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IZA DP No. 11537

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Pia Pinger
University of Bonn, briq and IZA

Sebastian Schäfer
Goethe-University Frankfurt

Heiner Schumacher
KU Leuven

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Locus of Control and Consistent Investment Choices*

We document that an internal locus of control can be hindering in financial market situations, where short-term outcomes are determined by chance. The reason is that internally controlled individuals may tend to (over-)react to random outcomes. Our evidence is based on an experiment in which subjects repeatedly invest in two identical, uncorrelated, risky assets and observe previous outcome realizations. Under mild restrictions, the optimal strategy is to make the same choice in each period. Yet, internals are more likely to make inconsistent risk choices. The effect size of locus of control is comparable with that of cognitive ability. Among inconsistent subjects, average switching behavior is in line with the gambler's fallacy. However, choices of very internally controlled individuals tend to correspond to the hot hand fallacy.

JEL Classification: D03, G02, C91

Keywords: locus of control, risk preferences, investment decisions, cognitive ability

Corresponding author:
Heiner Schumacher
Department of Economics
KU Leuven
Naamsestraat 69
3000 Leuven
Belgium

E-mail: heiner.schumacher@kuleuven.be

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1 Introduction

In many market situations, new information should trigger decision-makers to act. If the riskiness or the return expectations of an asset change, investors may want to buy or sell this asset, depending on their objectives. However, in some cases, the optimal strategy is to stick to a given allocation. Investors receive large amounts of information every day, and most of it can safely be ignored. Yet, many people struggle with "doing nothing" when confronted with new information and many options to act. Odean (1999) shows that investors with discount brokerage accounts trade too much and the stocks they buy underperform those they sell. They would be better off by adopting a "buy and hold" strategy and ignoring stock market movements.

Whether individuals respond wisely to new information depends on their ability to correctly interpret it. In this paper, we document that general beliefs about the world also matter. In a simple investment experiment, we expose subjects to outcomes generated by a random process. We make it very transparent that nothing useful can be learned from these outcomes. Under mild restrictions, it is optimal to choose the same allocation in each period. However, it may also be tempting for some subjects to react to random outcome patterns. We show that subjects with a strong belief that they can control the events that affect them are more likely to give in to this temptation. Psychologists define such beliefs, namely the conviction that reinforcement in life comes from their own actions rather than fate or luck, as "locus of control" (Rotter 1966). We show that internally controlled individuals are more likely to actively seek for patterns in random data that they could exploit, leading to inconsistent investment choices.[1]

To examine the importance of locus of control for decision-making under uncertainty, we choose a setting that mimics portfolio choice. In our experiment, each subject owns ten tokens and has to allocate this endowment among two identical, uncorrelated, risky assets that we call "entrepreneur 1" and "entrepreneur 2." Assets produce a success (high payoff) or a failure (low payoff) with equal probability. After each of ten periods, subjects observe the random outcome of each asset, which is uncorrelated with future

[1] In contrast, individuals with an "external locus of control" believe that what happens to them cannot be influenced by themselves.

outcomes. Their final payoff is the income earned in a randomly chosen period. Under mild restrictions, a rational subject would choose the same allocation in all of the ten periods. However, if subjects try to exploit the random pattern of outcomes, they may choose different allocations in different periods and therefore end up with inefficient portfolios. For example, a subject may start to believe that current outcomes are negatively correlated with previous outcomes ("gambler's fallacy"). Alternatively, she may believe in a positive correlation between past and current outcomes ("hot hand fallacy"). Depending on her beliefs, she may allocate more or less of her endowment to an asset that produced a success, while the other asset failed. We hypothesize that internally controlled subjects are more likely to follow such types of reasoning.

Only around one fifth of our subjects display consistent behavior and choose the same risk in each period. While consistent and inconsistent subjects have the same general willingness to take risks, inconsistent subjects choose on average riskier allocations, i.e., they hold less diversified portfolios. Internally controlled subjects are indeed more likely to make inconsistent choices. In contrast, subjects with high cognitive ability or with training in economics are less likely to make inconsistent risk choices. Importantly, the effects of locus of control and cognitive ability on consistency are roughly of equal size. These results hold in a number of different settings. We thus demonstrate that individuals with a high internal locus of control are more likely to react to random outcomes than individuals with a low internal locus of control. In doing so, they end up with inefficient portfolio allocations.

Our results offer a new perspective on the importance of internal locus of control for economic success. In the previous literature, an internal locus of control has mostly been regarded as a beneficial trait. Andrisani (1977), Osborne Groves (2005), Semykina and Linz (2007), Ahn (2015), and Piatek and Pinger (2016) show that an internal locus of control is positively correlated with success in labor markets. Coleman and Deleire (2003) argue that it positively affects education decisions by altering teenagers' expectations regarding the returns of human capital investments. Caliendo et al. (2015) and McGee (2015) find that unemployed individuals with an internal locus of control invest more into job search than externally controlled individuals. Similarly, Cobb-Clark et al. (2014) find that internally controlled individuals invest more into health capital and Borghans et al. (2008) document that they perform better on cognitive tests. Cobb-Clark and Schurer (2013) show that they also accumulate more precautionary savings, and Salamanca et al. (2016) find that internal locus of control is positively related to investments in risky assets. Most recently, Lekfuangfu et al. (2018) demonstrate that mothers with an internal locus of control invest more into their children, and that cognitive and emotional development are higher among the children of such mothers.[2]

In contrast, our results show that there may also be circumstances where internal locus of control leads to inefficient behaviors, in particular, if "doing nothing" is the optimal strategy (as it is the case for most private stock investors most of the time). Therefore, locus of control should be accounted for, along with behavioral biases such as overconfidence or confirmation bias, in empirical studies of financial decision-making.

If locus of control can have ambiguous effects on the quality of economic decisions, this has implications for the economic literature that analyzes the impact of non-cognitive skills on economic behaviors and outcomes (see, e.g., Borghans et al. 2008, Chiteji 2010, or Grönqvist et al. 2016). Non-cognitive skills are often viewed as characteristics that enhance the productive capacity of individuals. Our results suggest, however, that they are not necessarily productivity-enhancing in all circumstances.[3] Instead, one could argue that they induce situation-specific behaviors and payoffs. In that respect, non-cognitive skills differ from cognitive abilities, which tend to help individuals in almost any market situation.

