An Experimental Test of Portfolio Choice with Non-tradable Risk

Diego Pulido
McGill University and CIRANO

Jim Engle-Warnick
McGill University and CIRANO

Marine de Montaignac
CIRANO

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Abstract: This paper reports the results of a laboratory experiment on the effect of non-tradable risk, in the form of risky income, on investment choices. Consistent with theoretical predictions, we find that the chosen level of portfolio risk is positively correlated with the present value of expected income. Controlling for market history, we find that portfolio risk choices are negatively correlated with the degree to which income is risky and to the degree to which income is correlated with financial returns in the market. Our experiment is the first to empirically test theoretical predictions for portfolio choice in a repeated investment game.

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Corresponding author: Diego Pulido: diego.pulidolema@mail.mcgill.ca.

Introduction

People tend to reduce their exposure to risky investments as they get older (Fagereng et al. (2017)), and they are advised to do so as well (Malkiel (1999), Bodie and Crane (1997)). Standard portfolio theory does not make this prediction (Samuelson (1963, 1969), Mossin (1968), Merton (1969)), but such behavior is sensible if investors are facing non-tradable risk during their working lives (Merton (1971), Bodie et al. (1992), Guiso et al. (1996), Heaton and Lucas (2000), Cocco et al. (2005)).

Non-tradable, or uninsurable risk, is risk that cannot be traded or sold by an investor. It cannot be a part of a diversified traded investment portfolio. Perhaps the best example of non-tradable risk is labor income (Cunha et al. (2005, 2007), Liu (2011), Eiling (2013)). Indeed different types of human capital investment result in different occupational choices, and different occupational choices result in different types of non-tradable risk in the form of the resulting labor income (Campbell et al. (2001), Gourinchas and Parker (2002), Carnevale et al. (2013)). For example, it is well established that higher education results in higher wages, i.e., a higher present value of expected income. For another example, a government employee may face a fairly certain stream of income, while an entrepreneur may face a riskier stream (Carroll and Samwick, 1997). And this risk could be correlated or uncorrelated with markets. Think, for example, of a financial professional for a positively correlated income, and a low wage earner receiving counter-cyclical benefits for an income negatively correlated with the market (Heaton and Lucas, 2000).

It is difficult to determine the quality of the real-life investment decision in the presence of non-tradable risk. Whether or not this behavior is a sensible reaction to the realities of the employment and asset markets, and whether or not it could be done better, is nearly impossible to tell. Difficulties facing researchers include measurement error, the lack of knowledge of investor beliefs and preferences relevant to the investment decision, and difficulty observing exogenous variation of explanatory variables (Betermier et al. (2012), Calvet and Sodini (2014), Fagereng and Guiso (2017)).

It is important to investigate the quality of the investment decision because failure to invest appropriately under non-tradable risk at the very least implies a personal loss in returns to human capital. Economics experiments can alleviate, if not eliminate, many of the difficulties of inference on investment choices by controlling the decision making environment and isolating variables critical to decision making.

In this paper we present an experiment designed to study the quality of the investment decision with different qualities of non-tradable risk. The experiment consists of an eight-period portfolio choice game. The non-tradable risk takes the form of a stream of endowments analogous to income. Experimental treatments manipulate both income level and variance to test behavior against theory. The innovation in this project is the use of the laboratory to separate the decision to invest from the decision to save, thus allowing a focused investigation on the quality of investment decisions.

The experiment consists of three basic treatments. First, participants receive a stream of constant, certain income. The certain income establishes a base-line result against which we can compare behavior with risky income. Second, participants receive a stream of random income, which is either high or low with a known probability distribution, independently drawn each period, and independent of the asset market. Third, participants receive a stream of random income correlated with the asset market.

The asset market is modeled by a lottery that results in a positive or a negative return with a known independent probability distribution each period. The participants allocate their wealth between a cash account and an investment account that follows the asset market. Thus the problem in this experiment is a portfolio choice problem, and the task is to take future expected earnings into account when making the investment choice. Done according to theory, as is seen in real-life portfolio choices, exposure to risk should decrease over the eight-periods in the game. Additional predictions include a shift out of risky investments when income is risky, and a further shift out of risky investments when risky income is correlated with the market.

Consistent with theoretical predictions, we find that the chosen level of portfolio risk is positively correlated with the level of future expected income. Controlling for income history, also consistent with theoretical predictions, we find that portfolio risk choices are negatively correlated with the degree to which income is risky, and with the degree to which income is correlated with financial returns in the market. Our experiment is the first to empirically test theoretical predictions for portfolio choice under non-tradable risk in a repeated investment game.

The paper is organized as follows. Section 1 describes the theory tested by the experiment. Next, Section 2 explains the experimental design and procedures. Section 3 describes the results. Finally, section 4 discusses the results and concludes.

1 Theory

Our laboratory experiment simulates the standard portfolio choice model with an investor maximizing her/his expected utility from terminal wealth. The investor receives an income for a finite number of periods, and makes a portfolio choice in each period of the game. Since consumption is derived from last-period wealth, and last period wealth is the objective, our design allows us to abstract from the consumption/savings decision, while isolating the investment decision. The model, which is similar to Jagannathan and Kocherlakota (1996), is simplified for implementation in the experimental laboratory.[1]

In the model an investor lives for T periods. The investor begins each period allocating cash-in-hand W_t across two assets: cash B_t and a risky asset S_t (i.e., a lottery). Cash is risk-free, and offers no return: $B_t = B_{t+1}$. The risky asset offers a return r_t: $S_{t+1} = S_t(1 + r_t)$. The investor can neither borrow cash nor short-sell the risky asset: B_t, $S_t \geq 0$. At the end of each period, the investor receives an income y_t. Together, these assumptions imply

$$W_{t+1} = S_t(1 + r_t) + B_t + y_t, \text{ for } t \in \{0, ...T - 1\}.$$

The risky asset return r_t can be positive $r^{pos} > 0$ or negative $r^{neg} < 0$ with fixed and independent probabilities across periods: $p(r_t = r^{pos}) \equiv p_t^{pos} = p^{pos} = 1 - p^{neg}$. Likewise, income y_t is uncertain and could be low (y^l) or high (y^h) with probabilities p^l and $p^h = 1 - p^l$. Note that y and r can be contemporaneously correlated:

$$p^i = p^{neg}\, p(y_t = y^i | r_t = r^{neg}) + p^{pos}\, p(y_t = y^i | r_t = r^{pos}), \text{ for } i = l,\, h.$$

We assume that the preferences of investors over final wealth are represented by a constant relative risk aversion (CRRA) utility function.[2] Utility is thus given by:

$$U_t(W_T) = E_t\{\delta^{T-t} \frac{(W_T)^{1-\gamma}}{1-\gamma}\}.$$

[1] Campbell and Viceira (2002) provide a comprehensive survey of the theories of life cycle investment; Chapter 6 is most closely related to this paper.

[2] The choice of a constant relative risk aversion utility function is favored by the evidence on investors preferences (Wachter and Yogo (2010), Chiappori and Paiella (2011)).

Time preferences do not play a role in the finitely repeated game thus $\delta = 1$.

