility. Lacking an appropriate commitment device, however, the pre-committed path is not feasible, since the agent would deviate once he wakes up taking his beliefs as given. Thus the preferred personal equilibrium requires the agent to pick an overconsumption equilibrium path, relative to the pre-committed one.

Suppose there exists some period zero in which the agent does not experience gain-loss utility. How much consumption in period $T-1$ would he pre-commit to consume, C_3^c, for each realization of R_3? When choosing optimal pre-committed consumption, marginal utility is not only made up of the sensation of increasing consumption in that state any more but augmented by an additional term that captures the anticipated loss feelings of increasing consumption in other states. For instance, if the bad realization happens, marginal contemporaneous gain-loss utility under pre-commitment is given by $u'(C_3^l)\frac{1}{2}\eta\lambda - u'(C_3^l)\frac{1}{2}\eta$.[9] Therefore, while under non-pre-commitment marginal gain-loss utility is given by $u'(C_3^l)\frac{1}{2}\eta\lambda$, the term $-u'(C_3^l)\frac{1}{2}\eta$ is added under pre-commitment. In this latter term, the agent considers the fact that in the other state of the world (where $R_t = R^h$), he experiences less gain feelings and more loss feelings due to increasing consumption in that contingency. Marginal gain-loss utility is then given by $u'(C_3^l)\eta\frac{1}{2}(\lambda-1)$ for the bad realization and $-u'(C_3^h)\frac{1}{2}\eta(\lambda-1)$ for the good realization respectively and this constitutes the single difference in the first-order condition for optimal consumption and portfolio choice. As can be seen, marginal pre-committed gain-loss utility is generally lower and thus the pre-committed agent consumes generally less and invests less in the risky asset. Moreover, pre-committed marginal utility will be increased by news utility only if the realization is below the median, i.e., the low realization in our binomial setting. For the good realization marginal utility will be decreased. In contrast, on the non-pre-committed path, marginal gain-loss utility is inbetween $\{\frac{1}{2}\eta, \frac{1}{2}\eta\lambda\}$ and thus always positive, since the agent likes the sensation of increasing consumption and risk exposure to increase future consumption in any state. Thus, in good states the conceptual problem of beliefs-based present-bias kicks in more powerfully: Pre-committed marginal gain-loss utility is negative which never happens on the non-pre-committed path. Therefore, the degree of present bias in consumption and risk is reference-dependent and increasing in good states. Again there is a notion of stickiness in consumption and portfolio choice arising in the model. These considerations

[9] Differentiate contemporaneous gain-loss utility, $\frac{1}{2}\eta\lambda(u(C_3^l) - u(C_3^h)) + \frac{1}{2}\eta(u(C_3^h) - u(C_3^l))$, with respect to C_3^l; in the non-pre-committed case the second term containing C_3^l are the agent's beliefs that are taken as given and not optimized over.

yield the following testable hypotheses.

Hypothesis 4 *Pre-committed versus non-pre-committed consumption shares*

$$\frac{C_1^c}{W_1^c} = \rho_1^c < \rho_1, ..., \rho_{T-1}^c < \rho_{T-1}.$$

Hypothesis 5 *Variation in pre-committed versus non-pre-committed consumption shares*

$$\frac{d\rho_1^c}{dR_1} < \frac{d\rho_1}{dR_1}, ..., \frac{d\rho_{T-1}^c}{dR_{T-1}} < \frac{d\rho_{T-1}}{dR_{T-1}}$$

$$\Leftrightarrow \frac{d(\rho_1 - \rho_1^c)}{dR_1} > 0, ..., \frac{d(\rho_{T-1} - \rho_{T-1}^c)}{dR_1} > 0.$$

Hypothesis 6 *Pre-committed versus non-pre-committed portfolio shares*

$$\alpha_1^c < \alpha_1, ..., \alpha_{T-1}^c < \alpha_{T-1}.$$

Hypothesis 7 *Variation in pre-committed versus non-pre-committed portfolio shares*

$$\frac{d\alpha_1^c}{dR_1} < \frac{d\alpha_1}{dR_1}, ..., \frac{d\alpha_{T-1}^c}{dR_{T-1}} < \frac{d\alpha_{T-1}}{dR_{T-1}}$$

$$\Leftrightarrow \frac{d(\alpha_1 - \alpha_1^c)}{dR_1} > 0, ..., \frac{d(\alpha_{T-1} - \alpha_{T-1}^c)}{dR_1} > 0.$$

In contrast, the standard agent's optimal pre-committed consumption path corresponds to his actual one. The hyperbolic-discounting optimal pre-committed consumption path corresponds to the standard agent's path. Thus, his optimal pre-committed and actual consumption paths differ by a constant, as consumption shares and portfolio shares for the standard and hyperbolic-discounting agent do not depend on the return realization.

4 Experiment

In the following, we first discuss our design choices and motivate the use of internet as a proxy for real on-the-spot consumption. Subsequently, we present the actual experiment.

4.1 Design Details

Consumption. Life-cycle models focus on the maximization of utility over consumption instead of wealth. However, consumption is generally proxied via monetary payoffs in experimental studies. Monetary incentives are inappropriate to infer intertemporal consumption choice. Standard payment procedures do not have an intertemporal structure. Monetary earnings are either accumulated over all rounds or one round is determined randomly for payment. Both these procedures pay off at the very end of the experiment. Hence, there is no actual intertemporal structure in decision consequences. Bad decisions can be hedged by good decisions in later rounds without intermediate regret. Money is consumable only at the end of an experiment. We therefore decided to simulate real consumption by an actually consumable good. In addition, we wanted consumption to be on-the-spot, i.e., in the actual period for which a decision applies.

Specifically, we proxy consumption as follows. Subjects earn a fixed payment and have to choose how to spend the time in the lab: either perform a monotone clicking task or surf the internet instead. The clicking task is designed to actively bore subjects and to render the alternative activity (internet) more pleasurable. For the clicking task, we ask the subjects to confirm pop-up windows that appear randomly (approx. every 90 seconds) at random positions on their computer screen. When and where a window appears is independent across subjects. On appearance, subjects have ten seconds to click on a button to close the pop-up. If a subject does not close the pop-up, it will disappear automatically creating convex costs for this subject. This is an essentially unattractive task which is supposed to create no excitement at all.[10] The random appearance (both time and location) ensures that subjects focus on the computer screen during the whole experiment. The clicking task is thus basically a pure disciplining mechanism. Without this task, subjects could just decide to take the otherwise fixed payoff and do nothing (e.g., sleep).[11]

Investment. Subjects were endowed with an initial wealth of an experimental currency simply named "points". They decide each period how much experimental wealth to consume in that period or to save for consumption in future periods. Subjects can save wealth by storing it safely

[10] Comments in the post-experimental questionnaire confirm that subjects perceived this task as extremely unchallenging and boring.

[11] Hence, the clicking task enforces that subjects in a sense actively do nothing.

or investing it in a risky lottery. The risk-free rate is zero and the lottery is binary with equal probability to either triple the invested points, $R_t = 3$, or half them, $R_t = 0.5$.[12]

Closed life-cycle design. All remaining wealth is automatically transformed into internet time in the very last period. This is done because subjects hold an ex-ante payoff target when participating in an experiment. This may serve as a reference point from the mere participation in the experiment and run against the expectations formed within the experiment. An unfavorable return realization may influence subjects' subsequent investment choices just to meet this exogenous reference point. This would confound our results. Hence, we have to ensure that the expectations which influence subjects' decisions are formed within the experiment. That is, we have to control subjects' expectations regarding the experiment itself and the monetary payments, respectively. We do so by disentangling monetary payments from the consumption decisions. The instructions made very clear that points used for consumption were of no use outside the lab. In particular, it was pointed out explicitly that points could not be transformed into money.

Induced concavity. In line with the model, we require a certain concavity of the utility function to induce a preference for consumption smoothing. We induce concavity because the actual preferences for internet are unknown to us. However, we argue that actual utility, $u(.)$, over internet is non-convex, i.e., at least linear or even concave. If actual utility over internet time is concave, the transformation function (10) amplifies the desire for smoothing via $u \circ f(.)$. This implies that the concavity restriction is even less binding. We induce this preference via a concave transformation function of the CRRA type with an RRA > 1. Points were transformed into internet time according to

$$\text{Internet Time (Sec.)} = f(\text{Points}) = 2400 - 2400/\text{Points}^{0.1} \tag{10}$$

which corresponds to a coefficient of RRA of $\theta = 1.1$. Inducing concavity is standard in the literature on dynamic consumption experiments (Ballinger et al. 2003;Brown et al. 2009).[13]

[12]A non-testable implication of KR preferences is the low investment share compared to the standard agent. During the pre-tests we found some hesitation to invest in the lottery and therefore chose this high variance while on the other hand keep it simple by using integers as gross returns.

[13]Note, that the related experiments of Ballinger et al. (2003) and Brown et al. (2009) use RRA $= 3$. However, in our experiment, a too concave utility function would result in too less variation in outcomes, i.e., seconds to spend

Moreover, the model assumes consumption utility to have the same form in every period, i.e., marginal consumption utility stays the same for the same level of consumption. Since we do not observe $u(.)$, it is possible that subjects apply a kind of super-utility function over the entire experiment. Hence, actual marginal consumption utility may be higher in earlier rounds than in later rounds. We cannot control for this but we will present the results of a hypothetical willingness-to-pay (WTP) elicitation in the next section. We argue that over the short time interval of each period, internet is always more pleasurable than the clicking task. At least, subjects do not risk losing money while surfing the web as the clicking task is deactivated during that time.

4.2 Overview

The experiment consists of two parts. In the first part subjects have to complete the clicking task for ten minutes. This serves to familiarize them with the task and eliminate choices out of curiosity in the second part.

The second part consists of two stages: The "pre-commitment" stage and the "allocation-and-consumption" stage. In each stage, subjects have to make decisions for a total of four rounds of which each is 19 minutes long.[14]

In the initial pre-commitment stage, subject have to fill out a conditional consumption plan for every possible contingency similar to the strategy method for static decision problems. We present a horizontal decision tree in which subjects have to enter all choices conditional on the realization from the lottery, i.e., the risky asset. We framed this decision tree neutrally as "point manager". After the point manager was filled out and saved, it is decided via a die roll whether a subject is bound to the decisions made therein.

