Don’t Ignore Inflation Ignorance: An Experimental Analysis of the Degree of Money Illusion in Individual Decision Making

Abstract: Money illusion refers to the tendency to evaluate economic transactions in nominal rather than real terms. One aspect of this phenomenon is the tendency to neglect future inflation in intertemporal investment decisions. Empirical evidence for this “inflation ignorance” is, however, controversial due to the host of factors that simultaneously change with the inflation rate. We avoid these identification issues by conducting a controlled and fully incentivized investment experiment. We measure a substantial degree of money illusion. Lacking diligence, arithmetic problems, or misunderstandings of inflation do not drive this result. Instead, participants seem to anchor subconsciously to nominal returns, even though they are incentivized to base their decisions on provided real returns only. Our findings contribute towards understanding various anomalies on the individual and market level, such as insufficient savings efforts or equity mispricing.

Keywords: Money illusion, financial decision making, asset allocation.

JEL classifications: C91, D11, D14, D91.

1 Introduction

Money illusion refers to the tendency to evaluate economic transactions in terms of nominal rather than real monetary values (Fisher 1928). The ramifications of the behavioral phenomenon are manifold. Previous research has extensively explored individuals' focus on contemporaneous nominal values. For instance, irrelevant and fully anticipated nominal shocks impair the efficiency of experimental asset markets (e.g., Fehr and Tyran 2001). A very different aspect of money illusion, which is crucial in intertemporal decision problems, is the individuals' failure to anticipate future inflation appropriately. From a theoretical perspective, this "inflation ignorance" has significant implications for a variety of economic matters, such as life-cycle consumption behavior (Modigliani 1966), asset allocation (Lachance and Mitchell 2003), and market anomalies such as equity mispricing (Modigliani and Cohn 1979).

Existing empirical evidence for money illusion in intertemporal decision making (e.g., Campbell and Vuolteenaho 2004) is ambiguous, because many observable and unobservable factors covary with expected inflation (e.g., the perceived macroeconomic uncertainty). Existing experimental evidence (e.g., Shafir et al. 1997) relies on hypothetical choice surveys, which do not allow an unambiguous assessment of money illusion in intertemporal decision making either. First, hypothetical and real-world behavior often deviate (e.g., Cummings et al. 1995). Second, answers are usually dichotomous or elicited on ambiguous scales (like the perceived advantageousness of a financial transaction). Such survey data can be used to classify behavior as reflecting money illusion or not, but it does not allow a sensible analysis of the degree of money illusion.

The paper at hand overcomes these limitations. We conduct a controlled investment experiment, which mimics the effects of inflation in an incentive compatible way. Systematic variations in inflation rates allow separating the degree of money illusion unambiguously from other behavioral factors (e.g., risk aversion), while controlling for all external factors. We measure a substantial degree of money illusion in intertemporal decision making and show that it does not merely reflect lacking diligence, arithmetic problems, or misunderstandings of inflation. Instead, participants seem to anchor subconsciously to alluring nominal returns, which causes a substantial disregard of inflation and provided real returns. We argue that our estimated money illusion parameter can be applied to a wide range of formal economic models for predictively assessing the effects of money illusion in intertemporal settings. This contributes towards understanding various anomalies on the individual and the market level.

The design of our experiment is guided by three goals:

(1) The experimental task should be easy to understand to facilitate well-considered decision making. We frame the task as a two-period consumption problem; participants allocate their endowment between immediate consumption and an investment into a risky asset, whose payoff allows consumption at a much later point of experimental time.

(2) The effects of inflation should be captured in an incentive compatible way to improve reliability of the results. We use the declining conversion rate mechanism of Cordes and Langer (2019) for experimental incentivization. Experimental wealth is described in nominal terms at both points of experimental time. Real-world remuneration, however, is based on the corresponding consumption opportunities. To mimic the effects of inflation, the conversion rate between salient nominal wealth and remuneration-determining consumption opportunities declines over experimental time. That is, present wealth yields higher consumption opportunities (and therefore a higher real-world payment) than the same nominal wealth at a future point of experimental time.

(3) Money illusion should have a strong, predictable impact on behavior to facilitate identification. We define the real-world remuneration to depend on the sum of consumption opportunities at the two different points of experimental time, and abstract from potential consumption smoothing interests. This ensures high variation in optimal behavior and a large impact of money illusion on actual behavior.[1] If investing looks very attractive (unattractive), it is sensible to invest a very large (small) share of the endowment, possibly all or nothing. Under money illusion, investing appears more attractive than it "really" is, and investment levels increase with the degree of money illusion.

Given the incentive structure, the two-period consumption problem can be formalized by a buy-and-hold asset allocation model; participants maximize terminal consumption opportunities by splitting their endowment between a risk-free asset with zero real return (corresponding to "immediate consumption" in the experimental framing) and a risky asset whose return is exposed to inflation.[2] Assuming constant relative risk aversion (CRRA) preferences, the optimal decision can be approximated by a closed-form solution. If there is no inflation, money illusion is irrelevant

[1] Implementing consumption smoothing into the incentive structure should tilt behavior towards a 50-50 allocation, so that the full range of possible allocations would rarely be used and the relative impact of noise would be higher.

[2] This perspective is also in line with the experimental set-up in the respect that participants received their entire remuneration at the end of the experiment and not in two installments at different points of time. The only reason for describing the problem in the experiment as a consumption decision and not an asset allocation decision with nominal and real assets is that the consumption frame seems more accessible to participants.

and only the relative risk aversion determines the share invested into the risky asset. In the presence of inflation, money illusion becomes relevant; biased investors perceive the return of the risky asset to be larger than it "really" is, so that the investments in the risky asset increases with the degree of money illusion. We follow the asset allocation perspective for the remainder of the paper and use the corresponding model to estimate the degree of money illusion from observed behavior.

For a profound analysis of money illusion, we implement two treatments. In the nominal treatment, participants view the nominal long-term return of the risky asset. To judge the remuneration-determining real return, we provide the annual inflation rate. Accounting for inflation is difficult under this information condition, but it mimics what real-world investors mostly face; projected long-term returns are usually presented in nominal terms, and inflation information (which is mostly annualized) has to be actively collected, extrapolated and integrated. At least two behavioral biases may be relevant here. Firstly, participants might subconsciously "anchor" to the salient nominal returns and neglect to some extent the unobtrusive inflation rate when judging the real attractiveness of the risky asset. Secondly, even if participants fully appreciate the relevance of inflation, exponential growth bias suggests a systematic underestimation of the long-term effects of inflation when judging it based on an annual rate (Stango and Zinman 2009). This could also induce an insufficient consideration of inflation, a prediction that finds support in empirical data (Keren 1983, Jones 1984, Kemp 1984). Both biases, anchoring to nominal returns and exponential growth bias, might contribute to money illusion in the nominal treatment.

It is conceivable that real-world investors exert more effort in their attempt to account for inflation than participants in the nominal treatment do (e.g., due to higher monetary stakes). Thus, lacking diligence might cause behavioral effects in the nominal treatment that would not directly translate to higher-stake real world situations.[3] To address such concerns, we conduct a second treatment; the hybrid treatment provides the opportunity to switch without cost or effort from the display of the nominal long-term return of the risky asset to the corresponding real return. This should reduce (if not eliminate) both components of money illusion from the nominal treatment. Firstly, a subconscious neglect of inflation should be less pronounced, as the explicit display of real next to nominal returns renders the relevance of inflation much more salient. Secondly, arithmetic problems (like the exponential growth bias) should become irrelevant once participants switch to

[3] Similarly, Petersen and Winn (2014) contest Fehr and Tyran's (2001) notion that money illusion causes nominal inertia on experimental asset markets. They claim that it is cognitively challenging to adapt appropriately to nominal price shocks, which causes the stickiness of prices. Fehr and Tyran (2014) rebut this view by logical argument.

the real view, because investment returns are readily adjusted for the long-term effects of inflation. While we expect that money illusion is lower in the hybrid treatment than in the nominal treatment, we do not necessarily expect that it will be eliminated altogether: Participants may still anchor subconsciously to the initially displayed nominal return of the risky asset when judging its real attractiveness (Tversky and Kahneman 1974).

We start our analysis in the nominal treatment. In scenarios without inflation, our model (without money illusion component) fits the data very well and yields a plausible relative risk aversion estimate. This indicates that our model is generally suited to capture investment behavior adequately. Once inflation is present in the experimental environment, the same model loses all explanatory power and yields a highly implausible relative risk aversion estimate. We interpret this as evidence that money illusion affects investment behavior significantly. Extending our model by a money illusion component supports this notion; the extended model fits the data very well and yields a plausible relative risk aversion estimate again. Most importantly, we measure a substantial degree of money illusion; participants do not account for about 63% of the effects of inflation when judging the attractiveness of the risky asset.

The hybrid treatment shows that lacking diligence or arithmetic problems do not drive this result. Although participants inspect the risky asset's real return extensively, they do not account for about 52% of the effects of inflation. As participants know that they must account for inflation to optimize remuneration, this finding suggests that participants anchor (subconsciously) to alluring nominal returns and strongly neglect inflation and provided real returns.

To keep the experimental design simple, we initially consider only scenarios with deterministic inflation rates. Brunnermeier and Julliard (2008) and Cavallo et al. (2017) suggest that investors intuitively associate low inflation rates with low inflation risk, amplifying inattention towards inflation (i.e., increasing money illusion). The question how inflation expectations and inflation risk jointly shape the degree of money illusion is particularly relevant today, as inflation risk increased in the aftermath of the 2008 financial crisis while inflation rates remained at low levels (Illeditsch 2017). Therefore, we also consider scenarios with inflation risk. Inflation risk is modeled in its simplest form; the inflation rate can take either a high or a low value with equal probability. We find that inflation risk reduces money illusion in both treatments. The reduction can be partly attributed to an overweighting of the high inflation state, increasing inflation expectations and thereby mitigating money illusion. In other words, inflation risk reduces money illusion, because it draws attention towards “worst case” inflation scenarios. However, money illusion remains high (47% in the nominal treatment, 35% in the hybrid treatment), indicating that inflation risk does not annihilate the economic relevance of money illusion.

We conduct extensive robustness and plausibility checks. Misunderstandings of inflation do not drive our findings. Our findings are also robust towards controlling for learning or repetition effects. Accounting econometrically for the short sale constraint does not alter our findings either. Estimating money illusion on the participant level reveals that there is individual heterogeneity. Yet, most participants suffer from significant money illusion, indicating that money illusion is a widespread phenomenon and our aggregate estimates are not driven by the abnormal behavior of just a few participants. Regression analyses give plausible correlations between individuals’ money illusion and their personality traits, lending further support to our interpretations.

The paper proceeds as follows. Section 2 discusses the relation and contribution of our work to the existing literature. Section 3 presents the experimental design. Section 4 derives a model for optimal asset allocation under money illusion. Section 5 estimates the model parameters, in particular the degree of money illusion, in the specifications discussed above. Section 6 concludes.

2 Relation and Contribution to Existing Literature

2.1 On the Existence and the Degree of Money Illusion

Shafir et al. (1997) provide comprehensive evidence in hypothetical choice surveys that individuals tend to ignore future inflation. Mees and Franses (2014) replicate their US-based results in China, indicating that money illusion prevails across different cultures. Although this suggests that money illusion affects economic behavior, the caveat remains that hypothetical and actual behavior often differ (Cummings et al. 1995, Kang et al. 2011).[4] By assessing money illusion in an incentive compatible experimental setting, we address this concern and foster the reliability of our results.

[4] To put it in the words of Shafir et al. (1997, p. 366): “The present research does not tell us to what extent the attitudes documented in our surveys will be observed in the real economy, in people’s decisions to quit jobs, sign contracts, etc. However, the consistency of trends observed across diverse subject populations (students, shoppers, airline passengers), and a variety of problem contexts (contracts, acquisitions, fairness perception, judgments about others, trading experiments, etc.), provide strong presumptive evidence.” This notion is further supported by Weber et al. (2009) who document a neural basis for money illusion in fMRI scans; keeping real purchasing power constant, an increase in nominal wealth activates brain areas that are associated with anticipatory and experienced rewards.

Our experimental approach also addresses a second limitation of the survey-based evidence. The existing literature usually derives the relevance of money illusion from dichotomous choices or builds on answering scales that are not easily accessible to economic interpretation. For instance, Stephens and Tyran (2016) elicit money illusion by comparing the perceived "advantageousness" of financial transactions with the same real but different nominal returns. While these approaches allow classifying individuals as being influenced by money illusion or not, the data can hardly be used to discuss meaningfully the extent to which money illusion might affect behavior.[5] To the best of our knowledge, we are the first to estimate a concrete and useful parameter of the degree of money illusion. We argue that this parameter can be applied to a wide range of formal economic models to assess the effects of money illusion, which may contribute towards understanding various anomalies on the individual and market level.

Other studies document the existence of money illusion empirically by studying the relations between income, inflation, and life satisfaction (e.g., Di Tella et al. 2001, Boes et al. 2007). Yet, evidence for money illusion in empirical studies is typically subject to omitted variable concerns, because many observable and unobservable factors change simultaneously with inflation (e.g., perceived macroeconomic uncertainty). Our experimental approach provides full control over external factors, eliminating the threat of omitted variable bias.

Moreover, the relation between inflation and the dependent variable is often ambiguous in the real world, which might impair conclusions from empirical studies about the existence of money illusion. Bachmann et al. (2015) do not find a positive relation between inflation and the propensity to buy durable goods, which can be conceived as evidence for money illusion. Yet, many factors (e.g., uncertainty about technological developments) might simultaneously reduce the propensity to buy durable goods, impairing its positive relation to inflation. Our experimental approach allows modeling a strong, unambiguous link between inflation and optimal behavior.

2.2 The Effects of Money Illusion on Individual Investment Behavior

In the context of Gneezy and Potters' (1997) myopic loss aversion, He and Zhou (2014) show theoretically that money illusion increases risk taking as it veils the real loss probability of risky

[5] Shafir et al. (1997, p. 341) conclude their article: "We propose that people often think about economic transactions in both nominal and real terms, and that money illusion arises from an interaction between these representations, which results in a bias toward a nominal evaluation." Tyran (2007) reviews definitions of money illusion, all of which suggest that "no money illusion" and "complete money illusion" are the extreme cases on a continuous scale.

investments. Thaler et al. (1997) find support for this prediction in experimental data; when inflating the returns of both a risky and a risk-free asset by the same factor, participants allocate a larger share of their endowment to the risky asset. The increase in risk taking does not necessarily reflect money illusion though. Inflating all returns by the same factor makes participants objectively richer (they are paid according to their terminal portfolio value), and it reduces the loss probability of the risky asset. Thus, the increase in risk taking is consistent with a variety of alternative explanations, including decreasing absolute risk aversion or standard prospect theory preferences (Kahneman and Tversky 1979).[6] The declining conversion rate mechanism we use for experimental incentivization allows inflating nominal returns while keeping the decision foundation (i.e., real returns) constant. Thus, our approach rules out the possibility that evidence for money illusion in fact reflects changes in the decision foundation.

Lioui and Tarelli (2018) show theoretically that money illusion reduces investments in inflation-indexed securities, which they put forward as an explanation for the TIPS puzzle (the observation that real-world holdings of “treasury inflation protected securities” are far below theoretical optimum; Campbell and Viceira 2001, Brennan and Xia 2002). Stephens and Tyran (2016) find indirect empirical evidence for this proposition in the balance sheets of private households in Denmark; an ordinal money illusion index (constructed from a series of hypothetical survey questions) negatively predicts investments in inflation-protected assets such as stocks and real estate. Yet, survey responses might reflect an ex post rationalization of behavior rather than a (hypothetical) utility maximization process. Such endogeneity concerns, as discussed in Schmeling and Schrimpf (2011) or Armantier et al. (2015), limit the reliability of survey responses for verifying the impact of money illusion on actual behavior. As our experimental approach elicits money illusion from observed behavior directly, we do not face such endogeneity concerns.

2.3 The Effects of Money Illusion on Market Outcomes

Several studies find support in stock market data for the Modigliani and Cohn (1979) hypothesis; investors fail to anticipate that inflation increases future company earnings, driving equity undervaluation in times of high inflation (Ritter and Warr 2002, Sharpe 2002, Campbell and Vuolteenaho 2004, Cohen et al. 2005, Basak and Yan 2010, Lee 2010, Acker and Duck 2013a/b).

[6] A similar argument applies to studies documenting an aversion to realize nominal losses on the housing market (Genesove and Mayer 2001, Einiö et al. 2008).

