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An Experimental Study of Money Illusion in Intertemporal Decision Making

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Abstract

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Abstract

To examine the degree to which price fluctuations affect how individuals approach an intertemporal decision-making problem, we conduct a laboratory experiment in which subjects spend their savings on consumption over 20 periods. In the control treatment, the commodity price is constant across all periods. In the small (large) price-fluctuation treatment, the price rate of change is always 1% (20%), and the rate of change of savings is always the same as the commodity price. Therefore, the optimal amount of consumption is the same in all three treatments. Our main findings are threefold. First, the magnitude of misconsumption (i.e., the deviation from optimal consumption) is significantly high in order of the control, small price-fluctuation, and large price-fluctuation treatments. Second, in the control treatment, the magnitude of misconsumption shrinks over time, whereas it gradually increases in the small and large price-fluctuation treatments. Finally, regardless of the presence of price fluctuations, subjects exhibit under-consumption (over-saving) behavior, and the presence of price

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JEL Classification: C91, D91, E31

1. Introduction

Much research has been devoted to examining how people approach intertemporal decision-making (IDM) problems. IDM is a key formulation of dynamic models in financial theory, operation research, game theory, and micro- and macroeconomic theory, within which agents are usually assumed to be unboundedly rational and able to solve dynamic programming problems. However, the results of previous studies of experiments on IDM suggest that individuals are unable to correctly obtain the optimal strategy even though they try to solve complex decision problems rationally (Johnson et al. 1987, Hey and Dardanoni 1988; Anderhub et al. 2000; Carbone and Hey 2001; Houser and Winter 2004; Hey and Knoll 2011). Furthermore, the mistakes made by subjects are systematic, and they seem to adopt some heuristics or rules-of-thumb for dynamic problems. For example, Johnson et al. (1987) conducted a series of experiments associated with a lifecycle model and found that most subjects exhibit over-saving behavior. Carbone and Hey (2001) found in their fairly easy dynamic decision problem that many subjects were using backward induction and ignoring the fact they would be behaving optimally thereafter[1]. Thus, an increasing number of researchers have modeled bounded rationality in dynamic decision problems (Lettau and Uhlig 1999; Allen and Carroll 2001; Winter et al. 2011; Binswanger 2011, 2012).

The purpose of this study is to investigate how price fluctuations influence individuals' choices in an intertemporal consumption/savings problem. In real life, people fail to optimize IDM not only because such problems are complex but also because most transactions are in nominal terms and prices are not always constant; in other words, people may suffer from "money illusion." The concept of money illusion refers to the tendency for people to make economic decisions based on nominal rather than real monetary values. Money illusion has long been recognized (Fisher 1928) and is often mentioned to explain economic phenomena such as the rigidity of nominal prices and wages. To date, substantial proof on the existence of money illusion has been reported by experimental studies (Kahneman et al. 1986; Shafir et al. 1997; Thaler et al. 1997; Fehr and Tyran 2001, 2007; Svedsäter et al. 2007; Noussair et al. 2012), and its influence on the economy cannot therefore be disregarded.

This study explores whether money illusion influences intertemporal

[1] Some authors classify the types of strategies that seem to be applied in a dynamic decision problem. For example, Hey and Knoll (2011) showed that backward workers who derive (or try to derive) an optimal strategy using backward induction constitute 31% of the sample, forward workers who seem to ignore the fact that they are going to take decisions in the future account for 34% of the sample, and the others seem to operate with no strategy at all or randomly.

consumption/savings problems. Because the nominal terms that people face change over time in association with price fluctuations, how do these changing nominal terms influence individuals' consumption/savings behavior? Do the trend or volatility of price fluctuations interfere with individuals' learning for real values of transactions or affect the individuals' welfare? This study investigates these questions using a laboratory experiment.

Although experimental studies of money illusion have shown that nominal frames often influence individuals' decisions, the underlying decision problems in most of these works are static or a repetition of a static problem in which the nominal frame changes only once. For example, in the experiment of Fehr and Tyran (2001), a price-setting game is repeatedly played by subjects. They showed that after a monetary shock, the average price converges to the equilibrium more slowly when the game is presented in a nominal frame than in a real frame. However, this difference does not appear if all opponents are computer programs; in other words, money illusion does not matter in a repeated static problem without strategic interactions. An exception is the experiment of Noussair et al. (2012), in which subjects repeatedly played a continuous double auction by trading shares. Further, subjects' stock of shares carried over from one trading period to the next, meaning that they intrinsically faced an IDM problem. However, their research focused on aggregate market behavior rather than on individual behavior, and they showed that real asset market prices increase after a monetary deflationary shock, while they are unaffected by a monetary inflationary shock. Moreover, as shown by Fehr and Tyran (2001), because of the indirect effect of money illusion, the fact that a monetary shock affects games with strategic interaction does not necessarily imply that it influences IDM problems[2]. Thus, the question of how ongoing price fluctuations affect individual behavior in IDM problems remains.

Our study is based on an economic experiment in which subjects face a simple IDM problem with a lifetime of 20 periods. At the beginning, a subject possesses $40{,}000$ points (experimental currency units) in his/her savings account to spend during these 20 periods (hereafter, we use "his" for simplicity). Additional money is not credited to a subject's account. In each period, he can spend his savings to buy only one commodity. His overall payoff is the sum of an instantaneous payoff, which is given by the square root of the consumption amount. The commodity price in the first period is 80 points.

[2] Fehr and Tyran (2001) divided the effects of money illusion into direct and indirect effects. The direct effects of money illusion directly result from individual optimization mistakes, whereas the indirect effects arise because some agents expect others to be prone to money illusion, and they behave differently as a result. Following this classification, our research focuses only on the direct effects of money illusion.

Over time, the subject's savings and commodity price change at the same rate. In any period, subjects do not directly choose the *amount of* the commodity but rather their *expenditure on* it. In our experiment, price fluctuations are irrelevant to the budget set and there is no uncertainty in the payoffs.

We conducted three treatments. In the control treatment, price is constant across all periods. In the other two treatments, price and savings fluctuate over time. In both these treatments, price increases, decreases, or does not change at the beginning of each period. Each of these events occurs with an equal probability. In the small and large price-fluctuation treatments, the rate of change is always 1% and 20%, respectively. Because the subject's savings and commodity prices change at the same rate, the optimal amount of consumption is the same in all three treatments.

Findings based on our data are threefold. First, the magnitude of the deviation from optimal consumption in all periods is significantly high in order of the control, small price-fluctuation, and large price-fluctuation treatments. Thus, price fluctuations influence individuals' optimization regardless of their size. In other words, money illusion matters in IDM problems, and this effect is significant if the price fluctuations are sufficiently large. Then, the actual payoffs of subjects in the control treatment are significantly higher than those in the large price-fluctuation treatment. Second, in the control treatment, the magnitude of deviation from the optimal consumption gradually decreases over time. On the contrary, in the small and large price-fluctuation treatments, it gradually increases until the end of the 20th period. Finally, regardless of the presence of price fluctuations, subjects purchase only a small quantity compared with the optimal amount. In other words, subjects display under-consumption (over-saving) behavior in line with the findings of Johnson et al. (1987). Furthermore, we find that price fluctuations strengthen the tendency toward such behavior.

