Risk preferences and economic shocks: Experimental evidence[1]

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Abstract

We demonstrate in our experiment that an exogenous shock does not lead to increasing risk aversion, and has ultimately no significant impact on investors' risk preference in general. To do so, we keep subjects' risk and return expectations fixed and focus solely on loss in wealth. As a theoretical framework, we use the expected utility approach and take the class of HARA-utility functions to analyse subjects' preferences. Particularly, our methodical approach affords insights into the impact of economic fluctuations on investors' risk-taking and the measurement of risk preferences per se. We conclude that cautious investment behavior after an economic crisis might rather be due to changes in the perception of risk and return. Moreover, we give evidence that, in general, it is not sufficient to explain investors' risk-taking solely by preferences.

I. Introduction

In our experiment, we analyse changes in investor risk-taking after an exogenous shock. Campbell (2011) points out that the financial crisis of 2008 showed that the investment decision process is understudied, given its importance to the national and international economy. Such relative neglect is due to the fact that economic transactions of individuals and households are both hard to observe and hard to interpret. Especially, personal

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experiences may have significant impact on personal decisions.[3] Yet, standard models assume that risk preferences are unaltered by personal experiences. Hence, the question arises whether personal experiences primarily alter risk preferences or rather the perception regarding risky outcomes. The experimental literature has focused on the effect of personal experiences related to payoffs which were obtained from the same investment decision in the past. As opposed to reinforcement learning, macroeconomic shocks like the financial crisis in 2008 have rarely been investigated experimentally. Our experiment is based on a theoretical foundation by applying the expected utility approach and taking the standard class of HARA-utility functions to explain observed patterns of decision-making. We are particular interested in a clear-cut distinction between the perception of risk, risk preference and risk behavior.

So far, most relevant financial literature points out that personal experiences affect investors' risk attitudes. Some relevant experimental finance research assesses risk-taking behavior using the investments in a risky asset, which neglects the distinction between perception of risk and risk preferences. Against this background, we use the expected utility approach and take the class of HARA-utility functions to observe investors' preferences. We do not claim that people are expected utility maximizers, but rather that the approach allows us to model individual decisions in simple experiments and that the HARA-class is a good estimator to describe and explain subjects' preferences. To do so, we keep risk and return expectations fixed and focus solely on loss in wealth. Concerning the impact of an exogenous wealth shock, we calculate subjects' risk preference before the shock in our experiment and set this as an estimator for subjects' investment decisions after the shock. Afterwards, we compare our estimations with the decisions of our subjects. For example, no or marginal deviations would indicate that a macroeconomic shock should have no significant impact on investors' risk preferences. Our experimental design and the methodology, thus, indicate whether restricted activities on the stock market during an economic crisis are caused by a change in investors' risk preferences or rather by the perception of risk and return.

To make explicit statements, we conduct an experiment in which we confront subjects with two treatments of a one-periodic decision-making problem. In each treatment, subjects have to make five decisions regarding their certainty equivalent and depending on their total wealth. In treatment II, we modify the frame of the experiment to investigate whether and how risk preferences change for each individual after an exogenous shock. We do, however, not change the decision problem in order to show that this shock had no influence on future prospects. This could be one big difference to a real economic crisis where not only the

[3] [e.g. Weber et al. (1993), Hertwig et al. (2004)].

wealth but also the belief in future prospects could decrease. Importantly, we make sure that the decrease in wealth cannot be associated with the decision-making problem in the experiment. Changing behavior in our experiment would then indicate changes in investors' risk preferences after an economic shock.

Our results demonstrate that an exogenous shock has no significant impact on investors' risk preferences in general. Economic shocks could, therefore, primarily influence return and risk perception and ultimately trading decisions as well. Moreover, we give evidence that, in general, it is not sufficient to explain investors' risk-taking solely by preferences. In each treatment, we use the first decision (a simple 50/50 lottery) to calculate the benchmark risk aversion of the individual. Taking the quoted certainty equivalent, we calculate a utility function using HARA-preferences and estimate the expected certainty equivalents in the remaining lotteries. We take these to determine the deviations between quoted and estimated certainty equivalents. The results show that the expected utility approach, even using a simple class of utility functions, can be successfully applied to the selected choices and explains revealed patterns of decision-making under risk in simple lotteries with moderate probabilities. Concerning the impact of an exogenous shock, we select the standard benchmark of treatment I so we can forecast the certainty equivalent in treatment II of our experiment. However, only 19% of our subjects show an increase in risk aversion. Previewing our results, cautious investment behavior after an economic crisis might rather be due to changes in the perception of risk and return than to an increase in risk aversion.

Personal experiences are widely analyzed in the literature, but previous studies in experimental finance have focused on risk-taking behavior related to payoffs which were obtained from personal investment decisions in the past.[4] Most of those studies point out that reinforcement learning affects investors' risk preferences. Depending on breakeven opportunities, investors become more risk averse if they have suffered prior losses and cannot offset them, or less risk-averse if there is a breakeven opportunity. Such statements are often explained by the Prospect Theory of Kahneman and Tversky (1979) and are mostly justified by the fact that participants invested their assets differently during an experiment. Hence, preferences must be highly volatile, steadily adjusting to personal experiences in order to explain changing investment behavior. Recent studies allow for a differentiated consideration

[4] The effect of prior payoffs has been documented in several studies. Some experiments analyze the influence of evaluation periods [e.g. Thaler et al. (1997), Gneezy and Potters (1997), Barkan and Busemeyer (1999), Gneezy and Potters (2003), Bellemare et al. (2005), Langer and Weber (2008) or Mayhew and Vitalis (2014)], others investigate the disposition effect [e.g. Weber and Camerer (1998), Oehler et al. (2003)], the house-money effect [e.g. Thaler and Johnson (1990), Weber and Zuchel (2005), Ackert et al. (2006)], or the impact of emotions [e.g. Shiv et al. (2005), Demaree et al. (2012)].

of behavioral phenomena such as the disposition effect or the house-money effect and show that investment behavior changes substantially even for small changes in the framing.[5] Imas (2016), e.g., observes that past losses have a different impact if losses are realized after each investment period (realized losses) or cumulated at the end of the experiment (paper losses). Grosshans and Zeisberger (2018) demonstrate that for both, overall gains and losses, investors are most satisfied if their assets first fall in value and then recover and they are least satisfied with the opposite pattern. More specifically, they find that price paths affect risk and return expectations in such a way that investor use past returns and volatility as a proxy for future estimates. Gigerenzer (2015) adds in this context that it is not sufficient to explain individual behavior solely by risk attitude but also by the perception of risk. Hence, we investigate changes in investor risk-taking after a macroeconomic shock and are interested in a clear-cut distinction between risk-taking, the perception of risky outcomes, and risk preferences.

As indicated before, risk-taking behavior is also affected by economic fluctuations like financial crises. Investors pulled approximately 72 billion dollar from stock funds into government bonds and cash holdings in October 2008. Malmendier and Nagel (2011) point out that the level of risk-taking depends on personal experiences of economic fluctuations, but more recent experiences have stronger effect and can reduce the impact of older economic fluctuations. Vissing-Jorgensen (2003) and Amromin and Sharpe (2009) find similar results. In times of booms, individuals, primarily younger individuals, expect higher stock market returns than in times of recessions. Greenwood and Nagel (2009) observe similar results among professional investors. Gaham and Narasimhan (2004), Malmendier and Tate (2005), and Malmendier et al. (2011) show that economic fluctuations also influence corporate decisions.

Studies about the financial crisis of 2008/2009 mostly presume a decrease in risk-taking between September 2008 and March 2009 and an increase again by June 2009 because of countercyclical risk preferences. Cohn et al. (2015) show in an experiment that financial professionals who are confronted with an economic shock take lower risks even though they do not experience a financial loss. Guiso et al. (2018) report similar results. Guiso et al. (2018) combine lab/field data with naturally occurring data. Basically, Guiso et al. (2018) use data from a repeated survey of Italian bank clients in 2007 and June 2009 and compare them with the clients' bank accounts between September 2008 and February 2009. They conclude that increasing risk aversion is not significantly related to changes in wealth because they observed increasing risk aversion between 2007 and June 2009 for both types of clients, those

[5] [e.g. Frydman et al. (2014), Imas (2016), Grosshans and Zeisberger (2018), Nolte and Schneider (2018)].

that experienced a financial loss and those who did not experience any financial loss. In contrast to Guiso et al. (2018), we suggest that a macroeconomic shock generally has no significant impact on investors' risk preferences. Our result is consistent with Weber et al. (2013). They ask UK online-brokerage customers between September 2008 and June 2009 about their willingness to take risks. They find that changes in risk-taking are associated with changes in subjective expectations of risk and return. Similarly to us, they find that measures of risk preferences do not change after a macroeconomic shock. Their results are in line with observations by Malmendier and Nagel (2011) that show that past experiences with economic fluctuations alter beliefs about future returns. Roszkowski and Davey (2011) also find evidence that the financial crisis affected risk perception rather than risk preferences.