The remainder of the paper is organized as follows. Section 2 relates our findings to the literature. In Section 3, we derive predictions about the behavior of rational and biased subjects in our experiment. Section 4 describes the experimental setup. In Section 5, we present the main results from the experiment. In Section 6, we further study the switching behavior of subjects who make inconsistent risk choices. Section 7 con-

[2]Moreover, the psychological literature finds that internal locus of control correlates with a vast battery of outcomes, such as academic achievement, political behavior or job satisfaction (Bar-Tal and Bar-Zohar 1977, Judge and Bono 2001); it also positively correlates with self-esteem and emotional stability (Judge and Bono 2001).

[3]Relatedly, Alaoui and Fons-Rosen (2017) find that perseverance (which is usually regarded as a beneficial trait to achieve long-term goals) can have adverse effects in the domain of gambling.

tains additional robustness checks. Section 8 concludes. An Online Appendix contains mathematical details, experimental instructions, and further analyses.

2 Literature

Personal Characteristics and Biased Probability Judgment. The closest paper to ours is Dohmen et al. (2009) who examine the relationship between personal characteristics and biased probability judgment. They ask subjects to indicate the probability that the next toss of a fair coin is "tails" given that previous outcomes were tails - tails - tails - heads - tails - heads - heads - heads. Around a third of their subjects indicate a number different from 50 percent. Similar to Dohmen et al. (2009) we find that cognitive ability is negatively related to biased decision-making. However, while in their study, only crystallized intelligence (knowledge) has explanatory power, in our data also fluid intelligence (capacities of information processing) has a significant impact on behavior. Moreover, Dohmen et al. (2009) do not measure subjects' locus of control.[4]

Illusion of Control. A psychological concept that is related, but distinct from locus of control, is "illusion of control." It is defined as people's unjustified belief in their ability to control events they cannot influence (as in gambling). Langer (1975) introduces the concept and demonstrates that subjects who chose their lottery ticket are less willing to sell it than subjects who were randomly assigned a ticket. Davis et al. (2000) find in field data that subjects place riskier bids when they roll their own dice than when someone else rolls it. In fact, the illusion of control seems to be especially pronounced in pathological gamblers (Orgaz et al. 2013). Most recently, Sloof and von Siemens (2017) demonstrate that many subjects are willing to pay for the right to pick a lottery, in order to avoid someone else making the same uninformed choice for them. In our setting, subjects always choose the lottery by themselves. They may believe in an ability to predict

[4] On a more general level, this paper also relates to the literature on the impact of personality characteristics on economic decisions. See, for example, Heckman et al. (2006) on the importance of non-cognitive skills for schooling decisions; Benjamin et al. (2010) on how ethnical identity influences risk choices and intertemporal trade-offs; and Benjamin et al. (2013) on the link between cognitive ability and small-stakes risk aversion as well as short-run discounting.

which asset will be successful; however, such an illusion of control would not necessarily imply inconsistent risk choices.

Probability Matching. A somewhat related phenomenon to inconsistent investment behavior is "probability matching" (or "irrational diversification"). In several probability learning experiments, the subjects' task is to repeatedly choose between two alternatives where one alternative yields a high expected payoff and the other alternative a small one. After some rounds of learning, rational subjects would always choose the high payoff alternative. However, the typical outcome is that subjects' average response probability is close to the payoff probability; see Vulkan (2000) for an overview.[5] Similarly, Rubinstein (2002) observes that individuals diversify their choices in experiments with multiple decisions even though optimal behavior implies not to diversify. In this paper, we show that an internal locus of control may increase the propensity to engage in irrational diversification.

Dynamic Inconsistency in Gambling. A number of papers study how subjects change their plans if they gamble repeatedly. Barberis (2012) develops a model of gambling based on prospect theory in which an agent faces a dynamic inconsistency problem: Before entering the casino, she would like to commit to a plan under which she stops gambling if a certain amount of losses accumulates. However, when these losses materialize, the probability distribution over final outcomes changes, which through probability weighting leads to a change in plans. Several studies find such behavior in experiments. Barkan and Busemeyer (1999) compare subjects' plans before the first gamble is played and actual choices after the first gamble is realized. An experienced gain (loss) then leads to less (more) gambling than planned initially. Andrade and Iyer (2009) demonstrate that, after a loss, subjects bet more than they initially expected to bet (for gains such an effect is not observed). Alaoui and Fons-Rosen (2017) also compare planned versus realized betting and find that grittier subjects continue to gamble at a point where ini-

[5] The extent of probability matching is muted by financial incentives, feedback, and training (Shank et al. 2002).

tially they had planned to stop gambling. In our setting, subjects are forced to gamble in each period, but only one outcome becomes effective. Moreover, inconsistent choices in the experiment are not necessarily a result of dynamically inconsistent preferences.

Correlation Neglect. Our paper is also related to a literature that studies the textbook model of portfolio choice using lab experiments; see Kroll et al. (1988), Kallir and Sonsino (2009), Eyster and Weizsaeker (2011), and Enke and Zimmermann (2017). These papers find evidence of "correlation neglect." Many subjects ignore the correlation between assets or information sources and therefore choose inefficient allocations. In our experiment, assets are identical and uncorrelated so that the "1/n heuristic" (Benartzi and Thaler 2001) leads to the minimal variance portfolio. Nevertheless, many subjects change the riskiness of their portfolios in response to random outcomes.

3 Conceptual Framework

We briefly examine how an agent with rational preferences and expectations would behave in our experimental setup; how biased expectations about each asset's probability of success affect her choices; and why her expectations may be biased.[6]

Consider an agent who has to allocate 10 tokens among two assets (there is no other opportunity to store wealth). The investment into asset 1 is x and the investment into asset 2 is $10 - x$. Each asset has a high payoff with probability 0.5 and then pays off twice the investment; with probability 0.5 it has a low payoff and then pays off only half of the investment. There is no correlation between the assets' payoffs. So the expected payoff is 12.5 for any investment $x \in [0, 10]$ and the mean-variance efficient allocation is $x = 5$. Denote by α_1, α_2 the agent's subjective probability of a high payoff from asset 1 and 2, respectively. The investment decision is repeated in a number of periods and the payoff in one randomly chosen period becomes effective.

Rational Expectations. Suppose first that the agent has rational expectations, i.e.,

[6] The mathematical details of this section can be found in the Online Appendix.

