

Investment Behavior in the Laboratory Preliminary for GRI

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November 16, 2015

Abstract

This paper is an experimental study of dynamic investment decisions. The goal of the experiment is to test theoretical predictions of the effect of human capital on investment. Subjects make repeated portfolio allocation decisions, allocating their money between cash and a gamble that represents the market. Human capital is simulated by the degree to which income is correlated with the market. This preliminary paper describes the model and the experimental design.

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Introduction and justification

The economic well-being of individuals depends significantly on their investment decisions. Through their life, individuals must choose the portfolio of assets for their savings. This portfolio can include cash, real assets (real estate), and financial assets and instruments such as bonds, stocks or options. Some portfolios have higher expected returns, but normally this comes at a cost of a higher risk of losses. The main decision investors have to make is the level of risk they are willing to assume. This is not a one time decision. Normally, investors have the ability to adjust their portfolio along their life cycle.

The dynamic portfolio decision has been studied by economists for decades. The seminal work of Samuelson (1963, 1969) predicts that an investor's portfolio choice will be independent from her time-horizon. The chosen portfolio will depend mainly on the investor's attitude towards risk. Nonetheless, this prediction arises under a very restrictive set assumptions. One them is that the investor has no income. An individual's future income could be summarized by her human capital, which can be defined as the present value of the expected future income she expects to earn through her life-time:

$$\text{Human Capital}_t = E_t \left[\sum_{s=t+1}^T \beta^s \text{Income}_s \right] \quad (1)$$

Human capital acts as a form of wealth that can be added to a person's other assets in order to calculate her total wealth. By including human capital, the portfolio decision begins to depend on the time horizon. The main result is that, under a very general set of circumstances, human capital will act as an implicit investment on the riskless asset. This will lead investors to place a smaller share of their current savings in safe assets in order to reach their target level of portfolio risk. When making the investment decision what matters is not the current level of savings, but total wealth: human capital plus current asset holdings. By including human capital, the investment path will depend on 1) the amount of human capital relative to current period savings, 2) the uncertainty of human capital, and 3) the degree to which human capital is correlated with the returns of other assets.

Many studies have attempted to contrast the theoretical results with the data. Nonetheless, these analysis are difficult given the characteristics

of the available data. For instance, it is difficult to measure human capital because future income is unknown. This is difficult for both investors and researchers. Also, it is difficult to assess a person's attitudes towards risk, or how it evolves over time. Additionally, when looking at data one should take into account that it is whole households, instead of individuals who usually make investment decisions. Finally, one could expect that preferences will not remain unchanged at different stages of life. Instead, one can expect that they will evolve due to factors such as career histories or by the conditions currently experienced by the economy. Additionally, as Roussanov (2010) mentions, given the quality of the information available, the study of portfolio choices suffer from identification problems, mainly because it is difficult to disentangle in panel data the cohort effects on investment from the age effects.¹

Experimental economics is a tool that can overcome the limitations of other empirical approaches. The advantage of an experiment is that it allows us to study investment decisions in a controlled setting. This allows us to control the main variables and parameters relevant to the investment decision. It also allows us to measure the participants' attitudes toward risk and to have an accurate measure of their human capital.

This document describes an experiment whose aim is to study how investors make dynamic investment decisions. Specifically, our interest is centered on the effect of human capital on these decisions. This proposal is organized as follows. Section 1 highlights the most important theoretical results related with the proposed experiment. Section 2 summarizes the empirical studies related with human capital and portfolio choices. This includes studies using survey data and experimental results. Section 4 describes the theoretical model that will be used as reference for the experiment. Section 5 describes the experimental task.

1 Dynamic portfolio and human capital theory literature review

The seminal works of Mossin (1968), Samuelson (1969) and Merton (1969) lay the foundations of the theory of investment over the life cycle. These

¹This issue is explained in detail by Ameriks and Zeldes (2004) and Guiso and Sodini (2013)

models make two important predictions. The first is that, at any age, it is optimal to invest in risky assets. The second is that the share of an individual's wealth invested in risky assets should remain constant independent of the investment horizon.² This prediction is not in line with the habitual recommendation given by financial advisors: invest more in risky assets when one is young and less as one gets closer to retirement. Nonetheless, these models make a series of assumptions that limit their ability to explain actual investment behaviour. The most important are the following:

1. There is no labor income.
2. Asset returns are identical and independently distributed.
3. Preferences are additively separable over time.
4. Markets are frictionless (no transaction costs.)
5. There are no additional sources of income and all assets are tradeable.