We extend this stream of the literature in the following ways. First, our experimental approach directly addresses the effect of an exogenous shock and prevents any effects of reinforcement learning or adaptive behavior. Second, our methodology allows a more sophisticated analysis to explain risk-taking behavior by estimating preferences. Previous studies on the impact of an economic shock have either focused on naturally occurring data before and after a recession or on experimental data without direct financial reference to the shock. Against this background, we create an experimental setting where subjects are confronted with a financial loss due to an exogenous shock. Third, our results indicate the importance of well-designed risk profiles and how objective risk preferences can be determined without any confounding effects.

Particularly, our results show that risk preferences are quite consistent. Hence, we conclude that investor beliefs or perceptions should receive greater attention in a wide range of financial theories and models. One application is the equity premium puzzle, for which most literature has assumed that myopic loss aversion explains the high equity premium. Our results suggest that a macroeconomic shock creates a shift towards pessimistic beliefs about the risks of the stock market.[6] Cogley and Sargent (2008) show that, depending on the length and frequency of a recession, macroeconomic experiences may create a long-lasting shift in asset prices.

The rest of the paper is organized as follows. In section II we introduce our experimental design. We explain how we create an individual risk parameter and present our results as well as the robustness of our main findings in section III. Our paper ends with a discussion of our main findings and the experimental setting.

[6] [e.g. Rietz (1988), Cecchetti et al. (2000) and Cogley and Sargent (2008)].

II. Experimental design

We conduct an online experiment[7] to test whether a macroeconomic shock affects investors' risk preferences. At the beginning of our experiment, we ask our subjects about their individual wealth. This stated individual wealth forms the initial wealth for the participant's investment decisions in the experiment. We confront subjects in two treatments with the same one-stage decision-making problem in which our subjects experience the situation of investing their entire wealth in either a risky or a safe investment. In each treatment, subjects make five decisions regarding their certainty equivalent. For our analysis, we vary the prospects of the decision-making problem. The centerpiece of our experiment is that the subjects face a loss of wealth between treatment I and treatment II, where their original capital shrinks to a level of 80 % caused by an exogenous factor similar to a macroeconomic shock. Importantly, the subjects receive no feedback about the success of their decisions in treatment I in order not to influence their behaviour in treatment II. We make sure that the decrease in wealth cannot be associated with the decision-making in the experiment and the investment decisions are independent of one another in both treatments.

In total, we receive data from 194[8] Economics students from the University of Duisburg-Essen. All sessions were conducted online using PHP and MySQL. After registration via student email address, the subjects receive a nickname and password for registration as well as a direct link to the online experiment. To facilitate participation, the experiment only required an internet browser and internet connection. The experiment took around 20 minutes. Before subjects start with the main part of our experiment, we ask them about socio-demographic information and briefly inform the subjects about the payment process, the expected value of a risky asset, and the certainty equivalent of a risky asset. After the experiment, we give the subjects the opportunity to tell us about their experiences with our experiment. The mean age of the subjects are 23.29 years, 42% of the subjects are female, and 58% of the subjects are male.

Experimental procedure:

We start the main part of our experiment with a short training session. The subjects imagine that they are about to invest their entire wealth and are confront with a choice between a risky asset, which pays 240% or 90% (a loss of 10%) of their wealth after five years with equal probability and a certain fixed amount of money. We provide the opportunity

[7] In Appendix A, we give an overview and description of our experiment.

[8] We sort out these subjects who has made obviously fake entries, whose decisions are not explainable by other decision theories, normative as well as descriptive theories, or who submit incomplete data.

to receive at first glance a high profit in order to incentivize our subjects to take risky investment decisions. In Table 1, we show the sequence of different certain amounts. In each case, the subjects have to decide which of the alternatives they prefer. This part is similar to the study of Guiso et al. (2018)[9], which is nearly identical to the Holt and Laury (2002)[10] framing. Table 1 presents the decision-making problem and shows how it is adapted to subjects' indicated wealth.

Table 1:

Screenshot: Training Session.

The subjects imagine that they are about to invest their entire wealth and are confront with a choice between a risky asset, which pays 240% or 90% (a loss of 10%) of their wealth after five years with equal probability and a certain amount of money. Thus, the first certain amount at which a subject switches from the risky to the certain asset identifies (a lower and an upper bound for) his/her certainty equivalent.

Certain amount (wealth: 10,000 €)		(I)		(II)
9,000 €	○	certain amount	○	risky asset
11,000 €	○	certain amount	○	risky asset
13,000 €	○	certain amount	○	risky asset
15,000 €	○	certain amount	○	risky asset
17,000 €	○	certain amount	○	risky asset

Thus, the first certain amount at which a subject switches from the risky to the certain asset identifies (a lower and an upper bound for) his/her certainty equivalent. We introduce this training session with the purpose of preventing misunderstandings regarding the experimental setting, and especially the certainty equivalent approach. Hence, we do not use the answers to this question in our analysis.[11]

Treatment I:

In treatment I of our experiment, we ask the subjects about their certainty equivalent for five different risky investments. We start with the easiest risky investment, a 50/50 choice to win or lose, and calculate a risk parameter according to the HARA-preference from the certainty equivalent stated. Table 2 shows how we ask subjects for their certainty equivalent. The subjects then face an identical question for different risky assets with changing success probabilities: 40%, 60%, 20%, and 80%, where gain and loss remain at 240% and 90% of initial wealth. We choose all probabilities far from 0 in order to avoid overestimating small probabilities as Prospect Theory suggests. Subjects are clearly instruct about the probabilities

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[9] [e.g. Gusio et al. (2018) and Bombardini and Trebbi (2012)].

[10] Holt and Laury (2002) strategy has proved particularly successful in overcoming the under/over-report bias implied when asking willingness to pay/accept.

[11] [e.g. Gusio et al. (2018) and Guiso and Paiella (2008)].

and potential gains and losses. Therefore, subjects have to choose their certainty equivalent in five different situations in treatment I.

Table 2:
Screenshot: Treatment I (wealth: 10,000 €).
In treatment I of our experiment, we ask the participants about their certainty equivalent for five different risky investments. The subjects imagine that they are about to invest their entire wealth and are confront with a choice between a risky asset, which pays 240% or 90% (a loss of 10%) of their wealth after five years with 20%, 40%, 50%, 60% and 80% probability and a certain amount of money.

Enter now the certain amount for which the risk-free and risky investments are equally attractive.
"In my view, a certain amount in 5 years of __________€ would be similar to the risky investment 50/50."
Expected value of the risky investment 50/50: 16,500 €.

Treatment II:

Our intention is to differentiate between the main effects of an economic shock: decrease in wealth and changes in beliefs about future prospects. Before starting treatment II, subjects are confront with a 20% loss of their wealth. Then they have to take the same five decisions as in treatment I but with decrease wealth. To fix subjective expectation, we ask the subjects in treatment II to indicate the certainty equivalent for the identical risky assets and in the same order as in treatment I. However, we focus on the impact of the exogenous wealth shock in our experiment and exclude the impact of changes in beliefs about future prospects. Table 3 presents the decision-making problem in treatment II regarding an exogenous shock.

Table 3:
Screenshot: Treatment II (wealth: 8,000 €).
In treatment II of our experiment, subjects are confront with a 20% loss of their wealth. Then they have to take the same five decisions as in treatment I but with decrease wealth. To fix subjective expectation, we ask the subjects in treatment II to indicate the certainty equivalent for the identical risky assets and in the same order as in treatment I.

"Imagine that you have lost 20% of your own wealth, and you have again the option to invest your total wealth of now **8,000 €**, either in a risk-free or in a risky investment. Another option is not available."
Enter now the certain amount for which the risk-free and risky investments are equally attractive.
"In my view, a certain amount in 5 years of __________€ would be similar to the risky investment 50/50."
Expected value of the risky investment 50/50: 14,500 €.