$\alpha_1 = \alpha_2 = 0.5$. If she is risk-neutral, any choice $x \in [0, 10]$ is rational for her. However, under a few mild assumptions, she will choose the same level of risk in all periods. First, let the agent have complete and transitive preferences over $x \in [0, 10]$; second, let there be a unique $x^* \in \{0, ..., 5\}$ such that the agent strictly prefers the investments x^* and $10 - x^*$ to all other investments; and third, assume that the agent's preferences satisfy the Independence Axiom.[7] If these three assumptions are satisfied, the agent chooses the investment x^* or $10 - x^*$ in all periods.

We get sharper predictions for a subject's risk choice if we put more structure on preferences. Suppose the agent has expected utility preferences with utility function $u(w)$ over the final payoff w. If she is risk-averse (u concave), the unique optimal allocation is to invest equally in both assets, $x = 5$. If she is risk-loving (u convex), the unique optimal allocation is to invest the entire endowment in one of the two assets, $x \in \{0, 10\}$.

For small-stakes lotteries it is more sensible to assume reference-dependent loss aversion (Kahneman and Tversky 1979). Suppose the agent's utility from the final payoff w at the riskless reference point r is given by $u(w \mid r) = w + \mu(w - r)$, where μ represents her gain-loss utility. Let the reference point equal the agent's probabilistic beliefs about outcomes and let μ satisfy the properties proposed in Kőszegi and Rabin (2006, 2007), i.e., μ is concave in the domain of gains, convex in the domain of losses, and losses weight heavier than gains (see the Online Appendix for details). Then, we can show that if $\mid \mu'' \mid$ is not too large relative to μ', the agent chooses $x = 5$ in all periods. This allocation minimizes the expected utility loss and thus maximizes the agent's expected utility.

Biased Expectations. If the agent has biased expectations about each asset's probability of success, $\alpha_1 \neq 0.5$ and/or $\alpha_2 \neq 0.5$, she may choose other investments than under rational expectations. Suppose the agent has expected utility preferences and is risk averse. Then, for given $\alpha_1 \in (0, 1)$, if α_2 converges to one (zero), the optimal investment to asset 1 converges to $x = 0$ ($x = 10$). In fact, for any $\hat{x} \in [0, 10]$ we can find values of α_1, α_2 so that $\hat{x}$ is the optimal investment. Next, assume that the agent has

[7] Alternatively, we may assume that the agent brackets narrowly (she makes each choice as if it were her only one), see Rabin and Weizsaeker (2009).

reference-dependent loss aversion preferences. Then, for given $\alpha_1 \in (0,1)$, if α_2 converges to one, the optimal investment into asset 1 converges to $x = 0$; and if the degree of loss aversion is not too large, it converges to $x = 10$ when α_2 converges to zero.

We can derive the utility costs of biased decision making. For expected utility maximizers these are typically very small. Assume therefore that the agent is expectation-based loss-averse with gain-loss utility function $\mu(y) = \eta y$ in the domain of gains ($y \geq 0$) and $\mu(y) = \eta\lambda y$ in the domain of losses ($y < 0$), with $\lambda > 1$. For every marginal deviation from the optimal investment $x = 5$ the agent's expected utility then decreases by $\frac{3}{16}\eta(\lambda - 1)$. Thus, the expected utility loss increases in the size of the loss aversion parameters η, λ. For typical values, say $\eta = 1$ and $\lambda = 2.25$, the loss in expected utility is 2.6 percent if $x \in \{4,6\}$, 5.4 percent if $x \in \{3,7\}$, 8.3 percent if $x \in \{2,8\}$, 11.3 percent if $x \in \{1,9\}$, and 14.6 percent if $x \in \{0,10\}$.

Outcome Patterns and Biased Expectations. In our setting, subjects will see the previous outcome realizations of the two assets. Thus, they may search for patterns that they can "exploit." Several different fallacies may then cause biased expectations. It can happen that asset 1 has a high payoff three times in a row, while asset 2 yields a low payoff three times. If an agent believes in a "hot hand", she may expect that asset 1 is a better bet and therefore invest more in it. Conversely, if the agent falls prey to the "gambler's fallacy", she may believe that it is now time for asset 2 to catch up and adjusts her investment accordingly. Rabin (2002) and Rabin and Vayanos (2010) show that both fallacies may originate from the "law of small numbers" (Tversky and Kahneman 1971), which is the belief that the properties of large samples must also show up in small samples. In Section 6, we will examine the empirical relevance of both fallacies in our experiment.

4 Experimental Design

We set up an experiment which is easy to understand and allows subjects to react to random outcomes. After the experiment, we measure subjects' locus of control so that we can study its predictive capacity for decision-making in our framework.

Main treatment. The experiment has 10 periods. In each period, subjects have to allocate an endowment of 10 tokens among two assets that we call "entrepreneur 1" and "entrepreneur 2." In the main treatment, entrepreneurs are simulated by the computer. Denote by $x_t \in \{0, 1, ..., 10\}$ a subject's investment in entrepreneur 1 in period t. The investment in entrepreneur 2 in period t is then $10 - x_t$. Each entrepreneur is successful with probability 0.5 and then pays off two times the subject's investment; with the reverse probability it fails and then pays off half of the subject's investment. There is no correlation between the assets' payoffs. A subject's income in a given period is the sum of payoffs from the two assets. A subject's final payoff is her income in one randomly selected period. The exchange rate is one Euro for each token.

After each period, subjects observe the assets' payoffs in the previous period: If entrepreneur $j \in \{1, 2\}$ was successful (failed), they receive the message "The project of entrepreneur j has been successful (has failed)." Since there is no correlation between outcomes of different periods, there is nothing to be learned from this information. In each session, subjects are matched in groups of four. All subjects of a given group invest into the same assets, so they observe the same patterns of successes and failures. Random draws on the group level were made on the spot.

Locus of Control, Risk Preferences, and Cognitive Ability. After the experiment, we measured subjects' locus of control, risk preferences, and cognitive ability. The locus of control measures correspond to those in the German Socio-Economic Panel (SOEP) questionnaire. The psychometric scale was developed by Nolte et al. (1997). It comprises 10 items and each question is answered on a Likert scale ranging from 1 ("disagree completely") to 7 ("agree completely"). The test was originally designed to reflect two dimensions of locus of control, fairness, and social involvement. Table 1 contains all locus of control questions. Items Q1, Q6, and Q9 describe internal locus of control tendencies, while items Q3, Q5, Q7, Q8, and Q10 describe external locus of control tendencies (Weinhardt and Schupp 2011).[8] Items Q2 and Q4 describe an individual's sense of fairness and her degree of social involvement. They are not used in this study.