The subsequent allocation-and-consumption stage consists of four consecutive rounds. At the beginning of each round, NPC subjects have to allocate their initial wealth again for that specific period. For the PC subjects, the computer displays the conditional choice taken from their point manager. As in the point manager, the computer transforms all remaining points into internet

online.

[14]We chose this length such that subjects had a real incentive to fill out the point manager as it may be binding for 4 x 19 = 76 minutes. In addition, our pre-tests showed that, given 20 minutes, most subjects had the 10 minutes mark as a focal point for their decisions. Thus, we wanted to make this "half time" less salient.

Figure 1: Decision Box

Decision Box used under both pre-commitment and non-pre-commitment. The first line displays current wealth, W_t. The first scrollbar determines the points allocated to consumption ("transform"), C_t. The second scrollbar determines points allocated to the risky asset ("invest"), I_t. The remainder is automatically stored safely ("stored"). The last panel automatically calculates the resulting internet time resulting from the transformed points according to (10).

time for the NPC subjects in round 4. The two stages are explained in more detail below.

4.2.1 The Pre-Commitment Stage

The point manager displays all four rounds and all possible trajectories resulting from the lottery outcome (for screenshot see appendix A.1). Choices during the experiment were input to so called "decision boxes" (Figure 1). The binary lottery yields two possible paths in round 2: up (U) or down (D). In round 3 there are four possible trajectories: (1, U, UU); (1, U, UD); (1, D, DU); and (1, D, DD) where UU denotes "up up", UD denotes "up down" etc.[15] Hence, subjects have to fill out seven decision boxes in total as period 4 involves no choice.

In the very first round, subjects are endowed with an initial wealth of 110 points. Subject have to choose via scrollbars how many points to consume ("transform") and how many to invest. The remaining points are automatically saved ("stored") and the resulting internet time is automatically calculated and displayed according to (10). No initial values were displayed to avoid framing.

[15] In the following we abbreviate trajectories by their round-3 value, e.g., UD denotes the trajectory (1, U, UD) starting in round 1, going "up" in round 2 ($R_2 = 3$) and "down" in round 3 ($R_3 = 0.5$).

All points are rounded up to integer values. Internet time is rounded up to full seconds. Subjects are free to use the built-in computer calculator that is accessible via a button in all decision screens throughout the entire experiment.

The point manager also updates the wealth at subsequent nodes depending on the investment decision. If subjects change a decision in an early decision box, the point manager resets wealth and internet time at later branches to underline the dynamic structure of the decision problem and to prevent unintended changes at later nodes. The functionality was made clear in the instructions.

At the end of the pre-commitment stage, after the point manager was filled out and saved, we roll a die for each individual to determine whether the plan is binding for the entire allocation-and-consumption stage. If a one comes up, the subject is bound to his or her plan, i.e., pre-commited (PC). If a number between two and six comes up, the subject is not bound to his or her plan, i.e., non-pre-commited (NPC).

4.2.2 The Allocation-and-Consumption Stage

In the first round, NPC subjects are again endowed with 110 points as if the pre-commitment stage has not existed. PC subjects are displayed their decision box for round one from their point manager. At the beginning of a subsequent round, subjects are reminded of their previous-round allocation and the possible (two) consequences from that decision. Then we determine the investment outcome for each subject individually via a die roll. Subsequently, NPC subjects have to allocate their updated wealth while PC subjects were informed which decision node they now have reached. In addition, PC subjects are displayed the according decision box from their point manager.

After an NPC (PC) subject made (confirmed) his or her choice, a web browser opened in full screen.[16]

The browser shows six exemplary websites as tiles. This serves to signal the subjects that they are not restricted in what to do online.[17] After the current-period time was "consumed", the browser closes automatically and the experiment screen is shown in full screen again. Subsequently,

[16]"Minimize", "Maximize" and "Close" buttons were removed as were tabbing and certain other short keys. In addition, we displayed a timer next to the address bar of the browser.

[17]The instructions made clear that we were neither tracking their online behavior nor saving passwords etc.

the clicking task continues for the remaining time of that round. After the 19 minutes passed, a notification tells the subjects to wait for the start of the next round and for an experimenter to realize their individual investment outcome.

4.3 Procedural Details

The experiment was run at the Cologne Laboratory for Economic Research (CLER), University of Cologne, Germany. Subjects were recruited via the online recruitment system ORSEE (Greiner, 2004). Subjects could sign up on a first-come-first-serve basis. In total, 55 subjects from all faculties participated. Neither content nor expected payments were stated in the invitation e-mail. Decisions were inputs to a interface computerized via Z-Tree (Fischbacher, 2007). We conducted six sessions at the end October 2012. Each session lasted for around 2 hours and 55 minutes including payment.

Upon entering the lab, subjects draw a number from an urn determining their computer booth. A set of general instructions was already placed in each booth (**Appendix A.XX**). Subject had to deposit their personal belongings (backpacks etc.) into another vacant computer booth behind them. It was not possible for subjects to see each other's computer screens. Each booth was equipped with an air-cushion envelope. Subjects had to put their mobile phones and other electronic devices (mp3 players etc.) into this envelope which was then sealed by an experimenter.[18] In addition, each computer booth was equipped with a pair of headphones.

Subsequently, subjects were informed that the experiment consisted of two parts and received the instructions for part 1 (**appendix A.X**). Subjects then received the instructions for part 2 (**appendix A.Y**). At all stages of the experiment, subjects were allowed as much time as they needed to familiarize themselves with the procedure of the experiment, to ask questions, and make their choices. After all questions were answered in private, subjects had to answer some control questions (**appendix A.Z**). Subsequently, part two started with the pre-commitment stage followed by the allocation-and-consumption stage. In total ten subjects were bound to their decisions stated in their point manager. After the last round of the allocation-and-consumption

[18]This ensured that subjects had no way to substitute the provided internet during the experiment.

stage was finished, subject had to answer a questionnaire. Subjects were paid off in private. Payoffs consisted of 30 EUR from which the total costs accumulated from the clicking task were deducted. In addition, subjects received a show-up fee of 2.50 EUR. All subjects earned 32.50 EUR (approx. 42 USD), i.e., no subject missed a single pop-up.

5 Empirical Analysis

We begin with a more detailed description of the data set. Subsequently, we present the results in the order in which subjects made their decisions. First, we analyze PC choices and present evidence regarding hypotheses 5 and 7, i.e., consumption and portfolio shares decrease in the investment return under PC. Second, we evaluate NPC allocations and assess hypotheses 1, 2 (reaction to investment outcome under NPC) and hypothesis 3 (decreasing NPC investment shares over time). Third, we compare PC and NPC choices and assess differences in commitment status as stated in hypotheses 4 and 6, i.e., overconsumption and overinvestment under PC relative to NPC.

5.1 Data and Descriptives

In total, 55 subjects participated in the experiment. We drop one PC observation due to erroneous handling of the software by that subject.[19] This gives us 54 PC subjects with seven choices each yielding a total of 378 PC choices. Out of these 54 subjects, 45 were not pre-commited to their initial plan. These NPC subjects faced only one (realized) trajectory yielding three observed choices per subjects under this condition. However, one NPC subject consumed all her remaining wealth in the second period. This gives us 134 NPC choices in total of which 89 are in reaction to realized investment outcomes (rounds two and three). Hence, for the NPC choices, we have a micro-panel data set with a large cross-sectional dimension (large N) and few time periods (small T).

[19] This subject set all sliders in the point manager to zero before filling it out. However, after filling out the UU trajectory, the subject forgot to fill out the remaining four decision boxes (D, UD, DU, DD) before saving the point manager. Though, the subject pointed out this mistake and explained the intended strategy to us, we drop the according data. However, the subject remained in the experiment and was also paid in order not to disturb the other subjects.

Table 1: Demographics of Subjects.

Variable (N = 54)	Mean	Std. Dev.
Men	0.48	0.50
Age	25.19	4.05
German Native	0.94	0.23

Table 1 reports summary statistics on subjects' characteristics. Subjects consisted of 26 (48%) men, were on average 25.19 years old, and virtually the whole sample indicated German as their first language. Subjects were enrolled in all faculties with a majority of 23 (43%) from management, economics and social sciences.[20] Most subjects were undergraduates.[21]

The post-experimental questionnaire asked demographics and other individual characteristics (age, sex, faculty, native language, etc.) as well as a willingness to pay (WTP) for internet time in another (hypothetical) round of experimentation. Figure B.1 in the appendix presents an aggregated demand curve for internet time derived from the hypothetical WTP elicitation. As expected, WTP is significantly increasing in internet time. We find no indication for a non-linear relationship.[22] This indicates that $u(.)$ is linear with constant marginal utility. Note that the questionnaire was asked after three hours of experimentation and thus marginal utility could have been different at the beginning of the experiment. However, we see this as a justification of our design choice to induce concavity via (10).

Regarding the the realization of shocks, we find no significant difference in round 2 lottery outcomes between men and women (Fisher's exact test, $p = 0.785$). Women highly significantly got better returns in round 3 (fisher's exact, $p = 0.002$). This results in a highly significant difference in DU and DD trajectories between male and female subjects. We therefore control for sex in later analyzes.

[20] In addition, 12 subjects came from mathematics and natural sciences, 13 from philosophy, two from humanities, three from medicine, and one indicated no affiliation.

[21] The average number of semesters enrolled was 6.79 (Std. Dev. of 5.16, Min=1, Max=31) with 30 subjects pursuing a Bachelor's Degree, 17 a Master's (or equivalent), and seven a doctor's degree.

[22] By OLS regression, we find no significant influence of higher-order terms such as minutes^2 or minutes^3. This is supported by graphical inspection by plotting WTP over minutes and adding a lowess smoother. See the appendix for details.

5.2 Pre-Committed Choices

In Table 2, we present summary statistics for the two choice variables: consumption share, ρ^{PC}, and portfolio share, α^{PC}. In addition, the table shows the correlation of the choice variables with the (expected) realization of the risky asset, $Shock_t$, which is a dummy variable taking "1" in case of a good shock ($R_t = 3$) or "0" in case of a bad shock ($R_t = 0.5$). We see that subjects overall allocate roughly a third of their current wealth on consumption while investing around 43% of the remaining wealth in the risky asset. The range and standard deviation shows very heterogeneous choices among subjects. This is especially true for the portfolio share. With the exception of choices made for round 2, the correlation has the hypothesized sign. Figure B.2 displays the distribution of internet time per trajectory corresponding to the PC consumption choices.