In both treatments, we give subjects the opportunity to change previous decisions. Importantly, the subjects receive information about their payoffs in treatment I and the results of the risky assets only at the end of the experiment. The subjects thus face a situation where their original capital are shrunk by 20% due to an exogenous factor similar to a macroeconomic shock and not due to their individual decisions. In order to make the macroeconomic shock look as realistic as possible, we use empirical data from the recent financial crisis to determine the financial loss. The Global Wealth Report of the Boston Consulting Group (2010) shows that in 2008, in a period of high stock market uncertainty, the average wealth in the USA decreased by 20%. In our experiment, we implement this as a loss in wealth by 20%.

Incentives:

In order to create an incentive for the subjects, we offer a high possible compensation for participating which we link to the investment decisions of the subjects and only pay with a predetermine probability. The exact amount depends on the given answers (risk preference), which means that subjects' answers should be as truthful as possible in their own interest. At the end of our experiment, we randomly select one of the ten investment decisions for each subject. Depending on the randomly select investment decision and the subject's reveal certainty equivalent, we pay a compensation between 70 € and 240 € with a probability of 1/50 according to the result of the German public lottery (6 out of 49). Each subject receive three randomly chosen numbers between 1 and 49 (sampling without replacement) and detail information about the payment process at the beginning of the experiment. We compare these numbers with the results of the public lottery of the following weekend. If the numbers match the results of the public lottery (1/50), the payment are make to the subject. The compensation corresponds to an expected payment of approximately 12.50 € per hour.

To determine the payoff, we choose one out of 10 decisions and a random number for the safe investment are drawn. If the safe decision is better than the certainty equivalent reveal, the payoff match the safe outcome; if not, the higher or lower payoff is select according to the corresponding probability (20%, 40%, 50%, 60% or 80%).

III. Methodology and Results

For economic decision models, in particular the capital market theory, utility functions of the HARA class are often assumed for reasons of mathematical handling and the HARA functional form. Guiso and Paiella (2008) show that the absolute risk tolerance is an increasing function of consumers resources and give evidence that risk tolerance is a concave function of wealth, which goes in line with the HARA-class.[12] We test whether subjects' decisions are represented by HARA preferences and whether preferences differ with respect to the risk parameter γ before and after an exogenous shock. To test the applicability of the

[12] [see Appendix B].

HARA utility function, we use answers regarding the risky asset with equal probability (50/50) to calculate the benchmark risk parameter γ for each subject in both treatments. Taking this parameter, we forecast certainty equivalents for the remaining risky assets in each treatment in order to compare them to subjects' chosen amounts. If HARA preferences represent subjects' decisions, we are able to analyze the impact of an exogenous shock on investors' risk preferences. For this, we select the benchmark risk parameter γ before the shock in order to forecast certainty equivalents after the shock and compare it to subjects' chosen amounts. Both, consistently higher deviations as well as systematic deviations would indicate an effect of the exogenous shock on subjects' risk preferences. Otherwise, we conclude that cautious investment behavior after a macroeconomic shock might rather be due to changes in the perception of risk and return.

Applicability of HARA-class:

We find that HARA preferences are a good estimator for the subjects' remaining investment decisions. After remodelling[13], we use the HARA utility function for γ greater than 0 as $\mathrm{u(x)} = (c * x + 1)^{\gamma}$ and for γ lower than 0 as $\mathrm{u(x)} = -(c * x + 1)^{\gamma}$, with x as the net wealth, γ as the risk parameter, and c as a further degree of freedom. This restricts the domain to positive values of x and we ensure that wealth x is restricted to 0. In consensus with Prospect Theory and other behaviorist approaches, we allow γ to vary between both treatments of our experiment. We assume that risk preferences should not vary with respect to different prospects within one treatment.

In the course of determining an appropriate risk utility function, we compare the certainty equivalent of the subjects to the expected value of the benefits (Bernoulli principle). Based on EUT, we select the HARA utility function to represent the preferences corresponding to the revealed certainty equivalent in the equal probability setting (50/50). To test whether subjects' decisions can be modelled by HARA preferences, we forecast certainty equivalents for the remaining risky assets in each treatment in order to compare them to subjects' revealed certainty equivalents. Based on the comparison between HARA forecasts and subjects' chosen amounts, we use 1,517 observations to present the cumulative distribution of percentage deviations in Figure 1.

The number of observations we use is lower than the number of overall observations (1,552). We sorted out those observations which are attributable to inconsistent decisions of one of our subjects. Importantly, if we observe multiple non-monotonic decision behavior for

[13] [see Appendix B].

a subject which is not explainable by normative or rather descriptive theories, we delete all their entries for our analysis. We suppose that those answers are fake entries and assume that just one inconsistent decision is due to a slip-up by the subject. Appendix C presents the results including the slip-ups and shows no significant effect on any of our results.

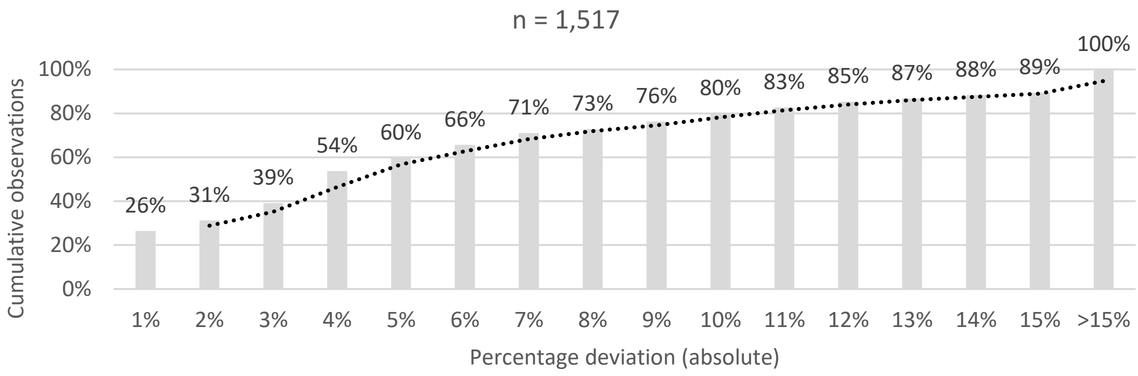

Figure 1:
Cumulative distribution of percentage deviations (I).
The figure shows the cumulative distribution of percentage deviations if we compare HARA forecasts and subjects' chosen amounts. For each subject, we calculate eight deviations from HARA forecasts and use altogether 1,517 observations. We observed that lower deviations occur significantly more often than higher deviations.

Additionally, we show the histogram of this data in Figure 2 and find that the distribution is positively skewed. Both figures show that lower deviations occur much more often than higher deviations. More than 50% of the observations are closer or equal to 4% and about 80% are closer or equal to 10%. We find only few higher deviations, which, however, might be due to carelessness of our subjects and under- or overestimations of higher or lower risk situations in our experiment.

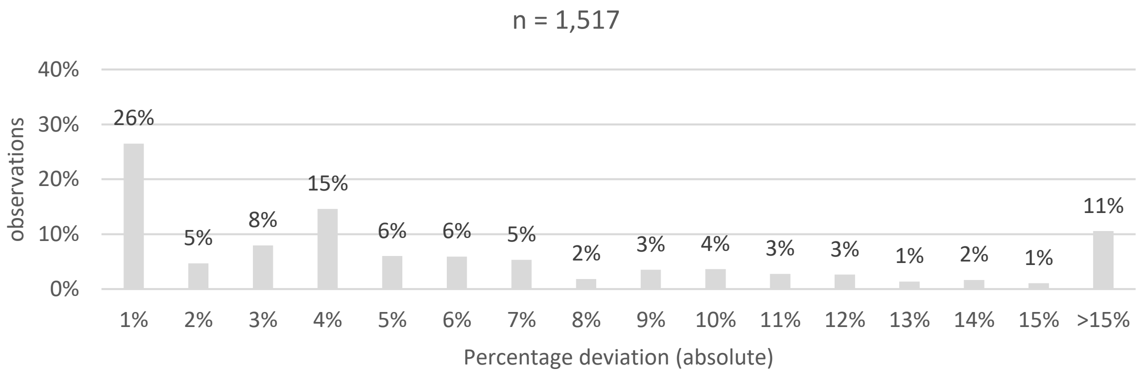

Figure 2:
Histogram of percentage deviations (I).
The figure shows the cumulative distribution of percentage deviations if we compare HARA forecasts and subjects' chosen amounts. For each subject we calculate eight deviations from HARA forecasts and use altogether 1,517 observations

For our investigation, we assume that subjects are not able to determine their certainty equivalent precisely and allow deviations from HARA forecasts within fixed boundaries.[14] To fix a feasible boundary, we focus only on observations in treatment I. Observations in treatment II would not change the selected boundary (see Table 5) but we use the boundary also for further analysis to determine changes in risk preferences between treatment I and treatment II. Hence, a clear-cut distinction makes our methodology more consistent and valid. Additionally, we sort out observations from risk-neutral subjects (n = 23) because they contain no information about the range of percentage deviations.[15] Furthermore, statistical tests delete such data anyway. We ultimately use 673 observations from 171 subjects to determine the cumulative distribution in Figure 3 and to fix a justified boundary we use for further investigations.