The rest of the paper is organized as follows. In Section 2, we describe our experimental design. In Section 3, the experimental results are presented. In Section 4, we summarize and interpret our results.

2. Experiment

2.1. Experimental design and procedure

We consider a simple IDM problem with a lifetime of 20 periods. At the beginning, a subject possesses $40{,}000$ points (experimental currency units) in his savings account to spend during these 20 periods. Additional money is not credited to his account. In each period, he can spend his savings to buy only one commodity. Let x_t be the amount of the commodity purchased in period t; then, his payoff function is given by

$$\sum_{t=1}^{20} \sqrt{x_t}.$$

The instantaneous payoff $\sqrt{x_t}$ is a constant relative risk-aversion utility function with a coefficient of $1/2$. The discount rate is always 1 and the money that remains after period 20 is irrelevant to his payoff. This setup is similar to the experimental design in Anderhub et al. (2000). Unlike the present study, however, their experiment was based on a dynamic decision problem with an uncertain time horizon: subjects had to allocate a given monetary amount over an uncertain number of periods. The introduction of uncertainty complicates the optimization problem dramatically. Instead of introducing price fluctuations to this model, we therefore exclude uncertainty in order to simplify the calculation of the subject's optimal consumption as much as possible.

The experimental design consists of three treatments. Regardless of the treatment, the commodity price in the first period is 80 points; both the subject's savings remain in his account and the commodity price change at the same rate over time. In the control treatment, denoted by C, price is constant across all periods. In the large (small) price-fluctuation treatment, denoted by L (S), price increases by 20% (1%), decreases by 20% (1%), or is unchanged at the beginning of each period. Each event occurs with an equal probability. Because price and savings always change at the same rate, price fluctuations are irrelevant to the budget of a subject and are therefore irrelevant to his optimal consumption. Thus, all treatments differ only in their nominal terms, and actual consumption in L and S should be the same as that in C if a subject makes decisions based only on real monetary values. Because there is no uncertainty in the payoffs, the risk attitude of subjects should not affect their decisions.

It is easy to see that the sequence $(x_t)_{t=1}^{20}$ of consumption, in which $x_t = 25\,(= 40000/(20 \times 80))$ for any t, maximizes a subject's overall payoff. However, once a subject's consumption deviates from such optimality, this consumption sequence is no longer optimal for the remaining periods. Let p_t and M_t be the commodity price and amount of money remaining in his savings account in period t, respectively. Then, in any period T, the payoff in the remaining periods, that is, $\sum_{t=T}^{20} \sqrt{x_t}$, is maximized by the sequence $(x_t)_{t=T}^{20}$ of consumption, in which

$$x_t = x(m_T) = \frac{m_T}{(20 - T + 1)}$$

for all t, where $m_T = M_T/p_T$ is the real value of savings in period T. Optimal consumption does not depend on any nominal variables, including future prices.

Our experiment was conducted at Takasaki City University of Economics. We recruited subjects by displaying posters and distributing fliers. They were undergraduate students from several departments at the university that had not participated in any prior IDM experiments; furthermore, each subject could only participate in one treatment. All treatments were conducted in the same laboratory, and each computer terminal in the laboratory was assigned a computer program associated with one of the treatments. Subjects were seated in front of a computer terminal at random. Each desk had a calculator and an envelope containing all the experimental materials, including the instructions, a recording sheet, and an identification number. The total number of subjects who participated in (i.e., assigned a computer terminal with) treatment C was 20, that in treatment S was 21, and that in treatment L was 23.

Each subject was asked to carefully read the instructions, which provided all the information about the structure of the treatment to which they had been allocated, including the price distribution[3]. Before the actual experiment began, subjects were told to solve the practice problems in order to confirm their understanding of the instructions for the experiment. The problem set contained a simple IDM problem with two periods and without price fluctuations. No subject could begin the actual experiment unless all problems had been answered correctly.

In each period in the actual experiment, each subject was asked to input his expenditure on the commodity for the current period. In other words, subjects did not choose the amount of commodity x_t directly but rather chose expenditure on the commodity, $p_t x_t$[4]. On the computer screen, each subject could always observe the amount of money he currently held in his savings account, the current commodity price, and the percentage price change from the previous period. Past consumption and expenditure were also displayed on the screen. Once the expenditure for the current period had been inputted, the next period automatically began.

The decision-making time was not restricted. Therefore, the session duration differed by participant but was approximately 1 hour for most subjects. After the experiment,

[3] The detailed experimental procedure and instructions are presented in Appendix.

[4] While the nominal variables do not affect optimal consumption, they do affect optimal expenditure, which is given by $p_t x(m_t)$ in period t.

each subject was asked to answer a questionnaire. One point was converted into 14 yen, and a cash reward was paid to each subject privately.

2.2. Hypotheses

Our analysis focuses on the difference between actual and optimal consumption (hereafter misconsumption) in each treatment. For treatment $\mathrm{A} \in \{\mathrm{C}, \mathrm{L}, \mathrm{S}\}$, let D_t^A be the misconsumption in period t in treatment A and let $|D_t^A|$ be its absolute value. Because optimal consumption $x(m_t)$ in period t is the same for all treatments, D_t^A can be written as

$$D_t^A = x_t^A - x(m_t),$$

where x_t^A is actual consumption in period t in treatment A. We focus on $|D_t^A|$ when analyzing the magnitude of misconsumption and on D_t^A when analyzing its direction.

The impact of price fluctuations throughout all periods can be measured by the difference in $|D_t^A|$ in the entire study period between C and L, or between C and S. Thus, we test the following hypothesis that price fluctuations do not affect subjects' behavior on average:

Hypothesis 1 (Money illusion does not matter on average)

$$\sum_{t=1}^{20} (|D_t^H| - |D_t^C|) = 0, and \sum_{t=1}^{20} (|D_t^L| - |D_t^C|) = 0.$$

We also analyze the round effects of price fluctuations in each treatment. $|D_t^A|$ approaches 0 if a subject learns the optimal solution over time. The subject does not face the same static decision problem repeatedly. However, the problem faced becomes easier over time, because the end of the periods is certain. In the last period, for the extreme case, optimal consumption simply implies spending all the remaining money. Therefore, we test the following hypothesis:

Hypothesis 2 (Learning optimal consumption)

$|D_t^A|$ is a decreasing function of t, and it converges to 0 for any $\mathrm{A} \in \{\mathrm{C}, \mathrm{L}, \mathrm{S}\}$.

As mentioned in Introduction, previous studies of IDM experiments have shown that deviations from the optimal solution of subjects' behavior are not random but rather systematic. Thus, we also test this observation in our experiment by formulating the following hypothesis:

Hypothesis 3 (Deviations from the optimal solution are random)

$$\sum_{t=1}^{20} D_t^A = 0 \text{ for any A } \in \{\mathrm{C}, \mathrm{L}, \mathrm{S}\}.$$

The subjects in our experiment can make mistakes in two ways, namely under-consumption (over-saving), that is, $D_t^A < 0$, or over-consumption (under-saving), that is, $D_t^A > 0$. In each treatment, if their misconsumption does not tend toward either mistake, this hypothesis should be supported.