Similar mechanisms have been documented for real estate prices (Brunnermeier and Julliard 2008, Piazzesi and Schneider 2008) and the post earnings announcement drift (Chordia and Shivakumar 2005). Such approaches face a joint hypotheses problem though (Fama 1991); when fitting formal models to empirical data, evidence for money illusion can reflect money illusion, an inappropriate model choice, or both. Our experimental approach mitigates this problem; the systematic variation of inflation rates and nominal returns allows verifying the appropriateness of our model when inflation is zero, before assessing money illusion in scenarios with positive inflation.

Money illusion has been explored extensively on experimental asset markets (e.g., Fehr and Tyran 2001/07/08/14, Bakshi 2009, Noussair et al. 2012); irrelevant changes in contemporaneous nominal prices cause market inefficiencies, as participants wrongly use nominal prices as a proxy for real values. Roughly speaking, individuals make an optimization mistake and choose a different bundle of goods when all prices and all wealth change by the same factor.[7] This may explain the non-neutrality of money (Sun 1992, Brandt and Wang 2003, Eraker et al. 2016) and impair macroeconomic growth (Miao and Xie 2013). It is important to note that we are interested in a very different aspect of money illusion; we explore the propensity to anticipate future inflation rather than the ability to respond appropriately to contemporaneous price changes. To the best of our knowledge, the ignorance of future inflation has not yet been studied in an incentive compatible experiment. We advance the understanding of money illusion by showing that this aspect of money illusion is widespread and substantial, in contrast to the typically rare and small individual errors in responding to contemporaneous price changes.[8] We harmonize these differences by acknowledging that future inflation is much less salient than contemporaneous price changes.

[7] Similar observations have been made in other contexts. Spending behavior changed systematically after the introduction of the common currency Euro in the European Union in 2002 (Gamble et al. 2002, Jonas et al. 2002, Kooreman et al. 2004, Cannon and Cipriani 2006). Economically irrelevant stock splits systematically affect the attractiveness of investing (Grinblatt et al. 1984, Svedsäter et al. 2007). The currency in which prices are denoted affect the valuation of otherwise identical consumer products systematically, even though experiment participants have full information about exchange rates (Raghubir and Srivastava 2002, Hsee et al. 2003).

[8] None of the cited studies quantifies the degree of money illusion, but they generally conclude that most participants do not suffer from money illusion. Among those who do, the degree of money illusion is considered small. For instance, Fehr and Tyran (2001, p. 1239) subsume their findings as follows: “This paper shows that a small amount of individual-level money illusion may cause considerable aggregate nominal inertia after a negative nominal shock.”

3 Experimental Design

3.1 Decision Situation

Our experiment builds on the design of Cordes and Langer (2019). The main task is framed as a two-period consumption problem; participants split their endowment of 10,000 monetary units (MU) between immediate consumption and an investment into a risky asset, whose payoff allows consumption at a known much later point of experimental time. Consumption opportunities are measured in consumption units (CU). To mimic the effects of inflation, the conversion rate between MU and CU declines over experimental time.

To facilitate the identification of money illusion, we keep the experimental design simple and do not enforce consumption smoothing; there is per se no gain from targeting similar consumption levels at both points of experimental time. Instead, remuneration simply depends on the sum of present and future consumption opportunities. If the risky asset looks very attractive (unattractive), it is sensible to invest a very high (low) part of the endowment, possibly all or nothing. Due to this incentive structure, the decision situation is captured formally by an asset allocation model, where investors maximize terminal consumption opportunities by splitting their endowment between a risk-free and a risky asset. The risk-free asset always yields a real return of zero (reflecting the "immediate consumption"-option in the experimental framing), whereas the risky asset's return is exposed to inflation (reflecting the "investment"-option in the experimental framing). It is important to note that the discrepancy between experimental framing and formal modeling does not compromise our results; we use the consumption-investment framing in the experiment, because it is the natural setup for inflation and makes it better accessible to participants. Yet, we follow the asset allocation perspective in the following description of the experimental task and in our analyses, because it properly reflects the experimental incentive structure.

3.2 Incentivization

Participants receive a real-world payment of 0.001€ per CU. The risk-free asset always yields a zero real return (i.e., each invested MU provides 1 CU with certainty). The risky asset is exposed to inflation; each MU of its payoff only provides $(1+i)^{-T}$ CU consumption opportunities, where i denotes the inflation rate and T the investment horizon. The payment rules and all relevant parameters are explicitly communicated to participants prior to their decisions.

An example may help to clarify the incentive structure. Consider a participant who invests 3,000 MU into the risk-free asset and 7,000 MU into the risky asset. The 3,000 MU invested into the risk-free asset provide 3,000 CU consumption opportunities with certainty. The return of the risky asset is unknown ex ante; assume it pays 9,000 MU at the end of a T = 10 year investment horizon. For i = 2% inflation, the purchasing power of 1 MU is $1.02^{-10} \approx 0.82$ CU then, and consumption opportunities are 9,000 MU · 0.82 CU/MU = 7,380 CU. In this case, the participant receives a real-world payment of (3,000 CU + 7,380CU) · 0.001€/CU = 10.38€. For i = 4% inflation, the purchasing power of 1 MU is only $1.04^{-10} \approx 0.68$ CU in T = 10, and the risky asset's payoff only provides 9,000 MU · 0.68 CU/MU = 6,120 CU. In this case, the participant receives a real-world payment of only (3,000 CU + 6,120 CU) · 0.001€/CU = 9.12€.

3.3 Presentation Format and Interface

We use a 10-state chart to visualize the possible portfolio payoffs, because this display has been found to be a particularly intuitive visualization of a payoff distribution (see Vrecko et al. 2009 and Vrecko and Langer 2013). A screenshot is provided in Figure 1. In this approach, 10 discrete states represent the 10 possible portfolio payoffs. All states are realized with the same probability (10% each) to minimize probability misperceptions, and payoffs are ordered by size to facilitate the comprehension of the distribution. To visualize the distinction between nominal and real values, payoffs are separated into the risk-free asset's CU payoff (dark-blue bars to the left) and the risky asset's MU payoff (light-blue bars to the right). In the presented example, 3,000 MU are invested into the risk-free asset, providing 3,000 CU in each state. The remaining 7,000 MU are invested into the risky asset, providing payoffs between 5,010 MU and 19,015 MU.

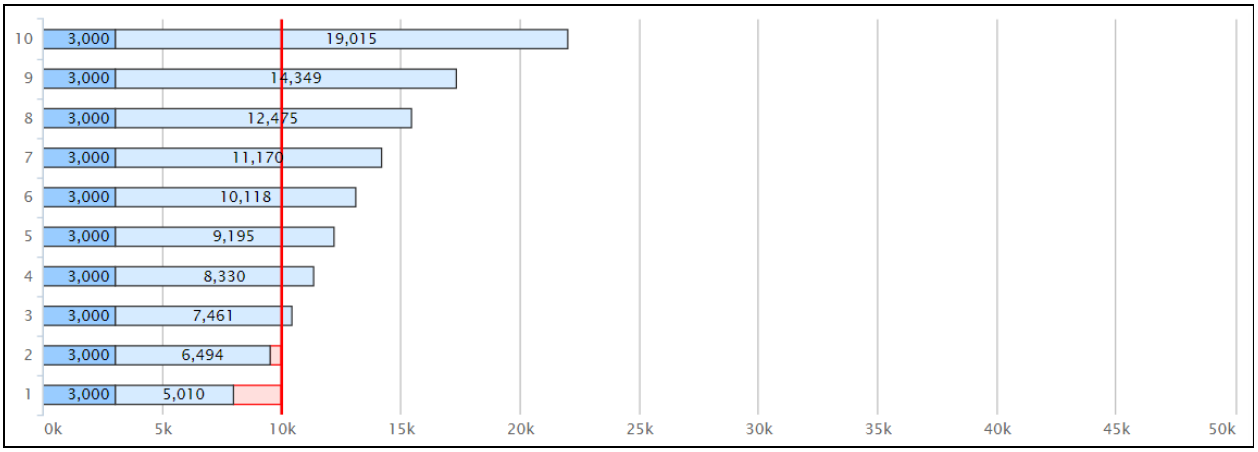

Figure 1: Screenshot of the 10-state chart in the nominal view. In the presented example, 3,000 MU are allocated to the risk-free asset and 7,000 MU are allocated to the risky asset. The risk-free asset yields a return of r_f = 0 and thus a payoff of 3,000 MU in each state (dark-blue bars to the left). The risky asset has an expected return μ_r = 4% p.a. and a standard deviation of σ_r = 12% p.a. in this example, providing payoffs between 5,010 and 19,015 MU. Details on the calculation of the payoffs are presented in Subsection 3.5.

To judge consumption opportunities from the risky asset's nominal payoffs, we communicate the annual inflation rate and the investment horizon explicitly; a pop-up window states the values at the beginning of each scenario and they are displayed on screen while participants make their decision. In contrast, we do not communicate the risky asset's expected return and standard deviation explicitly. Doing so would not add relevant information beyond what is already displayed in the 10-state chart, but might compromise intuitive judgment through the promotion of behavioral heuristics (e.g., a focus on expected returns). Note that, if anything, communicating these values renders the inflation rate comparatively less salient, which should further increase money illusion.

Portfolio weights can be changed with a slider below the 10-state chart. To avoid anchoring issues, participants decide on the initial weights at the beginning of each round by clicking on any position on the slider; afterwards the initial payoff distribution appears on screen. To allow for a quick evaluation of outcomes, the bars update automatically and in real-time to all changes.

3.4 Treatments

In the nominal treatment, the 10-state chart depicts the risky asset's nominal payoffs. Investment horizon and annual inflation rate are communicated explicitly below the 10-state chart to allow judging respective consumption opportunities. This information condition is the starting point for our analyses, because it comes closest to a real-world investment scenario. Projected payoffs of long-term investments are usually presented in nominal terms, and investors have to actively collect information on inflation (which is mostly annualized), extrapolate it to the specific investment horizon, and integrate it into the nominal payoff information for judging real wealth consequences.

There are (at least) two factors that may contribute to money illusion in the nominal treatment. Firstly, participants may focus on the nominal payoffs and neglect inflation to some extent when judging the real attractiveness of the risky asset. This seems likely, given that nominal investment payoffs are very saliently displayed in the 10-state chart while the annual inflation rate is mentioned only unobtrusively on screen. Such subconscious "anchoring" to nominal payoffs seems similar to the classic form of money illusion (e.g., Shafir et al. 1997, Fehr and Tyran 2001), where people generally understand how inflation affects economic wellbeing but do not sufficiently consider it in their decision making. Secondly, even if participants fully appreciate the relevance of inflation, exponential growth bias (e.g., Stango and Zinman 2009) suggests a systematic underestimation of the long-term effects of inflation when judging it based on the annual rate provided. This could also cause an insufficient consideration of inflation, a prediction that finds support in empirical data (Keren 1983, Jones 1984, Kemp 1984).

It can be argued that real-world investors are more diligent in their attempts to account for inflation than participants in the nominal treatment, because stakes are typically much higher. Real-world investors may also use calculators etc. to overcome possible arithmetic problems like the exponential growth bias. Thus, lacking diligence or arithmetic problems may cause behavioral effects in the nominal treatment that would not directly translate to real-world situations.

We address this concern with our second treatment, the hybrid treatment. Here, the risky asset's payoffs are initially displayed in nominal terms, same as in the nominal treatment. We call this the nominal view. Subsequently, participants can switch display to the corresponding consumption opportunities. We call this the real view. The only difference between nominal view (see Figure 1) and real view (see Figure 2) is that the risky asset's payoffs are adjusted for inflation (i.e., are displayed in terms of real CU rather than nominal MU). In the presented example, the risky asset's nominal payoffs {19,015 MU, 14,349 MU, …, 5,010 MU} from the nominal view are adjusted for i = 2% inflation over T = 10 years of experimental time (i and T are explicitly communicated to participants), which yields consumption opportunities of {15,599 CU, 11,771 CU, …, 4,110 CU} as displayed in the real view. Participants can switch back and forth between the nominal and the real view by clicking on separate buttons below the 10-state chart. A nice side effect of this design choice is that switching behavior directly proxies the interest in real return information.

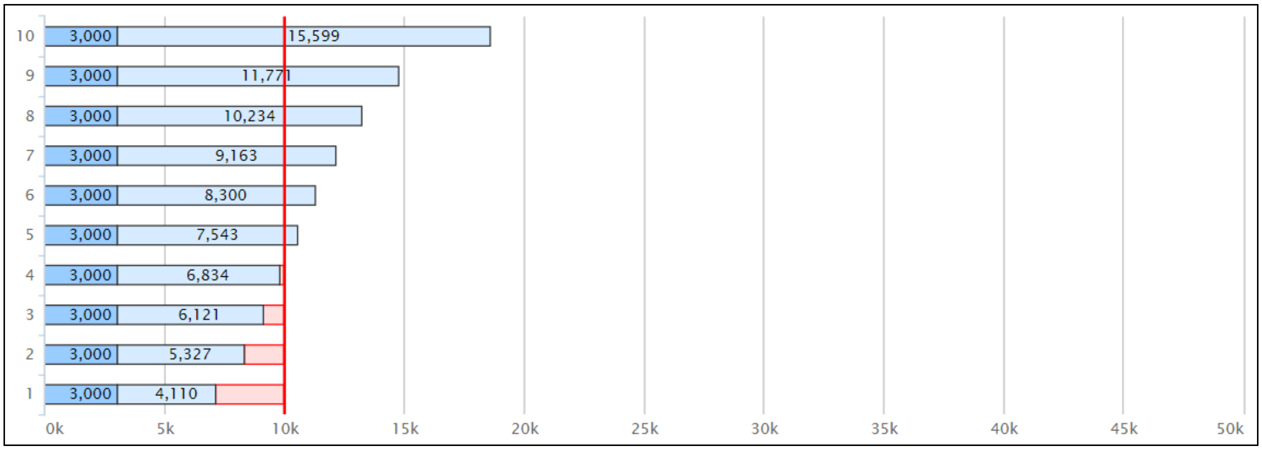

Figure 2: Screenshot of the 10-state chart in the real view. Parameters are identical to the ones described in Figure 1. Payoffs of the risky asset are translated from MU into CU assuming i = 2% inflation over an investment horizon of T = 10 years of experimental time.

Switching to the real view should reduce (if not eliminate) both components of money illusion from the nominal treatment. Firstly, the provision of the real view renders the difference between nominal wealth and real purchasing power more salient, and it should be less likely that participants neglect the effects of inflation. Secondly, arithmetic problems (like the exponential growth bias) should be greatly reduced, as investment payoffs are readily adjusted for the long-term effects of inflation when switching to the real view. However, the possibility remains that money illusion endures even in the hybrid treatment; the literature on anchoring-and-adjustment (e.g., Tversky and Kahneman 1974, Epley and Gilovic 2006) suggests that participants may anchor subconsciously to the initially displayed nominal investment payoffs from the nominal view, even after switching to the real view. We expect that money illusion will be substantially lower in the hybrid treatment, but do not necessarily expect that it will be eliminated altogether.

In the hybrid treatment, the nominal view is the default view at the beginning of each scenario because this reflects real-world investment situations: Investors are typically confronted with nominal investment payoffs first, before they may decide to adjust these payoffs for inflation. Conducting additional treatments where, for example, the real view is the default may yield additional insights on the psychological foundations of money illusion. Such treatments, however, do contribute towards the goal of this paper; estimating the degree of money illusion under representative information conditions.

It can well be that the provision of the nominal view confuses participants in the hybrid treatment and that they try to infer relevant information from it (despite the fact that the instructions explained extensively the difference between nominal and real view and stated explicitly that all relevant information is shown in the real view). Such confusions seem conceptually similar to money illusion documented in the real world, where people demonstrate to understand how inflation affects their economic wellbeing yet still focus on nominal values in their decision making (e.g., Shafir et al. 1997). Therefore, we do not interpret the use of the nominal view (per se) as a sign that participants do not understand the experimental instructions. After having verified that view choice behavior is unrelated to possible misunderstandings of the instructions (e.g., proxied by the number of errors in the comprehension questions following the instructions), we interpret it as one aspect of money illusion that arises in the real world as well.

3.5 Parameterization

All participants play 36 different scenarios. The investment horizon is T = 10 years of experimental time and the risk-free asset's real return is r_f = 0 throughout. To disentangle money illusion from risk preferences, the risky asset's nominal return and the inflation rate vary systematically (see Table 1). In Type 1 scenarios, inflation is zero and money illusion is irrelevant. These scenarios allow assessing the appropriateness of our model and yield a benchmark for risk preferences. In Type 2 scenarios, inflation is positive and money illusion may bias behavior. By controlling for the risk preferences estimated from Type 1 scenarios, these scenarios allow assessing the degree of money illusion. In Type 3 scenarios, we model the simplest form of inflation risk; inflation can take two possible values, both realized with 50% probability and independently of the risky asset's return. By controlling for risk preferences from Type 1 scenarios and the degree of money illusion from Type 2 scenarios, these scenarios allow assessing inflation risk misperceptions.