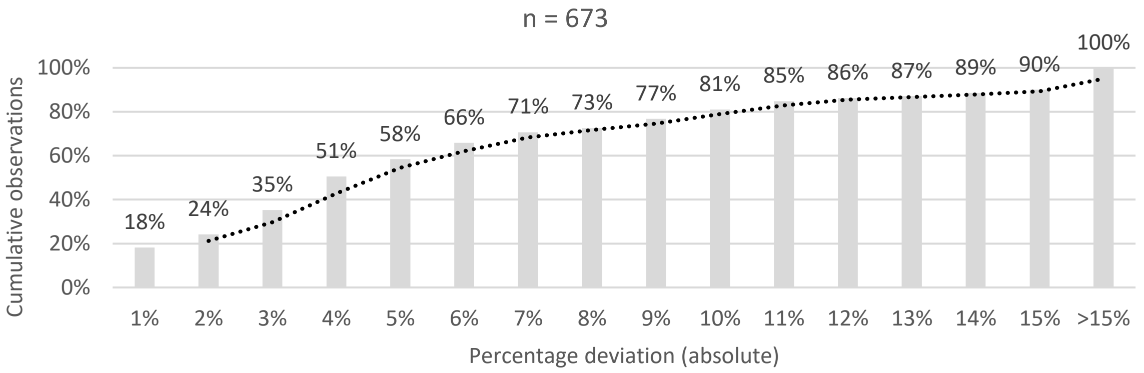

Figure 3:
Cumulative distribution of percentage deviations (II).
The figure shows the cumulative distribution of percentage deviations in treatment I if we compare HARA forecasts and subjects' chosen amounts. For each subject we calculate four deviations from HARA forecasts. We sort out observations from risk-neutral subjects (n = 23), because they contain no information about the range of percentage deviations. We ultimately use 673 observations from 171 subjects to determine the cumulative distribution in treatment I and to fix a justified boundary we use for further investigations.

Table 5:
Comparison of mean and standard deviations.
The table shows whether different data samples (rounded) lead to significant changes of our fixed boundaries.

	n	Mean deviation	Standard deviation	+/-Boundary
All	1517	6%	8%	+/-10%
Treatment 1	765	6%	8%	+/-10%
All (without risk-neutral)	1333	7%	9%	+/-11%
Treatment 1 (without risk-neutral)	673	6%	8%	+/-10%

[14] [e.g. Hey and Orme (1994)].
[15] We assume that most of these subjects had problems with our experiment or made fake entries, and were not risk neutral. Importantly, if we exclude this data for our analysis, we do not change our results qualitatively (see Table 5).

For our analysis, we use the mean value plus half a standard deviation to determine a justified boundary. The mean value across all observations comes to 6% and the standard deviation comes to 8%. Hence, we fix the boundaries to +/-10%. Additionally, Table 5 presents evidence that other data samples do not lead to significant changes of our selected boundaries. Rather, they confirm a fixed boundary of +/-10%.

Table 6:
Descriptive statistics.
The table presents descriptive statistics in case of a fixed boundary of +/-10%. We exclude data from risk-neutral subjects.

	Treatment I	Treatment I and II
Number of subjects:	n = 171*	n = 171*
○ Mean deviations inside boundary	82%	82%
○ Mean deviations outside boundary	18%	18%
Number of deviations:	n = 673*	n = 1333*
○ Inside boundary	81%	77%
○ Outside boundary	19%	23%
Deviations outside boundary	n = 128**	n = 304**
○ Positive deviations and outside boundary	64%	66%
○ Negative deviations and outside boundary	36%	34%
Deviations outside boundary and distributed by risky assets:***	n = 128**	n = 304**
○ 80/20-asset or 20/80-asset	67%	70%
○ 60/40-asset or 40/60-asset	33%	30%
Deviations outside boundary and distributed by highly or lowly risky	n = 86	n = 213
assets:***	41%	33%
○ 80/20-asset and positive deviation	14%	21%
○ 80/20-asset and negative deviation	20%	29%
○ 20/80-asset and positive deviation	26%	17%
○ 20/80-asset and negative deviation		

* Number of all subjects or observations.
** Number of observations that are higher than the selected boundary.
*** x/y-asset: x is the probability for a positive outcome and y is the probability for a negative outcome.

In Table 6, we take a closer look at deviant responses. Table 6 presents descriptive statistics for a boundary of +/-10% to show that subjects' decisions are represented by HARA preferences. Consistently deviant responses as well as systematically deviant responses across all subjects would argue against the HARA-class. This could be due to the fact that people's preferences are not HARA-preferences or that they do not maximize expected utility in simple experiments. We find that mean deviations of 82% of 171 subjects in both treatments are inside the boundary of +/-10% and the mean deviations of only 18% are outside the selected boundary. Across all subjects, we do not observe consistently higher deviant responses during the experiment. Additionally, we find that about 80% of all observations are inside the boundary and only 20% of all observations are outside the selected boundary. To verify systematic deviations, we compare the number of positive and negative deviations. Across all deviant responses, we do not find one clear direction of deviations outside the boundary. 66% of all deviations are positive and 34% negative, which show that differences between our estimations and subjects' decisions do not point in a definite direction (e.g. higher risk aversion). Thus, we observe neither consistently higher deviations, nor systematic deviations.

Table 6 also contains information about where observations outside the boundary occur. We show that deviations from the selected boundary primarily occur in risky assets where the probabilities are significantly higher or lower than 50%. These results are not surprising and consistent with Prospect Theory. It should be noted that the number of deviations is low and that there is neither a clear-cut overestimation nor an underestimation of risk. According to Prospect Theory, the closer we come to lower or higher probabilities, the harder it will be to apply the expected utility approach. Anyway, overestimation and underestimation of risk is a general problem caused by a lack of risk competence. Gigerenzer (2015) shows that people have problems to understand risk if the decision problem is presented in terms of probabilities. According to Gigerenzer, the handling of risk can be improved by using relative frequencies. An adaptation of the questionnaire could, thus, lead to a further reduction in the observed deviant responses. Despite these problems, the HARA-class gives quite conclusive forecasts. For this purpose, we use HARA-preferences to analyse the impact of external circumstances on investors' risk preferences.

Risk preferences and economic shocks:

The main contribution of this experiment lies in answering the question whether risk aversion increases after an economic shock. To do so, we keep investors' risk and return expectations fixed and focus solely on loss in wealth. Unlike the test of the applicability of the HARA-class, we select the standard benchmark of treatment I in order to forecast certainty equivalents for the risky assets in treatment II. At first, we calculate the deviations between our forecasts and subjects' chosen amounts for each situation. Afterwards, we simply compare the mean deviation in treatment I with the mean deviation in treatment II for each subject. A highly negative difference between treatment I and treatment II would indicate that subjects are more risk averse after an exogenous shock. Table 7 presents evidence that risk aversion is not the feasible factor for cautious investment behavior after an exogenous shock. Note that 44% of all subjects choose lower risk and 44% choose higher risk after an exogenous shock.[16] As before, we sort out observations from risk-neutral subjects (n = 23) which contain no information about changes in investors' risk-taking. Looking at the p-value in Table 7, we actually find that an exogenous shock does not increase investors' risk aversion significantly.