Table 2: Pre-Commitment Consumption and Portfolio Choices per Trajectory.

	N = 54	Consumption Share ρ^{PC}			Portfolio Share α^{PC}		
t	Trajectory	Mean	Std. Dev.	Corr(ρ^{PC},$Shock_t$)	Mean	Std. Dev.	Corr(α^{PC},$Shock_t$)
	All	0.350	0.114		0.425	0.223	
1	**1**	0.207	0.113		0.348	0.277	
2	**U**	0.300	0.148	0.0122	0.392	0.264	-0.002
	D	0.297	0.130		0.393	0.308	
3	**UU**	0.409	0.192	-0.059	0.453	0.307	-0.043
	UD	0.374	0.166		0.479	0.314	
3	**DU**	0.448	0.187	-0.051	0.434	0.332	-0.059
	DD	0.414	0.170		0.477	0.388	

Means and standard deviations of choice variables by Trajectory. The consumption wealth ratio is defined as $\rho_t := C_t/W_t$ where C_t is current absolute consumption and W_t is current wealth. The portfolio share is the proportion of remaining wealth invested into the risky asset, i.e., $\alpha_t := I_t/(W_t - C_t)$ where I_t is current absolute investment. $Shock_t$ is a dummy taking 1 for $R_t = 3$ and 0 for $R_t = 0.5$. N is the number of subjects.

We utilize random-effects regression methods in analyzing the two choice variables to account for within-subjects correlation. Primarily, we relate consumption and portfolio choices to the (potential) investment outcome, $Shock_t$. Hence, we effectively use the data from decision made for round 2 and 3 as subjects' decision for round 1 is their initial risk exposure which is not subject to potential shocks. As further covariates, we include, among others, a gender dummy Sex (1 indicates men), and the dummy $Round3$ taking "1" if the round is 3 and "0" if the round is 2. We control for time of day by the dummy $A.M.$ taking "1" in case that the session has been conducted in the morning and "0" if it has been conducted in the afternoon. This covariate could be potentially important as subjects may have different marginal utility for internet in the morning where it is likely that they had not previously consumed much internet compared to afternoon sessions.

[Insert Table 5 about here]

Table 5 reports the results of a random-effects regression of the PC choice variables on the return and other controls. While the effect of a bad return realization is not significant for the portfolio share, it is weakly significant for the consumption share but it actually goes in the opposite direction. This indicates that subjects plan to consume more after a good return realization. We can thus not reject the standard theory in favor of hypotheses 5 and 7. In addition, in decisions made for round 3, subjects increase both consumption and investment shares. For the consumption share, this is standard in life-cycle problems since subjects have to consume everything in the last round. For the portfolio share this leads us reject the standard theory predicting constant portfolio shares.

Using paired comparisons of trajectories, we find no significant difference in consumption or portfolio shares in the direction predicted by our behavioral theory (within-subject comparison of shares per round by trajectory: H1: U $<$ D, UU $<$ UD, and DU $<$ DD; two-sided paired t-test). Hence, we cannot reject the standard theory under pre-commitment. However, we note a highly significant difference in consumption shares between UD and DU trajectories (two-sided paired t-test, $p < 0.002$). This is surprising since the decision problem features a recombining decision tree as shocks are i.i.d. The point manager just does not recombine the trajectories UD and DU graphically. This gives some evidence against standard theory which considers both paths as identical.

As Figure B.3 in the appendix shows, portfolio choices cluster on the boundaries primarily on the lower trajectories DU and DD.[23] We therefore apply a random-effects two-censored tobit regression (see table 6 in the appendix). The results do not change qualitatively.

[23] Only two subjects chose a consumption wealth ratio of zero while only one subject chose a consumption wealth ration of 1 in the PC stage. Note that the latter is not the subject that consumed all her wealth in round 2 of the NPC stage.

5.3 Non-Pre-Committed Choices

We begin by reporting the correlation between consumption and portfolio shares with the investment return by round in table 3. As under PC, we see that the correlation between consumption and investment outcome is diametrical as hypothesized. The correlation with the portfolio share has the hypothesized sign.

Table 3: Correlation of NPC Consumption and Portfolio Choices with Realized Investment Outcomes.

			Consumption Share ρ^{NPC}			Portfolio Share α^{NPC}		
t	Trajectory	N	Mean	Std. Dev.	Corr(ρ^{NPC},$Shock_t$)	Mean	Std. Dev.	Corr(α^{NPC},$Shock_t$)
	All		0.290	0.168		0.399	0.280	
1	**1**	45	0.213	0.135		0.338	0.254	
2	**U**	20	0.282	0.201	0.061	0.304	0.200	-0.187
	D	25	0.261	0.162		0.397	0.277	
3	**UU**	9	0.339	0.170	-0.109	0.445	0.320	0.002
	UD	10	0.369	0.110		0.444	0.351	
3	**DU**	15	0.454	0.151	0.369	0.496	0.256	-0.231
	DD	10	0.351	0.095		0.633	0.345	

Means and standard deviations of choice variables by Trajectory. The consumption wealth ratio is defined as $\rho_t := C_t/W_t$ where C_t is current absolute consumption and W_t is current wealth. The portfolio share is the proportion of remaining wealth invested into the risky asset, i.e., $\alpha_t := I_t/(W_t - C_t)$ where I_t is current absolute investment. $Shock_t$ is a dummy taking 1 for $R_t = 3$ and 0 for $R_t = 0.5$. N is the number of subjects. Note that one subject consumed everything in round 2.

Corresponding to figure B.2, figure B.4 displays the respective distribution of internet time per trajectory corresponding to the actual NPC consumption choices.

Tables 7 and 8 show regression results for consumption and portfolio choice, respectively. We find a strong indication for inertia and control for this by including lagged dependent variables in the regressions. However, random or fixed-effects models may not be valid by including lagged dependent variables as this generally induces correlation with the error term and violates the strict exogeneity assumption underlying these models.[24] In addition, fixed effects would cancel out observations on the extreme trajectories UU and DD where there is no variation in shocks within subjects. Another justification to include lagged portfolio choices comes from recent empirical

[24] Random effects may still be valid if all other covariates are strictly exogenous (Ashley, 2010).

studies on microlevel data providing additional support for a high level of inertia in financial decision making, i.e., infrequent portfolio rebalancing (Brunnermeier and Nagel, 2008; Calvet et al., 2009b,a). As we effectively have just a two-period panel, we primarily focus on OLS estimates with standard errors clustered by subjects and control for time by *Round*3.

[Insert Table 7 about here]

We again find no significant impact of demographic factors such as age or sex on the level of shares in the population average. As with PC choices, NPC choices are significantly increasing over time. We find no indication that time of day matters, i.e., whether the session has been conducted in the morning or in the afternoon. We find a highly significant impact of previous-period choices and therewith inertia in both consumption and portfolio shares. Regarding the consumption share, this significant increase over time is expected in life-cycle models. Regarding the portfolio share, the higher the portfolio choice in the last period, α_{t-1}, the more remaining wealth is allocated to the risky asset in the current period, α_t, indicating strong inertia.

[Insert Table 8 about here]

Focusing on our main research question, we find that the reaction to shocks is different for consumption and portfolio shares. We find no evidence regarding hypothesis 1 that consumption shares vary systematically in shocks. On the other hand, portfolio shares depend on the shock (hypothesis 2). While the shock itself has no significant direct impact on current-period portfolio shares, we see that it interacts highly significantly with previous-period portfolio choices ($Shock_t \times \alpha_{t-1}$). The higher the magnitude of the shock the stronger the reduction in portfolio shares. Highly invested individuals are affected more strongly from the investment outcome. For each percentage point of investment in round 2, a_2, subjects with positive returns ($Shock = 1$) invest on average 0.603 percentage points less in round 3 than subjects with a bad investment outcome ($Shock = 0$). On the contrary, the magnitude of the round-three shock, $\alpha_2 \times Shock_3$, does not significantly affect round-three consumption decisions.

Our experiment does not allow to borrow cash or to go short in the lottery, i.e., the portfolio share is restricted to lie in the unit interval. Therefore, we estimate two-censored Tobit regressions to control for possible portfolio allocations outside these boundaries. Table 9 in the appendix presents the results of these estimations. The coefficients are comparable to those obtained by OLS regression. The coefficient of $a_2 \times Shock_3$ is strongly increased. For each percentage point invested in round 2, subjects invest nearly a whole percentage point less in round 3 given a positive investment outcome.[25] Separate regressions by sex reveal that this effect is mainly driven by male participants.[26]

Regarding hypothesis 3 (decreasing portfolio shares over time), we find that subjects actually increase their risk exposure in round 3 compared to round 2. This rejects the predictions of all alternative theories we discuss.In the following, we compare NPC choices with their PC counterparts.

5.4 Differences in Commitment

We observe pre-committed choices by each subject conditional on all possible trajectories. However, we only observe one actually realized trajectory under non-pre-commitment. Hence, for each subject we match the NPC trajectory with the according PC choice conditional on that specific trajectory. In other words, we match the actual NPC choices with those PC choices that would have applied in the actual trajectory if the subject had been pre-committed. We then subtract PC from NPC choices and regress this difference, $\Delta^{com}\alpha = \alpha^{NPC} - \alpha^{PC}$ and $\Delta^{com}\rho = \rho^{NPC} - \rho^{PC}$, respectively, on the investment outcome, $Shock$, and subject-specific demographics. Table 4 reports the correlation between differences in commitment and the realized investment outcome.

There is no clear effect and the regression analysis confirm this impression. Table 10 in the appendix shows that there is no systematic difference between choices under pre-commitment and those that were non-pre-committed. Even in the third round where it is likely that subjects have forgotten their choices stated in the point manager, we find no indication for our behavioral predictions. We find no significant difference in commitment depending on the investment outcome. Table 10 shows that there is no significant divergence between NPC and PC choices depending on the shock.