Merton (1971) extends the basic model by adding riskless and tradeable labor income. He shows that income leads people to invest more in the risky assets when young. The intuition of this result is that having labor income is equivalent to an implicit investment in a riskless asset. Individuals take this fact into account when making their investment decisions. As described in equation 1, future income can be summarized by human capital. When young, individuals have a large amount of human capital and few financial assets. Thus if they wish to invest a certain portion of their wealth (human capital plus financial assets) in a portfolio with a certain degree of risk, they will have to invest a relatively large portion of their financial wealth in the risky asset. As individuals get older, their financial assets grow and their human capital shrinks. As this happens, to keep their desired level of investment, they have to reduce the portion that they invest in the financial asset. The result is that, as individuals age, their share of the risky investment falls. This result is robust to the relaxation of other assumptions of the baseline model.

In general, human capital is neither easily tradeable over time nor riskless. Bodie et al. (1992) incorporate non-tradable flexible labor supply in

²This results is analogous to the one period separation theorem from static portfolio theory.

their model. They also make human capital uncertain, but they keep it independent from the movements in the returns of the financial assets. They show that, under these assumption, it is still optimal to hold a safer portfolio the closer the investor is to retirement. They also show that having labor flexibility increases risk-taking. Heaton and Lucas (1997) develop a similar model, but allow for stochastic income that is uncorrelated with the risky asset. They find that, as long as income is not highly correlated with the price of the risky asset, it will act as an implicit holding of the safe asset. This gives an incentive for the agents to hold a larger share of the risky asset. They find, for a wide range of parameters, that the optimal response is to invest all savings in stocks. In a similar way, Koo (1999) develops a model with uninsurable random income and liquidity constraints. He shows that these two conditions will lead the investor to invest less in the risky asset.

Viceira (2001) also presents a model with labor risk. He shows that employed investors will allocate more resources to the risky asset than unemployed ones. He also shows that as the idiosyncratic risk of human capital increases, the willingness to hold the risky asset drops. This drop increases even more if income is positively correlated with the risky asset. The optimal portfolio allocation for stocks is larger the longer the retirement horizon of the investor. They also show that a positive correlation between labor income and the market return further reduces the desired investment in the risky asset.

The models from Heaton and Lucas (1997), Koo (1999) and Viceira (2001) assume an infinite horizon. This feature makes these models of limited use to understand issues related with the life-cycle. Cocco (2005) build a finite-horizon model with uninsurable labor income risk. They find that despite this risk, labor income (uncorrelated with equity risk) is perceived as a better substitute for riskless bonds than equities. This leads to higher demand for equities, especially when individuals are young. Interestingly, they found that including a small probability of a very bad labor income lowers the allocation to equities, bringing it closer to empirical observations.

Benzoni et al. (2007) find contrasting results by assuming cointegration between the labor income and the market returns. They propose a model in which labor income is cointegrated with the dividend process of the market portfolio. In contrast with earlier results, these paper finds that it is optimal for young investors to hold short positions in the risky portfolio. The intuition behind this result is related to the fact that when human capital

is cointegrated with the risky asset it has stock-like characteristics. Young investors that have a large stock of human capital are very exposed to the market risk and will limit the additional risk that they will take by investing directly on risky assets.

In a similar manner as Bodie et al. (1992), Gomes et al. (2008) studies a model with variable labor supply, but assumes uncertain wages. He finds that variable labor supply raises the level of optimal equity holdings. Endogenizing the labor supply allows us to look at the insurance like characteristics of labor: people can work more to make up for losses in the financial market. Fagereng et al. (2013) builds on the model of Gomes et al. (2008) by adding a small probability of a large loss and a participation cost. These changes make the model fit better two empirical observations: the low level of participation in the stock market and the large share of investors leaving the risky asset market when they reach retirement.

Peijnenburg (2014) presents a model with ambiguity averse investors and uncertainty about the equity premium. With his model he is able to explain two empirical observations: the low percentage of the portfolio invested in equities and the low participation in the stock market.

2 Empirical literature on dynamic portfolio choice theory

Heaton and Lucas (2000) argue that households with more business income will invest less in stocks given the higher level of background income that they face.

Ameriks and Zeldes (2004) uses panel data from TIAA-CREF contributors, and find that the participation in the stock market has a hump-shape during the life cycle and that the composition of the portfolio shows little change. Fagereng et al. (2013) make a similar study, but with households instead of individuals. They use information about the life-cycle portfolio allocation on a sample of 164,000 households in Norway, using 15 years of tax registry information. They have the advantage of being able to see the entire portfolio (instead of only retirement savings as Ameriks and Zeldes (2004)) They find that share of risky assets in the household portfolio begins to diminish in middle life, as retirement approaches. They also find limited participation at all ages, and a tendency to exit the market before

retirement.

The level of sophistication of the participants in the market is related with their willingness to take risk. Using survey information for Norway, Calvet et al. (2007) find that more sophisticated and educated households take more risk, but also are more efficient investing.