Table 7:
Investment behavior after an exogenous shock (I).
The table shows the number of subjects who choose higher risk (column 1) and lower risk (column 2) after an exogenous shock. The third and fourth columns report the results of a two-sided Wilcoxon signed ranks test.

	+	-	z-value	p-value
Differences between the mean deviations from treatment I and II	86	85	-1.5254	0.1286

For our analysis, we do not only compare the direction of the differences within pairs (column 1 and 2), we also take the relative magnitude of the differences into account. For this, we use the Wilcoxon signed ranks test, which gives more weight to a pair that shows a large difference between the two conditions than to a pair that shows a small difference. The results show that an exogenous shock does not lead to increasing risk aversion. However, above results cannot explain whether an exogenous shock generally affects investors' risk preference. Hence, we conduct further analyses.

Figure 4 shows the distribution of the differences between the mean deviations from treatments I and II. We determine the differences by subtracting the mean deviation of treatment I from the mean deviation of treatment II. Negative values indicate that the subjects choose lower risk after an exogenous shock and vice versa. As shown in Table 8, almost 50% of the subjects choose higher risk and 50% choose lower risk after an exogenous shock. Consequently, we could not identify significantly higher risk aversion after an exogenous shock. Particularly, the results in Figure 4 and Table 8 show that an exogenous shock neither increases nor decreases investors' risk aversion because the majority of all differences is inside our selected boundary of +/-10%. We conduct a binomial test to verify the robustness of the results in Figure 4. Row A makes no distinction between positive and negative differences and shows that 114 of 171 subjects do not adapt their investment decisions after an exogenous shock. Rows B and C distinguish between subjects who choose lower investment risk (row B) or higher investment risk (row C) after an exogenous shock. The

[16] We also find that the mean deviations of 12% of all subjects are identical in treatment I and treatment II, which stems back to risk-neutral subjects. Which is due to?

results in row C show that higher risk attitudes after an exogenous shock are marginal and not significant. Hence, the results indicate that an exogenous shock does not lead to decreasing risk aversion. On the other hand, the results in row B are not as clear as in row C. It seems that an exogenous shock does lead to increasing risk aversion for a small part of the subjects. Since the binomial test neither confirms nor refutes an increase in risk aversion, we suppose that an exogenous shock generally has no significant influence on investors' risk preferences. All said, cautious investment behavior after an economic shock do not appear to be the result of increasing risk aversion.

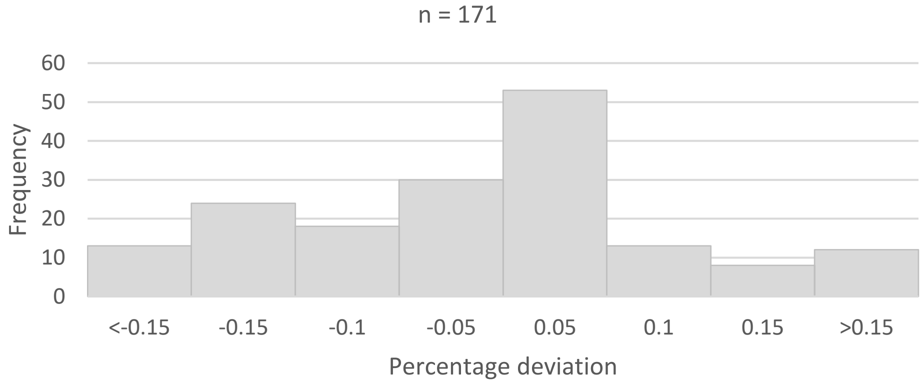

Figure 4:
Investment behavior after an exogenous shock (II).
The histogram shows the differences between the percentage deviations in treatment I and treatment II to explain the investment behavior after an exogenous shock. We use the standard benchmark of treatment I in order to forecast certainty equivalents for the risky assets in treatment I and treatment II. We compare this data with subjects' chosen amounts and compute the mean deviation in treatment I and treatment II for each subject. The difference between these values gives us information about the investment behavior after an exogenous shock. Negative values indicate that the subjects choose lower risk after an exogenous shock and vice versa.

Table 8:
Investment behavior after an exogenous shock (III).
The table reports the relative magnitude of the differences between the mean deviations from treatments I and II. Column 1 reports the number of differences that are lower than the selected boundary and column 2 the number of differences that are higher than the selected boundary. The third and the fourth column show the results of a two-sided binomial test which tests the effect of an exogenous shock on investors' risk preference. Row A makes no distinction between positive and negative differences. Rows B and C differentiate between negative and positive differences. Negative differences indicate less investment risk after an exogenous shock and vice versa.

	<10%	>10%	z-value	p-value
A. Differences between the mean deviations from treatments I & II	114	57	-4.4353	0.00006
B. Negative differences between the mean deviations from treatments I & II	48	37	-1.0846	0.2802
C. Positive differences between the mean deviations from treatments I & II	66	20	-4.8524	0.00006

In addition to our comparison of the mean deviations in both treatments, we test the mean deviations in treatment II by themselves without direct comparison to the decisions in treatment I. In both cases, we select the risk parameter of treatment I to forecast certainty equivalents for the risky assets in treatment II and determine the deviations between our forecasts and subjects' chosen amounts for each situation. Afterwards, we calculate the mean deviations of each subject. Instead of comparing the mean deviations in treatments I and II, we are now only interested in the level and the direction of the mean deviations in treatment II. Hence, we change the benchmark in our analysis. Before, we select the mean deviation in treatment I as the status quo; now, we select the forecast risk parameter as the status quo. If the mean deviations in treatment I equal zero, we receive identical results for both methods. Generally, we presume that both methods lead to similar results and conclusions.

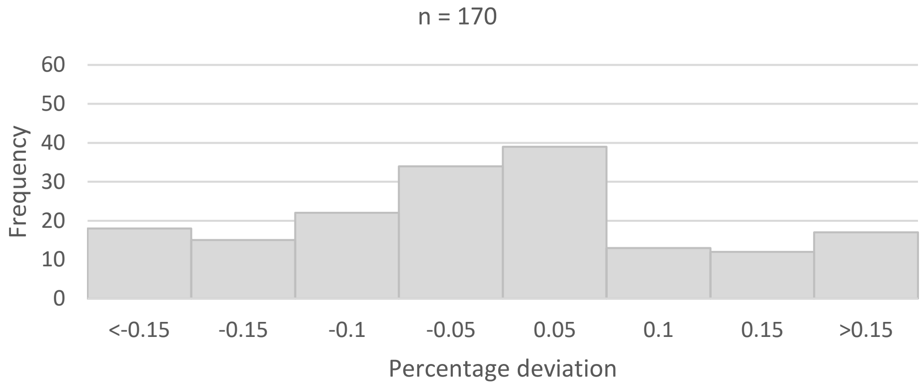

Figure 5:
Investment behavior after an exogenous shock (IV).
The histogram shows the distribution of the mean deviations in treatment II to explain the investment behavior after an exogenous shock. We use the standard benchmark of treatment I in order to forecast certainty equivalents for the risky assets in treatments I and II. We compare this data with subjects' chosen amounts and compute the mean deviation in treatment II for each subject. The mean deviation gives us information on how well the risk parameter in treatment I can explain the investment behavior in treatment II. High deviations indicate changes of investors' risk preferences.

Table 9:
Investment behavior after an exogenous shock (V).
The table show the relative magnitude of mean deviations in treatment II. Column 1 reports the number of differences that are lower than the selected boundary and column 2 the number of differences that are higher than the selected boundary. The third and the fourth column show the results of a two-sided binomial test, which tests the effect of an exogenous shock on investors' risk preference. Row A makes no distinction between positive and negative differences. Rows B and C differentiate between negative and positive differences. Negative differences indicate lower investment risk after an exogenous shock and vice versa.

	<10%	>10%	z-value	p-value
A. Mean deviations in treatment II	108	62	-3.4513	0.0006
B. Negative mean deviations in treatment II	56	32	-2.4518	0.0142
C. Positive mean deviations in treatment II	53	29	-2.5399	0.0114

Figure 5 presents the level and direction of the mean deviations in treatment II. As one might expect, the results are nearly identical to the comparison of the mean deviations from treatment I and II. Almost 50% of the subjects choose higher risk and 50% choose lower risk after an exogenous shock. Importantly, most of the observations are also inside the selected boundary, which suggests that an exogenous shock neither increases nor decreases investors' risk aversion. Table 9 shows similar results as well. For all three cases, the results in Table 9 show that an exogenous shock does not lead to significant changes in investors' risk attitude.