We model non-tradable risk (NTR)as a stream of income. Thus the expected value of non-tradable riski is the following:

$$E(NTR_t) = E_t\{\sum_{i=t+1}^{T} y_i\}$$
$$= \sum_{j=0}^{T-t} \binom{T-t}{j} (p^h)^j (p^l)^{T-t-j} (jy^h + (T-t-j)y^l).^3$$

We can summarize the value of non-tradable risk with its certainty equivalent CE_t:

$$U(CE_t + W_t) = \sum_{j=0}^{T-t} \binom{T-t}{j} (p^h)^j (p^l)^{T-t-j} u((jy^h + (T-t-j)y^l) + Wt).$$

Note that the certainty equivalent is the implicit present cash value of the non-tradable risk, i.e., the future expected income. Putting the assumptions together, the investor's maximization problem is:

$$\max_{(S_t,B_t)} E\{\frac{(W_{t+1} + CE_{t+1})^{1-\gamma}}{1-\gamma}\}, \text{ for } t = 0, ...T$$

subject to,

$$W_t \geq S_t + B_t$$
$$W_{t+1} = y_t + (1 + r_t^s)S_t + B_t$$
$$S_t,\ B_t \geq 0.$$

From the solution to the investor's problem, we derive the following testable hypothesis about the effect of future expected income on portfolio choices.

Hypothesis 1: *Everything else equal, investors with higher present value of expected income will invest a larger portion of their cash-in-hand in the risky asset.*

This result arises because future expected income is an implicit cash position (equal to the certainty equivalent) that cannot currently be invested in the risky asset. Consequently, investors with more future expected income will have to invest a larger portion of their cash-in-hand to reach their optimal level of portfolio risk.

Hypothesis 2: *If the investor is risk averse, riskier income leads to safer portfolio choices.*

A risk averse investor dislikes both financial and income risk and takes both into account when choosing a portfolio. To compensate for riskier income, the investor will choose a safer portfolio.

Hypothesis 3: *If the investor is risk averse, higher correlation between income and the return of the risky asset leads to safer portfolio choices.*

This is because, for a given portfolio choice, higher correlation results in larger overall risk.

The model in this section is simplified for our laboratory experiment. The theoretical conclusions about the effect of non-tradable risk hold under more general assumptions. For example, see Viceira (2001) and Cocco et al. (2005) for more general assumptions about the data generating processes for y_t and r_t.

2 Experimental Design and Procedures

2.1 Design

The experiment consists of a task in which participants make a sequence of eight investment decisions. Each decision is an allocation of accumulated wealth (cash-in-hand) between cash and a risky asset. Cash is risk free, while the risky asset offers a 50/50 chance of earning a return of −40% or 60%. The payoff in the game, i.e., consumption, is the wealth accumulated in the final period.

The participants receive an initial endowment and collect an income in each period. To test each hypothesis, we manipulate endowments and income to create four experimental treatments. Each treatment consists of two versions of the investment task. Table 1 summarizes the parameters used for each treatment.

We designed the first treatment to test Hypothesis 1, which states that larger present value of expected income is linked with riskier portfolio choices. In the first task of this treatment there is no income, while the second task there is a $1 per period income. To make the tasks equivalent in terms of expected final wealth, the initial endowment for the no income task is $7, while it is $2 for the fixed income task.

The second treatment tests Hypothesis 2, which states that uncertainty about income causes risk averse investors to be less willing to hold risky portfolios. In the first task there is an income of $1, per period, while in the second task there is a 50/50 chance of receiving $0 or $2, drawn independently each period. In both cases, the initial endowment is $2.

The third treatment tests Hypothesis 3, which states that a positive correlation between income and the risky asset lowers the incentives to take portfolio risk. In the first task there is a 50/50 chance of earning $0 or $2 in each period. In the second task there is no income whenever the market return is negative, and a $2 income whenever the market return is positive. Expected income is the same in both tasks, given the 50/50 chances of experiencing a positive or negative asset return.

Finally, a fourth treatment further tests Hypothesis 2. This treatment creates a larger incentive for a difference in risk exposure between its two tasks than Treatment 2 by increasing the variance of the income. To maximize income variance, income is only realized after the final period: $8 for sure in the first task, and a 50/50 chance of earning either $0 or $16 in the second task. In both tasks, the initial endowment is $3, making the expected payoff equivalent to that in the previous treatments.[4]

In the experiments, each participant completes two experimental tasks, thus we expect to find order effects. For this reason, we use a crossover design in which the starting task for each participant is chosen randomly. Thus in practice there are eight experimental treatments, accounting for the opposite-ordered versions of each treatment.

2.2 Experimental Procedures

We conducted the experiment at an experimental economics laboratory used by several universities in a large metropolitan area. The experiment was programmed using HTML, CCS, and Java script, coupled with jQuery. Figure 1 shows the main screen of the no income task.

We conducted ten sessions involving Treatments 1, 2 and 3 (the treatments were randomly allocated to participants), and four sessions with Treatment 4. The sessions lasted approximately an hour and a half. In total, 223 volunteers participated in the study. Table 1 presents the number of subjects assigned to each treatment. In every session, the computers were randomly assigned to the participants, and the treatments (and order) were randomly assigned to each computer.

[4] Given the salience of the final period income, we wanted to avoid the bias it could create between trials of the task. For this reason, participants experienced the realization of a single random income at the end of the experimental session.

For each experimental task, the participants practiced three times without pay before completing three for-pay trials. We determined the experimental payoff by randomly picking one for-pay trial from each of the tasks in a treatment. In addition, the participants received a $15 show up fee, and $5 for completing a survey after the experiment. On average, the participants earned $45.[5]

2.3 Testable Predictions

Figures 2a-f depict the investment patterns predicted by theory for the experimental tasks. Each figure shows the average investment derived from 10,000 simulations of each task. For each simulation, we drew the coefficient of relative risk aversion γ randomly from a uniform distribution from the interval 0.5 to 1.5. This interval is consistent with current laboratory empirical estimates (Charness and Gneezy (2012), Holt and Laury (2014), Harrison et al. (2007) and Crosetto and Filippin (2016)).[6]

From Hypothesis 1, we derive four predictions for Treatment 1. First, in the no income task, the portion invested in the risky asset should be constant, as illustrated in Figure 2a. Second, in the fixed income task, the proportion of risk in the investment portfolio should fall as the periods of the task progress (in fact this is true of all subsequent experimental treatments). This is represented in Figure 2b. Third, participants should assume less risk in the no income task compared to the fixed income task. This is represented by the difference between Figures 2a and 2b. Fourth, the portfolio proportion of risky investment in the fixed and no income tasks should converge as the periods of the task progress.

From Hypothesis 2, we derive one prediction for Treatments 2 and 4: if the participants are risk averse, the percentage invested in the risky asset should be greater in the fixed income task than in the random income task. This prediction is represented by the differences between Figures 2b and 2e and between 2c and 2f. The difficulty in designing an experimental treatment that can induce measureable differences in behavior is illustrated by noting that the difference between Figures 2b and 2e is too small to be discernible in the figure; on average the difference is close to 1%. In Treatment 4 we increase this variance by loading all of the income onto the final period of the

[5]The survey gathered data about socioeconomics, participants' attitudes toward financial risk, levels of trust, financial literacy, and cognitive abilities.

[6]Note that the comparative statics that comprise the hypotheses tested in our experiment are invariable to specific values of this parameter, as long as on average, the participants exhibit risk aversion.

game. This causes the average difference in risky investment rates between the two tasks to be around 10%.[7]

From Hypothesis 3, we derive one prediction for Treatment 3: the investment risk should be larger in the random (uncorrelated) income task when compared to the random (correlated) income task. This is represented by the differences between Figures 2d and 2e.

2.4 Controlling for History

We expect investment choices to be driven by the disposition effect, i.e., the tendency to hold losing investments too long, and to sell winning investments too quickly (Shefrin and Statman (1985), Odean (1998)). There is evidence that this effect drives both real world (Chang et al., 2016) and experimental investment decisions (Rau (2015), Peiran (2015)). Thus we expect participants to risk more when the past asset returns are low, and less when they are high. To control for this effect, we randomly pre-drew three return histories. We used this set of return histories in the two experimental tasks completed by each participant. The accumulated returns from these histories are represented in Figure 3. By fixing the market histories we can compare the choices made by each participant in each task of their treatment under the same return conditions. In a similar fashion we pre-drew the random income.