3. Results

This section discusses the laboratory experiment results. To test these hypotheses with regard to money illusion, we compare the results of the three treatment groups. The total number of observations in our experiment is 1,280 (=(20+21+23)×20), because each subject makes a decision over 20 periods and the number of subjects is 20, 21, and 23 in C, S, and L, respectively. Among the observations, some subjects always make extraordinary decisions because they may not understand the experiment. To avoid such extraordinary behaviors potentially influencing the results, from the sample of 64 subjects, we drop 2 subjects whose decisions were all in the 95 percentile. In addition, observations for the 20th period are excluded, because subjects easily choose to consume their remaining points without considering/calculating their optimal consumption. Consequently, 1,178 observations are used for our analysis.

3.1. Tests for Hypotheses 1 and 2

We first focus on the magnitude of misconsumption $|D_t^A|$. To illustrate all results for $|D_t^A|$, Figure 1 presents the distributions for each treatment. The number of observations, means, and standard deviations for each treatment are also presented in this figure. It is found that many subjects have small misconsumption that approaches 0. However, in the comparison among the three treatments, the fractions of subjects with small misconsumption in C and S are larger than that in L. The order of the magnitude of the means is mean (C) < mean (S) < mean (L), which implies that subjects facing high price fluctuations are likely to misconsume the commodity.

Insert

<Figure 1. Distribution of the absolute value of misconsumption>

The mean transitions of the absolute values of misconsumption by treatment are presented in Figure 2. The transition of C is represented as circular markers, while the transitions of the S and L treatments are represented using diamond and triangular markers, respectively. We find that the features of these transitions differ. In earlier periods, there is no large gap among the transitions, whereas the absolute value of the misconsumption in the L treatment is larger than those of the other two after the 6th period. Toward the end of the study period, the absolute values of the misconsumption of S and L are larger than that of C. We test these observations in the following econometric analysis.

Insert

<Figure 2. Transitions of the absolute values of misconsumption>

We regress the treatment dummies on the absolute value of misconsumption and control for other variables that may affect subjects' intertemporal decisions, such as individual characteristics. Let T_{Si} and T_{Li} be dummy variables that take a value of 1 if subject i is assigned to S and L, respectively. The period is written as R_t, which is a scale variable that takes values of 1 to 19. $\boldsymbol{X}_i$ is a control variable vector for capturing subject i's characteristics that affect misconsumption. In order to obtain subjects' characteristics, a questionnaire survey was conducted at the end of each laboratory experiment. To control for unobserved heteroscedastic effects, the individual fixed effect μ_i is incorporated. The idiosyncratic error term is represented as ε_{it}. The models for testing the former two hypotheses are written as follows:

$$\ln(|D_{it}|) = \boldsymbol{X_i A'} + a_1 T_{Si} + a_2 T_{Li} + a_3 R_t + \mu_i + \varepsilon_{it} \cdots (1)$$

$$\ln(|D_{it}|) = \boldsymbol{X_i B'} + b_1 T_{Si} + b_2 T_{Li} + b_3 R_t + b_4 R_t T_{Si} + b_5 R_t T_{Li} + \mu_i + \varepsilon_{it} \cdots (2)$$

where vector $\boldsymbol{A}$, vector $\boldsymbol{B}$, a_k $(k = 1, \dots, 3)$, and b_k $(k = 1, \dots, 5)$ are the parameters to be estimated. The estimations of Equations (1) and (2) aim to test Hypotheses 1 and 2, respectively. If insignificant $\hat{a}_1$ and $\hat{a}_2$ (estimated coefficients) are observed by estimating Equation (1), Hypothesis 1 is supported. Otherwise, money illusion matters on average in terms of individual IDM. To test the learning effects (Hypothesis 2), we add the interaction terms of S, L, and periods $R_t T_{1i}$ and $R_t T_{2i}$ as explanatory variables in Equation (2), and we check the magnitude and significance of the estimated $\hat{b}_4$ to $\hat{b}_5$. If the learning behaviors differ among treatments, the relations $\hat{b}_4 \neq 0$ and $\hat{b}_5 \neq 0$ are verified[5]. Figure 1 indicates that the absolute values of misconsumption are highly skewed. To avoid such skewness, logarithmic transformation is frequently used. However, the zero-value problem arises in performing the transformation, because 135 observations (11.5%) have a zero value. Therefore, we add 10^{-16} to the absolute value of misconsumption and then convert it into a logged variable (i.e., $\ln(D_{it} + 10^{-16})$), similar to the approach taken by Kahn (2005)[6].

The descriptive statistics for the explanatory variables are shown in Table 1. The variables Male, Faculty, and Alone are dummies that take a value of 1 if subjects are men, if they belong to the Faculty of Economics, and if they live on their own, respectively[7]. Instead of Age, unlike most studies, we use Grade to represent respondents' grade, which takes a value of 1 to 4. In optimal decision making, rationality is a key issue. People who like mathematics may be likely to choose optimal consumption. We therefore ask them the extent to which they like mathematics (Favorite for Math), which is a scale variable with five levels (1 and 5 indicate "my favorite subject is mathematics" and "my least favorite is mathematics," respectively). Income is also a scale variable that takes a value of 1 (no income) to 7 (more than 100 thousand yen per month). In addition to the described control variables, the survey contained five question items associated with knowledge about economics keywords: inflation, deflation, nominal wage, long-term bonds, and the real exchange rate. Each subject responded to all questions using five-point scales, with 1 and 5 representing "I know the word well" and "I do not know the word at all," respectively.

Insert

<Table 1. Descriptive statistics of the explanatory variables>

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5 To test Hypothesis 2, it is necessary to include the cross-terms of period and treatments as in Equation (2). In this case, the coefficients of b_1 and b_2 represent the respective effects of S and L on D_t^S and D_t^L, which are independent of the period. Therefore, by seeing b_1 and b_2, we cannot discuss money illusion on average as in Hypothesis 1.

6 Kahn (2005) added 1 to the dependent variables to avoid the zero-value problem. However, we add 10^{-16}, because a 1-value increment may drastically change the distribution of $|D_t^A|$ (see Figure 1).

7 There are two departments in the Takasaki City University of Economics: the Faculty of Economics and the Faculty of Regional Policy.

The estimation results for Equation (1), which tests Hypothesis 1, are presented in Columns (1) and (2) of Table 2. As a robustness check, two models (with and without individual fixed effects, respectively) are employed. They show that subjects in the L treatment are likely to misconsume commodities at the 1% significance level relative to those in the C treatment. This finding implies that people cannot make optimal consumption decisions under large price fluctuations. The coefficients of the S dummy in Columns (1) and (2) also suggest that subjects may make suboptimal intertemporal decisions relative to C. In particular, the magnitude of misconsumption in L is larger than that in S, suggesting that subjects are likely to misconsume commodities as the fluctuation rate rises[8].