Table 1: Parameter combinations in the experimental scenarios.

Type 1 scenarios (no inflation)		Type 2 scenarios (positive inflation)		Type 3 scenarios (inflation risk)		
(μ_r, σ_r)	i	(μ_r, σ_r)	i	(μ_r, σ_r)	μ_i	(i_{lo}, i_{hi})
(2%, 4%)	0%	(2%, 4%)	1%	(2%, 4%)	1%	(0%, 2%)
(2.5%, 6%)	0%	(2%, 4%)	2%	(2%, 4%)	2%	(1%, 3%)
(3%, 8%)	0%	(2%, 4%)	3%	(2%, 4%)	2%	(0%, 4%)
(3.5%, 10%)	0%	(2%, 4%)	4%	(2%, 4%)	3%	(2%, 4%)
(4%, 12%)	0%	(4%, 12%)	1%	(2%, 4%)	3%	(0%, 6%)
(4.5%, 14%)	0%	(4%, 12%)	2%	(4%, 12%)	1%	(0%, 2%)
(5%, 16%)	0%	(4%, 12%)	3%	(4%, 12%)	2%	(1%, 3%)
(5.5%, 18%)	0%	(4%, 12%)	4%	(4%, 12%)	2%	(0%, 4%)
(6%, 20%)	0%	(6%, 20%)	1%	(4%, 12%)	3%	(2%, 4%)
		(6%, 20%)	2%	(4%, 12%)	3%	(0%, 6%)
		(6%, 20%)	3%	(6%, 20%)	1%	(0%, 2%)
		(6%, 20%)	4%	(6%, 20%)	2%	(1%, 3%)
				(6%, 20%)	2%	(0%, 4%)
				(6%, 20%)	3%	(2%, 4%)
				(6%, 20%)	3%	(0%, 6%)
Σ = 9 scenarios		Σ = 12 scenarios		Σ = 15 scenarios		

All parameters are annualized. The risky asset's nominal return is log normally distributed with expectation μ_r and volatility σ_r. i denotes the inflation rate. In case of inflation risk, μ_i denotes the expectation and (i_{lo}, i_{hi}) the low and the high realizations. The investment horizon is T = 10 years of experimental time throughout.

For transforming the continuous return distribution of the risky asset into 10 discrete states (Figure 1-2), we rely on a solid theoretical foundation. Let $\ln x \sim \mathcal{N}(\mu_r - 0.5\sigma_r^2, \sigma_r)$ denote the return realization of the risky asset. The 10 discrete state returns are given by the conditional expectations:

$$x_j = \begin{cases} \frac{1}{0.1} \int_{-\infty}^{q_j} x f(x) dx & for \quad j = 1 \\ \frac{1}{0.1} \int_{q_{j-1}}^{q_j} x f(x) dx & for \quad j = 2, \dots, 9 \\ \frac{1}{0.1} \int_{q_{j-1}}^{\infty} x f(x) dx & for \quad j = 10\,, \end{cases} \tag{1}$$

where $f(x)$ denotes the probability density function of the return distribution with deciles q_j:

$$q_j = F^{-1}\left(\frac{j}{10}\right) \quad for \quad j = 1, \dots, 9\,. \tag{2}$$

3.6 Procedures

The experiment was conducted under controlled conditions in the experimental lab of a German university. The experiment was fully computer-based, except for a short introduction that was handed out and read aloud prior to the start of the experiment (see Online Appendix A). Pen and paper were provided for notes and calculations; the use of pocket calculators or other personal devices was prohibited. We recruited 96 participants from an undergraduate finance class (participation in the experiment was voluntary) and randomly assigned them to our two treatments. Table 2 compares sample characteristics between treatments. Treatments do not differ by key demographics (gender, age, nationality, and major). Given the nature of our experimental task, it is important to note that risk aversion does not differ between treatments, as measured by the Holt and Laury (2002) score and a self-judgment of risk aversion. As money illusion can be viewed as a simplifying heuristic where people use nominal payoffs as a proxy for real values, we also checked that the propensity to rely on simplifying heuristics versus rational thinking does not differ between treatments, as measured by the CRT score (Frederick 2005). We conclude that our randomization is effective in forming comparable samples, and that differences in behavior should be mainly induced by the information conditions rather than participant characteristics.

Table 2: Sample characteristics.

		Treatment		
	All	Nominal	Hybrid	| Difference |
Female [%]	48.96	45.83	52.08	6.25
	(5.13)	(7.27)	(7.29)	(10.29)
Age [years]	21.76	21.67	21.85	0.19
	(0.20)	(0.29)	(0.28)	(0.40)
Non-German nationality [%]	15.63	14.58	16.67	2.08
	(3.73)	(5.15)	(5.44)	(7.49)
Business major [%]	78.13	79.17	77.08	2.08
	(4.24)	(5.92)	(6.13)	(8.53)
Self-stated financial literacy [1;7]	4.12	4.08	4.15	0.06
	(0.13)	(0.18)	(0.19)	(0.26)
HL risk aversion [1;10]	6.08	6.13	6.04	0.08
	(0.21)	(0.29)	(0.30)	(0.41)
Self-stated risk aversion [1;7]	4.14	4.00	4.27	0.27
	(0.16)	(0.22)	(0.23)	(0.32)
CRT [0;3]	1.54	1.63	1.46	0.17
	(0.12)	(0.17)	(0.17)	(0.24)
N	96	48	48	

Average values of selected variables, by treatment. HL refers to the Holt and Laury (2002) risk aversion score. CRT denotes the score in the Cognitive Reflection Test by Frederick (2005). Robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance of the absolute difference between treatments on the 1%, 5%, and 10% level.

Figure 3 depicts the course of the experiment. Tutorial A explains the decision situation, the incentive structure, and the interface. We carefully check for understanding; participants can only continue if they answer 10 comprehension questions and tests correctly. The complete instructions and comprehension questions are provided in Online Appendix B. Next to simple multiple choice questions on the understanding of the decision situation and the incentive structure, we also include interactive tests on the handling of the software (like making a specific investment decision by using the slider). In the hybrid treatment, an additional test requires participants to switch from the nominal to the real view to ensure awareness of the real view and foster appreciation of the displayed information. In case of incorrect answers or no fulfillment of the test, the experimenter is notified on her computer screen and assists if necessary. Tutorial A concludes with a non-incentivized practice phase, where participants can familiarize themselves with the decision situation until they feel comfortable making their actual decisions.

Tutorial A (~15 minutes) Instructions, comprehension questions, and practice phase.
Investment Task A (~20 minutes) 9 scenarios with no inflation (Type 1), 12 scenarios with deterministic inflation (Type 2).
Tutorial B (~5 minutes) Explanation of inflation risk.
Investment Task B (~15 minutes) 15 scenarios with stochastic inflation (Type 3).
Questionnaire (~10 minutes) Demographics, preferences and attitudes, experiment feedback.

Figure 3: Course of the experiment.

Investment Task A comprises 9 scenarios of Type 1 (no inflation) and 12 scenarios of Type 2 (positive inflation; see Table 1). The ordering is randomized across scenario types and different for each participant. Scenarios are independent (i.e., decisions do not affect endowment in subsequent scenarios). Participants receive feedback on investment outcomes only after the experiment, because immediate feedback may affect subsequent behavior (Laudenbach et al. 2012).

Tutorial B explains inflation risk. In the hybrid treatment, it further shows how to switch between the nominal view, the real view under the low inflation rate, and the real view under the high inflation rate by clicking on separate buttons.

Investment Task B comprises 15 scenarios of Type 3 (inflation risk). Again, the ordering is randomized and different for each participant, scenarios are independent from each other, and participants do not learn about outcomes until after the experiment.

The experiment concludes with a questionnaire on demographics, attitudes, and preferences.

After the experiment, each participant is paid according to one of the 36 scenarios. The scenario is selected randomly and for each participant individually by the computer. In case a Type 3 scenario is selected, the computer further determines by a random draw whether the high or the low inflation rate is applied. To increase trust into the procedure, participants then draw a numbered ping-pong ball out of an urn with 10 balls themselves. The number on the ball represents the state in the 10-state chart that is realized and rewarded with real money (i.e., the return of the risky asset). Average remuneration is 11.40€ ($13.68) per participant and average completion time is 63 minutes.

4 Optimal Asset Allocation under Money Illusion

To estimate the degree of money illusion from participant behavior, we propose an asset allocation model. The investor has access to two assets, a risk-free asset and a risky asset. The risk-free asset earns a real risk-free rate r_f. The risky asset earns a nominal return R with expectation μ_r and volatility σ_r. The investor maximizes expected utility from terminal consumption. He is endowed with some initial wealth W_0. In line with the experimental setup, we assume that he follows a buy-and-hold strategy with a portfolio weight of the risky asset equal to π. His (real) terminal wealth and thus his (real) consumption C at the end of the investment horizon T is:

$$C_T = W_0 \left[(1-\pi) \cdot e^{r_f \cdot T} + \pi \cdot \frac{S_T}{S_0} \right], \tag{3}$$

where S denotes the real price of the risky asset. We furthermore assume that the investor has CRRA preferences with a relative risk aversion of $\gamma \neq 1$.[9] His optimization problem is thus:

$$\max_\pi E\left[\frac{C_T^{1-\gamma}}{1-\gamma}\right]. \tag{4}$$

[9] As a robustness check we have also considered an investor with CARA preferences and absolute risk aversion γW_0. Differences in optimal portfolio weights are small in our scenarios.

The problem can only be solved numerically.[10] For moderate parameters, however, the optimal solution for the buy-and-hold strategy is close to the optimal solution for continuous rebalancing (Rogers 2001).[11] For zero inflation, the optimal weight of the risky asset in the latter case is:

$$\pi = \frac{\mu_r - r_f}{\gamma \cdot \sigma_r^2}. \tag{5}$$

In our setup, the investor has to account for inflation. In general, the inflation rate i is stochastic with expectation μ_i and volatility σ_i. In line with the experimental setup, there is zero correlation between the risky asset's nominal return and inflation. The risky asset's real return is thus:

$$\ln R - i \qquad \text{with} \tag{6}$$

$$\ln E[R] - i = \mu_r - \mu_i \qquad \text{and} \qquad \sigma^2[\ln R - i] = \sigma_r^2 + \sigma_i^2\,. \tag{7 and 8}$$

If the investor is subject to money illusion, he does not (fully) account for inflation when judging the risky asset's real return, given the nominal return and the inflation rate. Instead of $\ln R - i$, he relies on $\ln R - (1-\theta) \cdot i$, where θ captures the degree of money illusion. For θ = 0, there is no money illusion (the investor correctly uses the risky asset's real return), while θ = 1 corresponds to full money illusion (the investor wrongly uses the risky asset's nominal return). The portfolio weight with continuous rebalancing in the presence of money illusion becomes:

$$\pi = \frac{\mu_r - (1-\theta) \cdot \mu_i - r_f}{\gamma \cdot [\sigma_r^2 + (1-\theta)^2 \cdot \sigma_i^2]}. \tag{9}$$

Besides suffering from money illusion, the investor may also misperceive inflation risk. We model inflation risk in the simplest way and assume that inflation can only take two values, i_{hi} and i_{lo} (where $i_{hi} > i_{lo}$) with equal probability. Misperception of inflation risk is captured by the parameter e_w. Instead of 0.5, the investor assigns a probability of 0.5 + e_w to the high inflation state and a probability of 0.5 – e_w to the low inflation state. With this misperception, it holds that:

$$\hat{\mu}_i = (0.5 + e_w) \cdot i_{hi} + (0.5 - e_w) \cdot i_{lo} = \mu_i + e_w \cdot (i_{hi} - i_{lo}) \tag{10}$$

$$\hat{\sigma}_i^2 = (0.5 + e_w) \cdot (0.5 - e_w) \cdot (i_{hi} - i_{lo})^2 = \sigma_i^2 - e_w^2 \cdot (i_{hi} - i_{lo})^2 \tag{11}$$

---

[10] The first-order condition for π is $E\left[\left((1-\pi) \cdot e^{r_f \cdot T} + \pi \cdot \frac{S_T}{S_0}\right)^{-\gamma} \left(\frac{S_T}{S_0} - e^{r_f \cdot T}\right)\right] = 0$.

[11] We have checked numerically that this is indeed the case in our scenarios.

and the portfolio weight finally becomes:

$$\pi = \frac{\mu_r - (1-\theta) \cdot [\mu_i + e_w \cdot (i_{hi} - i_{lo})] - r_f}{\gamma \cdot [\sigma_r^2 + (1-\theta)^2 \cdot (\sigma_i^2 - e_w^2 \cdot (i_{hi} - i_{lo})^2)]}. \tag{12}$$

5 Results

Our main analyses rely on non-linear least squares regressions to estimate the behavioral parameters of Equation (12) from the experimental data. In particular, we estimate the participants' degree of relative risk aversion (γ) and, if applicable, their degree of money illusion (θ) and inflation risk misperceptions (e_w) from the observed investment decisions (π). The risky asset's nominal return (μ_r, σ_r) and the inflation rate (i or i_{hi}, i_{lo}) are determined by the scenario (see Table 1), the risk-free asset's real return is r_f = 0 throughout.

Before turning to our main analyses, we briefly describe the experimental data. Figure 4 shows the distributions of the share of wealth allocated to the risky asset (π) for the different treatments and scenario types. In Type 1 scenarios (no inflation), the average weight of the risky asset (π) does not differ between nominal and hybrid treatment (79.23% vs. 83.65%, Δ = 4.42%, p = 0.18), indicating that risk preferences do not differ between treatments.[12] In Type 2 scenarios (positive inflation), the average weight of the risky asset is significantly higher in the nominal than in the hybrid treatment (58.69% vs. 50.22%, Δ = -8.47%, p = 0.04). The same holds for Type 3 scenarios (inflation risk; 55.65% vs. 45.50%, Δ = -10.15%, p = 0.02). This treatment effect is consistent to the idea that money illusion is higher in the nominal than in the hybrid treatment, because the weight of the risky asset increases in the degree of money illusion (see Equation 12). We will examine this explanation in Subsections 5.1 to 5.3 by contrasting the relevant behavioral parameters of our model (γ, θ, and e_w) between treatments.

Figure 4 further shows that the short sale constraint restricts investment behavior in all treatments and scenarios. As non-linear least squares regressions do not explicitly account for this, we thoroughly assess the impact of the short sale constraint on parameter estimates in Subsection 5.4 and verify that it does not drive our results.

[12] Throughout this paper, p-values refer to the results of two-sided t-tests. Robust standard errors are adjusted for clustering on the participant level if applicable.

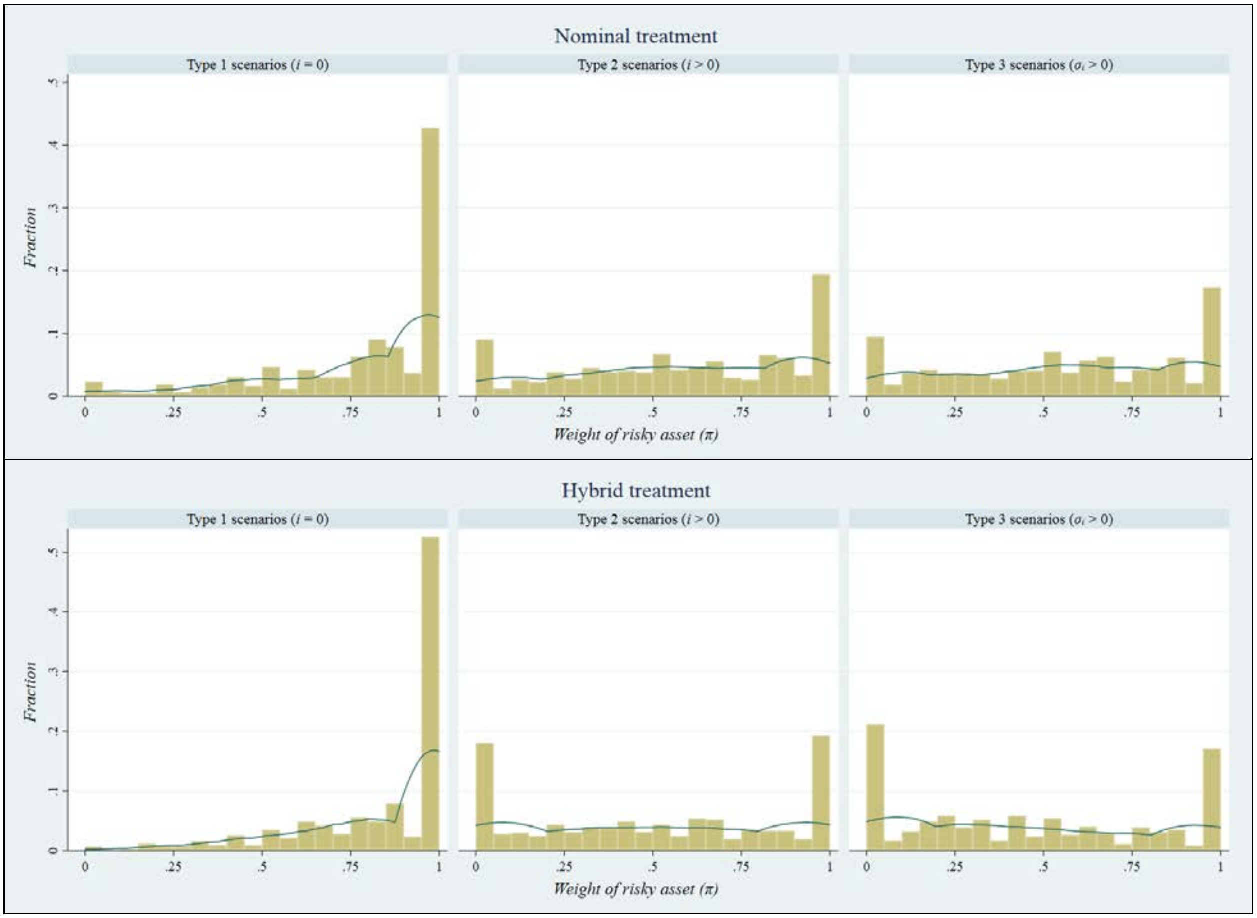

Figure 4: Distribution of weights of the risky asset (π) in the nominal treatment (upper panel) and the hybrid treatment (lower panel), by scenario types. The solid line indicates kernel density estimates.