Cardak and Wilkins (2009) studies the determinants of household portfolio decision looking at data from the Households, Incomes and Labour Dynamics in Australia survey. They find that risky asset holdings are negatively related with poor health and labor income uncertainty. Additionally, they find that risky asset holdings seem to be positively related with financial awareness and knowledge. Angerer and Lam (2009) uses information from the US National Longitudinal Survey of Youth and finds that permanent incomes risk reduces the level of investment in stocks, while temporary risk does not. An important factor that is taken into account is as estimation of human wealth.

Jin (2011) shows that by including housing and private business in the portfolio of risky assets of households the empirical evidence matches the theoretical prediction (Merton (1971), Bodie et al. (1992), Heaton and Lucas (1997)) that the share of risky assets in the portfolio of younger households is higher. Veld-Merkoulova (2011) studies the importance of age and self-reported planning horizon in portfolio investment. She finds that longer planning horizons are positively related with investments in risky financial assets.

Yilmazer and Lich (2013) approach the problem of how portfolio decisions are taken in a household with several people with different risk preferences. Using information from the health and retirement study, they show that the risky share in the portfolio increases depending on the risk preferences of the spouse who has more bargaining power.

Calvet and Sodini (2014) is able to overcome many of the identification problems by using portfolio information from a panel of 23,000 twins. They find evidence that both participation in risky financial asset markets and the risky share conditional on participation are positively correlated with wealth. Using twins also allows them to control for time, cohort and age effects. Their evidence provides evidence that expected human capital positively drives the risky share of investment portfolios.

3 Related experimental literature

To the best of our knowledge, no one has used experiments to study the importance of human capital on dynamic investment decisions in a way that is similar to the way we describe in this proposal. Nonetheless, several studies have used experiments to study how the length of the investment horizon affects the portfolio decisions.

Klos (2004) studies the importance of the time horizon in the dynamic portfolio decisions. He compares two treatments: one in which the participants made a single investment decision and one where they made a two period sequence in investment choices. Fifty-one business students took part in the study. All the participants participated in both treatments, but their order was randomized. They did not find a statistically significant difference in the average investment made in the one period treatment and in the first period of the two periods treatment. This is consistent with the empirical models.

Sundali and Guerrero (2009) studied an experiment in which subjects make repeated asset allocations to stocks, bonds and cash. The novel ingredient of the experiment is that in one of their treatments they gave the investors projections about the expected future value of their portfolio. Those participants that received projections allocate a larger share of their wealth to stocks. Their experimental task had 20 periods. The subjects were given an endowment in the first period that they had to reallocate, each period, between a risky and riskless assets. The expected returns on the stock came from the historical distribution. 60 subjects took part in the experiment.

Brocas et al. (2014) use a dynamic portfolio choice experiment to assess people's risk attitudes. They find a high heterogeneity of preferences among the subjects. Nonetheless, they find that decreasing absolute risk aversion and increasing relative risk aversion are the most prevalent risk types. Their experiment uses a dynamic investment task with two assets (one safe and one risky) and 10 investment periods. Each player goes through 15 investment paths (one is randomly chosen for compensation) for a total of 150 decisions. Additionally, the players go through 5 practice paths. All players are subject to the same market draws. A total of 120 subjects participate in the experiment. The return of the safe asset is 3% and the return of the risky asset is 6% with a standard deviation of 55%. The parameters do not change through the experiment. They do not allow borrowing and

short sales, because either could lead to taking money from the participants (participants ending the task with a negative balance).

Carbone and Infante (2014) Studies the saving and consumption decisions in a dynamic setting under three scenarios: certainty, risk and ambiguity. The saving-consumption choice is not directly relevant for our project. Nonetheless, the experimental design is interesting for our experiment. Each participant only follow one treatment.

Kapteyn and Teppa (2014) measures risk preferences and then used them in a portfolio models that explains portfolio shares and accounts for incomplete portfolios and fixed costs. The risk free asset has a 3% return. The risky asset is a binary lottery that can either increase 20% or decrease 10% with equal probability.

4 Theoretical model

4.1 Model description

This section describes the theoretical version of our experimental treatment. The treatment is a simplified version of the more general versions of the dynamic portfolio choice problem that are described in the literature. The version of the model described here follows closely the experimental task that we plan to apply in the lab, and most importantly, arrives to the same conclusions as the more general versions of the model.