[25] We do not estimate a Tobit regression for the consumption share as the inference would be misleading. Negative consumption does not make sense in our setting while subjects consuming their entire wealth would, of course, consume more if possible.

[26] However, keep in mind that the sample size is severely reduced in separate regressions.

Table 4: Correlation of Differences in Commitment with Realized Investment Outcomes.

			Consumption Difference $\Delta\rho$			Portfolio Difference $\Delta\alpha$		
t	Trajectory	N	Mean	Std. Dev.	Corr($\Delta\rho$,$Shock_t$)	Mean	Std. Dev.	Corr($\Delta\alpha$,$Shock_t$)
	All		-0.012			0.017	0.231	
1	**1**	45	0.004	0.397		0.012	0.164	
2	**U**	20	0.021	0.110	0.250	-0.013	0.202	-0.013
	D	25	-0.044	0.140		-0.008	0.154	
3	**UU**	9	-0.056	0.126	-0.274	-0.012	0.252	-0.090
	UD	10	0.007	0.111		0.038	0.327	
3	**DU**	15	-0.084	0.286	-0.292	0.125	0.445	0.168
	DD	10	0.057	0.125		0.007	0.104	

Correlation of differences in commitment with realized investment outcomes by round. The consumption wealth ratio is defined as $\rho_t := C_t/W_t$ where C_t is current absolute consumption and W_t is current wealth. The portfolio share is the proportion of remaining wealth invested into the risky asset, i.e., $\alpha_t := I_t/(W_t - C_t)$ where I_t is current absolute investment. $Shock_t$ is a dummy taking 1 for $R_t = 3$ and 0 for $R_t = 0.5$. $\Delta^{com}\rho = \rho^{NPC} - \rho^{PC}$ is the difference in commitment for consumption. $\Delta^{com}\alpha$ is analogously defined and represents the difference in commitment for the portfolio choice. N is the number of subjects. Note that one subject consumed everything in round 2.

6 Discussion

6.1 The Role of Shocks

We find no significant anticipation of gain-loss feelings in the pre-commitment stage. Subjects actually plan to consume more after good shocks but choose the same portfolio allocation no matter the possible investment outcome. The only exception is the significant difference of UD and DU path which a standard agent would consider identical due to the i.i.d. nature of shocks. This non-anticipation of adverse emotions can have several reasons. On possible explanation is that subjects could face a psychological cost of systematically vary their choices within the point manager. This may feel like an inconsistency which could bias subjects' choices similar to the consistency bias in survey studies. This psychological cost may outweigh the anticipation of adverse loss feelings.

On the other hand, subjects react to shocks under non-pre-commitment. In contrast to PC choices, subjects do not significantly vary their consumption share but we find that they significantly increase their risk exposure in reaction to bad shocks. In particular, subjects are affected by the magnitude of the shock, i.e., by the amount previously invested. While we think that this makes intuitive sense, it should not matter, theoretically, under CRRA utility. However, note that in experiments, payoff functions such as our transformation function are obviously discrete. In our design, for simplicity, values are rounded up to full seconds and therewith, small changes in wealth do not map into variation in internet time. Hence, to actually reach another step in the transformation function, you need a certain amount of points. Also, since we rounded up to full integers, outcomes of small investments are biased upwards. This explains why the magnitude of shocks matters. Intuitively, loss feelings may weigh the harder, the more important they are for the current consumption possibilities. Recall that the lagged portfolio share, α_{t-1}, is the proportion of remaining wealth, W_{t-1}–C_{t-1}, that has been allocated to the risky investment in the previous period. Hence, a high risk exposure implies a low amount of safe return. Now a bad investment outcome, i.e., $Shock_t = 0$, dramatically reduces a subject's wealth in the current period and, maybe more importantly, also consumption prospects in the periods to come. As NPC subjects do not significantly adjust their consumption share to shocks, not even to high-magnitude shocks, they counterbalance the deterioration of consumption prospects by an increase in risk exposure. This increased portfolio share does not alter consumption in the current period but increases future consumption in expectation. Subjects are willing to take the according increase in variance of consumption prospects to enjoy this feeling of a higher expected level of consumption.

6.2 The Role of Commitment

We find no significant divergence between PC and NPC choices in shocks by regressing the choice differences on the investment outcome, $Shock_t$. We find that men significantly consume more under non-pre-commitment than they had planned for this contingency under pre-commitment. However, a direct trajectory-wise comparison of matched PC-NPC pairs may suffer from the low number of observations within each trajectory.

Regarding our separate analysis of NPC choices, we do see a difference in behavior depending on commitment. Subjects planned to increase consumption after good shocks in the PC stage but do not react systematically to actual realizations if they were not pre-commited. On the contrary, subjects in the NPC stage systematically vary their risk exposure depending on shocks while this reaction is not intended or anticipated when making conditional choices under pre-commitment. These effects may be inherent in conditional-choice elicitations such as the strategy method as opposed to direct-response elicitations. Brandts and Charness (2010) survey the experimental literature and compare both elicitation mechanisms. While there is no clear overall difference, direct responses seem to be more extreme in special emotional situation such as punishments. Our result complement their findings and may indicate that subjects tend to choose less emotionally in conditional-choice environments than when having to react to realized shocks.

In addition, we observe a significant increase of both consumption and portfolio shares over time. The former is not surprising since, by definition, subjects have to consume everything in the last period. The latter however is neither predicted by standard preferences (constant portfolio shares) nor by our behavioral alternative (decreasing portfolio shares). We exclude learning as an explanation since subjects also deliberately planned to increase their shares under pre-commitment. Furthermore, subjects knew from the PC stage how current decisions map into the future which further reduces trial-and-error strategies in the subsequent NPC stage. However, we cannot explain this behavior.

7 Conclusion

We present a novel experimental design to investigate dynamic consumption and portfolio choice decisions in the laboratory. This design constitutes a test of the standard model against expectations-based reference-dependent and hyperbolic-discounting preferences. Our preliminary results are mixed. So far, we lack power to confirm or reject the predictions of the standard model relative to expectations-based reference-dependent and hyperbolic-discounting preferences. We hypothesized that subjects' consumption and portfolio shares are negatively correlated with the investment outcome. However, we cannot find a significant correlation for consumption shares. Thus, the preliminary results for the consumption share support the standard model. For portfolio shares, however, we see a negative correlation. The investment outcome is determined by rolling a die, thus the random procedure is transparent to subjects. That subjects increase their risk exposure after bad outcomes thus seems to correspond to a gambling-in-the-loss-domain motive to mitigate loss feelings about deteriorated consumption prospects and cannot be ex-post rationalized by a belief in improved investment opportunities. Moreover, such behavior reminds us of the disposition effect except that the purchase price of the risky asset is inexistent in the experimental design and thus unlikely to play a role here. We further analyze subjects behavior under pre-commitment. The negative correlation between the portfolio share and the investment outcomes does not seem to be anticipated, as subjects do not condition their choices on shocks under pre-commitment. Moreover, we cannot ultimately confirm that subjects overconsume or overinvest relative to their pre-committed plan. Thus, overall our preliminary results are consistent with the standard model.

We believe that our design is an important step towards controlled research of dynamic theories about consumption and portfolio choice as it simultaneously analyzes real consumption and portfolio decisions rather than monetary payoffs. We proxy consumption by utilizing the internet as surfing the web is likely to generate immediate utility and seems to fulfill the requirements of non-satiation and dominance (Smith, 1976), which can be inferred from the observed distribution of internet time over trajectories under both pre-commitment and non-pre-commitment.

References

Abeler, J., A. Falk, L. Goette, and D. Huffman (2011). Reference points and effort provision. *American Economic Review 101*(2), 470–92.

Ahn, D., S. Choi, D. Gale, and S. Kariv (2011). Estimating ambiguity aversion in a portfolio choice experiment. *Working Paper*.

Anderhub, V., W. Güth, W. Müller, and M. Strobel (2000). An experimental analysis of intertemporal allocation behavior. *Experimental Economics 3*, 137–152. 10.1023/A:1026589319018.

Ashley, R. A. (2010). A reconsideration of consistent estimation of a dynamic panel data model in the random effects (error components) framework. *Working Paper, Virginia Polytechnic Institute and State University*.

Augenblick, N., M. Niederle, and C. Sprenger (2013). Working over time: Dynamic inconsistency in real effort tasks. *Working Paper*.

Ballinger, P. T., M. G. Palumbo, and N. T. Wilcox (2003). Precautionary saving and social learning across generations: An experiment. *The Economic Journal 113*, 920–947.

Barberis, N. and W. Xiong (2009). What drives the disposition effect? an analysis of a long-standing preference-based explanation. *The Journal of Finance 64*(2), 751–784.

Barberis, N. and W. Xiong (forthcoming). Realization utility. *Journal of Financial Economics*.

Bossaerts, P., P. Ghirardato, S. Guarnaschelli, and W. R. Zame (2010). Ambiguity in asset markets: Theory and experiment. *Review of Financial Studies 23*(4), 1325–1359.

Bossaerts, P., C. Plott, and W. R. Zame (2007). Prices and portfolio choices in financial markets: Theory, econometrics, experiments. *Econometrica 4*, 993–1038.

Brandts, J. and G. Charness (2010). The strategy versus the direct-response method: A survey of experimental comparisons. *Working Paper*.

Brown, A. L., Z. E. Chua, and C. F. Camerer (2009). Learning and visceral temptation in dynamic saving experiments. *The Quarterly Journal of Economics 124*(1), 197–231.

Brunnermeier, M. and S. Nagel (2008). Do Wealth Fluctuations Generate Time-Varying Risk Aversion? Micro-Evidence on Individuals' Asset Allocation. *American Economic Review 98*(3), 713–736.

Calvet, L. E., J. Y. Campbell, and P. Sodini (2009a). Fight or flight? portfolio rebalancing by individual investors. *Quaterly Journal of Economics 124*(2), 301–48.

Calvet, L. E., J. Y. Campbell, and P. Sodini (2009b). Measuring the financial sophistication of households. *American Economic Review 99*(2), 393–98.

Campbell, J. and A. Deaton (1989). Why is Consumption So Smooth? *The Review of Economic Studies 56*(3), 357–373.