5.1 Money Illusion in the Nominal Treatment

We start our main analyses in the nominal treatment. In Type 1 scenarios, inflation is zero and money illusion is irrelevant. Hence, we only estimate the relative risk aversion parameter (γ) and fix the other parameters of Equation (12) to zero. Specification A of Table 3 shows that the model yields high explanatory power (R^2 = 0.57) and a relative risk aversion estimate with low estimation uncertainty (γ = 8.48, SE = 0.31). The relative risk aversion estimate seems plausible, as it is well within the range of assumptions in the relevant literature (often $\gamma \in [5; 10]$, see for example Brennan and Xia 2002 or Gomes and Michaelides 2005). We conclude that the model captures investment behavior accurately when there is no inflation and do not test different specifications.

Table 3: CRRA and money illusion estimates in the nominal treatment.

Specification	Scenarios	γ	θ	Adj. R^2	N
A	Type 1	8.48 ***	0	0.57	432
		(0.31)	(fixed)		
B	Type 2	672.56	0	-0.02	576
		(1,601.28)	(fixed)		
C	Type 2	9.13 ***	0.63 ***	0.50	576
		(0.44)	(0.02)		

Results from non-linear least squares regressions in the nominal treatment. γ denotes the CRRA parameter, and θ the money illusion parameter. Type 1 denotes scenarios with zero inflation (deterministic), Type 2 denotes scenarios with positive inflation (deterministic). Cluster-robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

We next study how the presence of inflation affects investment behavior (Type 2 scenarios). At first, we fix the money illusion parameter to zero. Explanatory power and relative risk aversion estimates should deteriorate substantially if money illusion affects investment behavior in an economically relevant manner. Specification B of Table 3 shows that this is the case. The model does not fit the data well, as can be learned from the low explanatory power (R^2 = -0.02) and the implausible relative risk aversion estimate with extremely high estimation uncertainty (γ = 672.56, SE = 1,601.28). Setting the starting value in the optimization to the benchmark (γ = 8.48) yields identical results, demonstrating the robustness of the parameters of Specification B.

There are many behavioral explanations for the bad model fit, including but not limited to a general aversion towards taking financial risks when inflation is present in the experimental environment. Obviously, we favor the competing explanation that risk aversion is unaffected by the introduction of inflation, and that money illusion exerts a systematic and significant impact on behavior. To support this conjecture, we increase the flexibility of the model now and jointly estimate a relative risk aversion and a non-zero money illusion parameter from the same data. Specification C of Table 3 shows that explanatory power increases substantially (R^2 = 0.50) and that the relative risk aversion estimate takes a plausible value again (γ = 9.13, SE = 0.44). The fact that relative risk aversion is statistically indistinguishable from the benchmark (8.48 vs. 9.13, Δ = 0.65, p = 0.26) validates that the introduction of inflation does not affect the intrinsic risk attitude. More importantly, we find an economically and statistically significant degree of money illusion; participants account for only 1 – θ = 37% of the effects of inflation when judging the risky asset's real return (θ = 0.63, SE = 0.02).[13]

[13] The joint estimation of relative risk aversion (γ) and money illusion (θ) does not overstrain our data; fixing γ to the benchmark (8.48) and only estimating θ provides very similar results (θ = 0.61, SE = 0.02; R^2 = 0.50).

Taken together, we find strong evidence that money illusion affects intertemporal investment behavior in an economically relevant manner. Our previously well-suited model (without money illusion component) loses all explanatory power and yields a highly implausible relative risk aversion estimate once inflation is present in the experimental environment. Extending our model by a money illusion component reconciles the deterioration of the model fit; participants do not account for 63% of the effects of inflation when judging the real return of the risky asset.

5.2 Money Illusion in the Hybrid Treatment

We now turn to the hybrid treatment, where participants can conveniently switch between the display of the risky asset's nominal and real return. Our analysis follows the same structure as in Subsection 5.1. First, we use Type 1 scenarios (no inflation) to estimate relative risk aversion. Specification A of Table 4 shows that the model has high explanatory power (R^2 = 0.59) and provides a plausible relative risk aversion estimate (γ = 8.01, SE = 0.21). We conclude that the model captures investment behavior adequately in the hybrid treatment, too. The fact that relative risk aversion does not differ between nominal and hybrid treatment (8.48 vs. 8.01, Δ = -0.47, p = 0.21) confirms the comparability of our samples and ensures trust into our estimations.

Table 4: CRRA and money illusion estimates in the hybrid treatment.

Specification	Scenarios	γ	θ	Adj. R^2	N
A	Type 1	8.01 ***	0	0.59	432
		(0.21)	(fixed)		
B	Type 2	49.62 ***	0	<0.01	576
		(9.79)	(fixed)		
C	Type 2	8.96 ***	0.52 ***	0.44	576
		(0.37)	(0.02)		

Results from non-linear least squares regressions in the hybrid treatment. γ denotes the CRRA parameter, and θ the money illusion parameter. Type 1 denotes scenarios with zero inflation (deterministic), Type 2 denotes scenarios with positive inflation (deterministic). Cluster-robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

We now turn to Type 2 scenarios (positive inflation). View choice behavior indicates that the explicit communication of the risky asset's real return substantially reduces the cognitive costs to account for inflation; upon starting each scenario in the nominal view, participants spend on average 62.15% of the overall decision time inspecting the real view (median: 68.83%). Surprisingly, money illusion seems to prevail; Specification B of Table 4 shows that the model without money illusion component has little explanatory power (R^2 < 0.01) and provides an implausible relative risk aversion estimate (γ = 49.62, SE = 9.79). Setting the starting value in the optimization to the benchmark (γ = 8.01) yields identical estimates, indicating that Specification B does not describe a local optimum.

Specification C of Table 4 estimates relative risk aversion and money illusion jointly from the same data; the extended model yields high explanatory power (R^2 = 0.44) and a plausible relative risk aversion estimate again (γ = 8.96, SE = 0.37). Most importantly, money illusion remains economically and statistically significant (θ = 0.52, SE = 0.02).[14] The fact that money illusion decreases only marginally compared to the nominal treatment (0.63 vs. 0.52, Δ = -0.11, p < 0.01) suggests that lacking diligence or arithmetic problems are not the key drivers of money illusion. Instead, it seems like participants anchor subconsciously to the risky asset's alluring nominal returns displayed in the nominal view, which biases the perception of the real attractiveness of the risky asset. We will verify this interpretation in Subsection 5.4, where we estimate money illusion parameters on the participant level and regress the estimated parameters on the participants' personality traits and patterns in the decision making process.

5.3 Money Illusion under Inflation Risk

We now assess how inflation risk affects money illusion (Type 3 scenarios). We start our analysis in the nominal treatment. For convenience, Specification C of Table 5 restates the relative risk aversion and money illusion estimates from scenarios with deterministic inflation rates (see Table 3). Specification D of Table 5 estimates the same parameters when inflation risk is present in the experimental environment, but misperceptions are not yet modeled. The explanatory power remains high (R^2 = 0.47) and the relative risk aversion estimate is plausible (γ = 7.77, SE = 0.42). Although money illusion remains substantial (θ = 0.47, SE = 0.02), it is significantly lower than the benchmark from Specification C with deterministic inflation (0.63 vs. 0.47, Δ = -0.16, p < 0.01).

[14] The result is not compromised by the joint estimation of γ and θ; fixing γ to the benchmark (8.01) and only estimating the degree money illusion yields a similar result (θ = 0.50, SE = 0.02; $\bar{R}^2$ = 0.44).

Table 5: Perception of inflation risk in the nominal treatment.

Specification	Scenarios	γ	θ	e_w	Adj. R^2	N
C	Type 2	9.13 ***	0.63 ***	0	0.50	576
		(0.44)	(0.02)	(fixed)		
D	Type 3	7.77 ***	0.47 ***	0	0.47	720
		(0.42)	(0.02)	(fixed)		
E	Type 3	7.62 ***	0.53 ***	0.12 ***	0.48	720
		(0.41)	(0.02)	(0.02)		

Results from non-linear least squares regressions in the nominal treatment. γ denotes the CRRA parameter, θ the money illusion parameter, and e_w the inflation risk misperception parameter. Type 2 denotes scenarios with positive inflation (deterministic), Type 3 denotes scenarios with stochastic inflation. Cluster-robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

To understand this reduction, Specification E of Table 5 accounts for misperceptions of inflation risk. Explanatory power (R^2 = 0.48) and relative risk aversion (γ = 7.62, SE = 0.41) are virtually unaffected by the extension. However, participants overweight the high inflation state (e_w = 0.12, SE = 0.02), which increases inflation expectations and puts less pressure on the money illusion parameter (θ = 0.53, SE = 0.02). About one third of the reduction that was initially attributed to the introduction of inflation risk (Specification C vs. D: 0.63 vs. 0.47, Δ = -0.16, p < 0.01) can be reconciled by the participants' focus on the high inflation rate (Specification D vs. E: 0.47 vs. 0.53, Δ = 0.06, p = 0.04). Explaining the remaining reduction is beyond the scope of our data (Specification C vs. E: 0.63 vs. 0.53, Δ = -0.10, p < 0.01); the idea that inflation risk renders inflation more salient and thereby reduces money illusion seems plausible though.

Table 6 verifies that lacking diligence or arithmetic problems do not drive this pattern; participants in the hybrid treatment overweight the high inflation rate as well (Specification E: e_w = 0.05, SE = 0.02). View choice behavior supports this result; participants spend much more time in the real view with the high inflation rate than in the real view with the low inflation rate displayed (53.88% vs. 24.41% of the overall decision time on average). This mitigates money illusion (Specification C vs. E: 0.52 vs. 0.39, Δ = -0.13, p < 0.01), but it does not annihilate the bias altogether (θ = 0.39, SE = 0.02).

Table 6: Perception of inflation risk in the hybrid treatment.

Specification	Scenarios	γ	θ	e_w	Adj. R^2	N
C	Type 2	8.96 ***	0.52 ***	0	0.44	576
		(0.37)	(0.02)	(fixed)		
D	Type 3	7.90 ***	0.36 ***	0	0.39	720
		(0.41)	(0.02)	(fixed)		
E	Type 3	7.81 ***	0.39 ***	0.05 **	0.39	720
		(0.41)	(0.02)	(0.02)		

Results from non-linear least squares regressions in the hybrid treatment. γ denotes the CRRA parameter, θ the money illusion parameter, and e_w the inflation risk misperception parameter. Type 2 denotes scenarios with positive inflation (deterministic), Type 3 denotes scenarios with stochastic inflation. Cluster-robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

In sum, we find that the introduction of inflation risk reduces money illusion. A large part of the reduction can be attributed to a focus on the worst case (i.e., the high inflation state), which increases inflation expectations and mitigates money illusion. Yet money illusion remains on an economically and statistically significant level, indicating that its economic relevance does not vanish in times of high inflation risk.

5.4 Robustness and Plausibility Tests

In this Subsection, we validate that our previous findings are not driven by misunderstandings of the experimental task (Tests 1, 4, and 5), learning or repetition effects caused by the mere length of the experiment (Tests 2 and 5), or the short-sale constraint (Test 3). Moreover, we explore the drivers of money illusion on the participant level, both in terms of our money illusion parameter (θ; Test 4) and a more direct proxy for money illusion (time in the nominal vs. real view; Test 5).

Test 1: Misunderstandings of the Experimental Task

To verify that misunderstandings of inflation or the experimental task do not drive the documented money illusion, we distinguish between participants who answered all 10 comprehension questions in the tutorial correctly at first attempt (18/12 participants in the nominal/hybrid treatment) and participants who did not (30/36). Table 7 shows the results in the nominal treatment (Panel A) and the hybrid treatment (Panel B) for our main specifications. Risk aversion (γ) tends to be higher among participants who made errors in the tutorials. This is consistent to the idea that having made an error reduces the perceived understanding of the experimental task, which in turn induces a tendency to avoid experimental risks. Given that only one of the differences is statistically significant (Type 2 scenarios in the hybrid treatment: 7.77 vs. 10.20, $\Delta = 2.43$, $p = 0.01$), we do not further investigate this pattern. Importantly, money illusion estimates (θ) are statistically indistinguishable between participants who did vs. did not answer all comprehension questions correctly (min. p = 0.61). The same holds for the misperception of inflation risk in Type 3 scenarios (min p = 0.35). All this lends support to the conclusion that misperceptions of the experimental task do not drive our key findings. We will revisit this claim in robustness tests 4 and 5, where we further validate it based on participant-level estimates of money illusion.

Table 7: Key results only with participants who answered all comprehension questions correctly.

Panel A: Nominal treatment.

Specification	Scenarios	Filter	γ	θ	e_w	Adj. R^2	N
A	Type 1	0 errors	8.36 ***	0	0	0.58	162
			(0.48)	(fixed)	(fixed)		
		≥1 error	8.56 ***	0	0	0.55	270
			(0.41)	(fixed)	(fixed)		
C	Type 2	0 errors	7.77 ***	0.62 ***	0	0.54	216
			(0.41)	(0.04)	(fixed)		
		≥1 error	10.20 ***	0.63 ***	0	0.47	360
			(0.70)	(0.02)	(fixed)		
E	Type 3	0 errors	6.85 ***	0.54 ***	0.10 **	0.50	270
			(0.51)	(0.04)	(0.04)		
		≥1 error	8.17 ***	0.53 ***	0.13 **	0.45	450
			(0.61)	(0.03)	(0.03)		

Panel B: Hybrid treatment.

Specification	Scenarios	Filter	γ	θ	e_w	Adj. R^2	N
A	Type 1	0 errors	7.92 ***	0	0	0.62	108
			(0.36)	(fixed)	(fixed)		
		≥1 error	8.04 ***	0	0	0.58	324
			(0.25)	(fixed)	(fixed)		
C	Type 2	0 errors	8.84 ***	0.52 ***	0	0.44	144
			(0.86)	(0.04)	(fixed)		
		≥1 error	9.00 ***	0.52 ***	0	0.43	432
			(0.40)	(0.03)	(fixed)		
E	Type 3	0 errors	8.05 ***	0.42 ***	0.08	0.33	180
			(1.04)	(0.05)	(0.05)		
		≥1 error	7.73 ***	0.39 ***	0.04 *	0.39	540
			(0.44)	(0.03)	(0.02)		

Results from non-linear least squares regressions in the nominal treatment (Panel A) and the hybrid treatment (Panel B). All participants who did not answer all comprehension questions in the tutorial correctly at first attempt are excluded. γ denotes the CRRA parameter, θ the money illusion parameter, and e_w the inflation risk misperception parameter. Type 1 denotes scenarios with zero inflation (deterministic), Type 2 denotes scenarios with positive inflation (deterministic), Type 3 denotes scenarios with stochastic inflation. Cluster-robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

Test 2: Learning and Repetition Effects

Participants made 36 investment decisions in total (see Table 1), and overall completion time was 63 minutes on average. It is conceivable that the mere length of the experiment biases our money illusion estimates in one way or the other. On the one hand, participants may gradually learn about the relevance of inflation. On the other hand, carelessness may increase due to the repetitive nature of the experiment. To address the question whether money illusion decreases or increases over the course of the experiment, we repeat our main analyses for early and late scenarios separately.