Ultimately, we could not identify significantly higher risk aversion after an exogenous shock. Economic shocks could therefore primarily influence return and risk perceptions, and, ultimately, trading decisions as well. Cautious investment behavior during or rather after the financial crisis of 2008 might therefore have been rather due to changes in the perception of risk and return.

IV. Conclusion

Our paper provides two main contributions which extend previous behavior and experimental finance research. In our view, the methodological approach is one main contribution. So far, most relevant experimental finance research has assessed risk-taking behavior using the investments in a risky asset or asking only for their certainty equivalent, thus neglecting a distinction between the perception of risky outcomes and risk preferences. We believe it is important to differentiate. Therefore, we search for a utility function to make direct statements about investors' preferences. As the expected utility approach and the class of HARA-utility functions explained investor behavior in our simple lab experiments, we are further able to analyse whether cautious investment behavior after an exogenous wealth shock is caused by a change in investors' risk attitude.

Thus, the second contribution is to investigate whether an exogenous shock leads to significantly higher risk aversion. Previous studies were unable to provide clear-cut evidence consistent with the increase in risk aversion during an exogenous shock. Guiso et al. (2018) combine survey data from 2007 and June 2009 with changes in subjects' bank accounts between September 2008 and February 2009, but changes in both datasets could also be attributable to other and different endogenous or exogenous effects. Thus, they use data without direct financial reference to the shock. Similar to us, Guiso et al. (2018) make assumptions about changes in subjects' risk preferences when asking subjects about their certainty equivalent. In both surveys, subjects must decide for which of the predetermined intervals of certainty equivalents they are indifferent to the presented risky outcome. Different selected intervals should, then, indicate changes in investors' risk preferences. Although, individuals are not able to make clear-cut decisions about their certainty equivalents[17] but we

[17] [e.g. Hey and Orme (1994)].

use several observations to make assumptions about investors risk preference and we determine boundaries for certainty equivalents endogenously. Further studies use naturally occurring data, which make it hard to differentiate between perception of risky outcomes and risk preferences.[18] In our experiment, we ensure that the subjects experience a direct financial loss due to an exogenous shock and simultaneously exclude the impact of changes in beliefs about future prospects. The combination of a theoretical framework and a simple lab experiment enable insights into the impact of economic fluctuations on investors' risk-taking and risk preferences.

Our results demonstrate that a macroeconomic shock has no significant impact on investors' risk preferences. In contrast to Gusio et al. (2018) or Cohn et al. (2015), we suppose that emotions or overestimation of rare events caused by an exogenous shock primarily influence return and risk perception, and, ultimately, trading decisions as well, but we are unable to provide direct evidence. Weber et al. (2013), who find that changes in risk-taking are associated with changes in subjective expectations of risk and return, support our conclusion. Finally, risk preferences must be highly volatile, steadily adjusting to personal experiences in order to explain countercyclical investment behavior.

Generally, targeted and simple lab experiments in combination with a theoretical framework help to identify effects that are difficult to analyse in empirical studies. Thus, we conclude that the perception of risk and return should receive greater attention in a wide range of financial theories and models. One possible application is the equity premium puzzle. A macroeconomic shock may create a shift towards pessimistic beliefs about the stock market. Depending on the length and frequency of a recession, macroeconomic experiences may create a long-lasting shift and, in the aggregate, affect asset prices.[19] Experimentally, it could be interesting to establish whether a different framing, like relative frequencies instead of probabilities, help to measure risk preferences, and ultimately lead to better risk understanding and more rational decisions (e.g. Gigerenzer 2015).[20] These results could also be relevant for banking practitioners when creating risk profiles of bank customers. Our results indicate the enormous importance of well-designed risk profiles and show how objective risk preferences can be determined without any confounding effects.

Finally, our results points out that risk preferences are more consistent than we believe. If the behavior we document is typical, recurring reviews of risk profiles seem to be less important than the Markets in Financial Instruments Directive (MiFID) states. In contrast to

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[18] [e.g. Malmendier and Nagel (2011)].
[19] [e.g. Rietz (1988),Cecchetti et al. (2000) and Cogley and Sargent (2008)].
[20] [e.g. Gigerenzer (2015)].

Weber et al. (2013), we do not confirm that subjective expectations should be continuously checked. We suppose that changes in subjective expectations are rather the cause of a lack of investors' risk competence (e.g. Gigerenzer 2015). Hence, bank practitioners should first determine the risk competence of bank customers before they create an individual risk profile. To sum up, our paper raises two interesting questions for future research: whether investors' risk preferences are nearly constant and whether investors' beliefs or rather perceptions could be a more sophisticated explanation for trading decisions, and ultimately for asset prices.

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Appendix A: Descriptions of our experiment

Preliminary Remarks:

You are participating in a study of choice behavior for the purposes of experimental economic research at the University of Duisburg-Essen. The experiment will take around 20 minutes and consists of two different financial situations. Before each of them, you will receive detailed instructions.

After completing the inquiry, you take part in a lottery. If you win (probability 1:50), you will receive between 70 € and 240 €. The exact amount and the risk will depend on your answers, which, in your own interest, should be as truthful as possible.

As a university, we assure that data (user name or email address) which give us any clue to your identity, are provided solely for the earnings release and thus uncoupled from your answers in the questionnaire. A subsequent mapping is excluded.

Socio-Demographic Data and Instructions at the beginning of the Experiment

Socio-Demographic Data:

The subject will be asked about their age, home town, gender, marital status, education, and financial situation in this part of the experiment. However, only the declaration of his financial situation is marked as required (An exemplary decision screen is depicted in Figure 6).

Socio-Demographic-Data

If you add up all the cash reserves you have and the amount of savings from investments (except for own-use real estate, life insurances, and pension insurances): Which of the following amounts correspond more or less your own wealth?

- 1.000 Euro
- 5.000 Euro
- **10.000 Euro**[21]
- 25.000 Euro
- 50.000 Euro
- 100.000 Euro
- 250.000 Euro
- 500.000 Euro
- 1.000.000 Euro
- 10.000.000 Euro

continue

Figure 6
Screenshot: Socio-Demographic Data

[21] Numbers marked in bold are either the participant's own input or numbers which relate to these inputs.

Introduction to your chances of profit and the amount of profit:

You can win money in this experiment. Six random numbers were determined for you:

5; 14; 17; 29; 35; 49

If next Saturday, *25.03.2017*, in the lottery 6 out of 49 not less than three identical numbers are drawn in the ARD (television channel), you will win. The resulting money depends on your decisions during the experiment.

In the following, you can choose between safe and risky investments. You will have to make a total of 10 different investment decisions concerning your total wealth of ***10.000 €***. You continuously have the opportunity to change your previous decisions if necessary. One of these investment decisions will be selected at the end of the survey, and then played out as a real investment decision. The realized wealth will be divided by ***100,*** so that your profit is between 70 € and 240 €.

Introduction to the expected value of risky investment decisions:

Investments are usually classified as risky investment options (such as shares) or relatively safe investments (such as day-to-day money).

The expected value of a risky investment option describes the average amount paid when the risky investment is realized often and in an identical way. In the current case, we only play once each. Hence, the expected value is an estimation of the average earnings of the risky investment.

If you are risk averse, you will get a discount on the expected value of the risk investment if you choose the safe investment instead of the risky one. If you are willing to take risks, you may prefer riskier investments with the same expected value.

<u>Training Session and Treatment I</u>

You have the choice to reinvest ***10.000*** € (your total wealth) either in a safe or in a risky investment. Another option is not available.

The safe investment guarantees a fixed capital gain of ***1.000*** € (10%) in 5 years to a total of ***11.000*** €.

Regarding the risky investment, you realize either a capital loss of ***1000*** € or a capital gain of *14.000* €; so you get back ***9.000*** € or you generate ***24.000*** €. Both scenarios have the same probability (50% each).

Enter now this certain amount, for which the safe and risky investments are equally attractive.

"In my view, a certain amount in 5 years of ***15.000*** € would be similar to the risky investment 50/50." An exemplary decision screen is depicted in figure 7.

Training Session

For which of the following investment alternatives you would opt, if the risky investment of the afore-mentioned example is unchanged?