Card, D. and G. B. Dahl (2011). Family violence and football: The effect of unexpected emotional cues on violent behavior*. *The Quarterly Journal of Economics*.

Charness, G. and U. Gneezy (2010). Portfolio choice and risk attitudes: An experiment. *Economic Inquiry 48*(1), 133–146.

Crawford, V. P. and J. Meng (2011). New york city cab drivers' labor supply revisited: Reference-dependent preferences with rational-expectations targets for hours and income. *American Economic Review 101*(5), 1912–32.

Doran, K. (2010). Wages, daily income goals and daily labor supply. *Working Paper, University of Notre Dame*.

Ericson, K. M. M. and A. Fuster (2011). Expectations as endowments: Evidence on reference-dependent preferences from exchange and valuation experiments. *The Quarterly Journal of Economics 126*(4), 1879–1907.

Fernandez-Villaverde, J. and D. Krueger (2007). Consumption over the Life Cycle: Facts from Consumer Expenditure Survey Data. *The Review of Economics and Statistics 89*(3), 552–565.

Fischbacher, U. . (2007). z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics 10*(2), 171–178.

Flavin, M. (1985). Excess Sensitivity of Consumption to Current Income: Liquidity Constraints or Myopia? *The Canadian Journal of Economics 18*(1), 117–136.

Février, P. and M. Visser (2004). A study of consumer behavior using laboratory data. *Experimental Economics 7*, 93–114. 10.1023/A:1026266122863.

Gill, D. and V. Prowse (2012). A structural analysis of disappointment aversion in a real effort competition. *American Economic Review 102*(1), 469–503.

Gneezy, U. and J. Potters (1997). An experiment on risk taking and evaluation periods. *The Quarterly Journal of Economics 112*(2), 631–645.

Gomes, F., J. Cocco, and P. Maenhout (2005). Consumption and Portfolio Choice over the Life-Cycle. *Review of Financial Studies 18*(2), 491–533.

Greiner, B. (2004). *An Online Recruitment System for Economic Experiments*, pp. 79–93. Göttingen.

Heffetz, O. and J. A. List (2011). Is the endowment effect a reference effect? *Working Paper*.

Houser, D., D. Schunk, J. Winter, and E. Xiao (2010). Temptation and commitment in the laboratory. *University of Zurich - IEW Working Paper 488*.

Jappelli, T. and L. Pistaferri (2010). The Consumption Response to Income Changes. *The Annual Review of Economics 2*, 479–506.

Karle, H., G. Kirchsteiger, and M. Peitz (2013). Loss aversion and consumption choice: Theory and experimental evidence. *Working Paper*.

Klos, A. and M. Weber (2006). Portfolio choice in the presence of non-tradable income: An experimental analysis. *German Economic Review 7*(4), 427–448.

Koszegi, B. and M. Rabin (2006). A Model of Reference-Dependent Preferences. *Quarterly Journal of Economics 121*(4), 1133–1166.

Koszegi, B. and M. Rabin (2007). Reference-Dependent Risk Attitiudes. *American Economic Review 97*(4), 1047–1073.

Koszegi, B. and M. Rabin (2009). Reference-Dependent Consumption Plans. *American Economic Review 99*(3), 909–936.

Kotlikoff, L. J., W. Samuelson, and S. Johnson (1988). Consumption, computation mistakes, and fiscal policy. *The American Economic Review 78*(2), pp. 408–412.

Kroll, Y. and H. Levy (1992). Further tests of the separation theorem and the capital asset pricing model. *American Economic Review 82*(3), 664–70.

Kroll, Y., H. Levy, and A. Rapoport (1988a). Experimental tests of the mean-variance model for portfolio selection. *Organizational Behavior and Human Decision Processes 42*(3), 388 – 410.

Kroll, Y., H. Levy, and A. Rapoport (1988b). Experimental tests of the separation theorem and the capital asset pricing model. *The American Economic Review 78*(3), pp. 500–519.

Luhan, W., M. Roos, and J. Scharler (2011). An experiment on consumption responses to future prices and interest rates. *Ruhr Economic Paper 248*.

Mas, A. (2006). Pay, reference points, and police performance. *The Quarterly Journal of Economics 121*(3), 783–821.

Mattei, A. (2000). Full-scale real tests of consumer behavior using experimental data. *Journal of Economic Behavior & Organization 43*(4), 487 – 497.

Merton, R. C. (1969). Lifetime portfolio selection under uncertainty: The continuous-time case. *The Review of Economics and Statistics 51*(3), pp. 247–257.

Odean, T. (1998). Are investors reluctant to realize their losses? *The Journal of Finance 53*(5), 1775–1798.

Ploner, M. (2003). The financial markets and wealth effects on consumption - an experimental analysis. *Working Paper* (0306).

Pope, D. G. and M. E. Schweitzer (2011). Is tiger woods loss averse? persistent bias in the face of experience, competition, and high stakes. *American Economic Review 101*(1), 129–57.

Samuelson, P. A. (1969). Lifetime portfolio selection by dynamic stochastic programming. *The Review of Economics and Statistics 51*(3), pp. 239–246.

Shefrin, H. and M. Statman (1985). The disposition to sell winners too early and ride losers too long: Theory and evidence. *The Journal of Finance 40*(3), pp. 777–790.

Sippel, R. (1997). An experiment on the pure theory of consumer's behaviour. *The Economic Journal 107*(444), pp. 1431–1444.

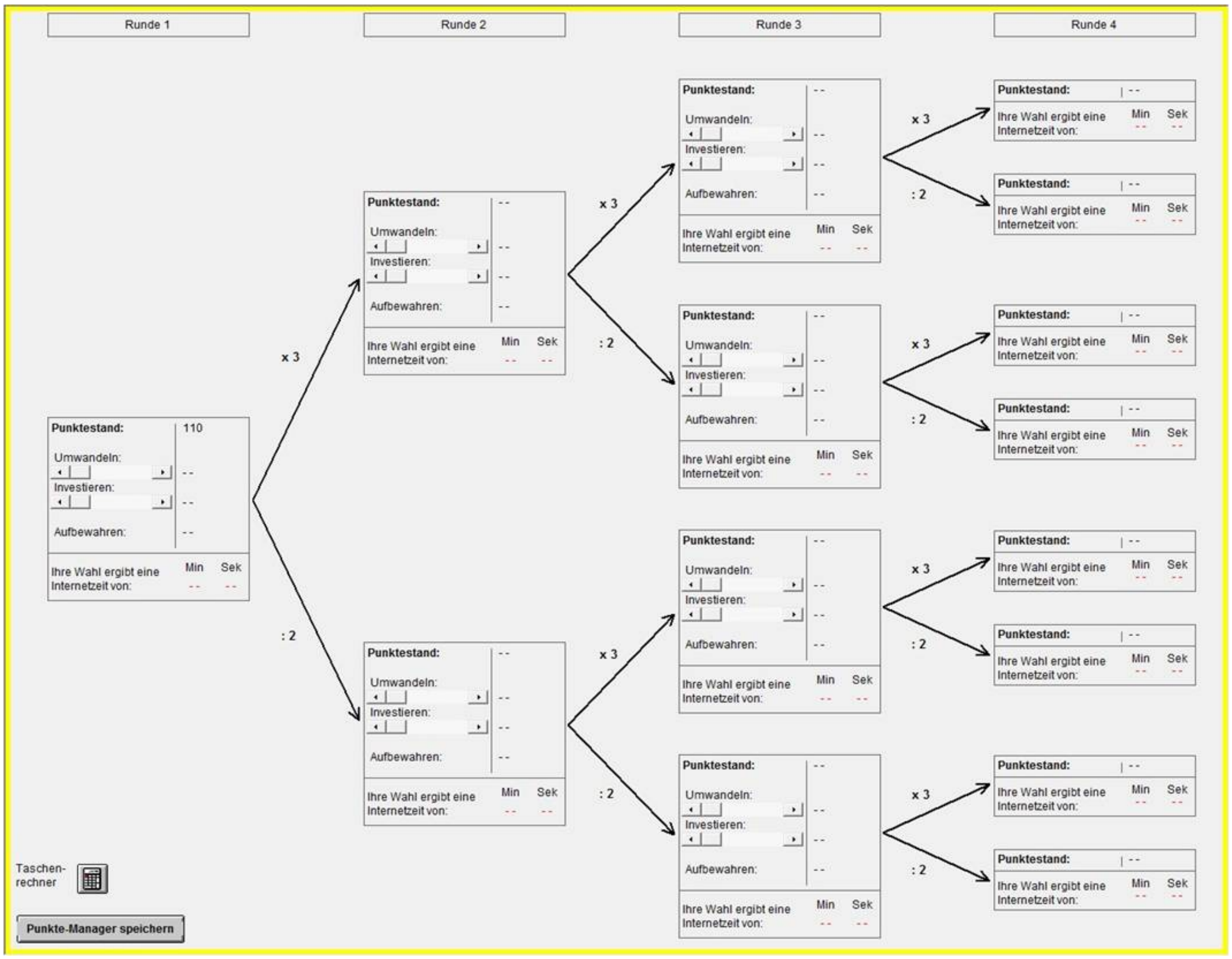
Smith, A. (2008). Lagged beliefs and reference-dependent utility. *Working Paper, University of Arizona, Tucson*.

Smith, V. L. (1976). Experimental economics: Induced value theory. *American Economic Review 66*(2), 274–279.

Sprenger, C. D. (2011). An endowment effect for risk: Experimental tests of stochastic reference points. *Working Paper, University of California, San Diego*.