We define early (late) scenarios to be the first (last) 1/3 of scenarios that the participant faced, for each scenario type separately. For example, participants faced nine Type 1 scenarios in total; the first three Type 1 scenarios that the participant faced are defined as early Type 1 scenarios, and the last three are defined as late Type 1 scenarios (for Type 2 and 3 analogously).

Panel A of Table 8 shows the results in the nominal treatment. There are notable differences in risk aversion (γ) between early vs. late scenarios. However, none of the differences is statistically significant (min. p = 0.22), and we conclude that the participants' intrinsic attitude towards taking financial risks does not change over the course of the experiment. Money illusion estimates (θ) are virtually identical in early vs. late scenarios (min. p = 0.90). In scenarios with inflation risk (Type 3), the overweighting of the high inflation state increases notably, yet the difference is only borderline significant (p = 0.102). Panel B of Table 8 shows the results for the hybrid treatment, where patterns are similar. Although differences in money illusion are somewhat larger, they remain unsystematic and statistically insignificant (min. p = 0.27). In sum, we conclude that neither learning nor repetition effects drive the key results of our paper.

Table 8: Key results for early and late scenarios separately.

Panel A: Nominal treatment.

Specification	Scenarios	Filter	γ	θ	e_w	Adj. R^2	N
A	Type 1	Early	8.38 ***	0	0	0.53	144
			(0.61)	(fixed)	(fixed)		
		Late	9.28 ***	0	0	0.55	144
			(0.71)	(fixed)	(fixed)		
C	Type 2	Early	8.61 ***	0.63 ***	0	0.52	192
			(0.79)	(0.04)	(fixed)		
		Late	10.13 ***	0.63 ***	0	0.48	192
			(0.96)	(0.04)	(fixed)		
E	Type 3	Early	8.52 ***	0.54 ***	0.04	0.47	240
			(0.89)	(0.05)	(0.08)		
		Late	7.35 ***	0.55 ***	0.14 *	0.50	240
			(0.70)	(0.05)	(0.08)		

Panel B: Hybrid treatment.

Specification	Scenarios	Filter	γ	θ	e_w	Adj. R^2	N
A	Type 1	Early	8.63 ***	0	0	0.60	144
			(0.48)	(fixed)	(fixed)		
		Late	7.43 ***	0	0	0.60	144
			(0.61)	(fixed)	(fixed)		
C	Type 2	Early	9.42 ***	0.54 ***	0	0.47	192
			(0.84)	(0.04)	(fixed)		
		Late	8.82 ***	0.49 ***	0	0.43	192
			(0.75)	(0.03)	(fixed)		
E	Type 3	Early	6.92 ***	0.34 ***	<0.01	0.40	240
			(0.67)	(0.05)	(0.05)		
		Late	8.39 ***	0.41 ***	0.07	0.35	240
			(0.92)	(0.04)	(0.06)		

Results from non-linear least squares regressions in the nominal treatment (Panel A) and the hybrid treatment (Panel B). Early (late) scenarios are defined to be the first (last) 1/3 of scenarios that each participant faced, within each scenario Type. γ denotes the CRRA parameter, θ the money illusion parameter, and e_w the inflation risk misperception parameter. Type 1 denotes scenarios with zero inflation (deterministic), Type 2 denotes scenarios with positive inflation (deterministic), Type 3 denotes scenarios with stochastic inflation. Cluster-robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

Test 3: Short-sale Constraint and Estimation Procedure

To assess the impact of the short sale constraint (i.e., the limitation of weights between 0 and 1, see Figure 4), we use Tobit truncated regression models.[15] The observed restricted weights of the risky asset are assumed to follow the ramp function:

$$\pi = \begin{cases} 0 & if \quad \pi^u \leq 0 \\ \pi^u & if \quad 0 < \pi^u < 1 \\ 1 & if \quad \pi^u \geq 1\,, \end{cases} \tag{13}$$

[15] Simply excluding the corner solutions (π = {0; 1}) yields similar results.

where π^u denotes the unrestricted, unobservable weights of the risky asset. Given that Tobit models assume a linear relation between π^u and the independent variables, we focus on Type 1 and 2 scenarios (σ_i^2 = 0).[16] This allows rewriting Equation (9) such that π^u depends linearly on $1/\gamma$ and θ/γ via the scenario parameters:

$$\pi^u = \frac{\mu_r - (1-\theta)\cdot i}{\gamma \cdot \sigma_r^2} + \nu = \frac{1}{\gamma}\cdot\frac{\mu_r - i}{\sigma_r^2} + \frac{\theta}{\gamma}\cdot\frac{i}{\sigma_r^2} + \nu\,, \tag{14}$$

where $\nu \sim \mathcal{N}(0,\sigma)$ denotes the error term (we neglect subscripts for individual observations here).

Table 9 shows the implied parameter estimates. Relative risk aversion (γ) is somewhat lower in both specifications and treatments compared to the previous analyses. This is plausible, considering that the short sale constraint restricted higher risk taking previously. Money illusion estimates (θ) are lower than the corresponding values in Table 3 (nominal treatment) and Table 4 (hybrid treatment), although the reduction is only significant in the latter case (nominal treatment: 0.63 vs. 0.59, Δ = -0.04, p = 0.28; hybrid treatment: 0.52 vs. 0.41, Δ = -0.11, p = 0.02). Money illusion remains economically and statistically significant though, and we conclude that our main results are not driven by the short sale constraint together with an inappropriate estimation procedure.

Table 9: Key results with unrestricted asset weights.

Panel A: Nominal treatment.

Specification	Scenarios	γ	θ	Pseudo R^2	N
A	Type 1	5.75 ***	0	0.28	432
		(0.59)	(fixed)		
C	Type 2	7.69 ***	0.59 ***	0.23	576
		(0.64)	(0.03)		

Panel B: Hybrid treatment.

Specification	Scenarios	γ	θ	Pseudo R^2	N
A	Type 1	4.70 ***	0	0.29	432
		(0.57)	(fixed)		
C	Type 2	6.86 ***	0.41 ***	0.17	576
		(0.60)	(0.04)		

Results from Tobit truncated regressions in the nominal treatment (Panel A) and the hybrid treatment (Panel B) based on Equation (13). γ denotes the CRRA parameter, and θ the money illusion parameter. Type 1 denotes scenarios with zero inflation (deterministic), Type 2 denotes scenarios with positive inflation (deterministic). Cluster-robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

[16] Equation (9) cannot be rewritten such that π linearly depends on γ and θ via the scenario parameters when inflation risk is present (Type 3 scenarios), and we therefore do not consider these scenarios in the subsequent analyses.

Test 4: Individual Heterogeneity in Money Illusion

We now study individual heterogeneity in money illusion to generate insights on the determinants of money illusion. The Tobit method proved to produce more reliable estimates than the non-linear least squares method due to the small number of observations per participants, and we therefore rely on the former. To further increase reliability of the results, we use Type 1-3 scenarios jointly in our estimations. Figure 5 shows the distribution of individual money illusion estimates in the nominal (left panel) and hybrid treatment (right panel). Median estimates (0.49 and 0.32 respectively) are comparable to the aggregate estimates in Table 9. There is substantial heterogeneity; individual money illusion estimates range between -0.13 and 1.15 in the nominal treatment and -0.85 and 0.78 in the hybrid treatment. The majority of estimates lies between 0 and 1 (45 in the nominal treatment and 33 in the hybrid treatment), indicating that most participants fall prey to money illusion. Yet, some participants get “inflation terror”; we find $\theta < 0$ for 2 participants in the nominal treatment and for 15 participants in the hybrid treatment, indicating that those participants overestimate the effects of inflation. It should be noted though that the majority of negative θ-estimates is close to zero, and that these deviations do not distort behavior from the real preferences in an economically relevant manner.

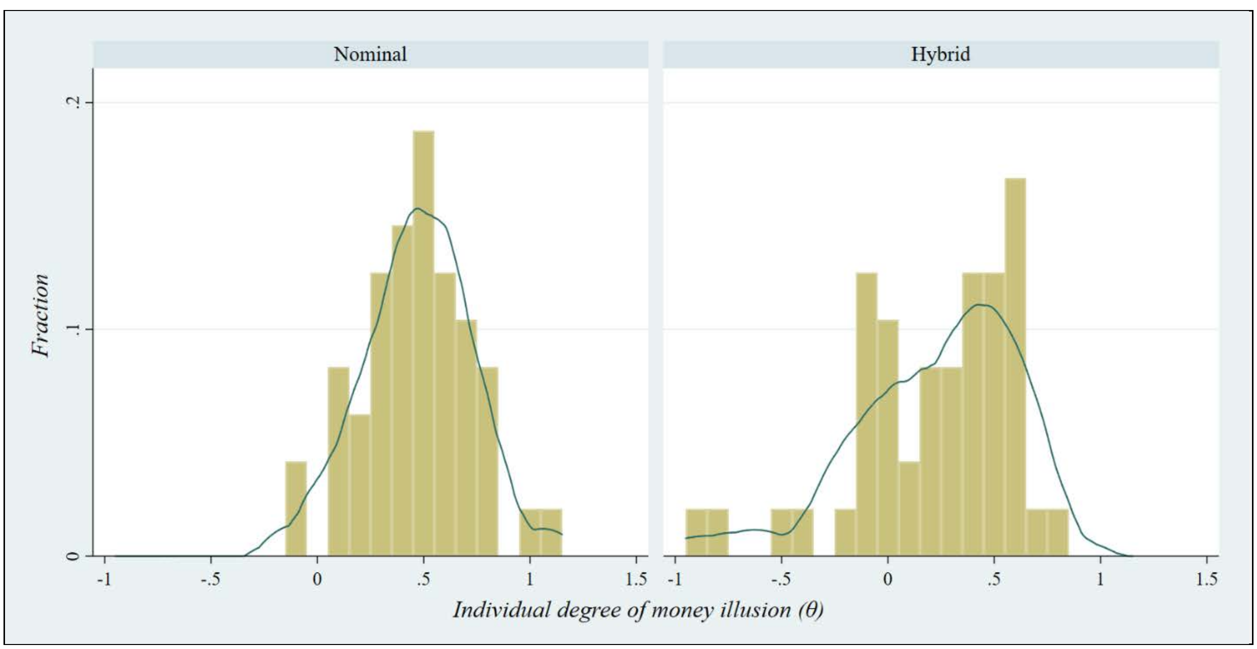

Figure 5: Distribution of individual money illusion (θ) estimates in the nominal treatment (left panel) and the hybrid treatment (right panel). Equation (14) is estimated for each participant individually from decisions in Type 1-3 scenarios. The solid line indicates kernel density estimates.

We next explore the determinants of individual money illusion. Table 10 shows regression results (we scaled θ into percent to increase readability of the table). Specification A studies the role of demographics (see Table 2 for descriptive statistics). Women suffer from significantly higher money illusion than men (Δ = 16.79%, p < 0.01). Interestingly, money illusion increases in age (β = 3.85%, p = 0.02). This speaks against the idea that money illusion decreases as individuals grow older and gather more inflation experiences. However, we do not overstress this finding, because age only ranges between 18 and 28 years in our sample.

Table 10: Determinants of individual money illusion estimates (in %).

	Specification A	Specification B	Specification C	Specification D
Female [1=yes]	16.79 ***			13.75 *
	(6.37)			(7.06)
Age [years]	3.85 **			3.12 **
	(1.61)			(1.45)
Non-German nationality [1=yes]	-12.06			-10.54
	(9.75)			(10.43)
Business major [1=yes]	-0.80			5.58
	(7.37)			(9.03)
Self-stated financial literacy [1;7]		-1.26		1.30
		(2.92)		(2.97)
HL risk aversion [1;10]		0.51		1.27
		(1.57)		(1.23)
Self-stated risk aversion [1;7]		0.07		1.16
		(2.50)		(2.24)
CRT [0;3]		-5.28 *		-2.62
		(2.88)		(2.86)
Avg. relative time in real view [%]			-0.70 **	-0.91 ***
			(0.29)	(0.28)
Avg. length of decision [seconds]			0.09	-0.02
			(0.29)	(0.27)
Self-stated understanding of inflation [1;7]			-5.43	-4.71
			(3.31)	(3.65)
Number of errors in tutorial [0;10]			1.49	0.78
			(1.13)	(1.23)
Hybrid treatment [1=yes]	-26.67 ***	-25.91 ***	18.94	31.06 *
	(6.42)	(6.54)	(18.96)	(17.55)
Constant	-41.20	57.75 ***	71.76 ***	-18.80
	(34.65)	(13.36)	(19.47)	(41.08)
Adj. R^2	0.23	0.18	0.23	0.32
N	96	96	96	96

Determinants of individual money illusion estimates (in %) from OLS regressions. HL refers to the Holt and Laury (2002) risk aversion score. CRT denotes the score in the Cognitive Reflection Test by Frederick (2005). Robust standard errors are provided in parentheses. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

Specification B assesses the impact of personality traits. The self-stated financial literacy does not predict money illusion (β = -1.26%, p = 0.67). This is not surprising, considering that financial literacy is high among our student participants (see Table 2) and that they went through extensive instructions and comprehension tests prior to the experiment. Risk aversion in terms of the Holt and Laury (2002) test score and a self-stated value does not predict money illusion either. This suggests that money illusion captures a different aspect of financial decision making than the participants' intrinsic risk aversion. The CRT score negatively predicts money illusion (β = -5.28%, p = 0.07). As the CRT score can be viewed as a proxy for the propensity to rely on simplifying heuristics (low scores) vs. rational thinking (high scores), money illusion seems to reflect a simplifying heuristic where people take nominal payoffs as a proxy for real values.

Specification C explores the role of the decision making process. In line with our behavioral arguments on anchoring-and-adjustment, the time in the real view negatively predicts money illusion (β = -0.70%, p = 0.02); the more time participants spend on inspecting real returns, the lower their money illusion. The average decision making time does not predict money illusion (β = 0.09%, p = 0.29). To the extent that this variable proxies the thoroughness of the decision making process, money illusion does not reflect lacking diligence. Further supporting the results from Table 7, misunderstandings of the experimental instructions do not drive the documented money illusion: Neither the self-stated understanding of inflation nor the number of errors in the comprehension questions following the instructions predict money illusion in a statistically significant manner. We checked for a non-linear effect of self-stated and factual understanding by including the square-terms of these variables into the regression (not reported), and could not detect a significant relationship either.

Specification D explores the effects of all previous variables jointly. Changes in effect sizes are generally small. Only CRT becomes insignificant due to its high collinearity to gender (ρ = -0.35, p < 0.01); women rely more heavily on simplifying heuristics than men (Frederick 2005), both of which are associated with higher money illusion (see Specifications A and B).

Test 5: A More Direct Proxy for Money Illusion

Table 10 revealed that the time in the real view negatively predicts individual money illusion. This is intuitively appealing, because the time in the real view can be interpreted as an expression of money illusion; the more participants look at real returns, the less they anchor to nominal returns and the lower their money illusion (θ). However, it may also foster concerns that the documented money illusion is driven by misunderstandings of the experimental task; the better participants understand the experimental instructions, the less they should look at the irrelevant nominal view.

To soothe these concerns, we next analyze the determinants of the time in the real view (which negatively proxies money illusion). Of course, this does not allow distinguishing directly between genuine money illusion and spurious money illusion caused by misunderstandings of the experimental task. However, it seems useful for assessing concerns that misunderstandings of the experimental task are the key driver of our results.

In contrast to our model-based money illusion parameter (θ), the time in the real view lacks economic usability (in the sense that it cannot be applied to formal modeling) and it is therefore not the focus of the preceding sections. Yet, it has three advantages over θ for proxying money illusion (both genuine and spurious). Firstly, it can be directly observed, which improves tangibility and intuition. Secondly, it does not suffer from estimation or modeling uncertainty. Thirdly, it provides a money illusion estimate for each participant in each scenario, which allows within-subject analyses of the drivers of money illusion. For instance, it allows studying how money illusion develops over the course of the experiment.

We only consider the hybrid treatment in our analyses, because the real view is not available in the nominal treatment. Moreover, we focus on scenarios with positive expected inflation (i.e., Type 2 and 3 scenarios). The nominal and real view are identical when there is no inflation (Type 1 scenarios), and considering these scenarios might bias our analyses in one way or the other.

Figure 6 displays the time in the real view (as a fraction of the overall time from the start of the scenario until the final decision was confirmed) for all considered participants and scenarios. On average, participants spend 67.29% of the overall decision time in the real view. This value constitutes a lower bound for the participants' true interest in real return information, because every scenario started by default in the nominal view and participants could only afterwards switch to the real view. Although lacking a normative benchmark, we conclude that participants generally understood the experimental instructions as they largely appreciate the relevance of the real view.