The economy in the model lasts T periods. in $t = 0$, the agent receives an initial endowment of W_0 . The decision made by the investor in every period from $t = 1, \dots, T$ is how to split the available wealth between a risky asset (S_t) and cash (B_t):

$$S_t + B_t = W_t \tag{2}$$

The amount invested in cash will gain no interest and will pass to the next period, free of risk. On the other hand, the amount invested in the risky asset will receive a return equal to r^s . The price of the risky asset evolves according to:

$$S_{t+1} = S_t(1 + r_t) \quad (3)$$

The return on the risky asset is uncertain. Each period, the risky asset return can have a negative or a positive return: r^d or r^u . The probability of having a negative or positive return, in a given period, is fixed and independent across periods:

$$p(r_t = r^d) \equiv p_t^d = p^d, \quad t \in \{1, \dots, T\} \quad (4)$$

The probability of a high market is,

$$p(r_t = r^h) \equiv p_t^h = p^h = 1 - p^d. \quad (5)$$

Additionally, in each period the agent receives an income (y_t), which could either take a low (y^l) or high (y^h) value. Each value can occur with probability p^l and $p^h = 1 - p^l$, respectively. The probability of having a high or a low income is correlated with the risky market outcome for that period, so that,

$$p_t^l \equiv p(y_t = y^l) = p^d p(y_t = y^l | r_t = r^d) + p^h p(y_t = y^l | r_t = r^h). \quad (6)$$

The correlation between income and risky asset processes stays the same across periods so that,

$$p_t^l = p^l, \quad t \in \{1, \dots, T\}. \quad (7)$$

and $p^h = 1 - p^l$.

Following the definition of Deaton, the cash in hand available to the subject to invest and save is

$$W_0 = S_0 + B_0 \quad (8)$$

and

$$W_t = y_{t-1} + (1 + r_{t-1}^s)S_{t-1} + B_{t-1} \text{ for } t \in \{1, \dots, T\}. \quad (9)$$

The preferences of the subject are described by a constant relative risk aversion (CRRA) utility function

$$u(W) = \begin{cases} \frac{(W)^{1-\gamma}}{1-\gamma} & \text{if } \gamma \neq 1 \\ \ln(W) & \text{if } \gamma = 1 \end{cases} \quad (10)$$

As its name implies, this function has the property that the level of risk aversion of the subject is independent from his level of wealth. His risk preferences are summarized by γ . A higher γ means a higher degree of risk aversion. If γ is zero, the agent is risk neutral. If γ is negative the agent is risk preferring. We could have instead assumed a function with decreasing relative risk aversion. Nonetheless, Wachter and Yogo (2010) and Chiappori and Paiella (2011) show that there is strong evidence that the investor preferences are better represented by a constant relative risk aversion utility function.

We abstract from the consumption decision in the model so that we can isolate the investment decision. The objective of the investor will be to maximize the expected utility of his wealth in period T : The optimization problem can be summarized as follows

$$\max_{(S_t, B_t)_{t=0}^{t=T-1}} E\left\{\delta^T \frac{(W_T)^{1-\gamma}}{1-\gamma}\right\} \quad (11)$$

subject to

$$W_0 = S_0 + B_0 \quad (12)$$

$$W_t = y_{t-1} + (1 + r_{t-1}^s)S_{t-1} + B_{t-1} \text{ for } t \in \{1, \dots, T\}. \quad (13)$$

The agent also faces a liquidity constraint

$$S_t + B_t \leq W_t. \quad (14)$$

In any period, the agent cannot invest more than his cash in hand.

A second restriction is that the agent can only invest positive quantities in the risky asset. This is the same as saying that he can not short sell the risky asset

$$S_t \geq W_0. \quad (15)$$

If we take into account these restrictions and the fact that the agent can decide every period how to invest, our problem at any $t \in 0, \dots, T-1$ boils down to maximizing the expected utility of wealth in $t+1$. We can make this simplification because the market return process is independent across periods and the income process is only contemporaneously correlated with the risky asset. This means that the decisions, market conditions, and income experienced up to t don't have any repercussions on the market, income or wealth accumulation beyond $t+1$.

Additionally, we will assume that $\lambda = 1$. This means that the agent doesn't experience impatience across periods. The reason for this assumption is that the lab treatment will not mimic in anyway the time dimension of the subject decision. The reason is that all the stages of the game will take place within the same experimental session. The only distinctive moments for the participants are when the experiment begins and when it ends. They never get the chance to show their time preferences, because they receive only a single payment.

Nonetheless, we should take into account that even though the agent is constrained to invest at most his cash in hand in every period, he will consider in his decision all his wealth (cash in hand and expected future income). We will denominate the sum of his future income as his human capital

$$HC_t = E_t \left\{ \sum_{i=t+1}^T y_i \right\}. \quad (16)$$

One important item to specify is how the agent will include his human capital in his period t investment decision. Because his human capital is uncertain, he cannot simply add up the value of his human capital. If we take into account the uncertainty associated with his human capital the agent will value his future human capital differently depending on his risk preferences. His future stream of income could end up taking many different accumulated values up to T . For the subject his future stream of income is like participating in a lottery that could take different values with different probabilities. Because we assume that the period income will take only two

values (y^h or y^l) with fixed probabilities (p^h and p^l), the stream of future income can be modeled with a Bernoulli process $\{y_i\}$ for $i \in \{t+1, \dots, T\}$, such that:

$$y_t \text{ i.i.d } \sim p^h = 1 - p^l \in [0, 1]. \quad (17)$$

The space of elementary events of $\{y_i\}$ will be given by

$$\Omega = \omega, \text{ where } \omega \text{ takes the form } \omega = (y^h, y^l, y^l, \dots). \quad (18)$$