Certain amount: 9.000 Euro
- safe investment
- **risky investment**

Certain amount: 11.000 Euro
- safe investment
- **risky investment**

Certain amount: 13.000 Euro
- safe investment
- **risky investment**

Certain amount: 15.000 Euro
- **safe investment**
- risky investment

Certain amount: 17.000 Euro
- **safe investment**
- risky investment

Enter now the certain amount, for which the safe and risky investment are equally attractive.

"In my view, a certain amount in 5 years of **15.000 €** would be similar to the risky investment 50/50."

continue

Figure 7
Screenshot: Training Session

In the following four questions of the experiment, the lottery is changed. The subjects will be confronted with lotteries with increasing and decreasing probability of making a profit. As before, the subjects will be asked for their certainty equivalent. The financial situation is the same as before (An exemplary decision screen is depicted in figure 8).

First Financial Situation (II)

"In my view, a certain amount in 5 years of **18.600 €** would be similar to the risky investment 80/20."
Expected value of the risky investment 80/20: 21.000 Euro

"In my view, a certain amount in 5 years of **16.200 €** would be similar to the risky investment 60/40."
Expected value of the risky investment 60/40: 18.000 Euro

"In my view, a certain amount in 5 years of **15.000 €** would be similar to the risky investment 50/50."
Expected value of the risky investment 50/50: 16.500 Euro

"In my view, a certain amount in 5 years of **14.000 €** would be similar to the risky investment 40/60."
Expected value of the risky investment 40/60: 15.000 Euro

"In my view, a certain amount in 5 years of **10.800 €** would be **now** similar to the risky investment 20/80."
Expected value of the **risky investment 20/80**: 12.000 Euro

correct | continue

Figure 8
Screenshot: Treatment I

Treatment II

You have lost 20% of your own wealth and you have again the option to reinvest your total wealth of now ***8000*** €, either in a safe or in a risky investment. Another option is not available.

The safe investment guarantees a fixed capital gain of ***1.000*** € in 5 years to a total of ***9.000*** €. Regarding the risky investment, you realize a capital loss of ***1.000*** € or a capital gain of ***14.000*** € so you get back ***7.000*** €, or you generate ***22.000*** €. Both scenarios have the same probability (50% each).

Enter now the certain amount, for which the safe and risky investment are equally attractive. "In my view, a certain amount in 5 years of ***12.500*** € would be similar to the risky investment 50/50."

Treatment II thus considers a new financial situation. Otherwise, there is no change with regard to the framing of treatment I.

Verification and Payment Process

Now you have the last opportunity to verify your entries or to change them by comparing the certain amount with the different risky investments (An exemplary decision screen is depicted in Figure 9).

Verify your entries

Treatment I:

"In my view, a certain amount in 5 years of **18.600 €** would be similar to the risky investment 80/20."

"In my view, a certain amount in 5 years of **16.200 €** would be similar to the risky investment 60/40."

"In my view, a certain amount in 5 years of **15.000 €** would be similar to the risky investment 50/50."

"In my view, a certain amount in 5 years of **14.000 €** would be similar to the risky inestment 40/60."

"In my view, a certain amount in 5 years of **10.800 €** would be similar to the risky investment 20/80."

Treatment II:

"In my view, a certain amount in 5 years of **16.800 €** would be similar to the risky investment 80/20."

"In my view, a certain amount in 5 years of **14.200 €** would be similar to the risky investment 60/40."

…

[correct] [accept]

Figure 9
Screenshot: Verification Opportunity

At the end of the experiment, one of the 10 responses will be chosen by a random process. The selected answer decides what amount of money can be won. Subsequently, the possible gain will be determined as the selected investment decision will be played out as a real investment.

Appendix B: Remodelling of HARA-utility function

Utility functions belonging to the HARA class satisfy the following functional equation:

$$\mathrm{u(x)} = \frac{1-\gamma}{\gamma} * \left(\frac{a * x}{1-\gamma} + b\right)^{\gamma},$$

with x as the net wealth, γ as the risk parameter, and a and b as further degrees of freedom. This restricts the domain to positive values of x, and we will assume wealth x being restricted away from 0. The specific risk attitude primarily depends on γ: for a risk-neutral person γ = 1, for a risk-averse person γ < 1, and for a risk-tolerant person γ > 1.
For our study, we simplify the HARA utility function without loss of generality:

$$\mathrm{u(x)} = \frac{1-\gamma}{\gamma} * \left(\frac{a*x}{1-\gamma} + b\right)^{\gamma} => u(x) = \frac{(1-\gamma)*b^{\gamma}}{\gamma} * \left(\frac{\frac{a}{b}*x}{1-\gamma} + 1\right)^{\gamma} => u(x) = d * (c * x + 1)^{\gamma}.$$

As a rescaling of the utility function $(u/|d|)$ does not affect the preferences, we can use the HARA utility function for γ not equal to 0 as follows:

$$\gamma > 0 => \; u(\mathrm{x}) = (c * x + 1)^{\gamma} \qquad\qquad \gamma < 0 => \; \mathrm{u(x)} = -(c * x + 1)^{\gamma}.$$

The risk aversion coefficients are calculated as follows:

$$ARA(x) = -\frac{u''(x)}{u'(x)} \; and \; RRA(x) = ARA(x) * x = -\frac{du'(x)}{dx} * \frac{x}{u'(x)}, with$$

$$u'(x) = \gamma c * (cx + 1)^{\gamma - 1} \; and \; u''(x) = (\gamma - 1) * \gamma c^{2} * (cx + 1)^{\gamma - 2}.$$

$$ARA(x) = -\frac{u''(x)}{u'(x)} = -\frac{(\gamma - 1) * \gamma c^{2} * (cx + 1)^{\gamma - 2}}{\gamma c * (cx + 1)^{\gamma - 1}} = \frac{(1-\gamma) * c}{(cx + 1)} > 0$$

$$RRA(x) = ARA(x) * x = \frac{du'(x)}{dx} * \frac{x}{u'(x)} = \frac{(1-\gamma) * \mathrm{x} * c}{(cx + 1)}$$

The multiplicative inverse of ARA, the absolute risk-tolerance function is

$$\omega(\mathrm{x}) = \frac{(cx + 1)}{(1-\gamma) * c},$$

which is increasing in x for the HARA utility. This is in line with findings about absolute risk tolerance as an increasing function of consumers' resources[22]. Guiso and Paiella (2008) estimate that the elasticity of absolute risk tolerance to consumers' resources is between 0,6 and 0,75 and suggest that risk tolerance is a concave function of wealth.

To calculate the certainty equivalent and the expected value of the risky asset, we identify the utility of the certain outcome s, u(s):

$$(c*s+1)^{\gamma} = \mathrm{p}*(c*g+1)^{\gamma} + (1-p)*(c*l+1)^{\gamma}$$

R is the risky asset that gives the gain g with probability p and the loss l with probability (1-p). Solving the equation for s gives:

$$s(a,b,\gamma,p,g,l) = -\frac{1}{c} + \frac{1}{c} * [\mathrm{p}*(c*g+1)^{\gamma} + (1-p)*(c*l+1)^{\gamma}]^{\frac{1}{\gamma}}.$$

Appendix C: Results including slip-ups

Applicability of HARA-class:

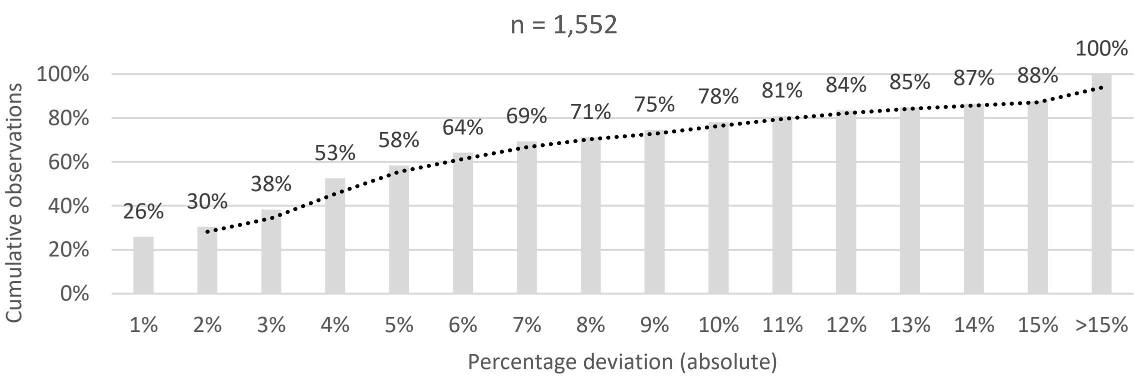

Figure 10:
Cumulative distribution of percentage deviations (III)

[22] [e.g. Guiso and Paiella (2008)].