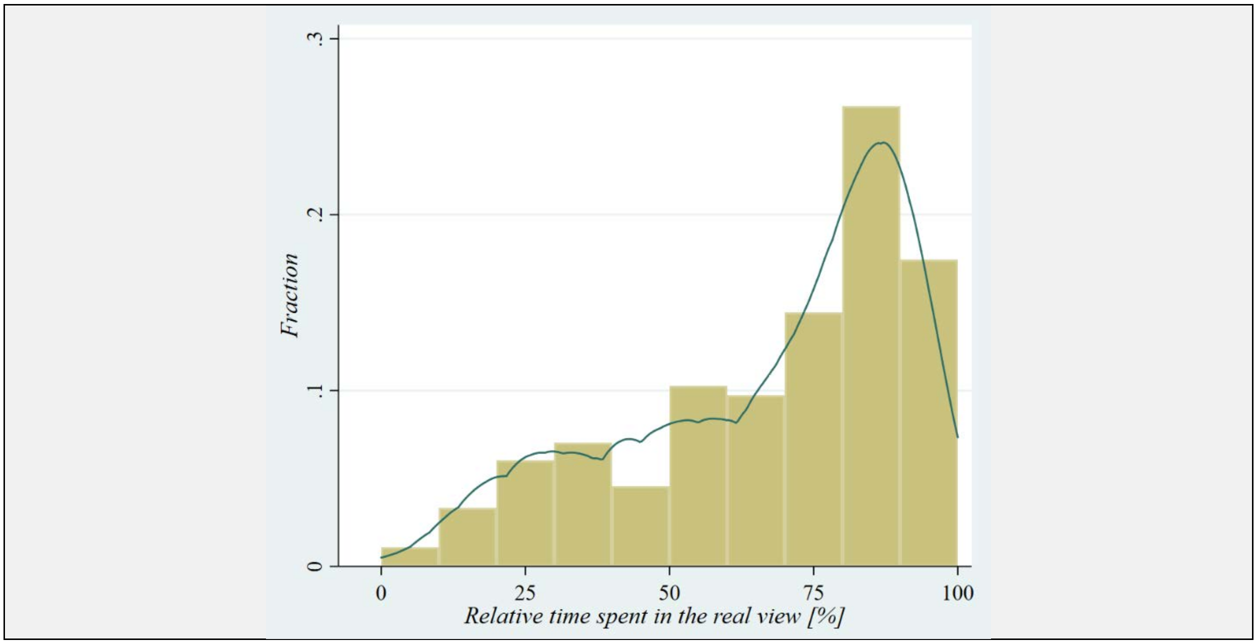

Figure 6: Distribution of the time spent in the real view (as a fraction of the overall decision making time in the respective scenario) in the hybrid treatment. The solid line indicates the kernel density estimate.

Next, we explore the determinants of the time in the real view. While money illusion (θ) is significantly affected by gender, age, and the CRT score (see Specifications A and B of Table 10), none of the considered demographics and personality traits has a significant impact on the time in the real view (see Specifications A and B of Table 11). This puts forward the idea that the time in the real view is a much more noisy proxy for money illusion than θ.

Specification C of Table 11 explores how aspects of the decision making process affect the time in the real view. The length of the scenario positively predicts the time in the real view (β = 0.32%, p < 0.01). This is likely to be a mechanical effect; the more time participants take to make a decision, the more likely it is that they eventually switch to the real view. The time in the real view is significantly higher in scenarios with inflation risk than without (Type 2 vs. 3; Δ = 7.99%, p < 0.01). This is consistent to the idea that inflation risk renders the effects of inflation more salient. Aside from this base effect, the time in the real view does not change significantly over the course of the experiment (β = 0.21%, p = 0.14). This suggests that neither learning effects (increasing appreciation of the real view) nor repetition effects (decreasing appreciation of the real view) are a key driver of the documented money illusion, and confirms the results from Table 8.

Table 11: Determinants of the relative time in the real view (in %) in the hybrid treatment.

	Specification A	Specification B	Specification C	Specification D
Female [1=yes]	2.59			0.67
	(4.36)			(3.43)
Age [years]	0.43			0.25
	(1.02)			(0.75)
Non-German nationality [1=yes]	-0.69			-5.32
	(5.98)			(5.70)
Business major [1=yes]	8.19			8.04 *
	(5.32)			(4.28)
Self-stated financial literacy [1;7]		2.29		2.15
		(1.86)		(1.32)
HL risk aversion [1;10]		0.76		1.27
		(1.11)		(0.86)
Self-stated risk aversion [1;7]		-0.43		-0.39
		(1.41)		(1.30)
CRT [0;3]		-2.87		-3.04 *
		(1.79)		(1.75)
Length of scenario [seconds]			0.32 ***	0.31 ***
			(0.05)	(0.04)
Inflation risk [1=yes]			7.99 ***	7.95 ***
			(2.49)	(2.44)
Scenario number [1;36]			0.21	0.21
			(0.14)	(0.14)
Self-stated understanding of inflation [1;7]			1.10	0.57
			(1.85)	(2.03)
Number of errors in tutorial [0;10]			-0.15	-0.50
			(0.52)	(0.49)
Constant	50.43 **	59.26 ***	45.53	28.47
	(22.73)	(8.62)	(11.46)	(19.01)
Adj. R^2	0.03	0.02	0.15	0.20
N	1,296	1,296	1,296	1,296

Determinants of the time in the real view (in %) in the hybrid treatment from OLS regressions. HL refers to the Holt and Laury (2002) risk aversion score. CRT denotes the score in the Cognitive Reflection Test by Frederick (2005). Robust standard errors are provided in parentheses, which are adjusted for clustering on the participant level. ***, **, and * indicate statistical significance on the 1%, 5%, and 10% level.

Most importantly, the time in the real view is unrelated to perceived and factual understanding of inflation, as can be learned from the insignificant coefficients of the self-rated understanding of inflation (β = 1.10%, p = 0.56) and the number of the errors in the comprehension questions (β = -0.15%, p = 0.52). Again, we checked for non-linear relationships (not reported) and could not detect any. We therefore conclude that misunderstandings of the experimental task do not seem to be a key driver of the documented money illusion, both in terms of the estimated θ (Table 7 and 10) and in terms of the directly observed time in the real view (Table 11).

Specification D of Table 11 assesses the impact of all previous variables jointly. Most coefficients do not change in a statistically significant manner. The dummy variable indicating business students is now significant (Δ = 8.04%, p = 0.07). This is consistent to the idea that individuals who make economic decisions on a regular basis are less prone to money illusion. Consistent to Table 9, the CRT score positively predicts the time in the real view; money illusion is less pronounced among participants who tend to rely on reflective thinking over spontaneous intuition.

6 Conclusion

We study in an incentive compatible, controlled investment experiment a specific aspect of money illusion; the failure to anticipate future inflation in intertemporal decision situations. Our experimental set-up does not only allow to identify money illusion in individual investment behavior, but also to provide explicit estimates of the degree of money illusion in different settings. We find that individuals largely ignore future inflation. The bias does not vanish when cognitive costs to account for inflation are eliminated from the experimental environment, indicating that the mere availability of alluring nominal returns distracts individuals from the effects of inflation for their future financial wellbeing. Inflation risk renders inflation more salient; individuals tend to focus on "worst case" inflation scenarios, which increases inflation expectations and mitigates money illusion. Yet, the ignorance of future inflation remains economically relevant.

As, to our knowledge, this paper is the first to provide model-based estimates for the degree of money illusion in intertemporal decision making, the explicit figures we derive from our incentivized investment task should be considered with caution when transferred to other economic scenarios and real world applications. There are important behavioral factors (e.g., the decision maker's age, experience and real world exposure to high inflation scenarios) and conceptual issues (e.g., the role of consumption smoothing motives) that are not systematically explored in this initial study but will likely influence investment behavior and money illusion.

Despite these limitations, we believe that our findings contribute to the literature on money illusion in important ways. Our experimental approach mitigates several problems of existing empirical studies (competing explanations, ambiguous relations, joint hypotheses) and helps to resolve the vagueness about the economic relevance of money illusion in intertemporal decision making. As the declining conversion rate mechanism is very flexible and, for instance, easily adjustable to reflect consumption smoothing motives, we also hope to have suggested an experimental paradigm that could inspire further systematic explorations of inflation ignorance. Our findings are also important as they advance the understanding of the psychological channels through which money illusion influences behavior.

Finally, we see a contribution of our paper in the demonstration that the explicit inclusion of money illusion into economic models can be vital to capture individual behavior adequately. We believe that this holds beyond the borders of our specific experimental framework; the extent to which individuals think about future monetary values in nominal or real terms has, in theory, important implications for many economic matters. Examples include life-cycle consumption behavior (Modigliani 1966), the optimal design and indexation of investment products (Lachance and Mitchell 2003), savings plans (Thaler and Benartzi 2004), wage agreements (Akerlof 2002), and market anomalies such as equity mispricing (Modigliani and Cohn 1979). Even if our money illusion estimate does not translate one-to-one into these decision situations, it can still provide a benchmark for assumptions about the magnitude of money illusion in such models.

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Online Appendix for
"Don't Ignore Inflation Ignorance: An Experimental Analysis of the Degree of Money Illusion in Individual Decision Making"

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Online Appendix A: Written introduction that was handed and read aloud by the experimenter out prior to the start of the experiment.

Dear Participant,

Welcome to our experiment – your participation is greatly appreciated! Participants from previous studies told us that they have enjoyed taking part in economic experiments. We hope that you will share this feeling! Today's experiment is fully computer-based and consists of three parts:

Part 1:	Introduction and explanations
Part 2:	36 different investment rounds
Part 3:	Concluding questionnaire

Detailed explanations of the exact tasks and payment rules will be given in Part 1. It is strictly required that you carefully read and understand all instructions. Please raise your hand if you have any questions or if you encounter any problems – the experimenter will immediately come and help you.

In each of the 36 different investment rounds of Part 2, you have to decide how much experimental money you want to keep safe at hand and how much experimental money you want to invest into a risky long-term investment product. The investment product will yield one out of 10 possible returns. All 10 returns have the same probability of occurrence (that is, 10% each). Some of the 10 possible returns will be positive and some will be negative. You will be told about the possible returns of the following investment round at the beginning of each round.
Please note: Decisions that you have made in earlier rounds will not affect later rounds – in every round of Part 2, you will have the same amount of experimental money available.

The experiment concludes with a questionnaire (Part 3). Please take your time and answer all questions carefully and truthfully. You can trust us that your answers will be treated anonymously and that they will be used for research-purposes only. No third party will obtain access to your answers at any time whatsoever!

After the experiment, the computer will randomly select one of the 36 investment rounds from Part 2. Only your decision from this one round will be relevant for determining your payment. Then, you will draw a ball out of an urn with 10 numbered ping-pong balls. If you pick the number "1", your investment in the round that was selected by the computer yields the lowest possible return of that round. If you pick the number "10", your investment yields the highest possible return of that round. Taken together, your payment for participating in this experiment will be determined by your decision from the round that was selected by the computer, and from the ping-pong ball that you have drawn from the urn. Of course, you do not know in advance which round the computer will select and what ping-pong ball you will draw. So take your time and think about all 36 decisions carefully.

During the experiment, the use of the internet or personal devices (such as cellphones or pocket calculators) is not allowed. Please do not talk to your neighbors or look at other participants' screens. The other participants will perform different tasks than you, so do not let their actions influence your own decisions.

Do you have any questions at this time?

We will now distribute the login passwords. You can then start with the experiment.

Online Appendix B: Instructions of the experiment. All paragraphs appeared consecutively on the computer screen with appropriate timely delay.

[Tutorial A - Screen 1]

General Information

General Information

Thank you for participating in our experiment, your assistance is greatly appreciated! We are interested in your uninfluenced judgement and decision-making.

During the experiment you are therefore not allowed to talk to other participants, look at other participants' screens, use the internet, and use personal devices (mobile phones, pocket calculators, etc.) If you violate any of these rules, you will be excluded from the experiment without pay.

Please click on "continue".

[Tutorial A - Screen 2]

Software

This experiment runs on a standard internet browser. Please do not click on any browser buttons. This would cause a crash of the experiment on your computer.

At certain points during the experiment, you will have to enter a number.

The software only allows full numbers (integers). For example, you cannot enter "4999.75" – you would have to round it to "5000".

The software does not allow the use of points or commas. The input "5000" would be allowed. Inputs like "5,000" or "5000.00" are not allowed.

There is no "Back" button in this experiment. Once you click to "continue", you cannot go back to the previous screen!

Therefore, it is strictly required to carefully read and comprehend all instructions on the current screen.

If you have any questions, please raise your hand. The experimenter will immediately come and help you.

Please click on "continue".

[Tutorial A - Screen 3]

Decision situation

Please put yourself into the follow scenario:

Today, you have 10000 monetary units (MU).

You have to decide how many monetary units you want to keep for today, and how many monetary units you want to invest into a long-term investment products.

In the different investment rounds, investment products will differ by their expected returns and their risk-levels.

The investment horizon in this experiment is 10 years.

You will be told about all these parameters before you have to make your decision.

Please click on "continue".

[Tutorial A - Screen 4]

How you are paid

The investment product is risky.
That is, the future payoff that you receive back from your investment can be higher than the amount of monetary units (MU) that you have initially invested, but it can also be lower.
The amount of MU that you keep for today (i.e., the amount of monetary units that you don't invest) is certain and unaffected by the development of the investment product.
Of course, the amount of MU that you keep for today and the amount of monetary units that you invest into the long-term investment product always sum up to 10000 MU.
Please click on "continue".

[Tutorial A - Screen 5]

How you are paid

Inflation
One factor that has to be considered when dealing with long investment horizons is inflation.
Inflation describes the effect that the prices of goods and services increase over time.
An example: Let's assume that 1 apple costs 1 monetary unit (MU) today. For an inflation rate of 2% per year, the price of 1 apple will be:
1 MU * $(1.02)^1$ = 1.0200 MU after 1 year.
1 MU * $(1.02)^2$ = 1.0404 MU after 2 years.
1 MU * $(1.02)^3$ = 1.0612 MU after 3 years.
If you have 1000 MU today, you can buy 1000 apples with that money today. Due to inflation, the amount of apples that you can buy with a fixed amount of 1000 MU decreases to:
1000 MU / 1.0200 MU ≈ 980 apples after 1 year
1000 MU / 1.0404 MU ≈ 961 apples after 2 years.
1000 MU / 1.0612 MU ≈ 942 apples after 3 years
Please click on "continue".

[Tutorial A - Screen 6]

How you are paid

Inflation in this experiment
In this experiment, consumption opportunities are measured in consumption units (CU).
Today, 1 CU costs 1 monetary unit (MU).
Due to inflation, the price of one CU will increase over time.
Consequently, the amount of CU that you can buy with a fixed amount of MU will decrease over time.
Please click on "continue" to see an example.

[Tutorial A - Screen 7]

How you are paid

Inflation in this experiment

Today, 1 consumption unit (CU) costs 1 monetary unit (MU). For an inflation rate of 2% per year, the price of 1 CU will be:
1 MU * $(1.02)^1$ = 1.0200 CU after 1 year.
1 MU * $(1.02)^2$ = 1.0404 CU after 2 years.
1 MU * $(1.02)^3$ = 1.0612 CU after 3 years.
For example, if you have 1000 MU today, you can buy 1000 CU with that money today. Due to the price increase of one CU over time, the amount of CU that you can buy with a fixed amount of 1000 MU decreases to:
1000 MU / 1.0200 MU ≈ 980 CU after 1 year
1000 MU / 1.0404 MU ≈ 961 CU after 2 years.
1000 MU / 1.0612 MU ≈ 942 CU after 3 years
Please click on “continue”.

[Tutorial A - Screen 8]

How you are paid

For each consumption unit (CU) that you are able to buy today and at the end of the investment horizon, you will be paid 0.001€ of real money after the experiment.
Please note: All information that is relevant for your decision (inflation rate, investment horizon, possible payoffs of the investment) will be told to you before you will have to make your decision.
Please click on “continue” to see some examples.

[Tutorial A - Screen 9]

How you are paid

If you are able to buy 5000 consumption units (CU) today and 8000 CU at the end of the investment horizon, you will receive (5000 CU + 8000 CU)*0.001€/CU = 13.00€
If you are able to buy 8000 CU today and 5000 CU at the end of the investment horizon, you will receive (8000 CU + 5000 CU)*0.001€/CU = 13.00€
Please click on “continue”.