With regard to the other variables, men may be likely to consume commodities closer to the optimal level than women do, although the coefficient in Column (2) is not significant. Students who study economics as their majors may optimally consume more compared with non-economics students, while students living alone tend to have small misconsumption levels relative to those living with their families. Although the coefficients of grades are statistically significant in both Columns (1) and (2), the signs are opposite each other (i.e., positive and negative signs are obtained in Columns (1) and (2), respectively). Moreover, favorite subject and income are found to be statistically related to IDM only in Column (2). Students whose favorite subject is mathematics are likely to more irrationally choose their consumption because of the positive sign. The signs of the coefficient of income are also significant and positive only in Column (2). These signs for favorite subject and income are contrary to our expectations. The results may thus reflect that subjects with higher grades and income levels aim to finish the experiment as quickly as possible because their opportunity costs are larger than those of students with lower grades and income levels. Additionally, it is found that knowledge related to economics has a significant influence on consumption. Knowledge on inflation and long-term bonds is significant and negative, implying that knowledge on economics makes people behave more correctly in terms of the magnitude of misconsumption.

We present the results of testing Hypothesis 2 in Columns (3) and (4) of Table 2. Similar to the test for Hypothesis 1, models with and without individual fixed effects are employed. The misconsumption in C decreases over periods, because the signs of the estimated coefficients for periods in Columns (3) and (4) are significant and negative. This finding suggests that subjects are likely to optimally consume commodities over time when there are no price fluctuations. The misconsumption in S increases by period

[8] These results are also supported by the Wilcoxon–Mann–Whitney test and the *t* test.

because the summation of the coefficients for periods (i.e., -0.809) and interaction terms (i.e., 1.281) is positive in all models. Therefore, subjects facing low price fluctuations tend to cumulate their misconsumption, which is contrary to the finding on constant price. For L, the summation of the coefficients for period (i.e., -0.809) and interaction terms (i.e., 0.812) is positive but close to 0, implying that the increasing speed of misconsumption is moderate compared to that in S.

Overall, the trend of the results of the other control variables in Columns (3) and (4) is similar to those of the previous results described in Columns (1) and (2) of Table 4. Those living alone are likely to make consumption choices that are closer to optimality, and students whose majors are economics also tend to behave more rationally.

Insert

<Table 2. Estimation results for testing Hypotheses 1 and 2>

3.2. Tests for Hypothesis 3

In order to assess whether subjects' misconsumption shows a trend toward under- or over-consumption, we next focus on the results for D_t^A. Table 3 shows the descriptive statistics of D_t^A for each treatment and the results of the *t* test for which the null hypothesis is that the mean equals zero. Their box plots are also illustrated in Figure 3. We find that regardless of the presence of price fluctuations, subjects purchase only a small quantity compared with the optimal value (i.e., they display under-consumption (over-saving) behavior overall). Such a tendency for subjects to make mistakes was also reported by Johnson et al. (1987).

Insert

<Table 3. Descriptive statistics of misconsumption>

Insert

<Figure 3. Box plots of misconsumption>

Furthermore, by comparing the box plots of C with those of the other treatments, we see that the existence of price fluctuations seems to strengthen the over-saving behavior of subjects. This observation is confirmed by the Wilcoxon–Mann–Whitney test results in Table 4.

Insert

<Table 4. Wilcoxon–Mann–Whitney test for Hypothesis 3>

We have already seen that subjects that face price fluctuations tend to cumulate their mistakes, which is noteworthy when price fluctuations are small. Furthermore, subjects display under-consumption behavior overall. These two facts suggest that the distribution of subjects' misconsumption becomes negative over time (i.e., the extent of under-consumption increases gradually). The distribution of misconsumption in each round is presented in Figure 4. This figure seems to support the stated suggestion, because in S, it is clear that the distribution of misconsumption is biased in the negative direction.

Insert

<Figure 4. Box plots of misconsumption in each period>

3.3. Payoff comparison among treatments

Earlier, we found that the magnitudes and tendencies of misconsumption differ among treatments on average. In this subsection, we focus on the payoffs described in Section 2. Different from the previous section, however, the number of observations here is 62 because each subject has only one payoff. Moreover, these payoffs are not the same as the rewards that subjects received according to the payoff after our experiment.

The distribution of the payoff for each treatment is presented in Figure 5. In this figure, the mean, standard deviation, and median are also shown. The Wilcoxon–Mann–Whitney test results in Table 5 show a significant distribution gap between treatments C and L. The payoff distribution between S and L is also different at the 10% significance level, whereas there are no significant gaps between the other combinations of any two treatments.

Insert

< Figure 5. Distribution of payoffs by treatment>

Insert

< Table 5. Wilcoxon–Mann–Whitney test for payoffs among treatments>

4. Concluding remarks

Previous studies have focused on how people approach dynamic decision problems, because it is often observed that they fail to choose optimal consumption. One of the reasons for this is the individual recognition of nominal term and price fluctuations, that is, money illusion. This study conducted a laboratory experiment in which subjects spent their savings on consumption over 20 periods without interaction with other subjects in order to study how money illusion affects individual IDM. We compared three treatment groups: a constant price (C) group and 1% (S) and 20% (L) price-fluctuation treatments. In all treatments, the optimal consumption is irrelevant to the price fluctuations, because commodity prices and savings simultaneously change at the same rate. In other words, optimal consumption depends on real terms instead of on nominal terms.

We first tested the hypothesis that money illusion does not matter. This hypothesis was rejected by the results of our experiment showing that the magnitude of misconsumption is large when price fluctuations are large. Similarly, Shafir et al. (1997) stated that money illusion is observed even in highly inflationary environments despite expecting "to find greater awareness of the difference between nominal and real values when inflation is high than when it is low." The previous observation suggests that money illusion appears more strongly when price fluctuations are larger, which seems to be a stronger claim than the statement by Shafir et al. (1997). Furthermore, it follows that the actual payoffs of subjects in the control treatment are significantly higher than those in the large price-fluctuation treatment.

We also tested the hypothesis that subjects learn the optimal solution over time. In the C treatment, we found that the magnitude of misconsumption gradually decreases over time. Thus, the hypothesis can be supported if there are no price fluctuations. On the contrary, in the S and L treatments, it gradually increases until the end of the 20th period. In particular, the tendency of cumulative misconsumption is noteworthy in the S treatment. Shafir et al. (1997) suggested that money illusion arises because it is easier and more natural to think in nominal rather than in real terms, and hence money illusion is not eliminated with experience. Their suggestion may be supported by our observation that without price fluctuations, subjects may learn the optimal solution and their mistakes shrink over time. Alternatively, with price fluctuations, mistakes gradually accumulate.

These two hypotheses are concerned with only the absolute values of misconsumption rather than its direction (i.e., over- or under-consumption). Previous studies of IDM experiments have shown that subjects' mistakes are not random but rather systematic. For example, Johnson et al. (1987) found in their series of experiments that most subjects display over-saving behavior. Therefore, we also examined the direction of misconsumption in our experiment. The results showed that our subjects display under-consumption (over-saving) behavior in line with those in Johnson et al. (1987). Furthermore, we found that price fluctuations strengthen the tendency toward such behavior.