The number of elements in Ω is given by $2^{(T-t)}$. Nonetheless, we can simplify it by grouping the elements of Ω giving the same accumulated income. In that case, we end up with only $T - t$ distinctive values for the future income. if N^h denotes the number of times that the income will be high in the future, we can find the probability of having N^h high incomes (and $T - t - N^h$ low incomes) as:

$$P[N^h = n] = \binom{T-t}{n} (p^h)^n (1 - p^h)^{T-t-n} = \binom{T-t}{n} (p^h)^n (p^l)^{T-t-n}. \quad (19)$$

With this probability we can calculate the expected value of the future human capital

$$HC_t = E_t \left\{ \sum_{i=t+1}^T y_i \right\} = \sum_{j=0}^{T-t} \binom{T-t}{j} (p^h)^j (p^l)^{T-t-j} (jy^h + (T-t-j)y^l). \quad (20)$$

The expression in the last set of brackets in the right hand side gives us each of the possible values of the accumulated income. The rest of the expression in the right hand side gives us the probability of getting j high and $T - t - j$ low incomes in $T - t$ trials.

Equation 20 shows the expected value of future income. Nonetheless, unless the agent is risk neutral, he will associate a lower value to his future income. To find the present value of the future uncertain income, we can observe that it is equivalent to participating in a lottery that will pay ($jy^h +$

$(T - t - j)y^l$ with probability $P[N^h = n]$. So, if we want to know the future value of this lottery, we have to find its certainty equivalent (CE): the certain amount for which the agent would be willing to trade his lottery. For this to be the case, this certain amount should give the subject at least as much utility as the one he gets from keeping it. It is important to keep the current cash in hand position of the agent when calculating the certainty equivalent. The reason is that we are comparing the following two situations: the certainty equivalent plus his cash in hand and his future uncertain income plus his cash in hand. Taking this into account we have that

$$U(CE_t + W_t) = \sum_{j=0}^{T-t} \binom{T-t}{j} (p^h)^j (p^l)^{T-t-j} u((jy^h + (T-t-j)y^l) + W_t). \quad (21)$$

One last item to take into account is the correlation between the next period risky asset return and labor income. This correlation is taken into account by the agent when making his investment decision. In the next period, the investor will face four possible situations: 1) r^u and y^h , 2) r^u and y^l , 3) r^d and y^h , and 4) r^d and y^l .

The labor income beyond $t + 1$ only enters the investment decision for the next period through the certainty equivalent for $t = 1$, as described by equation 21. The reason is because income from $t + 2$ onwards is independent from period's t market and from periods t and $t + 1$ incomes.

Given the conditions described above, we can rewrite the optimization problem of the investor as follows:

$$\max_{(S_t, B_t)} E\left\{\frac{(W_{t+1} + CE_{t+1})^{1-\gamma}}{1-\gamma}\right\} \text{ for } t = 0, \dots, T \quad (22)$$

subject to

$$W_0 = S_0 + B_0 \quad (23)$$

$$W_t = y_{t-1} + (1 + r_{t-1}^s)S_{t-1} + B_{t-1} \text{ for } t \in \{1, \dots, T\} \quad (24)$$

$$S_t + B_t \leq W_t \quad (25)$$

$$S_t \geq W_0 \tag{26}$$

There are some interesting things to notice about this new representation of the optimization problem. First, the future stream of income, from $t + 2$ onwards, can be summarized by the certainty equivalent. Given the liquidity constraint that does not allow the agent to take loans, the human capital beyond $t + 2$ acts as a cash position equivalent to the certainty equivalent. The agent may like to invest a certain fraction of his total wealth (cash in hand plus the certainty equivalent of the human capital) in the risky asset, but is constraint to invest at most W_t . on the other hand, next period income y_{t+1} is different from the income of the other periods because is correlated with the market return for which the subject has to make a decision in the current period. This income will have an effect in the decision of the agent depending on the kind of correlation that it has with the market.

4.2 Optimal strategy

This model has to be solved numerically. The optimal strategy of the subject depends on the specific path that the income and market return processes take. The main difference between different realizations of the income and returns processes is that they leave the investor with different quantities of cash in hand. Keeping other things equal, subjects who experience relatively unlucky paths (low market returns or income) will have a lower cash in hand, which will affect their level of total wealth. On the other hand, the expectations about the future are path independent. This is so, because our model (and the analogous lab experiment) assumes that there is no correlation across periods for the income or the risky asset returns.