The random draws of return histories that we used in the experiment have an unintentional and useful property that further allow us to control for market effect: the three market draws contain the same number of high and low returns in the first and last halves of the experimental task.

3 Experimental Results

3.1 Overview of Results

Each of the 223 participants completed three for-pay and three practice trials of two experimental tasks, while making eight decisions per trial. We thus gathered 10,704 incentivized investment choices. We did not include the practice trials in the analysis.

[7] An alternative approach to add variance to income would be to increase the variance of the period-period return. The difficulty is that in order get an equivalent increase in volatility, while keeping the expected value of human capital fixed, it would be necessary to allow the possibility of accumulated returns smaller than -100%, which is not an acceptable outcome in an experiment.

On average, the participants were 31 years old, and 53% were female. When asked about their employment situation, 42.15% responded student, 38.57% employee, 15.25% unemployed, 2.24% retiree, and 1.79% homemaker. The modal educational attainment was bachelor degree (26.01%), followed by master's degree (25.56%), some university or college (21.97%) or graduate education (9.87%), college (7.17%), high-school (5.38%), PhD (3.14%), and some high-school (0.9%).

The primary explanatory variable in the following analysis is the proportion of available cash-in-hand invested in the risky asset. We will call this proportion the risky investment. We summarize the average risky investment in Figures 4a-f. These figures are analogous to Figures 2a-f, which described the results from the simulations.

The figures show that in every treatment there was substantial variance in investment decisions. At first glance, there are no evident similarities between the two sets of figures. However, if the disposition effect is a driver of the choices, the unconditional patterns may not match the theoretical predictions. If the effect exists in the data, we will control for it when testing the hypotheses.

Figures 6a-f are useful to investigate whether the disposition effect holds. In the figures the risky investment is shown on the y axis. The return histories, computed as the proportion of times a subject experienced a positive return out of her/his total returns, are represented on the x axis. For example, for a participant at the end of Period 4 who has experienced one positive and three negative returns, the return history is 0.25. Figure 6 clearly shows that there is a negative association between these variables; this is the pattern predicted by the disposition effect. Below, we show that this negative correlation is statistically significant.

In Table 2, we test for evidence for order effects. The table summarizes the average investment in each task and treatment. The third column reports the mean risky investment made by all subjects from each experimental treatment. The next two columns report the choices made in the first and second tasks assigned to the subjects. In the last column, we report the t-test of the difference in average investment between the first and second task. With the exception of the random (independent) and the random (correlated) income tasks, we find statistically significant differences, providing evidence for order effects.

Finally, Figures 5a-f show the distribution of risky investments by treatment. These figures reveal whether the investment constraints (i.e., having to invest at least 0% of the cash-in-hand, and no more than 100%) were binding. Participants invested 100% of their cash-in-hand 15.56% of the time, while 18.07% of the investment choices were above 95%. On the other hand, only 1.78% of participants' choices risked nothing, and only 3.28% of the times did they risk less than 5%. These results are consistent with our simulation results. For many sensible risk preference parameters, the upper constraint was often binding and it was seldom the case that the investment choice was close to zero (and it was never below 0 for risk averse investors). In the following analysis we take this censoring into account.

3.2 Hypothesis 1: Higher Present Value of Expected Income Increases Risky Investments

3.2.1 Predictions 1 and 2

: Decreasing Exposure to Risk

The first experimental prediction derived from this hypothesis is that the portion of the cash-in-hand invested in the risky asset should not change in the eight periods of the no income task. By contrast, the second prediction is that this proportion should decrease as the periods progress in the fixed income task.

Our first approach to test these predictions is to compare the mean risky investment in the two halves of each experimental trial, dividing the trials between the initial and final four periods. Table 3 shows these means along with a t-test of their difference. The null hypothesis is that they are the same. For the no income task, we do not find evidence against this hypothesis. This finding is in line with Prediction 1. For the fixed income task, we reject the null hypothesis of no difference in favor of the alternative that, on average, the risky investment was larger in the first half. This result matches Prediction 2.

We designed the fixed income task specifically to test Prediction 2. However, the prediction also applies to the other two tasks with random income (uncorrelated and correlated). In both of these tasks, the present value of expected income also decreases as the game progress. Table 3 reports the results of the t-test for these treatments. Both are significant, giving additional evidence in favor of Prediction 2.

Prediction 2 also applies to the tasks in Treatment 4 with only final income. This is because, although the expected future income does not change along the periods of the task, the cash in hand grows as the game progress. This causes future income to fall as a share of total wealth, lowering the optimal risky investment. This is represented in the simulations by the downward slopes in Figures 2c and 2f. In this case we did not find evidence for this downward slope in the data, due to the small size of the effect.

3.2.2 Extending the Analysis of Predictions 1 and 2

The analysis of the averages of the risky investments of the first and second half of the trials does not consider the choices made in each period, nor does it condition on market histories. To overcome these limitations, we present the following random effects Tobit model:

$$\frac{S_{tmi}}{S_{tmi} + B_{tmi}} \equiv s_{tmi} = \alpha + \beta_1 t + \beta_2 \overline{Z_{t-1\,m}} + \nu_i + \eta_{tmi}.$$

In the equation, i indexes the participants, $t = 1, ..., 8$ the periods, and $m = 1, 2, 3$ the markets. Additionally, s_{tmi} is the share of the risky investment by subject i, in period t, in market m. The covariates are a constant, the investment period t, and the portion of times the risky asset return was positive in the previous period of each trial $\overline{Z_{t-1\,m}}$. Furthermore, ν_i is the unobserved effect associated with the characteristics of each participant. Finally, η_{tmi} is the idiosyncratic error, which can change across t, m, and i.

A random effects model is appropriate for the data from the experiment because our covariates are experimental parameters which, by construction, are uncorrelated with the unobserved effect of the subjects, a necessary condition to estimate the model: $Cov(\mathbf{x}_{it}, \nu_i) = 0$, for $t = 1, 2, ..., T$. We can make the stronger assumption that $E(\nu_i \mid \mathbf{x}) = E(\nu_i)$, which is necessary to fully justify the statistical inferences derived from the model. Likewise, the Tobit model takes into account the fact that the investment decision is bounded between two choices that can occur with positive probability: investing 0% or 100%.[8]

Note that β_1, which tests Predictions 1 and 2, can be interpreted as the expected change in the investment rate in the periods of the task. β_2 tells us whether the return experiences are associated

[8]The standard linear regression model can be used to model an unbounded version of the investment problem in which the investors could short the risky asset ($s < 0$) or receive loans to invest more than their cash in hand ($s > 1$). If we define the investment choice of the unbounded version of the problem as s°, we can redefine the experimental problem in terms of this latent variable:

$$s^{\circ}_{itm} = \alpha + \beta_1 t + \beta_2 \overline{Z_{t-1\,m}} + \nu_i + \eta_{itm} \qquad (\nu \mid x), (\eta \mid x) \sim normal(0, \sigma^2)$$

with the investment. A significant and negative point estimate of β_2 reveals evidence in favor of the disposition effect. The constant α does not have a particularly interesting interpretation in the model. It can be interpreted as the level of investment in the latent (see footnote 8), unbounded, investment asset in period zero.