[Insert Table 1 about here]

Next, we measure risk preferences by asking subjects to indicate their willingness to take risks on an eleven-point scale (as in the German Socio-Economic Panel, SOEP). Dohmen et al. (2011) show that the answer to this question strongly correlates with behavior in a standard risk aversion experiment with real money at stake. Finally, to measure subjects' cognitive ability we use a short version of Raven's Advanced Progressive Matrices (Bors and Stokes 1998). Subjects are asked to select one out of eight figures that fit the missing part in the matrix. They have 12 minutes to solve the Raven test. The Raven test measures fluid intelligence, i.e., it captures abstract and adaptive intelligence. In Table 2 below, we provide an overview of all variables used in our regressions.

HUMAN treatment. Subjects' reaction to random patterns may depend on their source. In an alternative treatment, which we call HUMAN treatment, the entrepreneurs are represented by student subjects.[9] The framing of the instructions is identical to that in the main treatment except that the assets are called "entrepreneurs" (instead of "computer-entrepreneurs"). The entrepreneurs have to select one out of two projects in each period. This choice has no real consequences. Each project succeeds with 50 percent chance. The entrepreneurs' final payoff is fixed to 11 tokens. Hence, the HUMAN treatment is technically identical to the main treatment. However, the representation by human beings – and their choice task – may cause some subjects to attribute streaks of successes to a human entrepreneur's "ability to pick the right project" (which of course does not exist).[10]

[8] Following the psychological literature, we use a locus of control scale that treats internal and external locus of control as two distinct underlying constructs. The empirical correlation between both types of locus of control is negative, significant, and small ($\rho = -0.24$, $p = 0.001$).

[9] We had four investors per group to economize on the number of entrepreneurs in this treatment.

[10] This behavioral tendency has been discussed among social psychologists as fundamental attribution error (Harris and Jones 1967) or correspondence bias (Gilbert and Malone 1995). Many individuals falsely infer outcomes from personal dispositions although they can be fully explained by external forces. The framing variation should therefore reduce the perception of randomness (Burns and Corpus 2004).

INFO treatment. In our second alternative treatment, which we call INFO treatment, we check whether misunderstandings of the context drive subjects' behavior in the main treatment. In the INFO treatment, we provide further verbal and graphical information about the consequences of all possible choices (in addition to the instructions). Specifically, we explain in words the consequences of all available options and then graphically display for each allocation the corresponding probability distribution over outcomes, see the Online Appendix for details. This information makes it salient to subjects that the preferred distribution over outcomes is all that should matter for their decision.

[**Insert Table 2 about here**]

Experimental Procedures. The experiment was programmed with z-Tree (Fischbacher 2007) and conducted at the Frankfurt Laboratory for Experimental Economics. We used ORSEE (Greiner 2004) to recruit subjects from all faculties. We had 72 subjects in the main treatment, 76 in the HUMAN treatment, and 32 in the INFO treatment. By asking several control questions before the experiment we made sure that all subjects understood the procedure. One control question explicitly asked about the relationship between past and future outcomes. If a subject did not correctly answer all control questions, she received additional assistance from the experimenters. Payments were made right after the end of the session. Each session lasted about 80 minutes (including time needed for instructions and payments). On average, subjects earned 12.32 EUR (this number excludes payments to human entrepreneurs).

5 Main Results

We first provide an overview of the subjects' choices in our experiment. To this end, we introduce measures for the concentration (i.e., riskiness) and consistency of subjects' investments. Define by $C_t = |x_t - 5|$ the concentration of the allocation chosen in period t and by

$$avc = \frac{1}{10}\sum_{t=1}^{10} C_t$$

the average concentration of a subject's investments. A subject will be called consistent, $cons = 1$, if she chooses the same concentration C in all periods; and inconsistent, $cons = 0$, if she varies the concentration of her investments in at least one period. Since this is a very strict definition of consistency, we will also use two alternative measures that allow for small mistakes. Define by csd the standard deviation from the average concentration,

$$csd = \sqrt{\frac{1}{10}\sum_{t=1}^{10}(C_t - avc)^2}.$$

The dummy variable $cons_{50}$ ($cons_{65}$) equals 1 if a subject's standard deviation from her average concentration is weakly smaller than 0.5 (smaller than 0.65). These consistency measures allow for patterns where the concentration alternates between two adjacent levels. For example, concentration $C_1 = 0$ in period 1, $C_2 = 1$ in period 2, $C_3 = 0$ in period 3, and so forth. In case of $cons_{65}$, a subject is classified as consistent even if she deviates from her usual concentration by two levels in one period, e.g., she chooses $C_t = 0$ in all periods $t \neq \tau$, and $C_\tau = 2$ in one period τ.

Table 3 provides an overview of the descriptive statistics. The average concentration of investments was 1.42 and 21.1 percent of our subjects were consistent (28.9/32.2 percent consistent according to measure $cons_{50}/cons_{65}$). On average, subjects solved 6.78 matrices in the Raven test; they rated their general willingness to take risks by 5.24. We find that internal locus of control[11] is positively correlated with the willingness to take risks ($\rho = 0.21$, $p = 0.004$) and negatively correlated with cognitive ability ($\rho = -0.15$, $p = 0.035$).[12] In contrast, the correlation between external locus of control and risk aversion or cognitive ability is low.

[11] We use classical confirmatory factor analysis to predict separate factors for internal and external locus of control. We specify the model such that higher scores of the latent factors are associated with a more internal (external) locus of control, and lower scores with a less internal (external) locus of control. For ease of interpretation, factor scores are then normalized to have a mean of zero and a standard deviation of one.

[12] These correlations are of similar magnitude as those reported in the literature for other personality traits (see, e.g., Almlund et al. 2011, p. 71). However, Almlund et al. (2011) find a small positive correlation between internal locus of control and cognitive ability. One reason for this difference may be that our subjects were students and thus drawn from the upper tail of the IQ distribution.