The main results from the model are the following:

1. More risk averse investors (those with higher γ) will invest an smaller share of their cash in hand in the risky asset.
2. The higher the volatility of the risky asset (higher $np(1-p)$) the lower the investor investment in the risky asset.
3. Investors with larger human capital will invest a larger share of their cash in hand in the risky asset. A corollary from this result is that, other things equal, people with longer time horizons will tend to invest more in the risky asset.

4. The higher the volatility of the labor income the lower the investment in the risky asset.
5. If the correlation between the labor income and the market return is positive, the investor will invest less in the risky asset, compared with the situation where there is no correlation. The intuition is that labor income equates partially to an implicit investment in the risky asset.
6. If the correlation between the labor income and the market return is negative, the investor will invest more in the risky asset, compared with the situation where there is no correlation. The intuition is that with negative correlation labor income partially hedges the market risk.

The theoretical predictions enumerated above are the ones that we want to test in the lab. The explicit solution to the model depends on the assumption made about the parameters of the model. In section 5, where we describe the set of specific treatments that we plan to follow in the lab, we will describe the expected optimal path of investment under different circumstances.

We want to simulate the following scenarios,

- no labor income;
- fixed labor income;
- risky income whose movement is independent from the financial market;
- risky income that is positively correlated with the financial market and;
- risky income that is negatively correlated with the financial market.

5 Experimental task

The experimental task follows the theoretical model described above. It will have the following phases:

1. First the subject learns about the rules of the task. Then they receive a complete description of the particular circumstances that they will face. They will be informed about
 - The number of periods of the task: T ;
 - Their initial endowment: W_0 ;
 - The values that the risky asset could take: r^u or r^d ;
 - The odds of getting and r^u or r^d return: p^u or p^d ;
 - The possible values that their income could take: y^h or y^l ;
 - The odds of getting a y^h or y^l return given the risky asset outcome: $p[y_t = y^l | r_t = r^u]$, $p[y_t = y^l | r_t = r^d]$, $p[y_t = y^h | r_t = r^u]$ and $p[y_t = y^h | r_t = r^d]$. Pedagogically, this is the most difficult piece of information to give to the participants. To make the probabilities easy to understand for the participants we will depict them with lottery wheels. First, we will represent the risky market two possible returns with a wheel. This wheel will spin first, deciding the outcome for the risky asset return. Once this outcome is known we will move to the income market that will be represented by two wheels. Each will operate depending on the risky asset return outcome. This means that each will for the income process is depicting the conditional probability of getting and low or high outcome conditional on the risky return outcome.
2. Next, the subjects are asked to split their endowment between the risky asset and cash. After making this choice, the economy moves to the end of the current period (beginning of the following period).
3. After making the decision, the risky asset return for the next period is determined.
4. Then, given the risky asset outcome the correct wheel is chosen for the income the period outcome is determined.
5. Given these two outcomes and the investment decision taken by the subject, the new cash in hand is determined.
6. After knowing about his new cash in hand, the agent has to make a new investment decision.
7. The same processes is repeated T times.

8. At the end of the treatment, the participant will be informed of her final period accumulated wealth.

When making their choices, the subjects face the restrictions faced in the theoretical description of the task. Namely:

- Their investment should be equal or lower to their current cash in hand.
- They cannot invest a negative quantity on the risky asset. This is, that they can not take short position on the risky asset.

The treatment described above will be repeated under different assumptions about the parameters. A treatment can be characterized by T , W_0 , r^u , r^d , p^u , p^d , y^h , y^l , $p[y_t = y^l | r_t = r^u]$, $p[y_t = y^l | r_t = r^d]$, $p[y_t = y^h | r_t = r^u]$ and $p[y_t = y^h | r_t = r^d]$.

5.1 Treatments

This section describes the parametrization of the different treatments that we plan to apply in the lab. In an ideal setting, we would practice the treatments with dozens of risky asset conditions. Nonetheless, given the time limitations, we will analyze two versions of each of the treatments described: one with high volatility and high risky asset returns and one with low volatility and low returns. The reason why this is useful is that these scenarios should allow us to get interesting responses from agents across wide levels of risk aversion.

The two risky asset settings that we plan to consider are the following

- **Low volatility:** $p^u = 0.5$, $p^d = 0.5$, $r^u = 0.35$, and $r^d = -0.25$
- **High volatility:** $p^u = 0.5$, $p^d = 0.5$, $r^u = 0.7$, and $r^d = -0.35$.