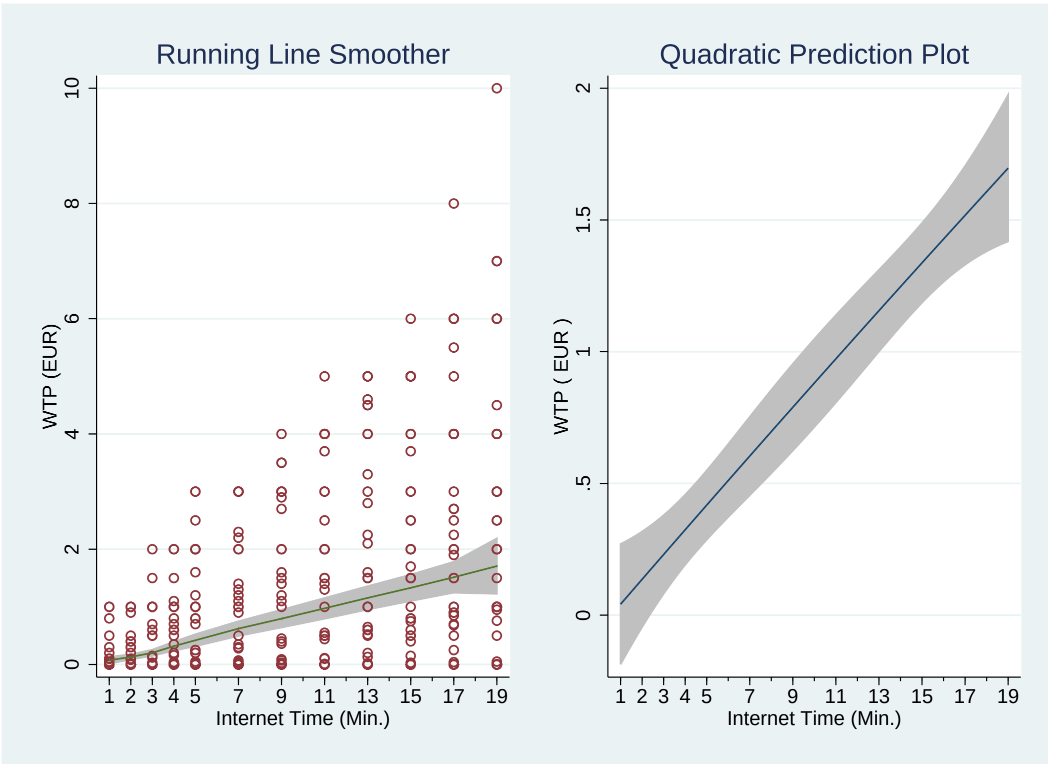
A Instructions and Screenshot

Figure A.1: The Point Manager for Decisions under Pre-Commitment



B Empirical Appendix

Figure B.1: Aggregated Willingness-To-Pay Curve



The first panel displays a running line smoother of willingness to pay (WTP) against minutes with pointwise confidence intervals. The second panel displays the predicted values of WTP regressed on minutes and minutes squared, i.e., $\hat{\text{WTP}} = \hat{\beta}_0 + \hat{\beta}_1 \times (\text{min}) + \hat{\beta}_2 \times (\text{min}^2)$.

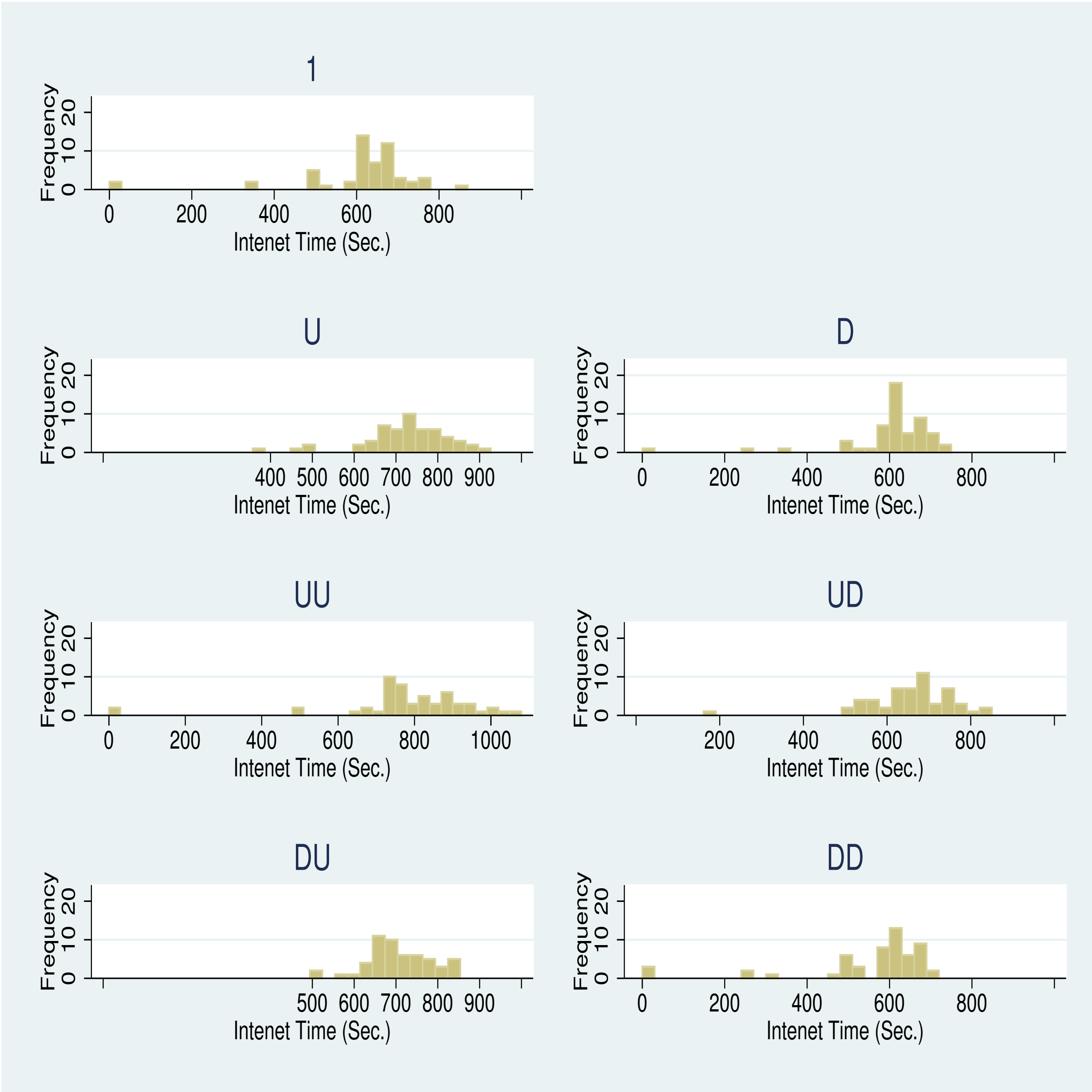
Instructions: Please imagine the following situation. There exists another round which again lasts for 19 minutes. During this time you can as before surf the internet or perform the clicking task. If you spend the full 19 minutes performing the clicking task, you receive 10 EUR. You can however spend some of these 10 EUR to acquire internet time. While you are surfing the internet, the clicking task is deactivated as before. Please declare in the following table, how much you are willing to dispense in order to spend the according number of minutes in the internet.

Variables used:

- I_t, absolute contemporaneous investment in the risky asset, C_t, absolute contemporaneous consumption, W_t, current wealth
- $\rho_t = C_t/W_t$, Consumption share (equivalently: consumption wealth ratio)
- $\alpha_t = I_t/(W_t - C_t)$, Portfolio Share
- ρ_{t-1}, previous-period consumption share
- α_{t-1}, previous-period portfolio share
- $Shock_t$, dummy variable: 1 = good shock ($R_t = 3$), 0 = bad shock ($R_t = 0.5$)
- $Round3$, dummy variable: 1 = round 3, 0 = round 2
- Sex, dummy variable: 1 = men, 0 = women
- Age, subject's age
- $A.M.$, dummy variable: 1 = morning session, 0 = afternoon session

B.1 Pre-Commitment Analysis

Figure B.2: Internet Time Distribution under Pre-Commitment (PC) by Trajectory



Distribution of internet time (in seconds) associated with the PC choices made in the point manager. These are the "planned" internet times by the subjects.