Table 4 summarizes the results of the estimation of the model. The table shows the result for the random effects Tobit model and, as a robustness check, a random effects linear model. In both cases we report the robust standard errors. The first two columns show the results from the estimation for the no income task. In this case, β_1 is not significantly different from zero. This result is in line with Prediction 1: investments do not trend over the periods. Columns 3 and 4 show the estimates using the data from the fixed income task. The period coefficient β_1 is significant, in line with Prediction 2. We also find that the estimate of β_2 is negative and significant: evidence for the disposition effect.

For a robustness check we also estimated the fixed income model using the data from Treatment 2, and combined the observations from both treatments. In every case, we arrived at the same conclusions. For an additional robustness check, we added a dummy variable to control for order effects. The dummy variable was not significant, while the other results remained unchanged.

The estimates from Table 4 do not include the data from the first decision of each trial. This is because to be able to calculate $\overline{Z_{t-1\,m}}$ it is necessary that the subject has at least one return observation in that trial. An alternative approach that allows us to use the data from the first period is to assume that, at the start of each trial, the participants expected a 50/50 chance of a high return. When we estimate the model under this assumption, we arrive at the same conclusions.

Finally, we modeled the disposition effect using return histories from all the previous trials. Under this assumption the estimate of β_2 was insignificant, while the other results remain unchanged. One way to interpret this result is that the participants reset their beliefs after each trial. Using the analogy of the mental bag filled with colored balls used to describe the belief in the law of small numbers, this result can be described as the participants replenishing the bag after each trial.

$$s = \begin{cases} 0 & \text{if} \quad s^\circ < 0 \\ s^\circ & \text{if} \quad 0 \leq s^\circ \leq 1 \\ 1 & \text{if} \quad s^\circ > 1 \end{cases}$$

3.2.3 Prediction 3: Income Variance Decreases Exposure to Risk

The third prediction derived from this hypothesis states that, for a given period and market history, subjects allocate a larger portion of their cash-in-hand to the risky asset in the fixed income task compared with the no income task. We tested the significance of the difference in investment rates between these tasks. The results are in Table 5. The first row shows the average in each task from all choices. In this case, we find evidence for Prediction 3 in all periods except Period 8. As we explain in the following section, the non-significance in Period 8 could be interpreted as evidence in favor of Prediction 4.

3.2.4 Prediction 4: Income Correlated with the Market Decreases Exposure to Risk

The fourth prediction derived from the hypothesis is that the difference in risky investment between the no income and fixed income tasks should fall as the periods of the task progress. The intuition is that as the periods go by future income falls, reducing exposure to risk. This is why the insignificance of the difference in investment rates we found for Period 8 can be interpreted as evidence in favor of Prediction 4, because, in that period, there is only $1 of future income left, and the risky investment should only be slightly superior in the fixed income task.

To test the prediction, we used the following random effects linear regression model:

$$s_{itm}^{FI} - s_{tmi}^{NI} = \alpha + \beta_1 t + \nu_i + \eta_{tmi},$$

where, FI stands for fixed income and NI for no income, so that $s_{itm}^{FI} - s_{tmi}^{NI}$ is the difference in rates of investment between in period t, under market m, by individual i. The sole covariate is the investment period. Our experimental design allows us to control for market experience by comparing the choices taken under the same market, by the same individual, in the two tasks. The results are presented in Table 6. The significance of the estimate of the constant α is further evidence in favor of Prediction 3, as it shows that the difference in investment rates is positive and significant, even after controlling for the difference between periods. In addition, we find that the estimate of β_1 is negative, which is in line with Prediction 4.

3.3 Hypothesis 2: Riskier Income Reduces Risky Investments

Hypothesis 2 states that risk averse investors should hold safer portfolios the riskier their income. The experimental prediction is that participants from Treatments 2 and 4 will take more risk in the fixed income task, compared with the random income task.

Our first approach to test the prediction is to look at the difference in the mean investment between the fixed and random income tasks. The results are presented in Table 7. The first row shows the average for all periods. We find a significant difference, in line with the predictions. Nonetheless, as the following rows show, when we perform the same test for the data of the individual periods, the difference is not always significant.

It is possible that, given our sample size, the statistical power of the t-test is too low to detect the small difference in investment rates that we expect between the fix and random periodic income tasks. The purpose of Treatment 4 is to increase the power of this test. The treatment does this by increasing the variance of future wealth by only containing income in the final period. The results of the t-test are presented in Table 8. We find a significant difference, both for the overall set of observations and the individual periods.

3.4 Hypothesis 3: Correlation Between Income and Asset Returns Reduces Risky Investments

Hypothesis 3 states that risk averse investors prefer safer investment portfolios when facing higher correlation between their income and the risky asset return. The prediction is that the risky investment in the random and uncorrelated task income task should be greater than in the perfectly correlated task. We test the prediction by comparing the mean investments in these tasks. The results are presented in Table 9. The first row shows the average risky investment over all choices. We find a significant difference in the amounts invested. The next rows show the differences for each period. They also are statistically significant. Both findings are in line with Hypothesis 3.

3.5 Robustness Check: Between Subjects Analysis

As we mentioned at the beginning of this section, we found evidence for order effects in the data. The objective of the crossover design was to control for this effect. Nonetheless, an alternative design is a between-subjects design. In a between-subjects design, each participant only completes one experimental task, leaving no room for order effects. This design can be considered more conservative, but demands larger samples (Charness et al., 2012). We can analyze our data as if it came from a between-subjects design if we only consider the choices from the first task completed by each participant. The drawback is that, in doing so, we do not use half the evidence in our experiment.

In Table 10, we contrast the results from the t-tests using the crossover and between subjects approaches. With the exception of Treatment 2, the tests of the mean differences are still significant. However, the non-significance for Treatment 2 was expected because, as we described earlier, the cross-over results were also non-significant in the analysis of the individual periods.[9]

4 Conclusions

Using a laboratory experiment, we studied the effect of non-tradable income on investment choices. Analyzing the data from 223 participants, we found evidence that the present value of expected income is positively associated with the preferred level of portfolio risk. Likewise, we found that portfolio risk was negatively associated with both the riskiness of income and with its correlation with financial asset returns. Finally, we also found evidence for the disposition effect. Our results provid strong and consistent evidence for the empirical relevance of theoretical predictions of the effect of non-tradable risk in the form of income on investing.

A question we do not consider in this paper is whether the socioeconomic and cognitive characteristics of the participants correlate with their choices. For instance, we can study whether cognitive ability, economic status, or financial literacy and experience are associated with how well the choices correlate with the theoretical predictions. We plan to explore these question in a future paper.

[9] In the t-test contrasting the fixed and random income choices, we only use the data from Group 2, which completed the two tasks. Alternatively, we could have used the data from the participants from Groups 1,2 and 3 whose first tasks was either the fixed or random income one. We tried this approach and the results were also insignificant.

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Cunha, F. and Heckman, J. J. (2007). The evolution of inequality, heterogeneity and uncertainty in labor earnings in the u.s. economy. *National Bureau of Economic Research Working Paper Series*, No. 13526. Author contact info: Flavio Cunha Department of Economics Rice University P.O. Box 1892 Houston, TX 77251-1892 Tel: 713-348-4875 E-Mail: flavio-cunha@rice.edu James J. Heckman Department of Economics The University of Chicago 1126 E. 59th Street Chicago, IL 60637 Tel: 773/702-0634 Fax: 773/702-8490 E-Mail: jjh@uchicago.edu http://www.nber.org/papers/w13526.pdf.

