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Efficiency of Monetary Exchange with Divisible Fiat Money: An Experimental Approach*

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Abstract

In this paper, we investigate a search model with divisible fiat money in a laboratory setting where transaction prices are endogenously determined. In the model, there exist welfare-ranked multiple stationary monetary equilibria and gift-giving equilibria. We find that endogenizing transaction prices enhanced the coordination of subjects through monetary exchange and deteriorated it through gift-giving. In other words, the subjects endogenously reduced the trade friction of monetary exchanges. We also compare our experimental results with those in search models with exogenously given transaction prices.

Keywords: Real Indeterminacy, Random Matching, Divisible Money, Experiment, Equilibrium Selection, Gift-giving

JEL Classification Number: C91, C92, D51, D83, E40

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1 Introduction

In the real-world economy, monetary exchange prevails, and gift-giving plays only an auxiliary role. In this paper, we study a search model with divisible fiat money in a laboratory setting and investigate whether the coordination through monetary exchanges is higher than it is in the case of indivisible money.[1] In so-called first-generation monetary search models, such as Kiyotaki and Wright's [11] model, both money and goods are indivisible, and the transaction price is exogenously given. That is, one unit of goods is traded for one unit of money. If money is divisible and agents can hold any amount of money, then a buyer and a seller can use any amount of money in their transactions, and thus, a transaction price is endogenously determined. The purpose of this paper is to show through experiments that endogenizing transaction prices enhances the coordination of subjects through monetary exchange and deteriorate it through gift-giving. We compare our experimental results with those in search models with exogenously given transaction prices, such as Camera and Casari [2], Camera, Casari, and Bigoni [3], and Duffy and Ochs [5]. We also compare our results with Duffy and Puzzero [6], where both money and goods are divisible and the goods are traded in search markets and in Walrasian markets.

The divisibility of money allows agents to trade using any amount of money, and thus, transaction prices are endogenized and opportunities for monetary exchange increase. Suppose there are 6 agents and 3 units of money in an economy. If money is indivisible and each agent can hold at most one unit of money, then the money holdings distribution is uniquely determined, i.e., 3 agents have one unit of money and the other agents do not have money. On the other hand, if money is divisible and agents can hold any amount of money, then a variety of money holdings distribution can be chosen through monetary transactions. Indeed, Kamiya and Shimizu [9] [10] show that in monetary search models with divisible money, there generically exists a continuum of stationary equilibria. Therefore, a money holdings distribution with small trade friction can be endogenously chosen. For example, suppose agents have 0, p, $2p$, or $3p$ amounts of money and the transaction price is p. Then agents with p, $2p$ and $3p$ (0, p, and $2p$) can buy (sell). That is, monetary exchange opportunities increase compared with the case in which money is indivisible and an agent can have at most one unit of money, where only an agent with money (without money) can buy (sell). Of course, a very inefficient allocation can also be endogenously chosen. For example, suppose that one agent has all money while the other agents do not; then, in most of the matched pairs, monetary exchange is infeasible. Therefore, we cannot theoretically predict which allocation agents choose through monetary exchanges. It is worth noting that in our experiments, such an inefficient distribution was not chosen.

Our baseline model is a variant of Zhou's [14] model with divisible fiat money. Agents are randomly matched pairwise, and each matched pair trades indivisible goods of which utility is u and production cost is c, where $u > c > 0$. In each matched pair, the roles of buyer and seller are randomly assigned. Bargaining over a price proceeds with the seller's take-it-or-leave-it offer. We investigate the stationary equilibria, called a single price equilibrium (SPE), in which every good is traded with a common price, say p, and the support of the stationary money holdings

[1] In our experiments, the total amount of money is 600, and a subject can use an integer amount of money in transactions.; 600 considered to be sufficiently large and money can be considered to be almost divisible.

distribution is $\{0, p\}$. Section 2 theoretically shows that there is a region of parameters in which multiple SPEs exist. It is worth noting that in an SPE, agents play the game as if money is indivisible, and they can hold at most one unit of money, i.e., the p amount of money is one unit, and it is traded for one unit of goods.