In our experiment, there were no inflationary and deflationary trends in price fluctuations. Studying how these trends affect individual IDM thus remains a task for future research.

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Figures and Tables

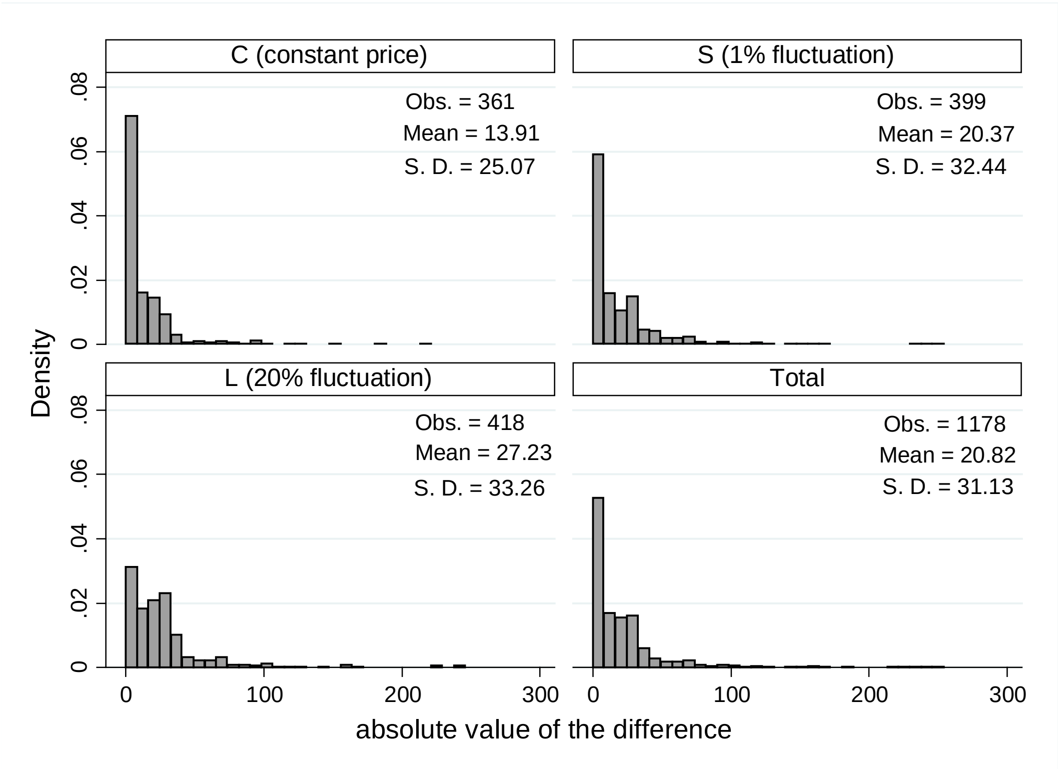


Figure 1. Distribution of the absolute value of misconsumption

Note: “S.D.” means standard deviation.