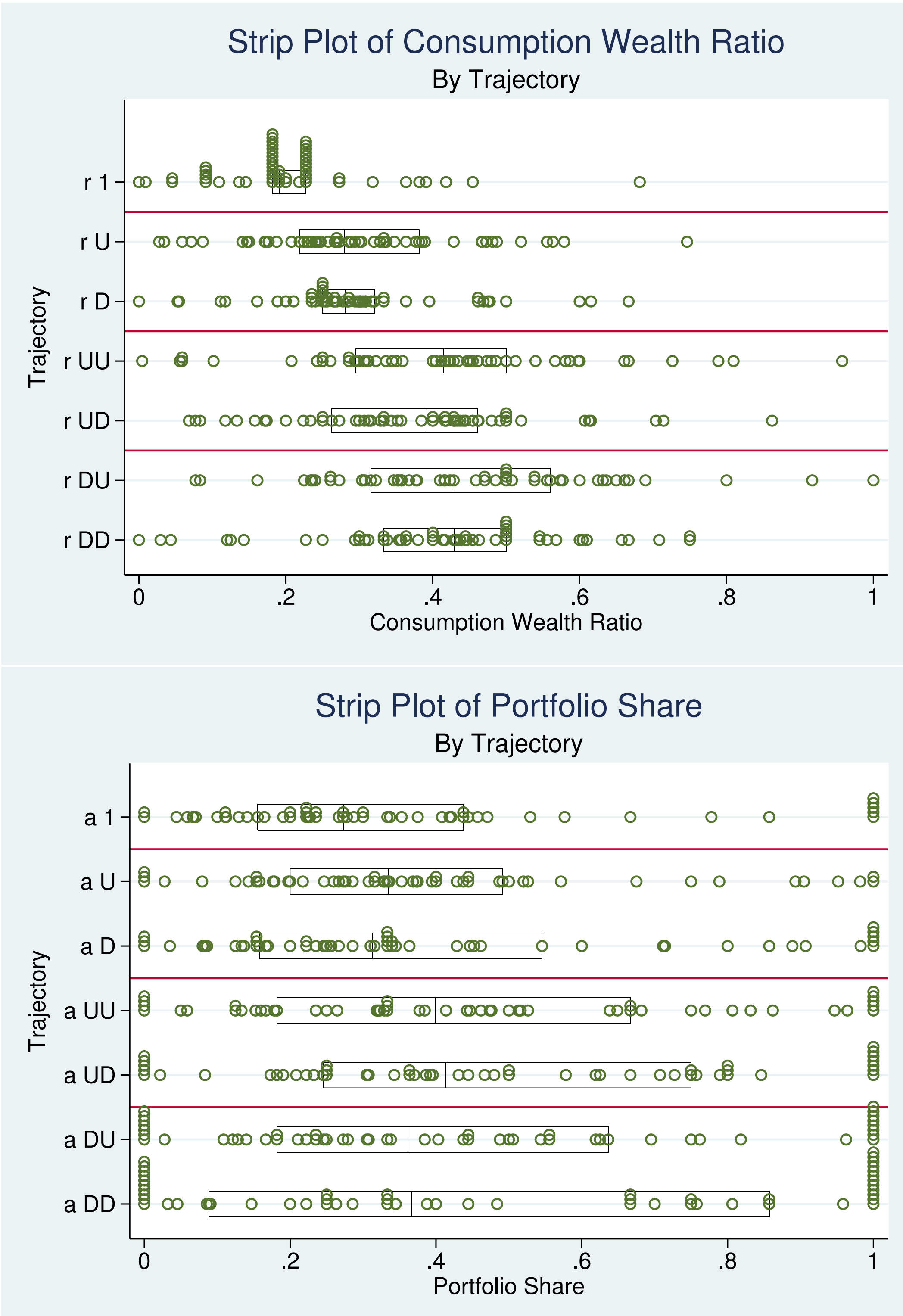
Table 5: Random-Effects Regression

	(1)	(2)	(3)	(4)
	ρ	ρ	α	α
$Shock_t$	0.0241*	0.0241*	-0.0233	-0.0233
	(0.0138)	(0.0139)	(0.0242)	(0.0243)
$Round3$	0.113***	0.113***	0.0683*	0.0683*
	(0.0153)	(0.0153)	(0.0349)	(0.0351)
Sex		-0.0440		-0.118*
		(0.0318)		(0.0613)
Age		-0.00382		-0.00525
		(0.00276)		(0.00645)
$A.M.$		0.0208		0.00565
		(0.0345)		(0.0647)
$Constant$	0.287***	0.396***	0.404***	0.591***
	(0.0171)	(0.0707)	(0.0358)	(0.171)
Observations	324	324	324	324
Clusters	54	54	54	54
σ_u	0.108	0.108	0.216	0.214
σ_e	0.128	0.128	0.236	0.236
Intraclass Corr.	0.416	0.415	0.456	0.450

Standard errors clustered by subjects in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure B.3: Distribution of Pre-committed Choice Variables by Trajectory



The first panel shows the distribution of consumption shares, ρ^{PC}, per trajectory. The second panel shows the distribution of portfolio shares, α^{PC}, per trajectory under pre-commitment.

Data points are horizontally stacked to enhance visibility and box plots are superimposed. Each trajectory consists of the choices of all N = 54 pre-committed subjects.

Table 6: Random-Effects Two-Censored Tobit Regression

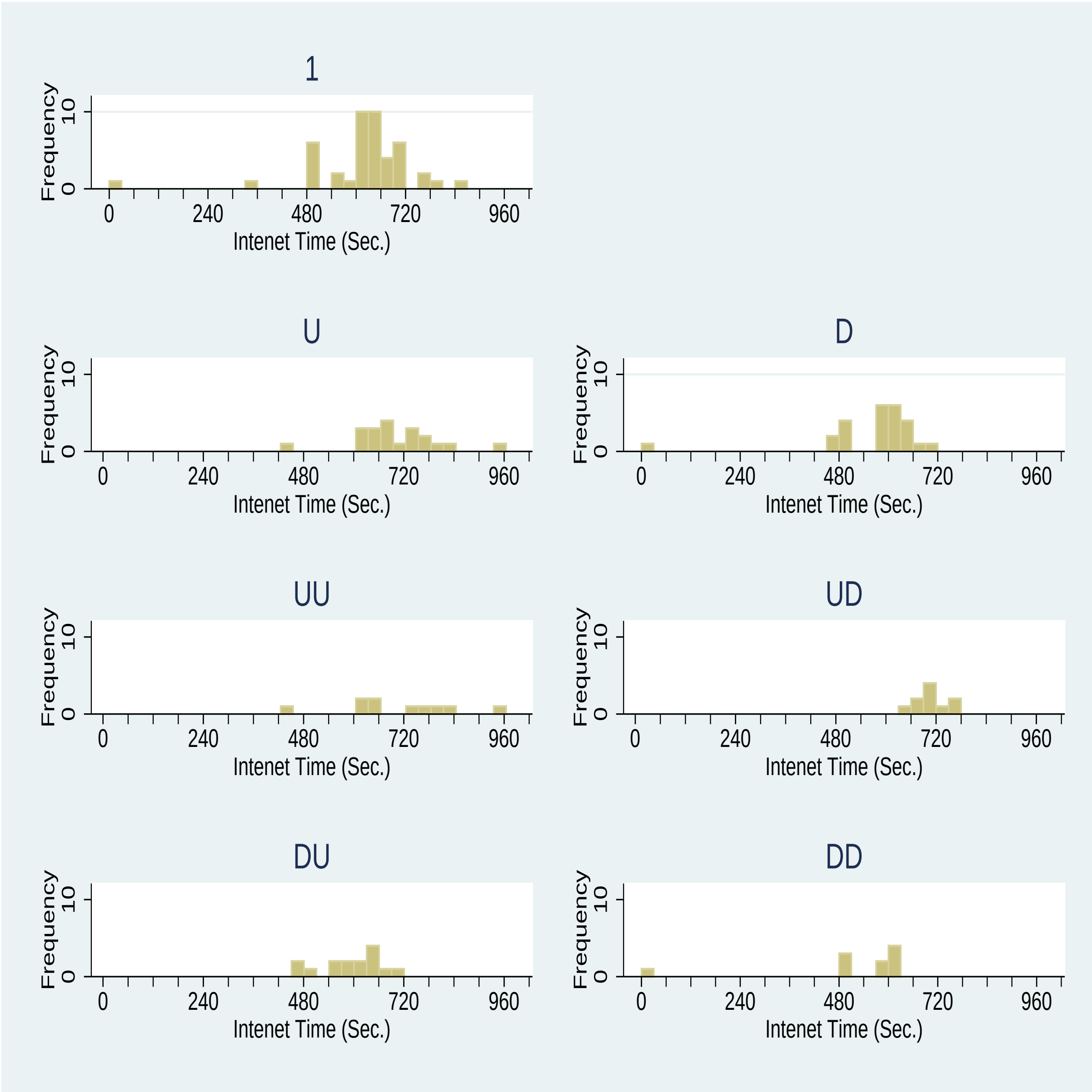
	(1)	(2)	(3)	(4)
	ρ	ρ	α	α
main				
$Shock_t$	0.0249*	0.0249*	-0.0303	-0.0301
	(0.0143)	(0.0143)	(0.0329)	(0.0329)
$Round3$	0.113***	0.113***	0.0750**	0.0750**
	(0.0152)	(0.0152)	(0.0346)	(0.0347)
Sex		-0.0447		-0.164**
		(0.0318)		(0.0804)
Age		-0.00387		-0.00873
		(0.00396)		(0.00998)
$A.M.$		0.0203		-0.0240
		(0.0323)		(0.0818)
$Constant$	0.286***	0.397***	0.404***	0.712***
	(0.0204)	(0.101)	(0.0503)	(0.255)
Observations	324	324	324	324
Left-Censored	2	2	32	32
Right-Censored	1	1	39	39
Cluster				
σ_u	0.107	0.103	0.281	0.265
σ_e	0.129	0.129	0.286	0.286
Intraclass Corr.	0.409	0.390	0.491	0.462

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

B.2 Non-Pre-Commitment Analysis

Figure B.4: Internet Time Distribution under Non-Pre-Commitment (NPC) by Trajectory



Distribution of internet time associated with the NPC choices. These are the actual internet times by the subjects.

Table 7: Pooled OLS of Consumption Share ρ

	(1) I	(2) II	(3) III	(4) IV
$Shock_t$	0.0363	0.0330	0.0105	-0.00531
	(0.0338)	(0.0336)	(0.0592)	(0.0551)
$Round3$	0.114***	0.114***	0.109***	0.0807***
	(0.0259)	(0.0260)	(0.0282)	(0.0267)
Sex		-0.0178	-0.0247	
		(0.0384)	(0.0421)	
Age		-0.00105	-0.00173	
		(0.00414)	(0.00472)	
$A.M.$		0.0118	0.00285	
		(0.0403)	(0.0427)	
α_{t-1}			0.170	-0.0608
			(0.156)	(0.0970)
$Shock_t \times \alpha_{t-1}$			0.0592	0.0929
			(0.203)	(0.172)
ρ_{t-1}				0.843***
				(0.124)
$constant$	0.254***	0.286**	0.254*	0.0994***
	(0.0253)	(0.118)	(0.128)	(0.0248)
Observations	89	89	89	89
Clusters	45	45	45	45
Adj. R2	0.112	0.0842	0.153	0.553

Standard errors clustered by subjects in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Pooled OLS of Portfolio Share α

	(1)	(2)	(3)	(4)
	I	II	III	IV
$Shock_t$	-0.0769	-0.0837	0.127	0.128
	(0.0626)	(0.0621)	(0.0853)	(0.0867)
$Round3$	0.157***	0.157***	0.145***	0.136***
	(0.0436)	(0.0448)	(0.0478)	(0.0487)
Sex		-0.00811	-0.0501	
		(0.0743)	(0.0488)	
Age		0.00207	0.00105	
		(0.00765)	(0.00501)	
$A.M.$		0.0526	0.000509	
		(0.0761)	(0.0515)	
α_{t-1}			0.967***	0.897***
			(0.0874)	(0.105)
$Shock_t \times \alpha_{t-1}$			-0.630***	-0.603***
			(0.217)	(0.214)
ρ_{t-1}				0.199
				(0.179)
$constant$	0.390***	0.324	0.0632	0.0438
	(0.0526)	(0.212)	(0.144)	(0.0455)
Observations	89	89	89	89
Clusters	45	45	45	45
Adj. R2	0.0641	0.0390	0.435	0.449

Standard errors clustered by subjects in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Tow-Censored Tobit of Portfolio Share α