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Figure 1: Screenshot of the Experimental Application

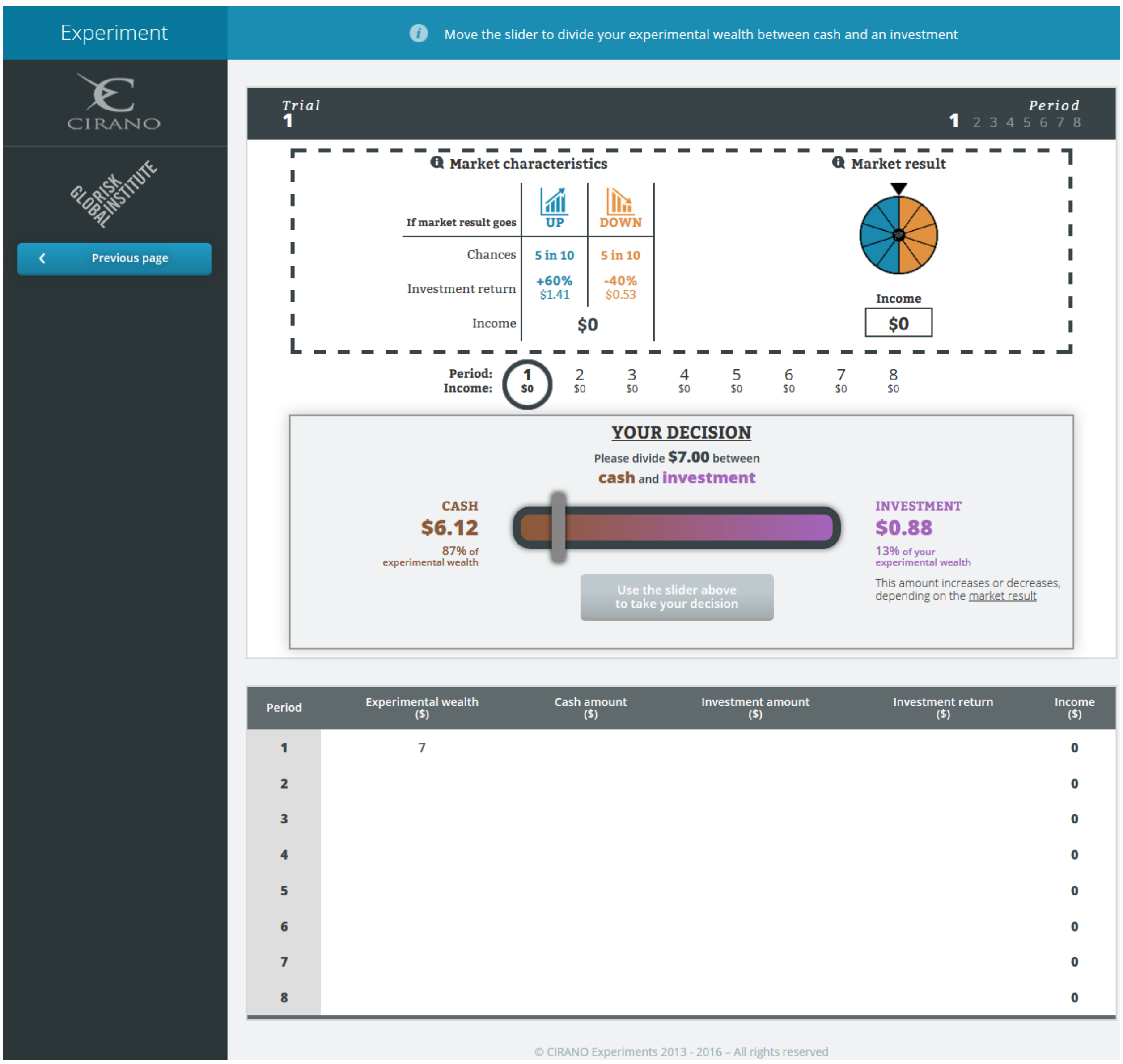

Table 1: Experimental Tasks and Treatments

Tasks	Initial Endowment	Income Low	Income High	Treatments 1	2	3	4
No Income	$7	$0	$0	X			
Fixed income (Each period)	$2	$1	$1	X	X		
Fixed income (Final period)	$3	$8	$8				X
Random Income (Each period)	$2	$0	$2		X	X	
Random Income (Final period)	$3	$0	$16				X
Income correlated with asset return	$2	$0	$2			X	
Subjects per treatment (tot = 223)				54	55	54	60

Figure 2: Simulation, Average Risky Investment, by Task and Period - 10,000 replications - σ 0.5 and 1.5