[Tutorial A - Screen 10]

Summary: How you are paid

Today, you have 10000 monetary units (MU).
You have to decide how many MU you want to keep for today, and how many MU you want to invest into a risky long-term investment product to receive a MU-payoff in the future.
The future MU-payoff from your investment may be higher than the amount of MU that you have initially invested, but it may also be lower.
All MU that you keep for today (that is, all monetary units that you don't invest) will be immediately spent for consumption today.
All MU that you receive back from your investment at the end of the investment horizon will be spent for consumption at this point of time.
Consumption opportunities are measured in consumption units (CU).
Please click on "continue".

[Tutorial A - Screen 11]

Summary: How you are paid

Today, you can buy 1 consumption unit (CU) with 1 monetary unit (MU).
Inflation increases the price of CU over time.
In the future, the price of 1 CU will be 1 MU*$(1+i)^T$. (i denotes the annual rate of inflation and T denotes the number of years from today).
In other words: In the future, you can only buy $1/(1+i)^T$ CU with 1 MU.
For every CU that you are able to buy today or at the end of the investment horizon, you will receive 0.001€ of real money.
Please click on "continue" to start with some check-up questions.

[Tutorial A - Screen 12]

Check-up question 1

Assume that you have kept 3000 monetary units (MU) for today. How many MU have you invested into the investment product?

(a) 3000 MU

(b) 7000 MU

(c) You cannot say, there is missing information.

(d) None of the above

[Tutorial A - Screen 13]

Check-up question 2

Assume that you have kept 3000 monetary units (MU) for today. How many consumption units (CU) can you buy today with that money?

(a) Less than 3000 CU.

(b) Exactly 3000 CU.

(c) You cannot say, it depends on the inflation rate.

(d) None of the above.

[Tutorial A - Screen 14]

Check-up question 3

Assume that you have invested 7000 monetary units (MU) into the investment product. How many consumption units (CU) can you buy at the end of the investment horizon?

(a) Less than 7000 CU.

(b) Exactly 7000 CU.

(c) More than 7000 CU.

(d) You cannot say, there is missing information.

[Tutorial A - Screen 15]

Check-up question 4

Assume that you have invested 7000 monetary units (MU) into the investment product. How many consumption units (CU) can you buy at the end of the investment horizon?

(a) It depends on the return of the investment product.

(b) It depends on the inflation rate.

(c) It depends on the investment horizon.

(d) It depends on all three.

(e) None of the above.

[Tutorial A - Screen 16]

Check-up question 5

Assume that you receive 12000 monetary units (MU) from your investment at the end of the investment horizon (10 years). In which scenario can you buy the most consumption units (CU) at the end of the investment horizon?
(a) The inflation rate is 0%.
(b) The inflation rate is 2%
(c) The inflation rate is 4%
(d) You cannot say, there is missing information.

[Tutorial A - Screen 17]

Check-up question 6

Assume that you have kept 3000 monetary units (MU) for today and that you have invested the remaining 7000 MU into the investment product. At the end of the investment horizon, your investment yields a payoff of 8880 MU, with which you can buy 6000 consumption units (CU) then. What is your total payoff in this example?
(a) 3.00€.
(b) 6.00€.
(c) 7.00€.
(d) 8.88€.
(e) 9.00€.
(f) 10.00€.
(g) 11.88€.
(h) You cannot say, there is missing information.

[Tutorial A - Screen 18]

How to use the software

Please click on “Continue”.

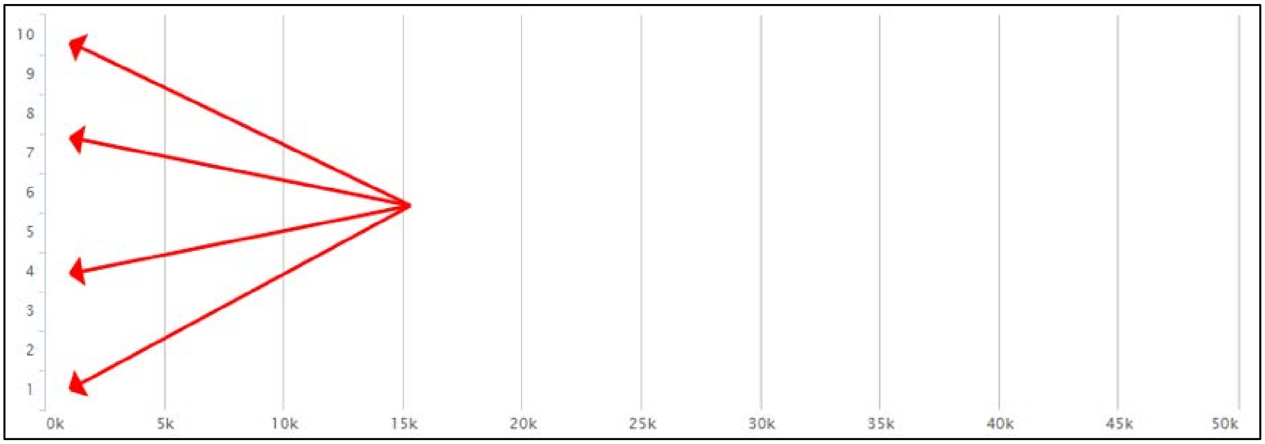
[Tutorial A - Screen 19]

How to use the software

Each investment product can yield one out of 10 possible returns.
Each return will have the same probability of occurrence (that is, 10%).
To determine which of the 10 possible returns will occur, you will draw a numbered ping-pong ball out of the urn after the experiment (number 10=highest return, number 1=lowest return).
Please click on “continue”.

[Tutorial A - Screen 20]

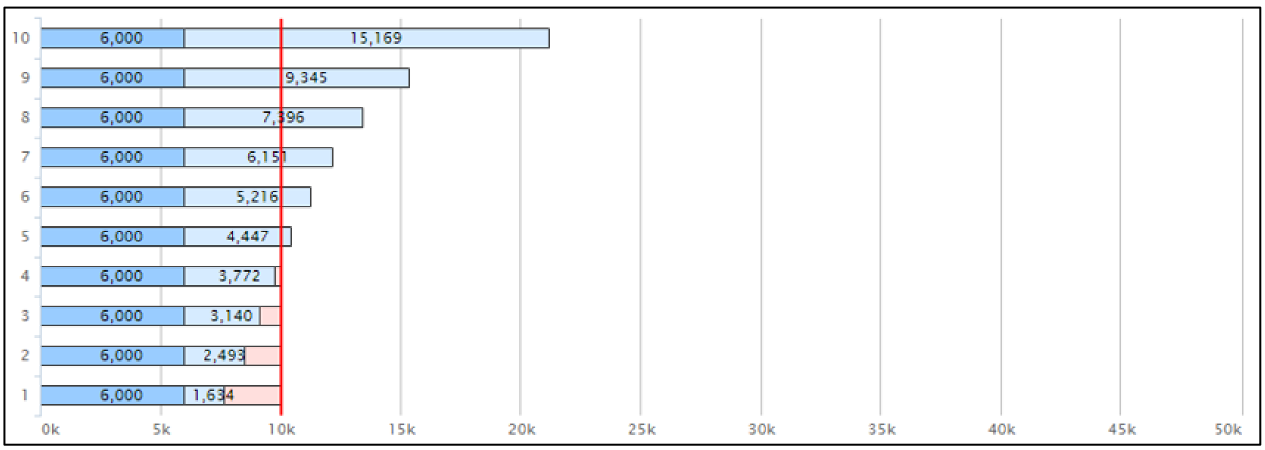
How to use the software



At the end of the investment horizon, your investment can yield 10 possible payoffs (1-10).
All 10 payoffs have the same probability of occurrence (that is, 10% each).
Please click on "continue".

[Tutorial A - Screen 21]

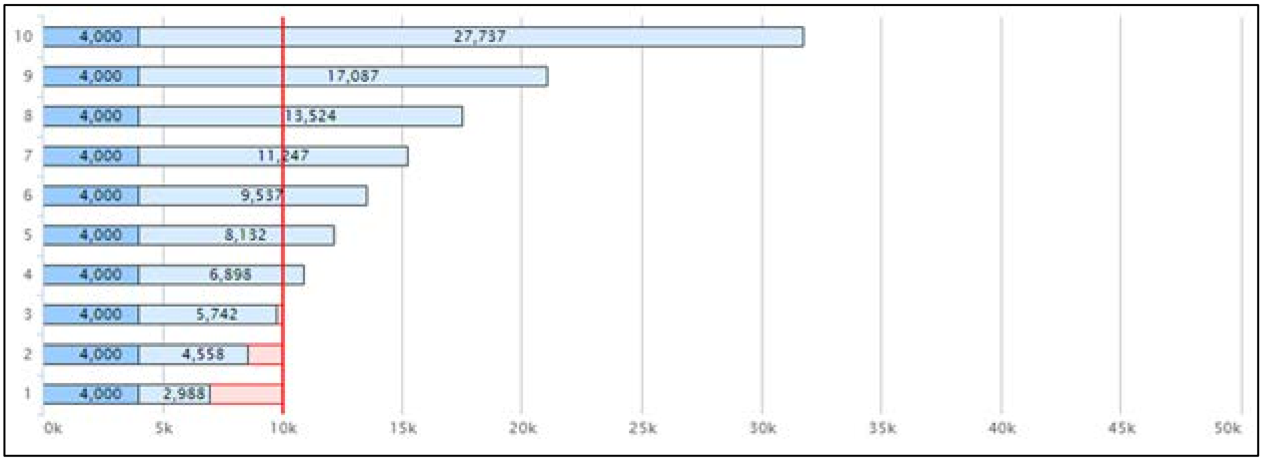
How to use the software



The dark-blue bars represent the amount of monetary units (MU) that you keep for today (5000 MU in this example). This amount is unaffected by the outcome of the investment product.
The remaining 5000 MU are invested into the investment product. The light-blue bars represent the 10 possible payoffs at the end of the investment horizon from your 5000 MU investment.

[Tutorial A - Screen 22]

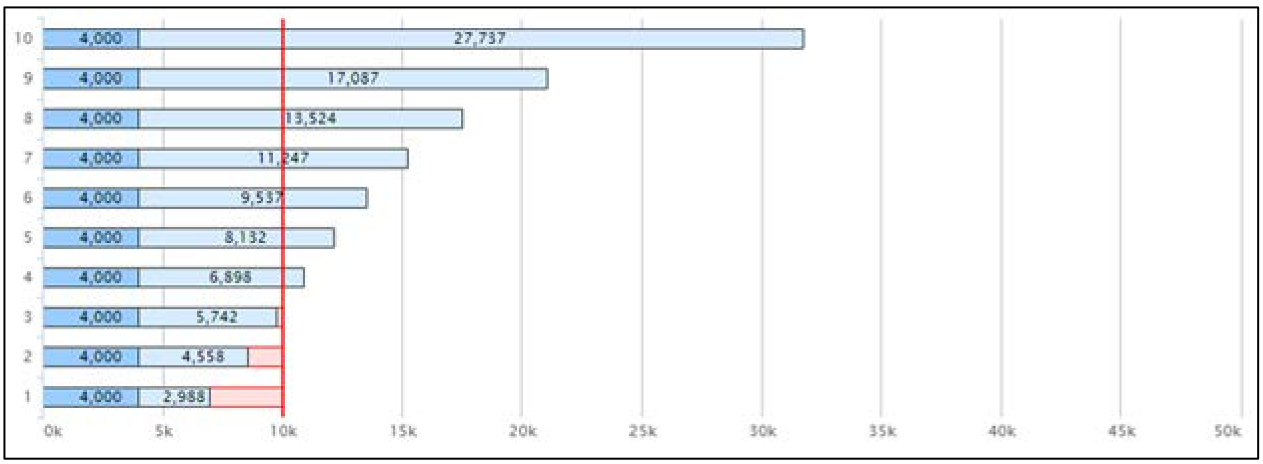
How to use the software



In this example, you keep 4000 monetary units (MU) for today (dark-blue bars). Accordingly, you invest 6000 MU into the investment product. In the graph, these 6000 MU are indicated by the distance between the end of the dark-blue bars (at 4000 MU) and the red line, which indicates your initial wealth of 10000 MU.

[Tutorial A - Screen 23]

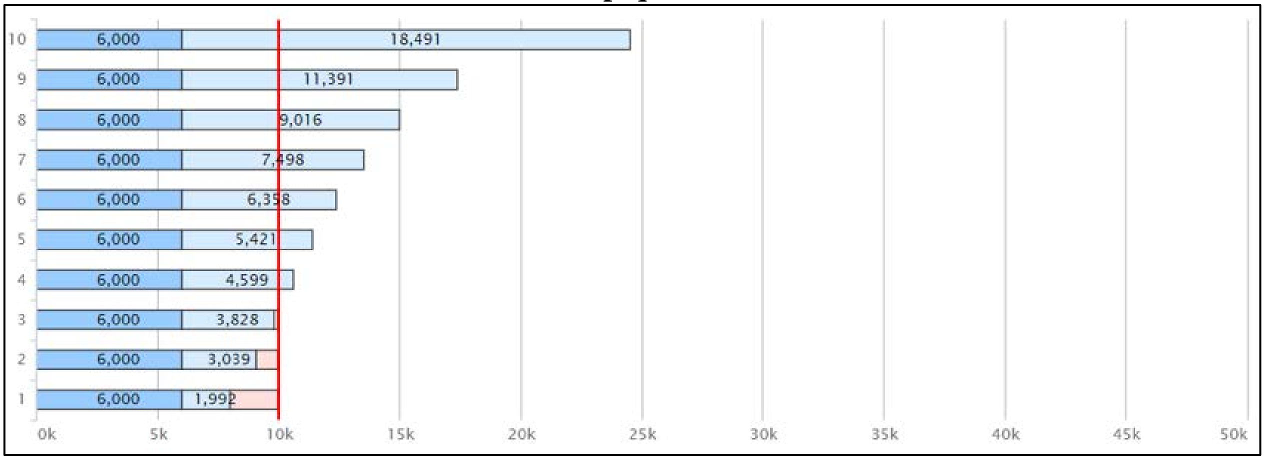
How to use the software



In this example, the future payoffs from investing 6000 monetary units (MU) range between 27737 MU (state 10) and 2988 MU (state 1). If the investment product yields state 10 at the end of the investment horizon, you make a gain of (27737 - 6000) = 21737 MU. If the investment product yields state 1, you make a loss of (2988 - 6000) = -3012 MU.

[Tutorial A - Screen 24]

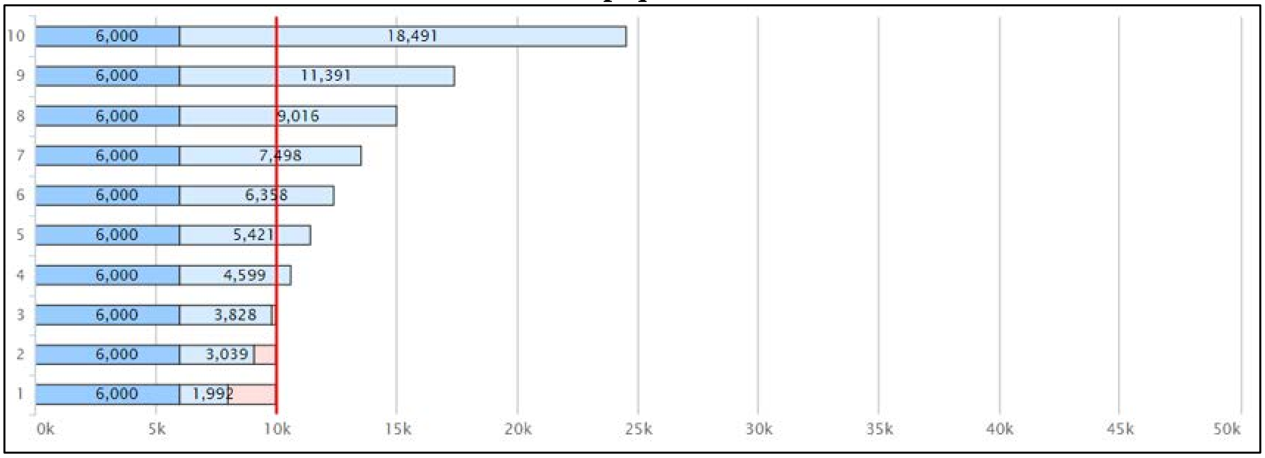
Check-up question 7



In this example, you keep <textbox> monetary units (MU) for today and you invest <textbox> MU into the investment product.