	(1) ALL	(2) Women	(3) Men
$Shock_t$	0.199*	0.115	0.201
	(0.110)	(0.164)	(0.146)
$Round3$	0.158***	0.206*	0.131*
	(0.0543)	(0.106)	(0.0713)
Sex	-0.0652		
	(0.0563)		
Age	0.00136	0.0115*	-0.0144*
	(0.00540)	(0.00681)	(0.00792)
$A.M.$	0.000195	0.105	-0.104
	(0.0579)	(0.0785)	(0.0706)
α_{t-1}	1.337***	1.168***	1.377***
	(0.188)	(0.299)	(0.190)
$Shock_t \times \alpha_{t-1}$	-0.949***	-0.785	-0.867**
	(0.300)	(0.484)	(0.327)
$constant$	-0.0400	-0.286	0.335
	(0.169)	(0.222)	(0.217)
σ			
cons.	0.236***	0.242***	0.204***
	(0.0258)	(0.0334)	(0.0326)
Observations	89	47	42
Clusters	45	24	21
Left-Censored	6	3	3
Right-Censored	9	5	4

Standard errors clustered by subjects in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

B.3 Differences-in-Commitment Analysis

Table 10: Pooled OLS of Differences in Commitment

	(1)	(2)
	Δ_{ρ}^{com}	Δ_{α}^{com}
$Shock_t$	0.0406	-0.0456
	(0.0498)	(0.0824)
Sex	0.0816**	-0.0146
	(0.0373)	(0.0663)
Age	0.00261	0.00333
	(0.00542)	(0.00754)
$Round3$	-0.00921	0.0558
	(0.0293)	(0.0413)
α_{t-1}	0.0214	0.0122
	(0.107)	(0.0843)
$\alpha_{t-1} \times Shock_t$	-0.129	0.174
	(0.155)	(0.242)
$Constant$	-0.126	-0.0984
	(0.140)	(0.194)
Observations	89	89
Clusters	45	45
Adj. R2	0.0173	-0.0358

Standard errors clustered by subjects in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

C The Model

The model environment. We consider a simple partial-equilibrium model. The agent lives for $t = \{1, ..., T\}$ periods and is endowed with initial wealth W_1. Each period the agent optimally decides how much to consume C_t out of his wealth W_t and how to invest $W_t - C_t$. The agent has access to a risk-free investment with return R^f and a risky investment with i.i.d. return R_t. The risky investment's share is denoted by α_t such that the portfolio return in period t is given by $R_t^p = R^f + \alpha_{t-1}(R_t - R^f)$. Accordingly, the agent's maximization problem in each period t is given by

$$max_{C_t}\{u(C_t) + n(C_t, F_{C_t}^{t-1}) + \gamma \sum_{\tau=1}^{T-t} \beta^{\tau} \boldsymbol{n}(F_{C_{t+\tau}}^{t,t-1}) + E_t[\sum_{\tau=1}^{T-t} \beta^{\tau} U_{t+\tau}]\}. \tag{11}$$

subject to the budget constraint

$$W_t = (W_{t-1} - C_{t-1})R_t^p = (W_t - C_t)(R^f + \alpha_{t-1}(R_t - R^f)). \tag{12}$$

Equilibrium. Since the agent fully updates his beliefs each period and the return process is i.i.d., we look for an equilibrium consumption process which is "Markovian" in the sense that the consumption-wealth ratio depends on the current return realization R_t and calendar time t only.

Definition 1 *The consumption and wealth processes* $\{C_t\}_{t=1}^T$ *and* $\{W_t\}_{t=1}^T$ *are Markovian if in each period* t *the consumption-wealth ratio* $\rho_t = \frac{C_t}{W_t}$ *depends on the i.i.d. return realization* R_t *and calendar time* t *only* $\rho_t = \frac{C_t}{W_t} = \rho(R_t)$ *with the function* $\rho(\cdot)$ *being independent of the absolute levels of consumption* C_t *or wealth* W_t.

We derive the equilibrium recursively under the assumption of rational expectations. The "Markovian rational-expectations equilibrium" is subgame-perfect and corresponds to the preferred-personal equilibrium solution concept as defined by Köszegi and Rabin (2006).[27]

Definition 2 *The Markovian rational-expectations equilibrium consists of a Markovian consumption process* $\{C_t = W_t\rho_t = W_t\rho(R_t)\}_{t=1}^T$ *adhering to a solution* $\{C_t^*, \alpha_t^*\}_{t=1}^T$ *of the maximization problem (5) subject to the budget constraint (6).*

Derivation. The maximization problem in any period t is characterized by the following first-order condition

$$C_t^* = W_t \frac{1}{1 + (\frac{\psi_t + \gamma Q_t(\eta F_R(R_t) + \eta\lambda(1 - F_R(R_t)))}{1 + \eta F_R(R_t) + \eta\lambda(1 - F_R(R_t))})^{\frac{1}{\theta}}} = W_t\rho_t.$$

Thus, in each period t, optimal consumption C_t^* is a fraction of current wealth W_t and ρ_t varies with the realization of R_t and time t only as Q_t and ψ_t are determined by exogenous parameters,

[27] This equilibrium is subgame-perfect and thus time-consistent. The first-order condition is derived under the premise that the agent enters period t, takes his beliefs as given, and optimizes over consumption. Moreover, he expects rationally to behave like this in the future so that behavior maps into correct beliefs and vice versa.

time t, and the realization of R_t

$$Q_t = \beta E_t[(R^p_{t+1})^{1-\theta}\rho^{1-\theta}_{t+1}+(R^p_{t+1})^{1-\theta}(1-\rho_{t+1})^{1-\theta}Q_{t+1}] \text{ as } C_{t+\tau} = (W_t-C_t)R^p_{t+\tau}\rho_{t+\tau}\prod_{j=1}^{\tau-1}R^p_{t+j}(1-\rho_{t+j})$$

$$\text{and } \psi_t = \beta E_t[(R^p_{t+1})^{1-\theta}\rho^{1-\theta}_{t+1} + \eta(\lambda-1)\int_{(R^p_{t+1})^{1-\theta}\rho^{1-\theta}_{t+1}}^{\infty}((R^p_{t+1})^{1-\theta}\rho^{1-\theta}_{t+1} - r)dF^t_{(R^p_{t+1})^{1-\theta}\rho^{1-\theta}_{t+1}}(r)$$

$$+\gamma\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\mu(c-r)dF^{t+1,t}_{(R^p_{t+1})^{1-\theta}(1-\rho_{t+1})^{1-\theta}Q_{t+1}}(c,r) + (R^p_{t+1})^{1-\theta}(1-\rho_{t+1})^{1-\theta}\psi_{t+1}].$$

As can be easily seen, the indirect utility function is proportional to the power utility of wealth

$$V_t = u(W_t)\psi_t.$$

The optimal portfolio share α^*_t is determined by the following first-order condition

$$\gamma\beta E_t[(R^p_{t+1})^{-\theta}(R_{t+1}-R^f)\rho^{1-\theta}_{t+1}+(R^p_{t+1})^{-\theta}(R_{t+1}-R^f)(1-\rho_{t+1})^{1-\theta}Q_{t+1}](\eta F_R(R_t)+\eta\lambda(1-F_R(R_t)))+\frac{\partial\psi_t}{\partial\alpha_t} = 0$$

and varies with time t and the realization of R_t. The only difference to the pre-committed path is that marginal gain-loss utility is given by $\eta(\lambda-1)(1-2F_R(R_t))$ instead of $\eta F_R(R_t)+\eta\lambda(1-F_R(R_t))$.

The standard model's equilibrium, $\eta = 0$, has a similar structure. In each period t optimal consumption C^{s*}_t is a fraction of current wealth W^s_t so that $C^{s*}_t = W^s_t\rho^{s*}_t$. The consumption-wealth ratio ρ^{s*}_t is

$$\rho^{s*}_t = \frac{C^{s*}_t}{W^s_t} = \frac{1}{1+(\psi^s_t)^{\frac{1}{\theta}}}.$$

with ψ^s_t being determined by exogenous parameters and time t, so that ρ^{s*}_t varies with time t only.

$$\psi^s_t = \beta E_t[(R^p_{t+1})^{1-\theta}(\rho^s_{t+1})^{1-\theta} + (R^p_{t+1})^{1-\theta}(1-\rho^s_{t+1})^{1-\theta}\psi^s_{t+1}]$$

Again, the indirect utility function is proportional to the power utility of wealth

$$V^s_t = u(W^s_t)\psi^s_t.$$

The optimal portfolio share α^{s*} is determined by the following first-order condition

$$\frac{\partial \psi_t^s}{\partial \alpha_t^s} = 0 \Rightarrow E_t[(R^f + \alpha^s(R_{t+1} - R^f))^{-\theta}(R_{t+1} - R^f)] = 0$$

(as ρ_{t+1}^s and ψ_{t+1}^s do not vary with R_{t+1} and thus cancel) and is constant over time.

Moreover, let us introduce the hyperbolic model's equilibrium (γ is the hyperbolic-discounting parameter usually denoted by β), which has a similar structure to the standard model. In each period t optimal consumption C_t^{b*} is a fraction of current wealth W_t^b so that $C_t^{b*} = W_t^b \rho_t^{b*}$. The consumption-wealth ratio ρ_t^{b*} is

$$\rho_t^{b*} = \frac{C_t^{b*}}{W_t^b} = \frac{1}{1 + \gamma(\psi_t^b)^{\frac{1}{\theta}}}. \tag{13}$$

with ψ_t^b being determined by exogenous parameters and time t, so that ρ_t^{b*} varies with time t only

$$\psi_t^b = \beta E_t[(R_{t+1}^p)^{1-\theta}(\rho_{t+1}^b)^{1-\theta} + (R_{t+1}^p)^{1-\theta}(1 - \rho_{t+1}^b)^{1-\theta}\psi_{t+1}^b].$$

Again, the indirect utility function is proportional to the power utility of wealth

$$V_t^b = u(W_t^b)\psi_t^b.$$

The optimal portfolio share α^{b*} is determined by the same first-order condition as in the standard model

$$E_t[(R^f + \alpha^b(R_{t+1} - R^f))^{-\theta}(R_{t+1} - R^f)] = 0$$

and is constant over time.