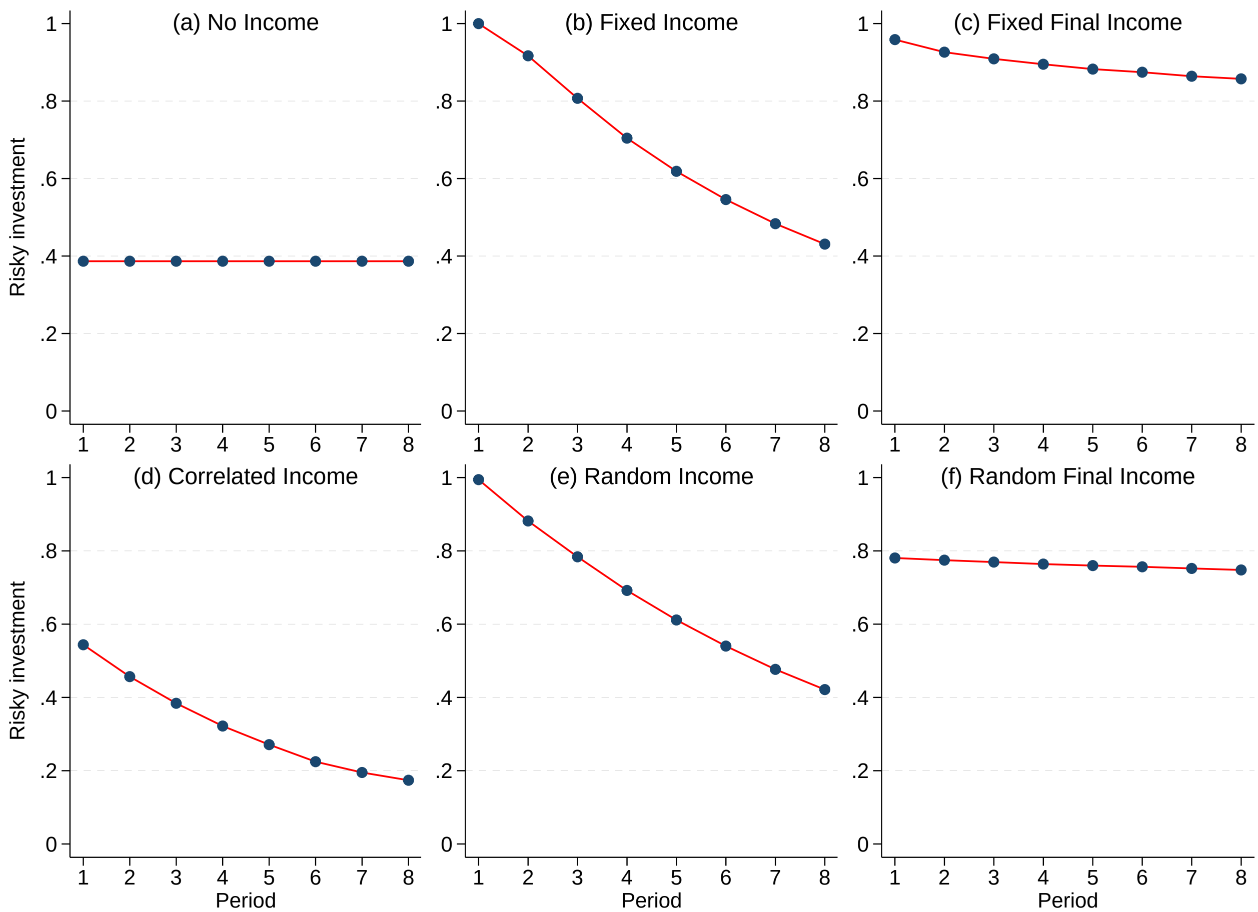

Figure 3: Market histories - Accumulated Return

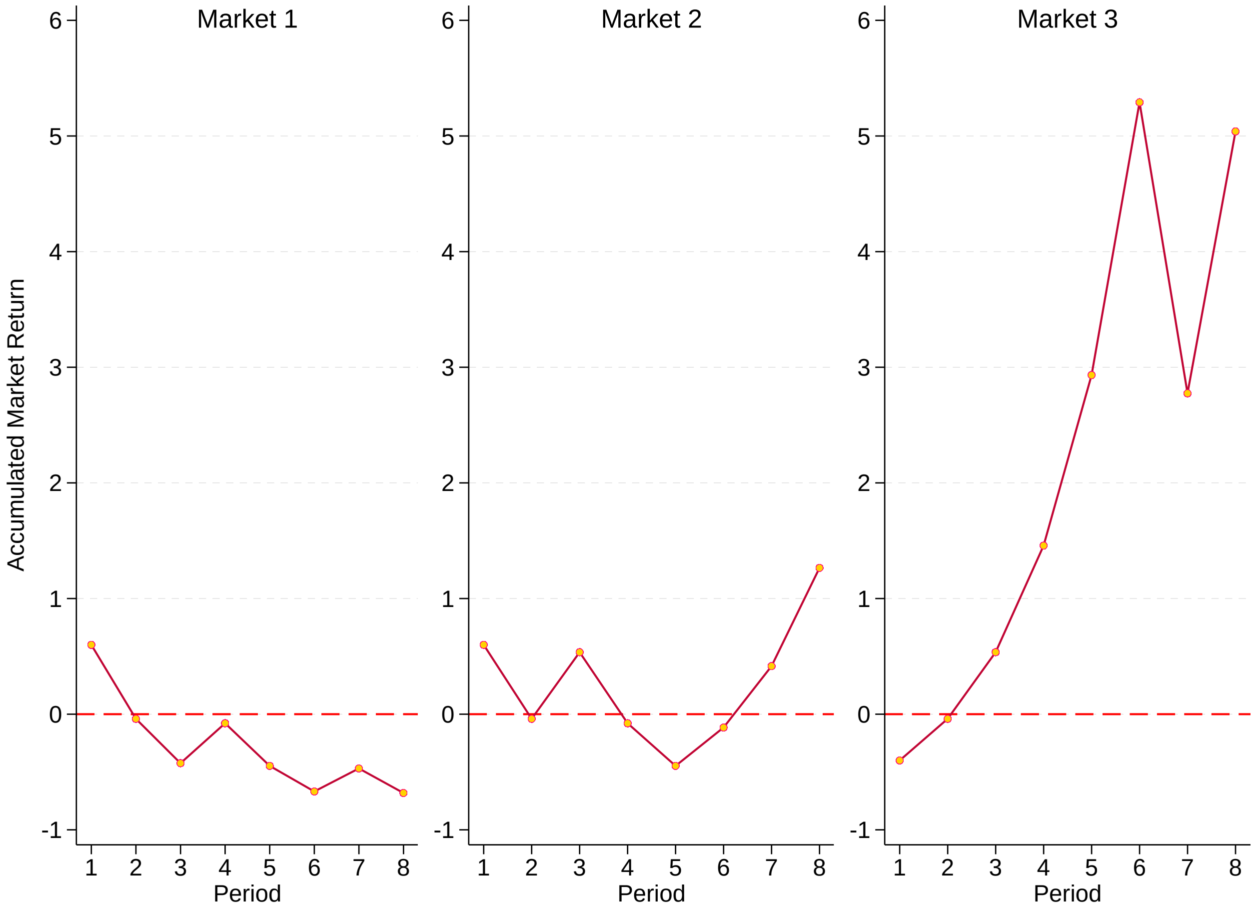

Figure 4: Mean Investment by Task and Period

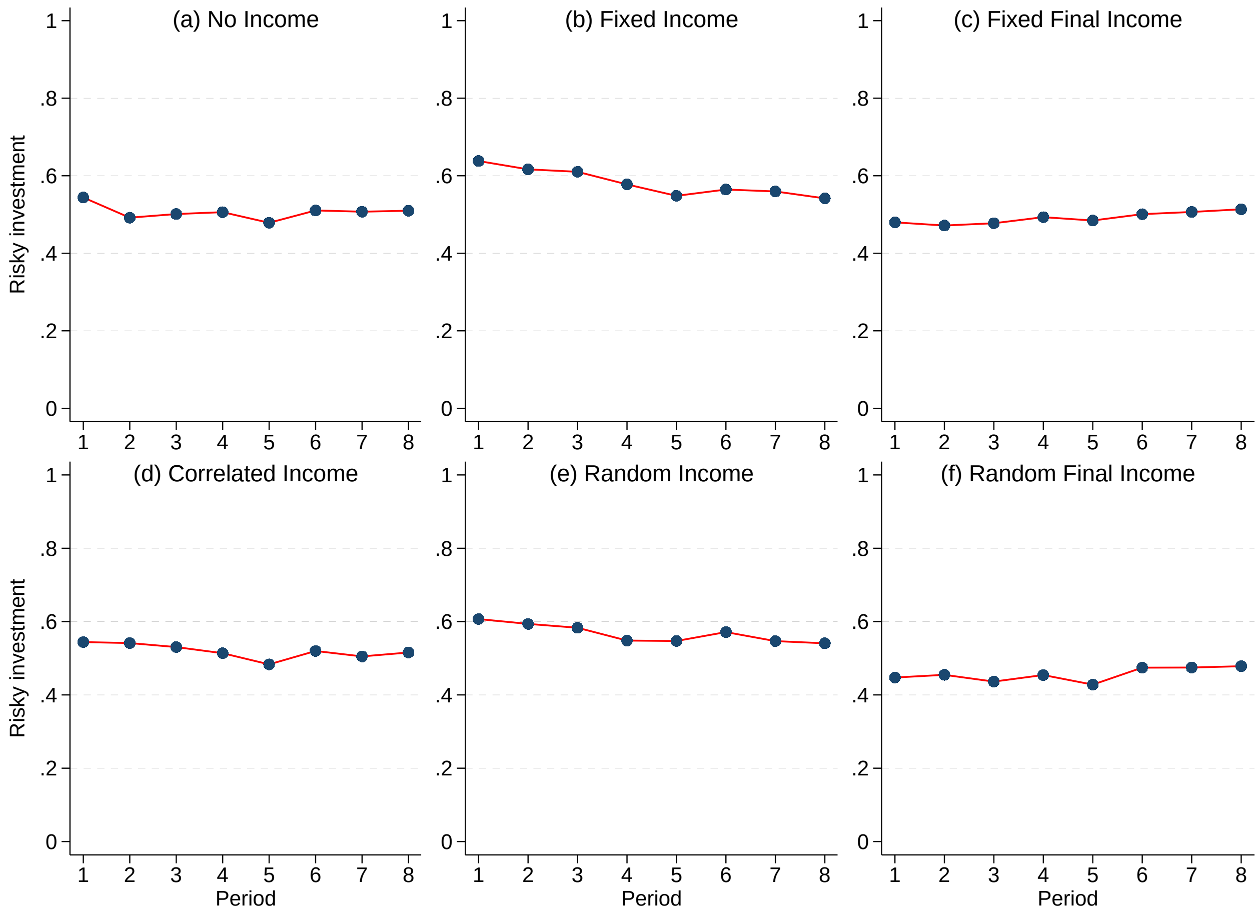

Figure 5: Histograms - Risky Investment

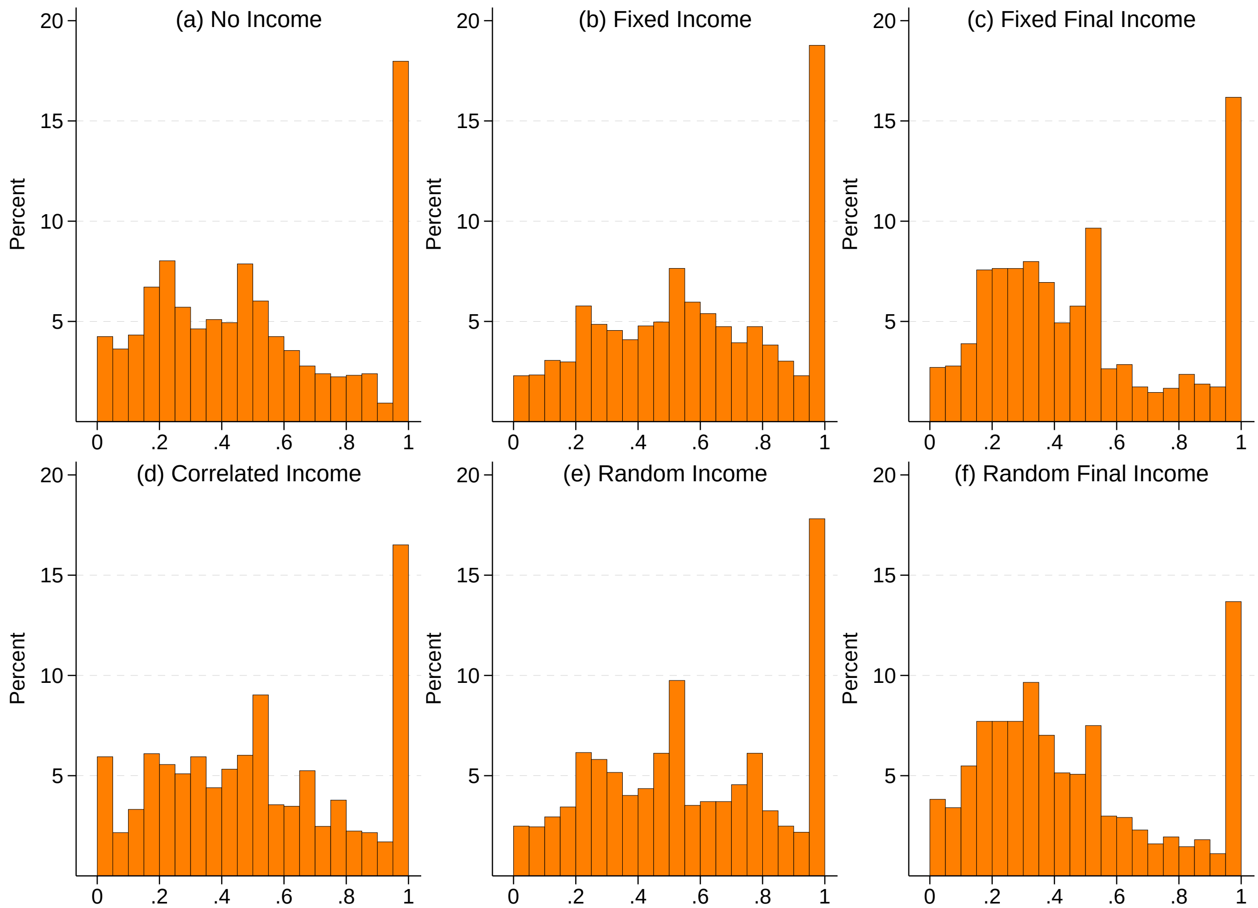

Table 2: Average first and second task

Task (treatment)	n	Total Mean (SD)	First Task Mean (SD)	Second Task Mean (SD)	t-test p-value
No Income (t.1)	54	0.506 (0.313)	**0.481 (0.337)**	0.533 (0.283)	0.003***
Fixed Income (t.1)	54	0.569 (0.313)	0.590 (0.246)	**0.550 (0.336)**	0.014**
Fixed Income (t.2)	55	0.595 (0.286)	**0.577 (0.296)**	0.614 (0.285)	0.023**
Random Income (t.2)	55	0.580 (0.286)	0.593 (0.263)	**0.569 (0.305)**	0.134
Random Income (t.3)	54	0.554 (0.308)	**0.561 (0.286)**	0.548 (0.322)	0.430
Correlated Income (t.3)	54	0.519 (0.308)	0.513 (0.313)	**0.526 (0.302)**	0.472
Fixed Income, Final Per. (t.4)	60	0.491 (0.295)	**0.471 (0.299)**	0.511 (0.298)	0.012**
Random Income, Final Per. (t.4)	60	0.456 (0.295)	0.433 (0.272)	**0.479 (0.315)**	0.003***

Table 3: Mean Investment Rates, First and Second Halves of the Experiment

Period	n	First Half Mean (SD)	Last Half Mean (SD)	t-test p-value
No Income (t.1)	54	0.511 (0.328)	0.502 (0.298)	0.2985
Fixed Income (t.1)	54	0.598 (0.302)	0.541 (0.288)	0.0003***
Fixed Income (t.2)	55	0.623 (0.299)	0.566 (0.281)	0.0002***
Random Income (t.2)	55	0.597 (0.291)	0.564 (0.281)	0.0181**
Random Income (t.3)	54	0.569 (0.309)	0.539 (0.300)	0.0381**
Correlated Income (t.3)	54	0.532 (0.315)	0.506 (0.299)	0.0608*
Fixed Income, Final Per. (t.4)	60	0.481 (0.306)	0.501 (0.292)	0.9071
Random Income, Final Per. (t.4)	60	0.448 (0.307)	0.464 (0.282)	0.8428