[Insert Tables 3 and 4 about here]

Average Concentration. Models 1 and 2 in Table 4 present tobit estimates with the average concentration as dependent variable. The independent variables are internal and external locus of control, the general willingness to take risks, cognitive ability, gender, age, economics studies, as well as the two treatment dummies. We cluster our standard errors by group, since all patterns of successes and failures varied only at the group level. Three variables have a robust and significant effect on the average concentration of choices. First, the larger is the general willingness to take risks, the larger is the average concentration of the chosen allocations. This is an important consistency check, since it shows that subjects' risk preferences do indeed matter for investment behavior in our experiment. Second, the INFO treatment surprisingly causes subjects to choose riskier allocations. The coefficient is statistically significant at the 10 percent level. Third, students of economics choose on average significantly less risky investments.

A Wilcoxon-Mann-Whitney ranksum test (henceforth, MW) indicates that consistent and inconsistent subjects do not differ in their general willingness to take risks (MW, $p = 0.774$). However, consistent subjects choose on average less risky allocations than inconsistent ones. The mean average concentration of investments is 0.70 for consistent subjects and 1.63 for inconsistent ones (MW, $p < 0.001$).[13] So those who react to the information about previous outcomes end up with less diversified portfolios than those who choose a consistent investment strategy.

Consistency. Next, we analyze the influence of internal locus of control on consistency. Models 3 to 5 in Table 4 present the probit estimates with our consistency dummy *cons* as dependent variable, which indicates whether a subject chose the same concentration in 10 periods. We observe that the lower is internal locus of control, the larger is the probability of consistent investment choices. The average marginal effect indicates that an increase in internal locus of control by one standard deviation decreases the probability of consistency on average by 6.7 percentage points ($p = 0.001$), which corresponds to a

[13] In particular, 82.5 percent of consistent subjects choose $x = 5$; 7.5 percent choose intermediate risks and 10 percent choose the riskiest allocations $x \in \{0, 10\}$.

relative effect of 30.1 percent.

There are two more personal characteristics that have a robust and significant effect on consistency. First, those with higher cognitive ability are ceteris paribus more likely to make consistent risk choices. The effect is relatively large and remains constant across specifications. The marginal effect indicates that an increase in cognitive ability by one standard deviation raises the probability of consistent investment choices on average by 9.2 percentage points ($p = 0.003$), which corresponds to a relative effect of 41.4 percent. This result is intuitive. Those with higher cognitive ability are more likely to solve the investment problem at the outset and follow their solution throughout the ten periods. Note that the effect of locus of control on the probability of being consistent is of similar size as the effect of cognitive ability.

Second, economic education increases the probability of consistent behavior. The marginal effect indicates that economics studies increase the probability of choosing the same risk in all periods by about 34.4 percentage points ($p < 0.001$), controlling for age, gender, cognitive skills, risk aversion, and locus of control. Indeed, 70.6 percent of the economists in our sample are consistent. Somewhat surprisingly, the different treatments have no significant effect on the share of consistent subjects. Specifically, this is true for the INFO treatment in which we tried to de-bias subjects by providing additional verbal and graphical information. Thus, our results are not due a misunderstanding of the context.

We check the robustness of our results by using the consistency measures $cons_{50}$ and $cons_{65}$. Models 6 and 7 in Table 4 present the regression results. As in the baseline regression, we observe that cognitive ability and economics studies have a significant positive effect on consistency, while a subject's internal locus of control has a significant negative effect.[14]

Result 1. *Internal locus of control has a significant negative impact on the probability of consistent behavior. Cognitive ability and economic education have a significant positive*

[14]If we add decision-times as a covariate to the model, we find that longer decision-times are negatively associated with consistency. The coefficient on internal locus of control increases slightly in size and significance.

impact on the probability of consistent behavior.

Does behavior converge over time? It could be the case that inconsistent subjects vary their risk choices in the first periods of the experiment, but become consistent and always choose the same concentration later on. To study convergence, we consider the probability of a risk allocation change. For consistent subjects this probability is always zero. We examine the average probability of an allocation change taken over all subjects. If behavior converges, we should observe that this value decreases over time. As Figure 1 (top panel) reveals, this is not the case. The average behavior of inconsistent subjects does not converge in our experiment. Moreover, for internally controlled individuals the average probability of an allocation change consistently lies above the one for less internally controlled individuals, see Figure 1 (bottom panel). Thus, internally controlled individuals are more likely to change their risk allocation across all periods. Separate analyses for the first five periods and for the last five periods reveal that the locus of control effect becomes more pronounced during the second half of the experiment, indicating that internally controlled individuals are particularly perseverant in changing their risk allocation (see Table D1 in the Online Appendix).

[**Insert Figure 1 about here**]

The above analysis suggests that there exist certain types of investors that are particularly prone to making inconsistent risk choices. To the extent that this reflects suboptimal investment behavior, it could be of interest to identify these types. The results displayed in Table 5 indicate that for individuals whose IQ lies in the bottom third of the IQ distribution, the probability to make consistent risk choices drops by almost 50 percent. This effect is even more pronounced among individuals whose internal locus of control lies in the top third of the internal locus of control distribution. Moreover, as shown in the last column of Table 5, low IQ and high internal locus of control are factors that cumulate in inducing agents to make inconsistent investment choices.

[**Insert Table 5 about here**]

6 Switching Patterns

We now discuss how subjects change their risk allocation between periods. First, we examine to what extent previous successes or failures influence subjects' decisions. Second, we study how often and by how much subjects change their risk allocation. Throughout this section, we focus on inconsistent subjects. Thus, we consider the degree to which subjects reallocate their portfolios, provided that they are inconsistent.

Response to past outcomes. Our setting implies that subjects observe very different outcome patterns over the ten periods. We therefore focus on the influence of investor successes or failures in the previous period on current allocations. Subjects see the outcome of the previous period shortly before they make a new allocation decision. There are four equally likely outcome combinations for the two entrepreneurs: (failure, failure), (success, failure), (failure, success), and (success, success).