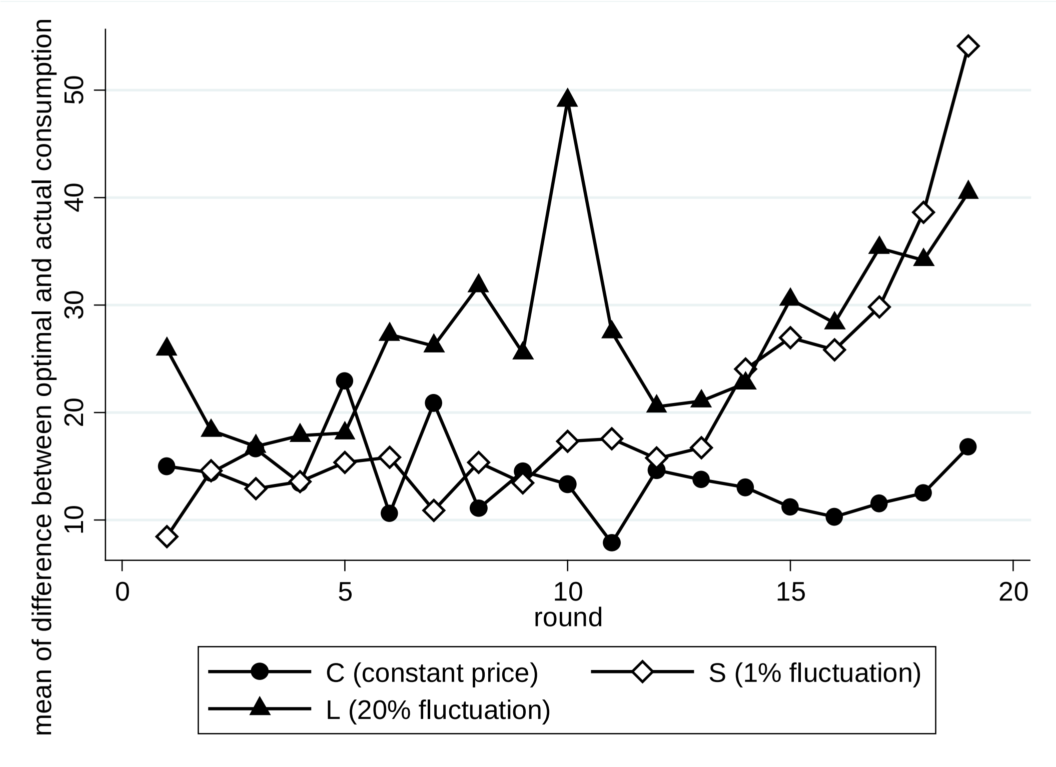


Figure 2. Transitions of the absolute values of misconsumption

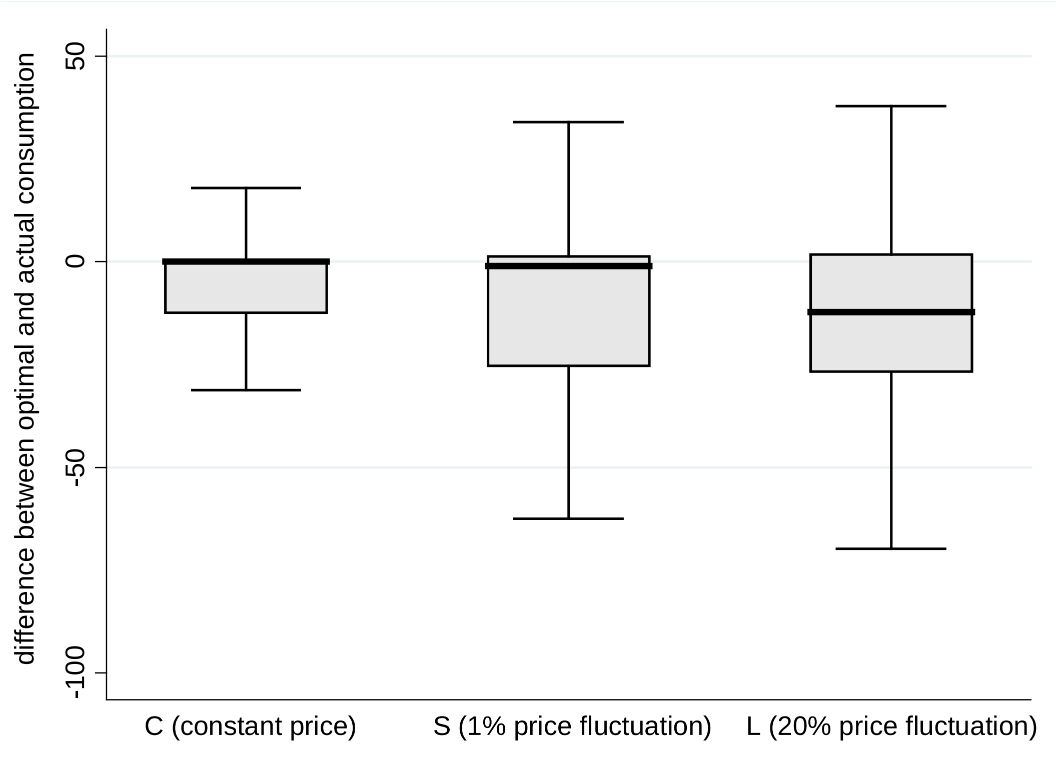


Figure 3. Box plots of misconsumption

Note: The bold horizontal line represents medians. Ranges between the 25 to the 75 percentiles are expressed as boxes drawn in gray. The upper and lower adjacent lines are obtained from the procedure defined by Tukey (1977). The maximum and the minimum values, which are usually represented by the line segments of the box, are omitted.

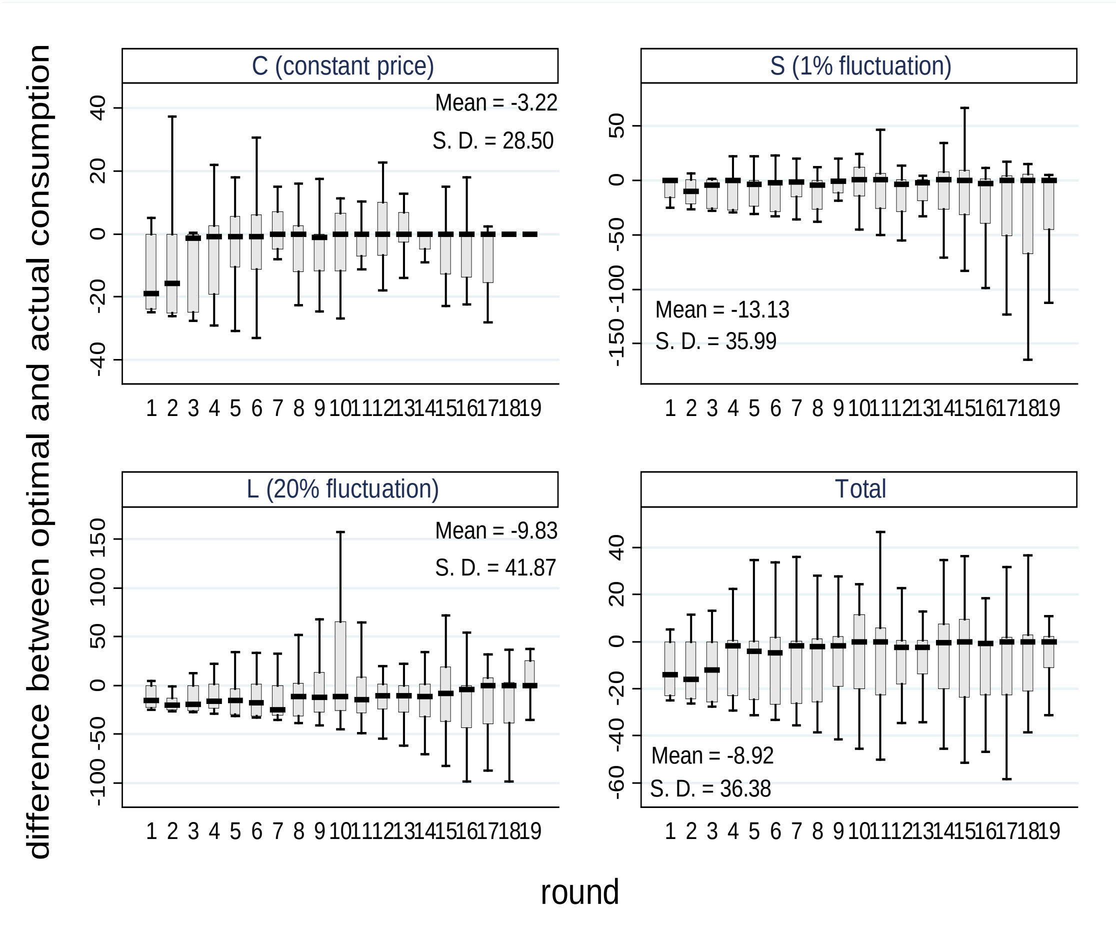


Figure 4. Box plots of misconsumption in each period

Note: "S. D." means standard deviation.

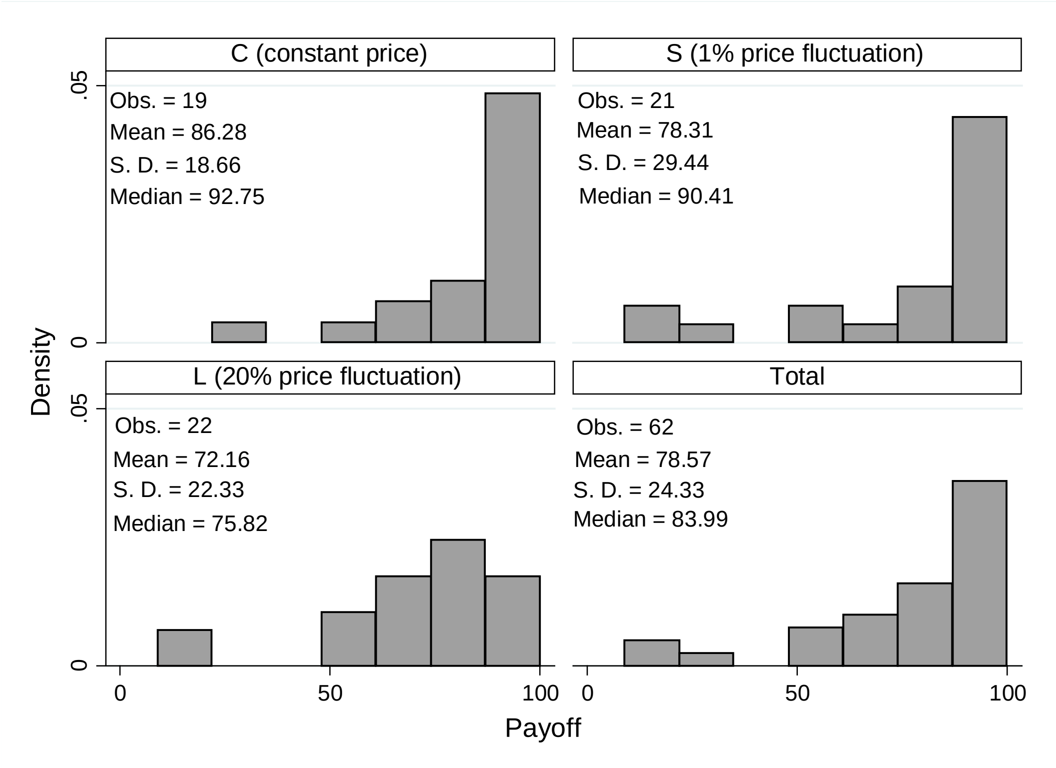


Figure 5. Distribution of payoffs by treatment

Note: "S. D." means standard deviation.