Figure 6: Mean Investment vs. Portion of Positive Returns

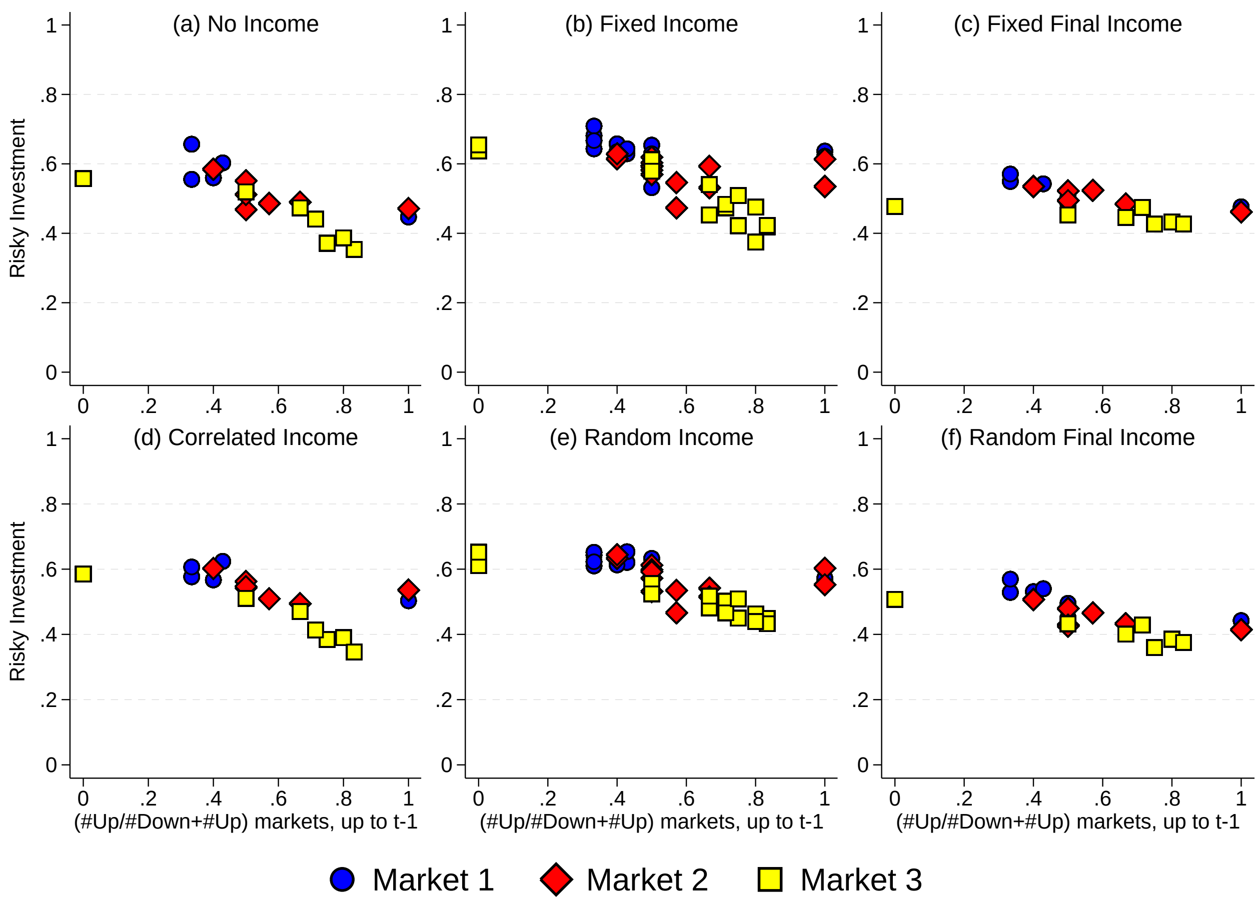

Table 4: Random Effects Tobit and linear Models

	Inv. No Inc.		Inv. Fixed Inc.	
	Tobit	OLS	Tobit	OLS
Port. of positive returns ($\hat{\beta_2}$)	-0.2971***	-0.2365***	-0.2555***	-0.2065***
	(0.033)	(0.044)	(0.022)	(0.027)
Period ($\hat{\beta_1}$)	0.0020	0.0009	-0.0158***	-0.0136***
	(0.004)	(0.003)	(0.003)	(0.003)
Constant ($\hat{\alpha}$)	0.6915***	0.6305***	0.8277***	0.7589***
	(0.049)	(0.047)	(0.019)	(0.034)
Observations	1,134	1,134	2,289	2,289
Subjects	54	54	109	109
ll	-285.9	.	-463.5	.
p	0	1.11e-07	0	0
$\hat{\sigma}$	0.243	0.206	0.234	0.201

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Mean Investment Rates, No Income and Fixed Income Tasks

Period	n	No Income Mean (SD)	Fixed Income Mean (SD)	t-test p-value
All	**54**	**0.506 (0.313)**	**0.569 (0.297)**	**0.000*** **
1	54	0.544 (0.307)	0.641 (0.306)	0.000***
2	54	0.492 (0.290)	0.603 (0.286)	0.000***
3	54	0.501 (0.301)	0.592 (0.271)	0.000***
4	54	0.506 (0.294)	0.555 (0.286)	0.016**
5	54	0.479 (0.311)	0.515 (0.297)	0.053*
6	54	0.511 (0.324)	0.554 (0.302)	0.018**
7	54	0.507 (0.335)	0.566 (0.307)	0.006***
8	54	0.510 (0.342)	0.529 (0.304)	0.238

Table 6: Random Effects Tobit and linear Models

	Inv. Fixed Inc. - Inv. No Income
Period	-0.0115***
	(0.004)
Constant	0.1146***
	(0.030)
Observations	1,134
Subjects	54
ll	.
p	1.11e-07
$\hat{\sigma}$	0.206

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Mean Investment Rates, Fixed and Independent Random Income Tasks

Period	n	Random Income Mean (SD)	Fixed Income Mean (SD)	t-test p-value
All	**55**	**0.580 (0.286)**	**0.595 (0.292)**	**0.013****
1	55	0.616 (0.275)	0.635 (0.286)	0.142
2	55	0.609 (0.275)	0.630 (0.281)	0.118
3	55	0.600 (0.280)	0.628 (0.275)	0.057*
4	55	0.561 (0.291)	0.600 (0.285)	0.018**
5	55	0.567 (0.283)	0.580 (0.285)	0.231
6	55	0.569 (0.294)	0.575 (0.305)	0.397
7	55	0.555 (0.291)	0.554 (0.298)	0.527
8	55	0.563 (0.300)	0.554 (0.310)	0.686

Table 8: Mean Investment Rates, Fixed and Randon Final Income Tasks

Period	n	Random Income Final Per. Mean (SD)	Fixed Income Final Per. Mean (SD)	t-test p-value
All	**60**	**0.456 (0.295)**	**0.491 (0.299)**	**0.000*****
1	60	0.447 (0.276)	0.480 (0.288)	0.048**
2	60	0.455 (0.286)	0.472 (0.291)	0.216
3	60	0.436 (0.277)	0.478 (0.290)	0.032**
4	60	0.454 (0.292)	0.493 (0.301)	0.029**
5	60	0.428 (0.289)	0.485 (0.293)	0.002***
6	60	0.474 (0.314)	0.501 (0.298)	0.088*
7	60	0.475 (0.305)	0.507 (0.320)	0.054*
8	60	0.478 (0.321)	0.514 (0.314)	0.059*

Table 9: Average Investment Rates, Independent Random and Perfectly Correlated Income Tasks

Period	n	Correlated Income Mean (SD)	Random Income Mean (SD)	t-test p-value
All	**54**	**0.519 (0.308)**	**0.554 (0.305)**	**0.000*****
1	54	0.544 (0.299)	0.597 (0.310)	0.006***
2	54	0.541 (0.312)	0.578 (0.294)	0.058*
3	54	0.530 (0.288)	0.566 (0.300)	0.039**
4	54	0.514 (0.300)	0.536 (0.295)	0.143
5	54	0.483 (0.300)	0.527 (0.299)	0.011**
6	54	0.520 (0.317)	0.573 (0.304)	0.005***
7	54	0.505 (0.320)	0.539 (0.321)	0.064*
8	54	0.516 (0.325)	0.518 (0.312)	0.458

Table 10: Crossover vs. Between-Subjects Design t-test

Task (Treatment)	n	Total Mean (SD)	t-test p-value	n	First Task Mean (SD)	t-test p-value
No Income (t.1)	54	0.506 (0.313)	0.000***	28	0.481 (0.337)	0.000***
Fixed Income (t.1)	54	0.569 (0.297)		26	0.590 (0.246)	
Fixed Income (t.2)	55	0.595 (0.292)	0.013**	29	0.577 (0.296)	0.163
Random Income (t.2)	55	0.580 (0.286)		26	0.593 (0.263)	
Random Income (t.3)	54	0.554 (0.305)	0.000***	26	0.561 (0.286)	0.002***
Correlated Income (t.3)	54	0.519 (0.308)		28	0.513 (0.313)	
Fixed Income, Final Per. (t.4)	60	0.456 (0.295)	0.000***	30	0.471 (0.299)	0.005***
Random Income, Final Per. (t.4)	60	0.491 (0.299)		30	0.433 (0.272)	