We conducted experiments using the above model. We first investigate whether gift-giving occurred. To see this, we count the number of transactions with zero price and find that it was close to zero, i.e., gift-giving rarely occurred. Next, we investigate monetary exchanges. We calculate successful trade rates of monetary exchanges and find that it was more than or close to that of the most efficient SPE (MSPE). More precisely, there were four treatments, and the successful trade rate was more than that of the MSPE in one treatment, while it was close to that of the MSPE in the other treatments. For the money holdings, a significant number of subjects had more than or equal to twice the transaction price in all treatments. Therefore, we can conclude that the agents did not play any SPEs. We also investigate whether an initial money holding affects the efficiency of trades and find that successful trade rates increased as the initial money holding became equal.

Some experiments using monetary search models are closely related to ours. Camera and Casari [2] investigated an equilibrium selection problem in an economy with indivisible fiat money. In their model, the agents can hold at most two units of money and can use only one unit in transactions; that is, a transaction price is exogenously given. They found that the subjects used both monetary transactions and gift-giving, and the former was 61.4 % when monetary exchange was feasible and the latter was 12.5% when it was infeasible. Camera, Casari, and Bigoni [3] investigated the same game with various numbers of subjects. They observed that the successful trade rate of monetary transaction increased and that of gift-giving decreased as the number of subjects increased. Duffy and Puzzello [6] investigated an equilibrium selection problem in an economy with divisible fiat money. Their model is a variant of Lagos and Wright's [12] model, and there are unique stationary monetary equilibrium and multiple non-monetary gift-giving equilibria. In their model, there are two types of markets: a search market and a Walrasian market, and both money and goods are divisible. One of their main concerns was whether subjects chose an efficient non-monetary gift-giving equilibrium. They found that the monetary equilibrium was selected in almost all cases because more than 95% of the accepted offers included positive token (money) quantities. We will more precisely discuss the above results in Section 5.

The plan of this paper is as follows. In Section 2, we present the variant of Zhou's [14] money search model used in the experiments. In Section 3, we report the experimental design, including our parameterization and the hypotheses. We report the results of the experiments in Section 4. In Section 5, we discuss the findings of the experiment and conclude the paper.

2 Theoretical Considerations

2.1 Environment

Below, we present a monetary model with an infinite number of agents and a model with a finite number of agents. Both models are variants of Zhou's [14] model with fiat money. We first present the common environment of the models.

Time is discrete, and the time horizon is infinite, as denoted by $t = 1, 2, \ldots$. Each agent can produce one unit of indivisible goods in each period, and he or she cannot consume his or her production good, while he or she can consume the other agents' production good. Money is perfectly divisible, and the agents can hold any amount of money. The total amount of money in the economy is denoted by $M > 0$.

The timeline in each period is as follows. In the beginning of each period, agents observe the current economy-wide money holdings distribution. Then, pairwise random matching occurs. In each matching, each agent cannot observe his or her partner's money holding, and one agent becomes a seller with probability $\frac{1}{2}$, while the other becomes a buyer. Then, bargaining over the price proceeds with the seller's take-it-leave-it-offer. That is, the seller posts a price $p \geq 0$, and if the buyer accepts it, then the trade occurs, i.e., the seller produces one unit of goods, and the buyer pays p and consumes one unit of goods; otherwise, there is no trade. Finally, the matching resolves and the economy ends with probability $1 - \delta$ and moves to the next period with probability δ. If the economy ends, the utilities of the agents are zero thereafter.

u is the utility of consumption and c is the cost of production. We assume $u > c > 0$. The agents do not discount future payoffs, and they maximize time-additive expected utility. Clearly, δ plays a role as a discount factor because a future payoff is multiplied by a probability. Below, we investigate the Nash equilibria with Markov strategies; that is, depending only on each agent's money holding and an economy-wide money holdings distribution, each seller chooses an offer price and each buyer chooses a reservation price, i.e., he or she accepts any offer price less than or equal to the reservation price.

2.2 The Model with a Continuum of Agents

We first consider a model with a continuum of agents and a measure is normalized to 1.