Table 1. Descriptive statistics of the explanatory variables

Variables	Mean	S. D.	Min.	Max.
S (1%) dummy	0.33	0.47	0	1
L (20%) dummy	0.36	0.48	0	1
Period	10.38	5.71	1	20
Male	0.72	0.45	0	1
Economics	0.69	0.46	0	1
Grade	2.27	0.99	1	4
Alone	0.77	0.42	0	1
Favorite for Math	3.65	1.12	1	5
Income	3.41	1.87	1	7
Knowledge: inflation	1.50	0.61	1	4
Knowledge: deflation	1.53	0.69	1	4
Knowledge: nominal wage	3.21	1.25	1	5
Knowledge: long-term bond	2.57	1.07	1	5
Knowledge: real exchange rate	2.95	1.06	1	5

Table 2. Estimation results for testing Hypotheses 1 and 2

	(1)	(2)	(3)	(4)
S (1%) dummy	8.789***	4.531*	-4.018*	-8.276***
	(1.124)	(2.553)	(2.120)	(2.690)
L (20%) dummy	9.548***	12.61***	1.429	4.491***
	(0.909)	(1.314)	(1.739)	(1.644)
S (1%) dummy × Period			1.281***	1.281***
			(0.186)	(0.135)
L (20%) dummy × Period			0.812***	0.812***
			(0.166)	(0.113)
Period	-0.0868	-0.0868*	-0.809***	-0.809***
	(0.0665)	(0.0518)	(0.153)	(0.100)
Male	-4.637***	-3.227	-4.637***	-3.227*
	(0.599)	(2.117)	(0.600)	(1.883)
Grade	-1.584***	6.190***	-1.584***	6.190***
	(0.457)	(0.860)	(0.457)	(0.764)
Faculty	-1.570**	-5.461***	-1.570**	-5.461***
	(0.778)	(2.103)	(0.739)	(1.817)
Alone	-4.567***	-11.15***	-4.567***	-11.15***
	(0.526)	(1.907)	(0.528)	(1.666)
Favorite for Math	-0.340	3.169***	-0.340	3.169***
	(0.308)	(0.574)	(0.291)	(0.536)
Income	0.119	2.213***	0.119	2.213***
	(0.198)	(0.334)	(0.191)	(0.316)
Knowledge: inflation	-1.079	-14.96***	-1.079	-14.96***
	(1.805)	(3.635)	(1.650)	(3.113)
Knowledge: deflation	2.567	12.80***	2.567*	12.80***
	(1.682)	(2.978)	(1.523)	(2.557)
Knowledge: nominal wage	-0.469	2.077**	-0.469	2.077**
	(0.317)	(1.034)	(0.307)	(0.888)
Knowledge: long-term bond	-1.176***	-1.254***	-1.176***	-1.254***
	(0.421)	(0.314)	(0.384)	(0.300)
Knowledge: real exchange rate	-0.160	0.250	-0.160	0.250
	(0.405)	(1.162)	(0.399)	(0.990)
Constant	7.072**	-38.26***	14.29***	-31.04***
	(3.115)	(2.891)	(3.308)	(3.131)
Individual fixed effects	no	yes	no	yes
F-value	27.42***	33.95***	30.95***	41.48***
Adj. R-squared	0.239	0.635	0.289	0.688

Note: Robust standard errors are in parenthesis. ***, **, and * represent the 1%, 5%, and 10% significance level, respectively.

Table 3. Descriptive statistics of misconsumption

	C (Control)	S (1% fluctuation)	L (20% fluctuation)
mean	-3.22**	-13.13***	-9.83***
median	0	-1.01	-12.28
S.D.	28.50	35.99	41.87

Note: The null hypothesis under the *t* test is that the mean is equal to zero. ***, **, and * represent the 1%, 5%, and 10% significance level, respectively.

Table 4. Wilcoxon–Mann–Whitney test for Hypothesis 3

		X	
		S (1% fluctuation)	L (20% fluctuation)
Y	C (constant Price)	-2.41 **	-5.20 ***
	S (1% fluctuation)	-	-1.76 *

Note: The null hypothesis under the test is that the distribution of X is equal to that of Y. The Wilcoxon statistic, which is approximately a standard normal random variable, is calculated based on the sum of the ranks of the observations of X. ***, **, and * represent the 1%, 5%, and 10% significance level, respectively.

Table 5. **Wilcoxon–Mann–Whitney test for payoffs among treatments**

		X	
		S (1% fluctuation)	L (20% fluctuation)
Y	C (constant Price)	-0.66	-2.75 ***
	S (1% fluctuation)	-	-2.04 **

Note: The null hypothesis under the test is that the distribution of X is equal to that of Y. The Wilcoxon statistic, which is approximately a standard normal random variable, is calculated based on the sum of the ranks of the observations of X. ***, **, and * represent the 1%, 5%, and 10% significance level, respectively.

Appendix

Appendix contains the English translation of the general instructions in Japanese and instructions for the small price-fluctuation treatment.

General instructions: working process until the start of the experiment and the cautions (the original text was in Japanese)

Thank you very much for participating in our economic experiment. Please prepare according to the following procedures before beginning the experiment.

1. You will find the following materials on your desk. Please check whether or not you have all of them on your desk. If you are missing any items, please let us know by raising your hand quietly.
    - ID card
    - Envelop
    - Consent form
    - Calculator

2. Please read the following precautions.

Do not talk to anyone, and any eye contact is forbidden. Turn off your cellphone. Do not touch the computer until you are instructed to do so. If you do any of these, you will be removed from the experiment. If you have any questions during the experiment, please raise your hand quietly.

3. Please fill in your name and student ID number on the back of the ID card.

4. Please read the consent form. If you consent to the content, please sign the form (you must promise to not discuss the experiment description with anyone).

5. Please read the instructions in your envelop carefully.

When you have finished all of the preparation, please let us know by raising your hand quietly.

Instructions for the small price-fluctuation treatment
(the original text was in Japanese)

You are now taking part in an economic experiment. Please read the following instructions carefully.