As we will see in the description of the different treatments, other things equal, we would expect that agents with low risk aversion ($\gamma = 0.2$, for example) will often invest close to 100% of the cash in hand in the low volatility treatments. On the other hand, agents with high risk aversion

($\lambda = 2$, for example) will tend to invest close to 0% in the high volatility treatment. We will see this more clearly in the description of each of the treatment scenarios.

Each treatment will last $T = 6$ periods. This number of periods is convenient because it is long enough to allow us to make meaningful comparisons and short enough to be able to limit the possible values of the accumulated return. Additionally, making each treatment shorter allow to play more treatments, before the time is up or the participants may have exhausted their concentration to solve questions. With 6 periods, the main test that we will perform is to compare the behavior in the first three and the last three periods.

After completing all the treatments, one of them will be chosen at random to make the payment to the participants.

5.1.1 No income treatment

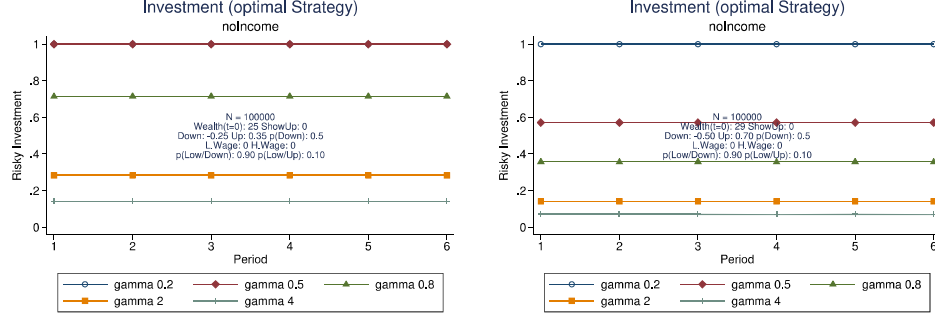
The defining characteristics of this treatment is that there is no income. The participants only receive the initial endowment, W_0 . The parameters for this treatment are the following:

- $T = 6, W_0 = 10, p^u = 0.5, p^d = 0.5$
- $y^h = 0, y^l = 0,$
- $p[y_t = y^l | r_t = r^u], p[y_t = y^l | r_t = r^d]$: N/A (no income)
- $p[y_t = y^h | r_t = r^u], p[y_t = y^h | r_t = r^d]$: N/A (no income)

One important adjustment made to this treatment is that the initial endowment is larger compared with the treatments that have period income. We make this to make the expected payoff from this treatment comparable to the expected payoff of the treatments with income where $W_0 = 10$

The optimal strategy predicted by our theoretical model is described in the following figure.

As the figure shows the percentage that the person is predicted to invest in this scenario is the same independent of the level of income. The only



thing that makes a difference in the choice is how volatile is the risky market return and how risk averse is the subject.

5.1.2 Fixed income treatment

The defining characteristics of this treatment is that period income y_t is fixed and known with certainty. We choose the period income so that it will be equal to the expected value of the income in the risky treatments that are described below. The parameters for this treatment are the following

- $T = 6$, $W_0 = 10$, $p^u = 0.5$, $p^d = 0.5$
- $y^h = y^l = 2$,
- $p[y_t = y^l | r_t = r^u]$, $p[y_t = y^l | r_t = r^d]$: N/A (fixed income)
- $p[y_t = y^h | r_t = r^u]$, $p[y_t = y^h | r_t = r^d]$: N/A (fixed income).

Having income has the effect of making agents want to invest a larger part of their cash in hand in the beginning and a smaller one at the end. This has a simple intuition. What happens is that each period the subject wants to invest a fraction of his wealth in the risky asset. The problem is that his wealth is not only composed of his cash at hand but also by his human capital. Because in the initial periods his cash in hand is relatively low to his total wealth, he will invest a relatively large portion of this cash in hand in the risky period. He could even want to invest more than 100% of his cash in hand, but is constrained by the fact that he does not have access to credit. As the periods progress a smaller portion of his wealth is in

human capital and the portion that he want to invest in the risky asset will be available as cash in hand, making the percentage investment smaller.

5.1.3 Risky income uncorrelated with the risky asset

The defining characteristic of this treatment is that the period income is risky. Each period, the income will take a high(y^h) or low (y^l) value with probabilities p^h and $p^l = 1 - p^h$, respectively. Nonetheless, the income probabilities are independent from the risky asset returns. For this treatment the parameters are the following

- $T = 6, W_0 = 10, p^u = 0.5, p^d = 0.5$
- $y^h = 4, y^l = 0,$
- $p[y_t = y^l | r_t = r^u] = 0.5, p[y_t = y^l | r_t = r^d] = 0.5$
- $p[y_t = y^h | r_t = r^u] = 0.5, p[y_t = y^h | r_t = r^d] = 0.5.$

The values of y^h and y^l were chosen so that $E_t[y_{t+1}] = 2$. This is the income used in the fixed income treatment.