We consider a benchmark equilibrium called SPE. We compare it with the experimental results in the following section. An SPE is defined as a stationary (time-invariant) equilibrium with the following features:

- there exists a common price $p > 0$,
- a stationary money holdings distribution is defined by $h = (h_0, h_1)$, where h_n is the measure, i.e., the proportion of agents holding np amount of money, $n = 0, 1$,
- p satisfies $M = ph_1$,
- when an agent is a seller, the agent offers price p if his or her current money holding η is less than p, and otherwise, he or she offers a price that is never accepted, e.g., $2p$, and

- when an agent is a buyer, the agent accepts a price offer p if he or she holds $\eta \geq p$.

Note that, for simplicity, the strategy is not completely specified in the above. For example, strictly speaking, a buyer has a reservation price strategy depending on his or her money holding η, denoted by $R(\eta)$, such that $p \leq R(\eta)$ for $\eta \geq p$.

In the SPEs, the agents play the game as if money is indivisible and they can hold at most one unit of money, i.e., the p amount of money is one unit and it is traded for one unit of goods. Note that any h satisfying $h_0 + h_1 = 1$ is stationary, since before trades the potential sellers are agents without money, and the potential buyers are agents with p amount of money; after trades, the former have p amount of money and the latter have no money. That is, the outflow of agents from 0 (the number of sellers) is equal to the inflow of agents to 0 (the number of buyers), and a similar argument applies to the outflow from p and inflow to p.

Next, we investigate the condition for the existence of SPE. The value function for agents holding np amount of money is defined as:

$$V(np) = \begin{cases} \frac{h_1}{2}\left\{-c + \delta V(p)\right\} + \left(1 - \frac{h_1}{2}\right)\delta V(0) & \text{if } n = 0, \\ \frac{h_0}{2}\left\{u + \delta V((n-1)p)\right\} + \left(1 - \frac{h_0}{2}\right)\delta V(np) & \text{if } n \geq 1. \end{cases}$$

Solving the above, we obtain

$$V(np) = \frac{h_0}{2(1-\delta)}u - \left\{\frac{\delta h_0}{2(1-\delta) + \delta h_0}\right\}^n \left\{\frac{2(1-\delta) + \delta h_0}{2(1-\delta)(2-\delta)}\right\}(h_0 u + h_1 c).$$

Based on this, we consider the incentive condition for the prescribed strategy. First, the following condition must hold:

$$-c + \delta V(1) \geq \delta V(0),$$

This means that if an agent without money becomes a seller, then the agent wants to sell his or her production good with the price p instead of offering a price that cannot be accepted by any buyer. This condition is equivalent to

$$\frac{u}{c} \geq \frac{2(1-\delta) + \delta h_0}{\delta h_0}. \tag{1}$$

Second, the following condition must hold:

$$\delta V(np) \geq -c + \delta V((n+1)p) \quad \forall n \geq 1.$$

This condition means that if an agent with np amount of money becomes a seller, then he or she wants to offer a price that cannot be accepted rather than selling his or her production good at the price p. By the concavity of the value function, this expression is reduced to

$$\delta V(p) \geq -c + \delta V(2p),$$

which is equivalent to

$$\frac{u}{c} \leq \frac{2(1-\delta)(2-\delta) + 2\delta(1-\delta)h_0 + \delta^2 h_0^2}{\delta^2 h_0^2}. \tag{2}$$

It is verified that (1) and (2) are sufficient for an SPE, i.e., all the other conditions of the definition of an SPE can be verified.[2]

Zhou [14] also analyzes another type of single price equilibrium in which the equilibrium money holdings distribution is on $\{0, p, 2p, \ldots, Np\}$, where $N \geq 2$. The features of an equilibrium are as follows:

- there exists a common price $p > 0$,
- a stationary money holdings distribution is defined by $h = (h_0, h_1, \ldots, h_N)$, where h_n is the proportion of agents holding np amount of money,
- p satisfies $M = p\sum_{n=1}^{N} nh_n$,
- when an agent is a seller, the agent offers price p if his or her current money holding η is less than Np; otherwise, he or she offers a price that is never accepted, e.g., $(N+1)p$, and
- when an agent is a buyer, the agent accepts a price offer p if he or she holds $\eta \geq p$.