Summary of experiment

- Suppose that you are the consumer of a hypothetical commodity. First, you have 40,000 points (experimental currency units) for purchasing the commodity.
- The experiment consists of 20 trading periods. In each period, you decide the amount of points used to purchase the commodity from your remaining points. The remaining points in each period are carried over to the next period.
- In each period, the price of the commodity is stochastically determined. The probability that the price of the commodity in the next period is 1% higher than the price in the current period is 1/3. The probability that price of the commodity in the next period is the same as the price in the current period is 1/3. The probability that price of the commodity in the next period is 1% lower than the price in the current period is 1/3. Such probabilities are independent of past prices and your decisions.
- The amount of remaining points carried over to the next period changes at the same rate as the price of the commodity. For example, if the price of the commodity increases by 1% in the next period, the amount of remaining points also increases 1% in the next period.

Calculation of your reward

The monetary amount you earn in each trading period is determined according to the following formula.

Your earnings in a trading period

$$= ¥14 \times \sqrt{Quantity\ of\ the\ purchased\ commodity\ in\ this\ period}$$

The mark "¥" stands for "Japanese Yen." Your reward in this experiment is the sum of your earnings in all periods in addition to the showing-up fee of ¥1,000. Your reward will be paid in cash at the end of the experiment.

Note: The quantity of the purchased commodity is not necessarily an integer but is sold by measure. For reward amounts smaller than ¥1, round down.

Experimental procedure

Note: Please do not start to use the PC until directed to do so.

Step 1: Please answer the practice exercises.

The following figure shows a sample computer screen. Please input your answer within the box marked in yellow. Please answer all questions. After you check over all questions, please click the next button.

Problem ##

(1) **

answer

(2) **

answer

Please click the next button after answering all questions.

Next

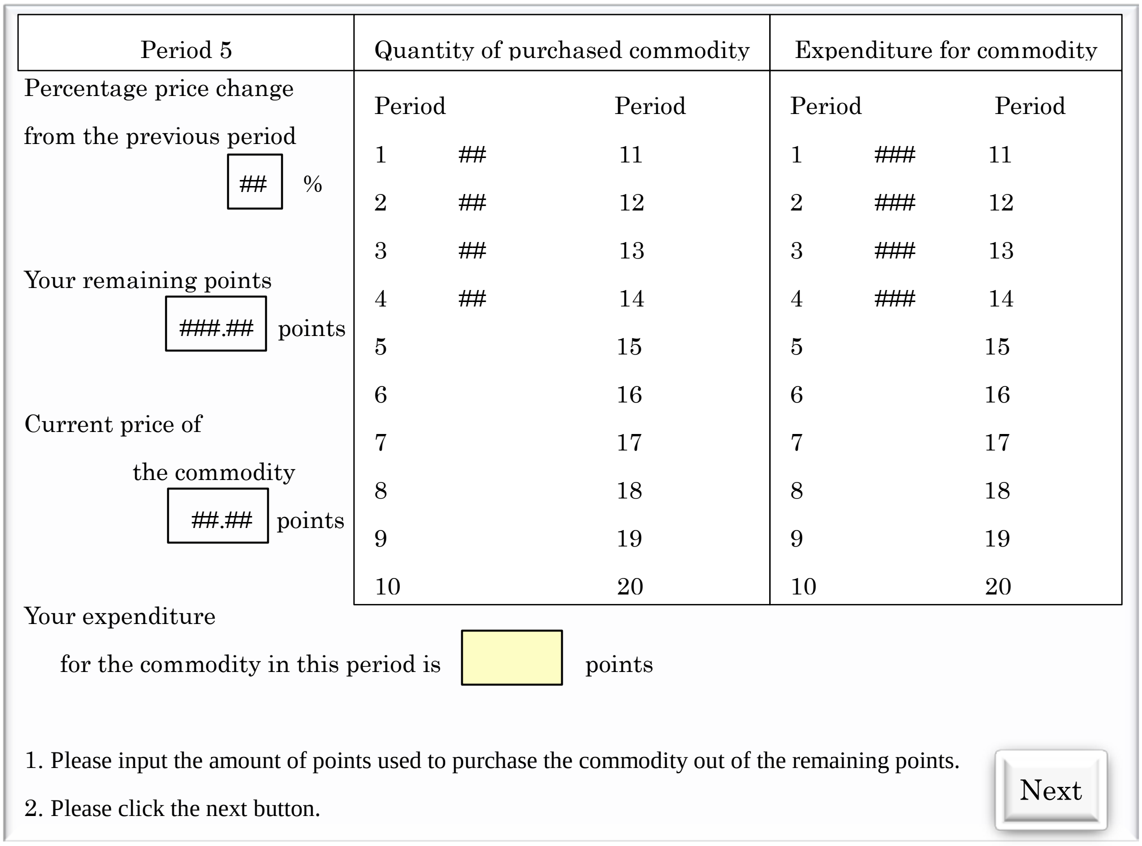
If the question is answered incorrectly, a warning is displayed. If a warning message appears, please find the mistakes and answer the question again. You can progress to the next step after correctly answering all questions.

Step 2: Please confirm your ID number.

After you finish Step 1, you will see your ID number on the display. Please confirm your ID number. If your ID number is wrong, please let us know by raising your hand.

Step 3: Please start the experiment.

Please decide the amount of points used to purchase the commodity from the 1st period to the 20th period in order. The following figure shows a sample computer screen at the 5th period.



On the computer screen, you can confirm the following information.

- The percentage price change from the previous period. In the first period, it is displayed as 100% here.
- Your remaining points. This is the amount of money you currently hold, which is the maximum expenditure amount you can spend in this period. Points are displayed with up to 2 decimal places.
- Current price of the commodity. This is the price of the commodity in this period. The points are displayed with up to 2 decimal places.
- Quantity of purchased commodity. In this space, quantities of the commodity you purchased in the past period are displayed.
- Expenditure for commodity. In this space, the amounts of points you spend in the past period are displayed.

After you confirm your remaining points and the price of the commodity in this period, please input <u>the amount of points</u> used for purchasing the commodity within the yellow box. You can input a decimal number in this box. However, you cannot input a negative number or a number that exceeds your remaining points. If you spend all your points in a prior period (i.e., your remaining points are 0), you can only input “0.” If you need a calculator, please use the one on your desk. You are prohibited from using any calculator applications installed on your PC.

Step 4: Please confirm your earnings and call a staff member.

After the 20th period is completed, your earnings in this experiment are displayed on the computer screen.

Your earnings in this experiment are

¥ ##### .

Please confirm your earnings and then call a staff member, who will then save your experiment result.

Step 5: Please answer the questionnaire

A staff member will give you a questionnaire. Please answer all the questions.

Step 6: Please move to the second floor of this building.

After answering all the questions of the questionnaire, please go to the second floor of this building with your ID card and the questionnaire. Your cash reward will be paid there. When you exit this room, please do not bring handouts except for your ID card and the questionnaire.

Warning

If you do something that is not part of the instructions, a system error may occur. If we cannot obtain the experiment results because of your mistake, you will not be rewarded.

If you fully understand these instructions, please raise your hand quietly. A staff member will activate your computer.