When we compare this treatment with the one with fixed income, we can see that the main difference is each period the agent is willing to invest a slightly larger portion of his cash in hand in the risky income. The intuition behind this given that the income is smaller, his future value is smaller for a risk averse agent.

5.1.4 Risky income positively correlated with the risky asset

The defining characteristics of this treatment is that the period income is risky and positively correlated with the risky asset return. This means that when $r_t = r^u$, y_t is more likely to be equal to y^h , and when $r_t = r^l$, y_t is more likely to be equal to y^l . The parameters associated with this treatment are the following:

- $T = 6, W_0 = 10, p^u = 0.5, p^d = 0.5$
- $y^h = 4, y^l = 0,$

- $p[y_t = y^l | r_t = r^u] = 0.1, p[y_t = y^l | r_t = r^d] = 0.9$
- $p[y_t = y^h | r_t = r^u] = 0.9, p[y_t = y^h | r_t = r^d] = 0.1.$

The values of the conditional probabilities of y_t were picked to guarantee that the unconditional probabilities match the values from the treatment without correlation.

$$p[y_t = y^l] = p^u p[y_t = y^l | r_t = r^u] + p^d p[y_t = y^l | r_t = r^d] = 0.5 \quad (27)$$

$$p[y_t = y^h] = p^u p[y_t = y^h | r_t = r^u] + p^d p[y_t = y^h | r_t = r^d] = 0.5. \quad (28)$$

The intuition behind the the optimal investment path is that now that the income process is correlated with the return process, the risk associated with the income is implicitly a long position in the risky asset return. Because of this link, a risk averse subject will be less willing to take risk in this case.

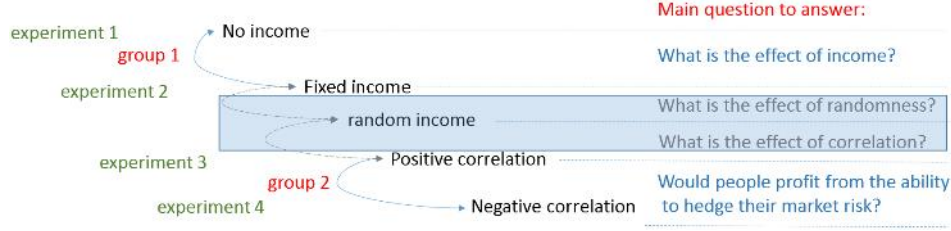
5.1.5 Risky income negatively correlated with the risky asset

In this treatment, the correlation between income and return reverses. When $r_t = r^u$, y_t is more likely to be equal to y^l , and when $r_t = r^d$, y_t is more likely to be equal to y^h . The parameters for this treatment are the following:

- $T = 6, W_0 = 10, p^u = 0.5, p^d = 0.5$
- $y^h = 4, y^l = 0,$
- $p[y_t = y^l | r_t = r^u] = 0.9, p[y_t = y^l | r_t = r^d] = 0.1$
- $p[y_t = y^h | r_t = r^u] = 0.1, p[y_t = y^h | r_t = r^d] = 0.9.$

The intuition behind the result is that because next period income is negatively correlated with the risky asset return, having income hedges the market risk: when the market goes down, income is high and when it is up the income is down. Under these circumstances, the agents have incentives to invest more in the risky asset, because, from their hedge position the risky asset is a less risky bet.

Figure 1:



5.2 Suggested treatments

The experimental treatments are summarized in figure 1. For each group, we split the participants in half, each starting the experiment with a different parameterization.

5.2.1 Measuring risk preferences

We plan to measure risk preferences using an experimental task similar to the one suggested by Holt and Laury (2002, 2005). Additionally we plan to include several questions that are commonly used in surveys to measure investors attitudes towards risk.

5.2.2 End of the experiment survey

In addition to the main experimental treatments described above, we also plan to make a survey at the end of the experiment. The purpose of the questions from the survey is to study the relation between the characteristics of the participants in the experiment and their choices. In particular, we are interested in contrasting the experiment results with the following:

- The socioeconomic profile: Age, gender, income, wealth, education.
- The risk attitudes.
- The level of financial literacy.
- The cognitive reflection profile as described by Frederick (2005). This questions allow to differentiate between intuitive thinkers (fast thinkers)

and reflexive thinkers (slow thinkers), in the way described by Kahneman (2011).

5.2.3 Who will participate in the experiment?

There are several populations that will participate in the experiment. The first one will be the group of people that are part of CIRANO's data base of volunteers to participate in experimental tasks. One limitation of working with this population is that it might not be very representative of the population at large. In particular, this sample has a very large participation of students.

A second group of participants that will take part in the experiment are members of households that participate in the program ask Canadians.

The third population that will take part in the experiment is the one composed by finance professionals.

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