In the case of a continuum of agents, Kamiya, Morishita, and Shimizu [8] show that there exists a stationary money holdings distribution consistent with the above features. However, in the case of a finite number of agents, it can be shown that a money holding distribution with $N \geq 2$ cannot be stationary. Let $I \geq 4$ be the total number of agents. To guarantee that all agents match pair-wise, we assume that I is an even number. Suppose $N = 2$ and $h = (h_0, h_1, h_2)$, $h_n > 0, n = 0, 1, 2$, is a stationary distribution. Then, h_n can be expressed as I_n/I, where $\sum_{n=0}^{3} I_n = I$. Suppose $I_1 > 0$ is an even number. With a positive probability, each agent with p meet another agent with p, and in the other matches monetary exchange is not feasible. Then agents with p trade and the other agents do not trade, i.e., after trades, the buyers with p have zero, the sellers with p have $2p$, and the money holdings of the other agents remain the same.[3] Then, I_1 becomes zero in the next period and thus h is not stationary. Suppose $I_1 > 0$ is an odd number larger than one. With a positive probability, all agents with p except one agent meet each other, one agent with p meets an agent without money, and in the other matches monetary exchange is not feasible. Then all agents with p and one agent without money trade, and the other agents do not trade. Then, after trades, h_0 and h_2 increase and h_1 decreases, i.e., h is not stationary. Suppose $I_1 = 1$ and $I_0 \geq 2$. Then, with a positive probability, the agent with p and at least one agent with $2p$ buy goods. Then, h_2 decreases, and thus, h is not stationary. Suppose $I_1 = 1$ and $I_2 \geq 2$. Then with a positive probability, the agent with p and

[2] In almost all analyses of models with a continuum of agents, the optimality off the equilibrium distribution is not required as an equilibrium condition because it cannot be reached by the deviation of a single agent.

[3] In the case of a continuum of agents, this probability is zero due to the law of large number.

at least one agent without money sell goods. Then, h_0 decreases, and thus h is not stationary. A similar argument applies to all $N \geq 2$. Therefore, in a stationary distribution, N must be one.

In the following sections, we show that the subjects were playing the above strategy with $N \geq 3$, although the money holdings distributions were not stationary. It is worth noting that the total welfare can be considered to be an increasing function of N. Indeed, among all pair-wise matchings, only in the case that a buyer does not have money or a seller has Np, a trade does not occur. That is, the buyer does not have money to accept p and the seller does not have an incentive to trade because he or she has a sufficient amount of money. It can be considered that the number of agents with Np and without money decreases as N increases. Therefore, trade opportunity is increasing in N.[4]

2.3 The Model with a Finite Number of Agents

We consider a model with I agents, where I is a finite even integer larger than one. Because only SPEs can have a stationary distribution in the case with a finite number of agents, we focus on a class of SPEs, in which some agents have $p \geq 0$ amount of money, the other agents do not have money, and the equilibrium price of goods is p. Similar to the case of a continuum of agents, p must satisfy

$$M = pI_1, \tag{3}$$

where $I_n, n = 0, 1$, is the number of agents holding np amount of money.

In the case of finite agents, the value function is defined as follows:

$$V(np) = \begin{cases} \frac{H_1}{2}\{-c + \delta V(p)\} + \left(1 - \frac{H_1}{2}\right)\delta V(0) & \text{if } n = 0, \\ \frac{H_0}{2}\{u + \delta V((n-1)p)\} + \left(1 - \frac{H_0}{2}\right)\delta V(np) & \text{if } n \geq 1, \end{cases}$$

where $H_n = \frac{I_n}{I-1}$. Solving this, we obtain

$$V(np) = \frac{H_0}{2(1-\delta)}u - \left\{\frac{\delta H_0}{2(1-\delta) + \delta H_0}\right\}^n \left\{\frac{2(1-\delta) + \delta H_0}{2(1-\delta)\left(2 - \delta(2 - H_0 - H_1)\right)}\right\}(H_0 u + H_1 c).$$