[**Insert Table 6 about here**]

Table 6 displays the results of a linear panel model with the allocation to entrepreneur 1 as dependent variable. As explanatory variables we include the outcomes from the previous period interacted with internal locus of control. All outcome effects are interpreted with respect to the outcome (failure, failure). We observe that subjects tend to invest around 0.8 tokens less into entrepreneur 1 if it was successful while entrepreneur 2 failed. The reverse effect – fewer investments into entrepreneur 2 after the outcome (failure, success) – also occurs, but is not significant. So on average subjects' behavior is consistent with the gambler's fallacy. However, subjects with a very internal locus of control tend to invest more into entrepreneurs who have been successful in the past, which indicates a tendency to act according to the hot hand fallacy. This tendency is particularly prevalent in the HUMAN treatment. If subjects are one standard deviation more internally controlled, this increases the amount invested into entrepreneur 1 after the outcome (success, failure) by 0.64 tokens in the HUMAN treatment. We summarize these results.[15]

[15]We do not observe significant changes in allocations depending on how much agents have invested

Result 2. *On average, subjects switch away from successful entrepreneurs, consistent with the gambler's fallacy. However, internally controlled individuals are more likely to invest into successful entrepreneurs, especially in the HUMAN treatment. Thus, they show a tendency to act according to the hot hand fallacy.*

Switching frequency and magnitude. Next, we investigate the extent of switching over the ten periods. Let $frequency$ be the number of periods in which a subject changed the riskiness of her allocation; and *magnitude* the average size of these switches. Formally, we have $frequency = \sum_{t=2}^{10} \mathbf{1}_{cr_t \neq 0}$, where $\mathbf{1}$ is the indicator function and $cr_t = |C_t - C_{t-1}|$; and $magnitude = \frac{1}{frequency} \sum_{t=2}^{10} cr_t$.

[Insert Table 7 about here]

Table 7 shows the results for our baseline regression with $frequency$ and *magnitude* as dependent variables. Both very internally controlled individuals and very externally controlled individuals are slightly less likely to make large risk changes, but the effects are insignificant and small. There are two notable significant effects. First, men change the risk of their allocation less often than women, but when they change it, the magnitude of change is larger than for women. Second, more intelligent individuals tend to change their risk less often, but if they change it, their changes are of larger magnitude.

Result 3. *Among the inconsistent subjects, internally and externally controlled individuals do not differ significantly in terms of frequency or magnitude of the allocation changes they make. Females and less intelligent subjects, however, change the risk of their allocation relatively more frequently. When a change in risk occurs, the magnitude of change is on average larger for males and for high cognitive ability subjects.*

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in the previous period. There exists a slight tendency that very internally controlled individuals invest more in entrepreneur 1 after outcome (success, failure) if they had invested a higher amount on that entrepreneur in the previous period.

One possible interpretation of the gender difference is that women process information differently than men. Women tend to consider information more comprehensively including more details and contextual attributes (Meyers-Levy and Sternthal 1991). In contrast, men are more likely to follow simple heuristics and information-processing strategies (Chung and Monroe 1998).

7 Robustness

Boredom. In our experiment, subjects had 30 seconds in each period to choose their allocation. So, depending on the treatment, the experiment took quite a while given that subjects only had to make one substantive decision (and repeat it ten times). One concern could be that subjects were bored and therefore chose different risks in different periods. We therefore conducted a second version of our experiment, with two added features that enable us to check whether our results are driven by boredom. First, and most importantly, we drastically shortened decision-times. As a consequence, subjects had to make ten quick decisions in a row, which made the task more challenging and dynamic. Second, we asked subjects about their emotions during the experiment, so that we can check whether "boredom" causes subjects to make inconsistent choices (see the Online Appendix for details).

We find that our results hold even when decision-times are short. As expected, boredom has a negative effect on consistency (see Table C1 in the Online Appendix).[16] The internal locus of control coefficient, however, remains stable if we add our boredom measure to the analysis. Specifically, we find that a one standard deviation increase in internal locus of control decreases the probability of consistency by 9.4 percentage points ($p = 0.019$), which corresponds to a relative effect of 37 percent (versus 6.7 percentage points and 30.1 percent in our main treatment). This effect increases to 12.4 and 13.6 percentage points when we use the consistency measures $cons_{50}$ and $cons_{65}$ (the corresponding re-

[16] While boredom is strongly negatively associated with consistency, we cannot fully rule out that individuals indicated to be less bored if they were active rather than passive during the experiment. Note that measurement error in the boredom variable would bias our results if it occurred differentially for individuals with high and low internal locus of control. Since controlling for boredom hardly affects our estimates, this is scenario is rather unlikely.

sults are displayed in Tables C2 and C3 in the Online Appendix). Thus, we conclude that the results in our main experiment cannot be explained by the fact that internally and externally controlled subjects were differentially bored during the experiment.

Locus of Control Measurement. Another concern may be that locus of control was elicited only *after* the end of the experiment. Hence, lucky or unlucky experiences during the experiment may have affected the subjects' locus of control measurements.[17] We address this concern by regressing our measure of internal locus of control on the total payoff over all periods and on the total number of entrepreneurial successes as indicators of having been lucky during the experiment. The results indicate that the experiences during the experiment have no statistically significant association with our internal locus of control measurement (see Table D2 in the Online Appendix).

8 Conclusion

In this paper, we examined a simple investment experiment in which we expose subjects to sequences of random outcomes. Under mild restrictions, the unique optimal strategy is not to react to outcomes and to choose the same risk in each period. However, subjects who strongly believe that they can control the events that affect them may be tempted to react to irrelevant information. Indeed, we find that subjects with an internal locus of control are more likely to make inconsistent risk choices in the experiment. The same is true for subjects with lower cognitive ability. The effects of locus of control and cognitive ability are of similar size.

Regarding the mechanisms, our results suggest that internally controlled individuals are more likely to search for patterns in past realizations, even if those do not have meaningful implications for future outcomes. In particular, they are more likely to bet on assets that were successful in the past. Compared to other subjects, the behavior of internally controlled individuals is thus relatively more in line with the "hot hand

[17]However, the literature shows that locus of control tends to be stable in adults. Thus, many studies rely on ex-post measures (for a discussion, see Cobb-Clark and Schurer 2013).