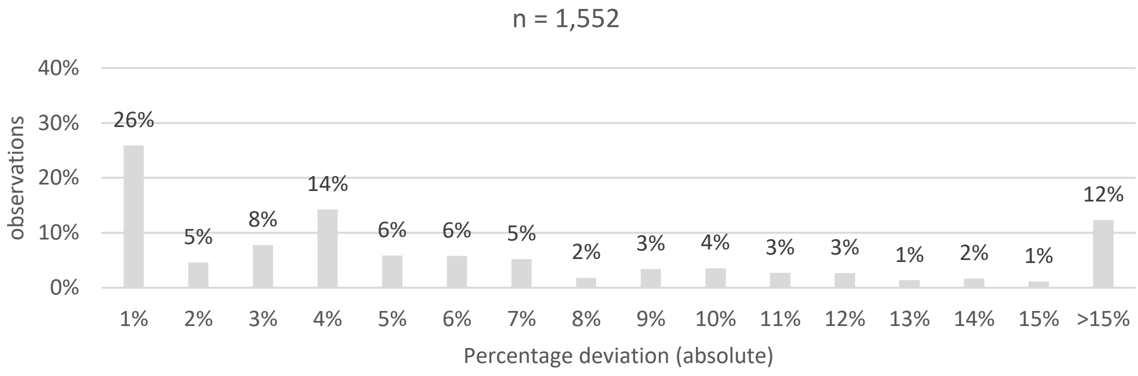

Figure 11:
Histogram of percentage deviations (II)

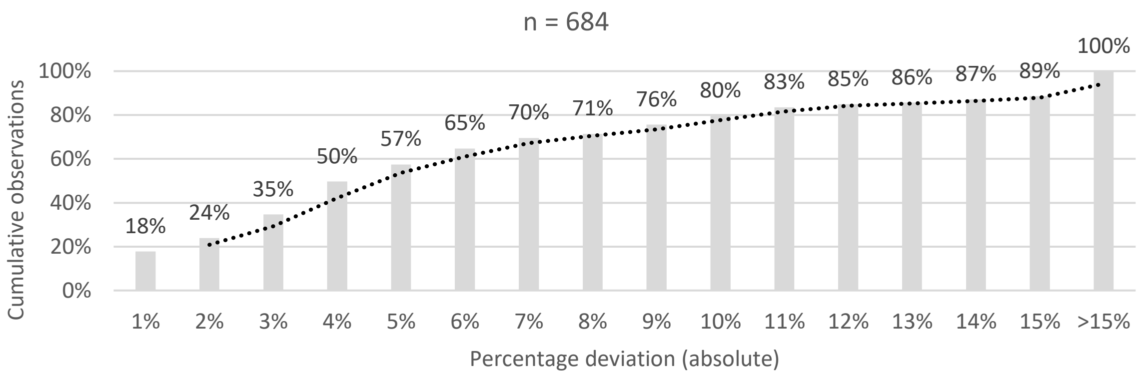

Figure 12:
Cumulative distribution of percentage deviation (IV).

Table 10:
Comparison of mean and standard deviation (II).

	n	Mean deviation	Standard deviation	+/-Boundary
All	1552	7%	10%	+/-12%
Treatment 1	776	6%	9%	+/-10%
All (without risk-neutral)	1368	8%	10%	+/-13%
Treatment 1 (without risk-neutral)	684	7%	9%	+/-11%

Table 11:
Descriptive statistics (II).

	Treatment I	Treatment I and II
Number of subjects:	n = 171*	n = 171*
○ Mean deviations inside boundary	78%	76%
○ Mean deviations outside boundary	22%	24%
Number of deviations:	n = 616*	n = 1232*
○ Inside boundary	80%	75%
○ Outside boundary	20%	25%
Deviations outside boundary	n = 139**	n = 339**
○ Positive deviations and outside boundary	64%	65%
○ Negative deviations and outside boundary	36%	35%
Deviations outside boundary and distributed by risky assets:***	n = 139**	n = 339**
○ 80/20-asset or 20/80-asset	63%	65%
○ 60/40-asset or 40/60-asset	37%	35%
Deviations outside boundary and distributed by highly or lowly risky	n = 88	n = 222
assets:***	40%	32%
○ 80/20-asset and positive deviation	14%	22%
○ 80/20-asset and negative deviation	22%	30%
○ 20/80-asset and positive deviation	25%	16%
○ 20/80-asset and negative deviation		

* Number of all subjects or observations.
** Number of observations that are higher than the selected boundary.
*** x/y-asset: x is the probability for a positive outcome and y is the probability for a negative outcome.

Risk preferences and economic shocks:

Table 12:
Investment behavior after an exogenous shock (VI)

	+	-	z-value	p-value
Differences between the mean deviations from treatment I and II	85	86	-1.7197	0.0872

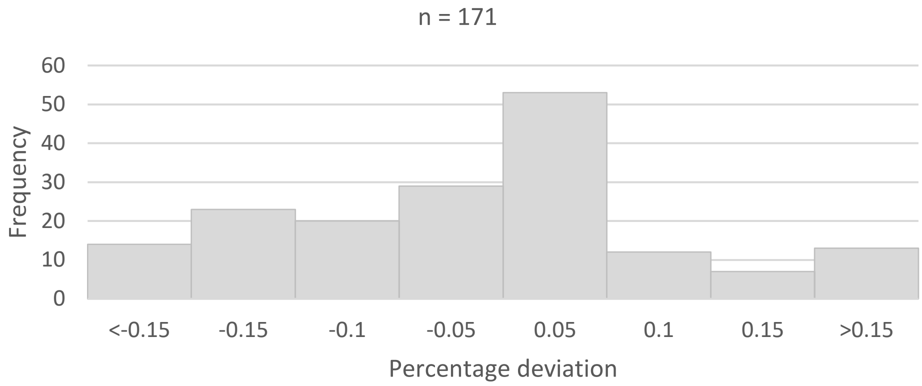

Figure 13:
Investment behavior after an exogenous shock (VII)).

Table 13:
Investment behavior after an exogenous shock (VIII).

	<10%	>10%	z-value	p-value
A. Differences between the mean deviations from treatment I & II	114	57	-4.4353	0.00006
B. Negative differences between the mean deviation from treatment I & II	49	36	-1.3015	0.1902
C. Positive differences between the mean deviation from treatment I & II	65	21	-4.6368	0.00006

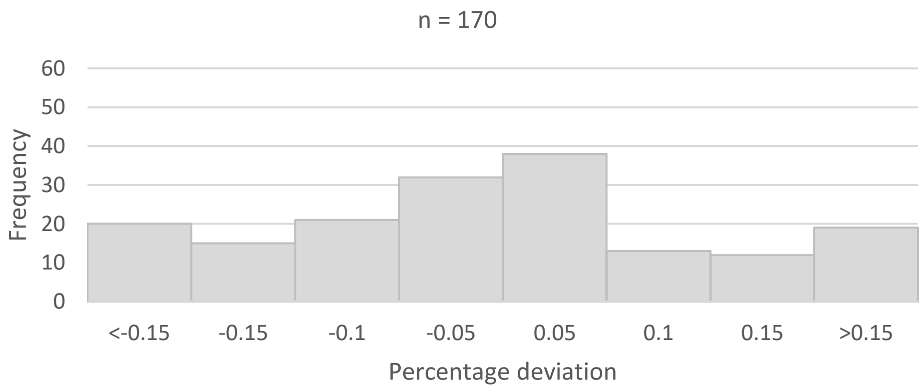

Figure 14:
Investment behavior after an exogenous shock (IX).

Table 14:
Investment behavior after an exogenous shock (X).

	<10%	>10%	z-value	p-value (two sided)
A. Mean deviations in treatment II	104	66	-2.8377	0.0046
B. Negative mean deviations in treatment II	53	35	-1.8122	0.0702
C. Positive mean deviations in treatment II	51	31	-2.0981	0.0366