Then, the equilibrium conditions in the case of a continuum of agents, (1) and (2), are respectively written as follows:

$$\frac{u}{c} \geq \frac{2(1-\delta) + \delta H_0}{\delta H_0}, \tag{4}$$

$$\frac{u}{c} \leq \frac{\left(2(1-\delta) + \delta H_0\right)\left(2(1-\delta) + \delta(H_0 + H_1)\right) - \delta^2 H_0 H_1}{\delta^2 (H_0)^2}. \tag{5}$$

[4]For a given N, there exist multiple stationary equilibrium money holdings distributions. Therefore, strictly speaking, we cannot conclude that trade opportunity is increasing in N. However, if we compare the most efficient stationary equilibrium money holdings distribution for each N, we can prove that it is increasing in N.

3 Experimental Design and Hypothesis

The experiments were conducted at Kansai University on January, February, and December in 2015 and June and July in 2016. In total, 180 subjects voluntarily participated at The Center for Experimental Economics, Kansai University. The subjects were all undergraduate students at Kansai University with no prior experience in the game we conducted.

We considered the case of $I = 6$. In each session, 24 or 18 subjects were randomly divided into 4 or 3 groups, respectively, consisting of 6 members and interacted through z-Tree software (Fichbacher [7].) In the beginning of each session, subjects were given written instructions on the game they were about to play.[5] After the written instructions were read aloud, subjects had to correctly answer a number of questions about the rules of the game.

Specifically, in our experiment, we used the term "substitute currency" ("daiyo-kahei" in Japanese) as the equivalent of fiat money in our model. The instruction clearly stated that the substitute currency can not be exchanged for rewards in the experiments. Furthermore, the comprehensibility test confirmed this fact.

Each session consisted of several *cycles*. A cycle consisted of an indefinite number of periods of a stage game. In each stage game, members of each group were randomly matched in pairs. Each pair bargained over a price according to the process we described in Section 2. At the end of each stage game the cycle continued with probability $\delta = 0.9$. If a cycle ended and less than one hour had passed, since the instructions were given, the current group was dissolved and new groups comprised of 6 subjects were randomly formed.

We choose the following parameter values across all treatments:

- the production cost of the seller is $c = 10$, and
- the total amount of money in the economy is $M = 600$.

As for the information structure, we set up the environment in which each subject is informed about the prices of the group with which trades were successfully made.

We focused on two treatment variables: the levels of utility from trade u and the initial distributions of money. First, we selected two different values of u: $u = 14$ and $u = 20$. In the case of $u = 14$, from (4) and (5), it is verified that there exist the following 3 types of SPE:

- the price is 200, 3 agents hold 200 units of money, and the other agents hold no money in a stationary money holdings distribution,
- the price is 300, 2 agents hold 300 units of money, and the other agents hold no money in a stationary money holdings distribution, and
- the price is 600, 1 agent holds 600 units of money, and the other agents hold no money in a stationary money holdings distribution.

In the case of $u = 20$, from (4) and (5), it is verified that there exist the following 2 types of single price equilibria:

[5] Instructions are given in the Appendix.

- the price is 150, 4 agents hold 150 units of money, and the other agents hold no money in a stationary money holdings distribution, and
- the price is 200, and 3 agents hold 200 units of money and the other agents hold no money in a stationary money holdings distribution.

Then we can make the following hypothesis under the assumption that the subjects are playing an SPE.

Hypothesis 1 *A transaction price in* $u = 20$ *is less than or equal to that in* $u = 14$.

The intuitive explanation is as follows. As u increases, the incentive condition for the seller without money becomes relaxed. Because the right-hand sides of (4) decrease in the number of agents without money, h_0, then the condition still holds even if h_0 decreases. Decreasing h_0 means increasing h_1 so that the number of agents with money increases. Because the total amount of money M is constant and $M = ph_1$, then transaction price must decrease.

Of course, the above argument can be applied under the assumption that the subjects play an SPE. If the above hypothesis is not verified, it could be an indirect evidence that the subjects were not playing any SPE. In the following section, we show that the hypothesis cannot be verified, and directly find that the subjects were not playing any SPE.