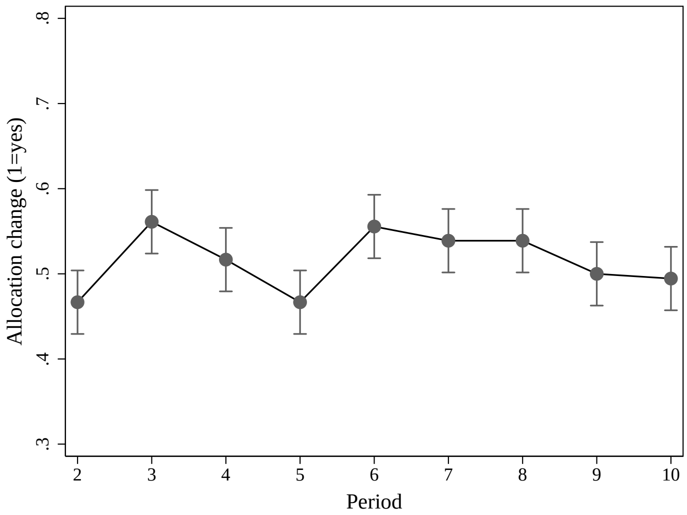
fallacy."

These are important results. An internal locus of control is mainly regarded as a beneficial trait in the literature. Internally controlled individuals invest more into human capital, are more active job seekers, exhibit higher stock market participation, and adopt a more active parenting style. Our results suggest that there may also be circumstances where internal locus of control leads to suboptimal choices.

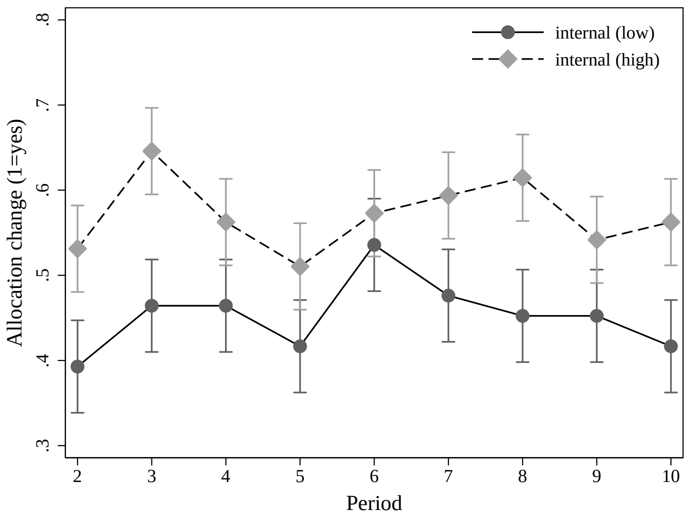
We also found that it may be very difficult to improve decision-making in risky environments such as the stock market. Our subjects are highly educated as compared to the average person and we explained the stochastic setup to them in great detail. Nevertheless, only a minority chose an investment strategy that is rationalizable under standard assumptions. This share does not change when we make the consequences of their decisions salient through graphical information (which of course does not prove that there is no method to de-bias subjects). However, economic education had a large positive effect on the share of consistent subjects. This suggests that specific types of education may weaken or eliminate the relationship between locus of control and inconsistent risk choices. Thus, one can de-bias subjects, but only at very high costs. Future research may try to better understand the relationship between personality, education, and decision-making in risky environments.

FIGURE 1
Allocation change probabilities per period

(a) All individuals



(b) By internal locus of control



Notes: Figure (a) shows the unadjusted probability of an allocation change among all subjects. Figure (b) displays the unadjusted probability of an allocation change among individuals with high (low) internal locus of control. Internal locus of control was dichotomized using the mean as cutoff. Error bars indicate standard errors.

TABLE 1
Locus of control item definition

Q1	**My life's course depends on me**
Q2	I have not achieved what I deserve
Q3	Success is a matter of fate or luck
Q4	Social involvement can help influence social conditions
Q5	Others decide about my life
Q6	**Success is a matter of hard work**
Q7	In case of difficulties, I doubt about own abilities
Q8	Possibilities in life depend on social conditions
Q9	**Abilities are more important than effort**
Q10	I have little control over what happens to me

Notes: Internal locus of control items in bold font.

TABLE 2
Variable definitions

Variable	Definition
avc	Dependent variable indicating subject's average concentration of investments
cons	Dependent binary variable indicating that subject chooses the same risk in all periods
$cons_{50}$	Dependent binary variable indicating that the standard deviation from the average concentration is weakly smaller than 0.5
$cons_{65}$	Dependent binary variable indicating that the standard deviation from the average concentration is weakly smaller than 0.65
frequency	Dependent variable indicating the number of periods in which subject changes the risk of her investment
magnitude	Dependent variable indicating by how much the risk changes on average when a change occurs
Risk	General willingness to take risks; 11-point Likert-scale adopted from the SOEP
IQ	Number of correctly solved matrices from Raven's Advanced Progressive Matrices
Internal locus	Factor extracted from the SOEP internal locus of control scale
External locus	Factor extracted from the SOEP external locus of control scale
Female	Dummy indicating that subject is female
Economics	Dummy indicating that subject's field of study is economics
Math	Dummy indicating that subject's field of study is math
Law-econ	Dummy indicating that subject's field of study is law with minor in economics
Other	Dummy indicating that subject's field of study is not listed (most likely business economics)
HUMAN	Dummy indicating that treatment includes student subjects as entrepreneurs
INFO	Dummy indicating that treatment includes additional verbal and graphical information about the consequences of investment choices
(success, failure)	Dummy indicating that entrepreneur 1 was successful in the previous period while entrepreneur 2 failed
(failure, success)	Dummy indicating that entrepreneur 2 was successful in the previous period while entrepreneur 1 failed
(success, success)	Dummy indicating that both entrepreneurs were successful in the previous period
Bored (1-7)	Measure of a feeling of boredom during the experiment; 7-point Likert-scale

TABLE 3
Summary statistics

Experiment	mean	sd	min	max
Average concentration (*avc*)	1.42	1.21	0	5
Share of consistent subjects ($cons = 1$)	22.2 %			
Share of consistent subjects ($cons_{50} = 1$)	28.9 %			
Share of consistent subjects ($cons_{65} = 1$)	32.2 %			
Personal characteristics				
Age	24.9	6.09	19	67
Gender (share of female subjects)	53.3 %			
Cognitive ability (number of solved matrices)	6.78	2.56	0	11
Risk preferences (SOEP scale)	5.24	1.90	1	10
Study category				
Economics	9.4 %			
Law	14.4 %			
Science	13.9 %			
Humanities	47.2 %			
Medical science	13.3 %			
Other	1.8 %			
N	180			