[Tutorial A - Screen 25]

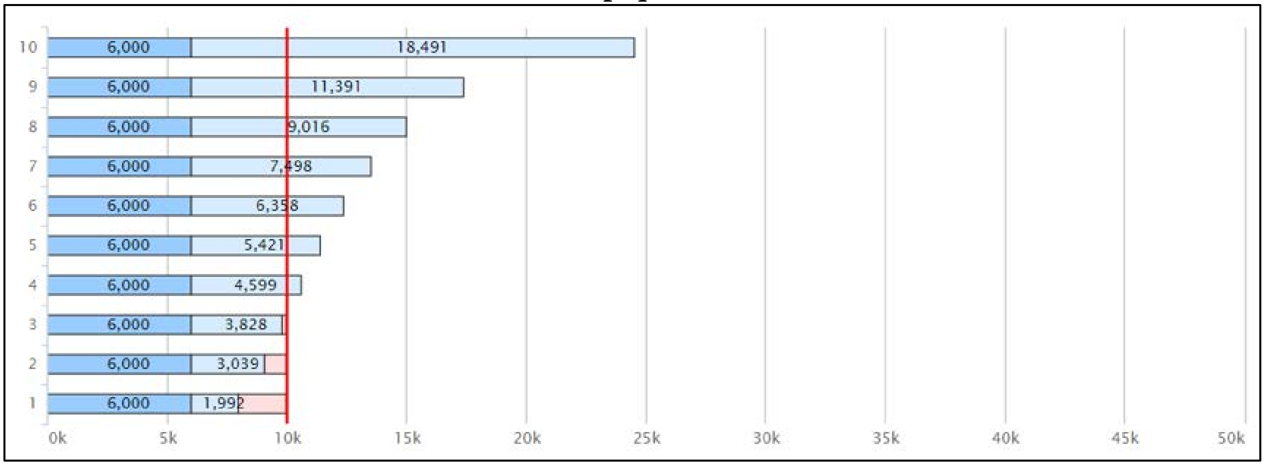
Check-up question 8



In this example, the highest possible payoff from your investment is <textbox> MU. The lowest possible payoff from your investment is <textbox> MU.

[Tutorial A - Screen 26]

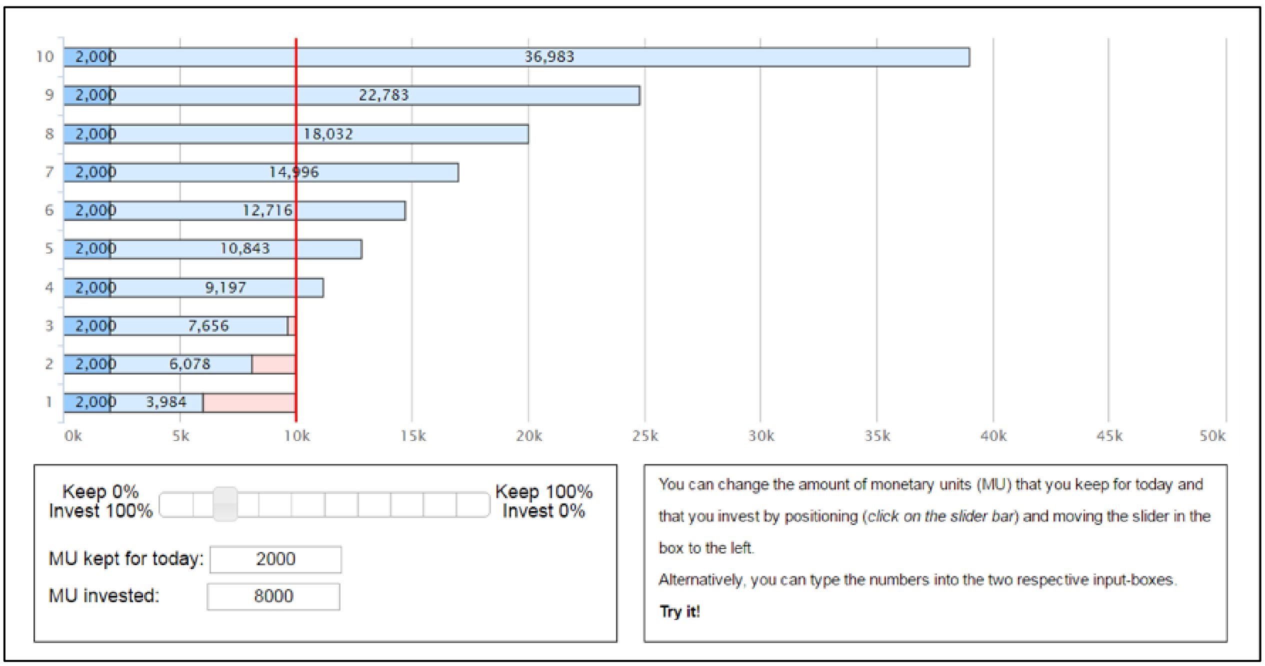
Check-up question 9



The most probable payoff from the investment product amounts to:
(a) 18,491 MU
(b) 6,358 MU
(c) 1,992 MU
(d) You cannot say, there is missing information.

[Tutorial A - Screen 27]

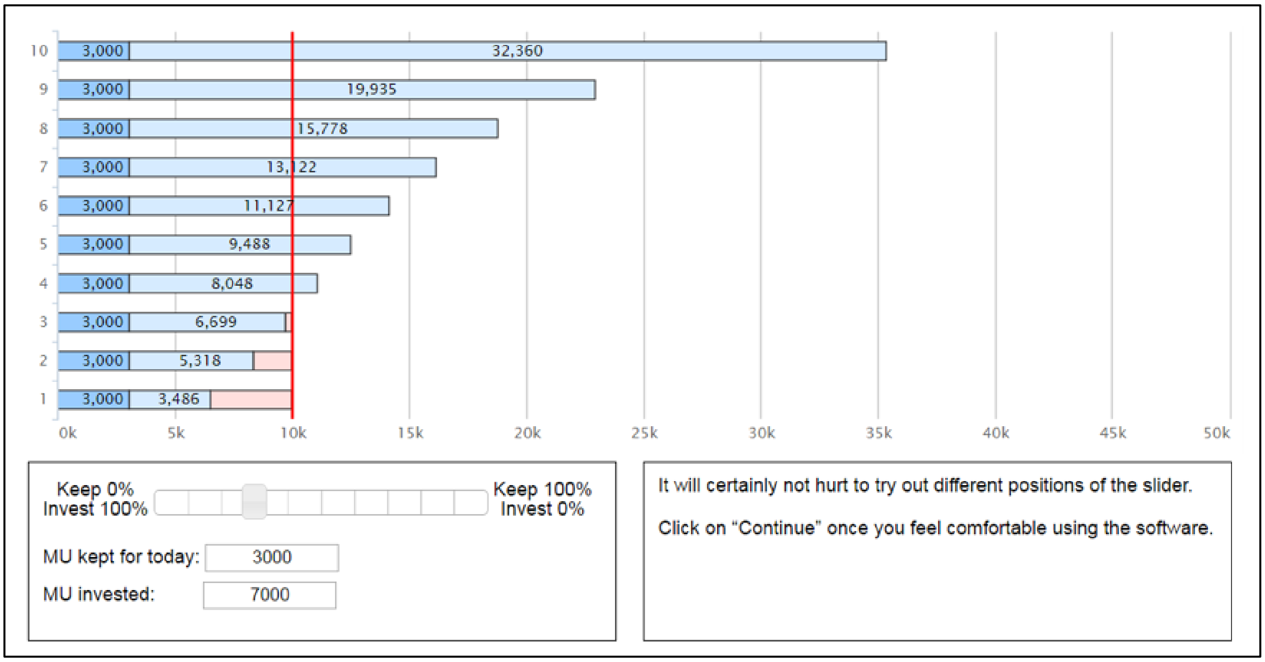
How to use the software



[Tutorial A - Screen 28]

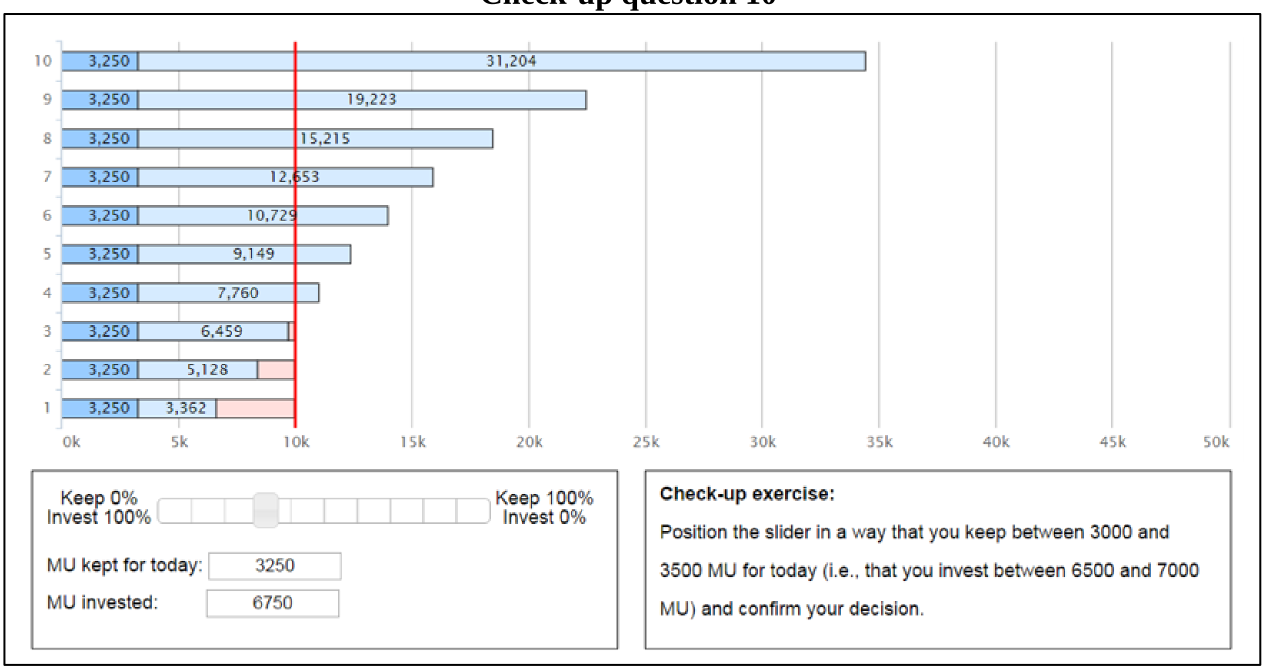
[Participants could only continue after 30 seconds to motivate diligent experimentation.]

How to use the software



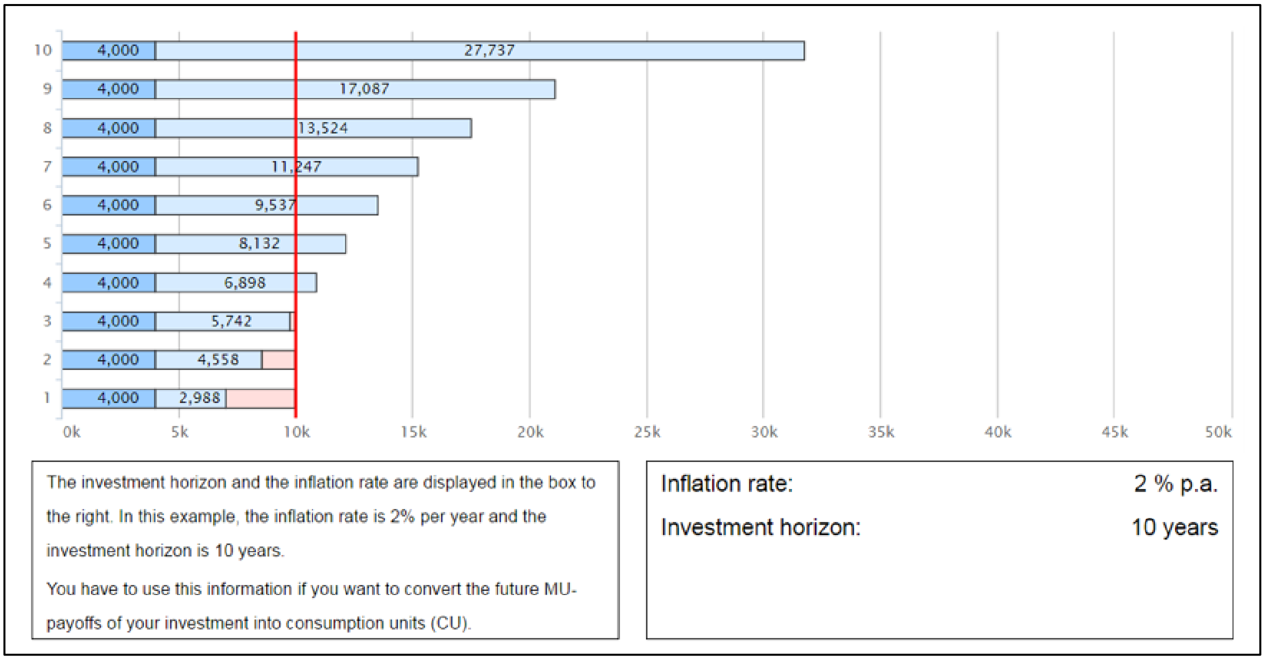
[Tutorial A - Screen 29]

Check-up question 10



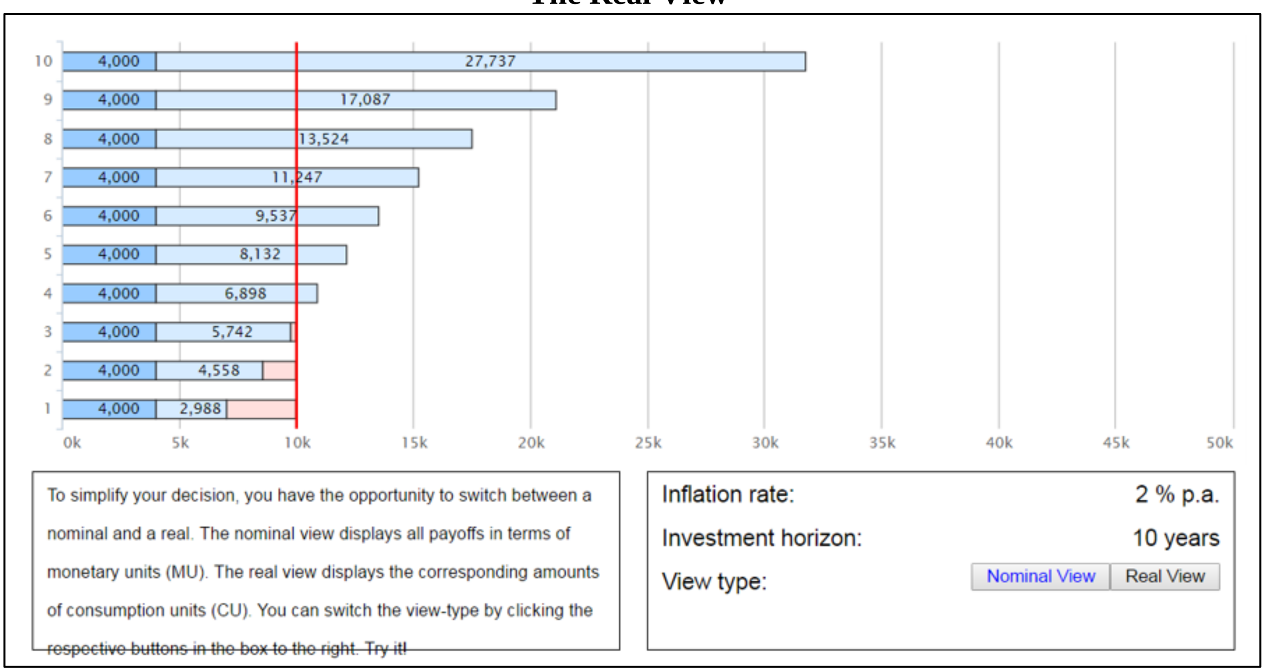
[Tutorial A - Screen 30]

How to use the software



[Tutorial A - Screen 31]
[Only in the hybrid treatment.]

The Real View



[Tutorial B - Screen 1]
[Only in the nominal treatment.]

Introduction

Uncertain inflation rate
In this investment task, the annual rate of inflation is uncertain.
In particular, the inflation rate can take a low value or a high value here.
Which inflation rate occurs will be randomly determined by the computer after the experiment.
The probability that the low inflation rate or the high inflation rate will occur is 50% each.
Please click on “continue” to start.

[Tutorial B - Screen 1]
[Only in the hybrid treatment.]

Introduction

Uncertain inflation rate
In this investment task, the annual rate of inflation is uncertain.
In particular, the inflation rate can take a low value or a high value here.
Which inflation rate occurs will be randomly determined by the computer after the experiment.
The probability that the low inflation rate or the high inflation rate will occur is 50% each.
You can use the “Switch view-type”-buttons to switch between the nominal view, the real view with the low inflation rate, and the real view with the high inflation rate.
Please click on “Continue” to start.