TABLE 4

Determinants of average concentration and consistency (extensive margin)

	avc		*cons*			$cons_{50}$	$cons_{65}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Locus of control							
Internal locus	0.188**	0.076	-0.091***	-0.066***	-0.067***	-0.077***	-0.080***
	(0.09)	(0.10)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
External locus	-0.167	-0.168*	-0.015	-0.006	-0.008	-0.008	0.003
	(0.11)	(0.10)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Risk and cognitive ability							
Risk		0.349***		0.016	0.010	-0.015	-0.002
		(0.11)		(0.03)	(0.03)	(0.03)	(0.03)
IQ		-0.124		0.090***	0.092***	0.085***	0.089***
		(0.11)		(0.03)	(0.03)	(0.03)	(0.03)
Gender, age and major							
Female		-0.072		0.015	0.015	-0.024	-0.005
		(0.20)		(0.05)	(0.05)	(0.07)	(0.07)
Age		-0.023		0.008*	0.008**	0.007	0.009
		(0.02)		(0.00)	(0.00)	(0.01)	(0.01)
Economics		-0.714*		0.338***	0.344***	0.380***	0.366***
		(0.41)		(0.07)	(0.07)	(0.08)	(0.09)
Treatments							
HUMAN		-0.216			0.035	0.068	0.027
		(0.21)			(0.05)	(0.06)	(0.06)
INFO		0.484*			-0.091	-0.068	-0.089
		(0.28)			(0.10)	(0.09)	(0.11)
Observations	180	180	180	180	180	180	180
Rsq-adj.	0.03	0.05	0.05	0.19	0.21	0.16	0.13

Notes: The first two columns (1)–(2) contain tobit estimates with *avc* as dependent variable; *avc* is the average concentration of a subject's investments. The latter columns (3)–(7) contain binary probit estimates. In columns (3)–(5), the dependent variable *cons* equals one if a subject chose the same risk in 10 periods and zero otherwise. Columns (6)–(7) report robustness checks for our alternative consistency measures $cons_{50}$ and $cons_{65}$. A more detailed variable description is shown in Table 2. Group fixed effects are controlled for if indicated at the bottom of the table. All models contain a constant. Average marginal effects reported. Standard errors (in parentheses) are robust and clustered at the group level. Significance at * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 5
Investor types

		Low IQ	High Loc	Low IQ+ High Loc
Share of consistent subjects ($cons = 1$)	21.11 %	12.73 %	11.86 %	9.52 %
Share of consistent subjects ($cons_{50} = 1$)	28.89 %	18.18 %	16.95 %	9.52 %
Share of consistent subjects ($cons_{65} = 1$)	32.22 %	21.82 %	20.34 %	9.52 %
N	180	55	59	21

Notes: Low IQ (High Loc) investors comprise all investors whose IQ (internal locus of control) lies in the bottom third (top third) of the IQ (internal locus of control) distribution.

TABLE 6

Reaction to past outcomes

	Investment in entrepreneur 1	
	ALL	HUMAN
Locus of control		
Internal locus	-0.218*	-0.307
	(0.12)	(0.20)
External locus	-0.113	-0.164
	(0.10)	(0.17)
Outcomes in $t-1$		
(success, failure)	-0.767***	-0.889***
	(0.18)	(0.25)
(failure, success)	0.019	-0.110
	(0.18)	(0.22)
(success, success)	-0.368**	-0.379
	(0.17)	(0.29)
Outcomes in $t-1$ $\times$ internal locus		
(success, failure) $\times$ Internal locus	0.261	0.641**
	(0.16)	(0.27)
(failure, success) $\times$ Internal locus	0.160	0.291
	(0.18)	(0.38)
(success, success) $\times$ Internal locus	0.072	0.461
	(0.22)	(0.36)
Risk and cognitive ability		
Risk	-0.089	-0.050
	(0.09)	(0.18)
IQ	0.034	0.058
	(0.11)	(0.13)
Observations	1278	531
Rsq-adj.	0.02	0.03
Treatments	YES	NO
Gender, age and major	YES	YES

Notes: The table contains estimates from a linear panel data model (with N subjects and T periods). The dependent variable is the amount invested in entrepreneur 1. (success, failure) is a dummy that equals one if entrepreneur 1 was successful in the previous period while entrepreneur 2 failed (and zero otherwise); (failure, success) and (success, success) are defined accordingly. (failure, failure) is the base. Column (2) contains results from the HUMAN treatment sample. All models contain a constant. Standard errors (in parentheses) are robust and clustered at the group level. Significance at * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 7
Determinants of changes in the risk allocation among inconsistent subjects

	frequency			*magnitude*		
	(1)	(2)	(3)	(4)	(5)	(6)
Locus of control						
Internal locus	0.153	-0.165	-0.153	-0.083	-0.010	-0.012
	(0.15)	(0.17)	(0.17)	(0.08)	(0.09)	(0.09)
External locus	-0.035	-0.120	-0.133	-0.097	-0.067	-0.062
	(0.16)	(0.13)	(0.13)	(0.08)	(0.08)	(0.08)
Risk and cognitive ability						
Risk		0.318	0.325		-0.010	0.004
		(0.23)	(0.24)		(0.10)	(0.11)
IQ		-0.366*	-0.408**		0.194**	0.207**
		(0.20)	(0.20)		(0.09)	(0.09)
Gender, age and major						
Female		1.607***	1.532***		-0.423**	-0.404**
		(0.38)	(0.37)		(0.20)	(0.19)
Age		-0.073*	-0.079**		0.011	0.012
		(0.04)	(0.04)		(0.02)	(0.02)
Economics		0.825	0.690		-0.266	-0.158
		(0.83)	(0.94)		(0.31)	(0.32)
Treatments						
HUMAN			-0.182			0.237
			(0.35)			(0.24)
INFO			0.800*			0.065
			(0.48)			(0.21)
Observations	140	140	140	140	140	140
Rsq-adj.	-0.01	0.18	0.19	-0.00	0.05	0.04

Notes: The table contains OLS estimates. In columns (1)–(3), the dependent variable *frequency* is the number of periods in which an inconsistent subject changed the risk of her investment. In columns (4)–(6), the dependent variable *magnitude* indicates by how much the risk changes on average when a change occurs. A more detailed variable description is shown in Table 2. All models contain a constant. Standard errors (in parentheses) are robust and clustered at the group level. Significance at * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

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