Any SPE mentioned above cannot attain the full efficiency because there always exists a positive probability that a mismatch between the seller and buyer occurs. Theoretically, we can compute the successful trade rate for each SPE as in Table 1. [6] Table 1 also shows that the SPE with $p = 200$ is the most efficient in both $u = 14$ and $u = 20$. That is, a half of the agents have money, and the probability of a trade is the maximum.

I_1	Theoretical Prediction	$u = 14$	$u = 20$
1	$5/30 \approx 0.166$	○	-
2	$8/30 \approx 0.266$	○	-
3	$9/30 = 0.3$	○	○
4	$8/30 \approx 0.266$	-	○

Table 1: Theoretical Successful Trade Rates

However, we cannot determine which level of utility increases successful trade more by using only an equilibrium analysis. For example, Table 1 shows that if the equilibrium with $I_1 = 3$ is realized in $u = 14$ and the equilibrium with $I_1 = 4$ is realized in $u = 20$, successful trade occurs more in $u = 14$. However, if the equilibrium with $I_1 = 2$ is realized in $u = 14$ and the equilibrium

[6] The idea of the computation is as follows. A subject becomes a money holder with probability n/I. Then, with probability $1/2$, he or she becomes a buyer, and with probability $(I - n)/(I - 1)$, he or she meets a seller without money. Therefore, he or she can successfully trade with probability $\frac{n(I-n)}{2I(I-1)}$. Additionally, a subject becomes a non-money holder with probability $(I - n)/I$. Then, he or she becomes a seller with probability $1/2$, and with probability $n/(I - 1)$, he or she meets a buyer with money. Therefore, he or she can successfully trade with prob. $\frac{n(I-n)}{2I(I-1)}$. Hence, he or she can successfully trade with prob. $\frac{n(I-n)}{I(I-1)}$ in total.

with $I_1 = 3$ is realized in $u = 20$, successful trade occurs more frequently in $u = 20$. Therefore, we apply the arguments in Blonski et al. [1] to our environment. Based on their theory, the range of discount factors required for equilibrium affects the successful monetary transactions rate. [7] Because the ranges of the discount factors are wider in the case of $u = 20$ than in the case of $u = 14$, successful trades might occur more in $u = 20$. This argument can be applied to the case that the subjects are not playing an SPE because the incentive to sell a good is always larger in the case of $u = 20$, and the ranges of the discount factors are considered to be wider in the case of $u = 20$. Therefore, we can always make the following hypothesis.

Hypothesis 2 *Successful trades occur more in* $u = 20$ *than in* $u = 14$.

Second, we choose two different initial distributions of money holdings:

- $dis = 200$: 3 agents hold 200 units of money and the other agents have no money,
- $dis = 100$: all agents hold 100 units of money.

Note that $dis = 200$ constitutes SPE both in the cases of $u = 14$ and $u = 20$. Note also that $dis = 100$ does not constitute SPE either in the cases of $u = 14$ or $u = 20$. Therefore, we can make the following hypothesis.

Hypothesis 3 *Successful trades occur more in* $dis = 200$ *than in* $dis = 100$.

Of course, the above hypothesis can be applied under the assumption that the subjects play an SPE. If the hypothesis is not verified, it could be an indirect evidence that the subjects are not playing any SPE.

Although we have focused on equilibria using positive amount of money, there exists another type of equilibrium in our game, called a gift-giving equilibrium. Let us consider the strategy with two phases: C and D. In phase C,

- a seller offers $p = 0$, and
- a buyer accepts the seller's offer if and only if he or she has enough money to accept the offer.

In phase D,

- a seller offers a price that exceeds the maximum amount of money in that period, and
- a buyer accepts the seller's offer if and only if he or she has enough money to accept the offer.

[7] Because our model is different from infinitely repeated prisoner's dilemma, there is no negative payoff associated with "strategic uncertainty." Therefore, we do not use here risk dominance as an index for the occurrence of successful trades.

The transition rule is as follows. The strategy starts in phase C. If players do not observe any sign of deviations, i.e., they have observed that all the three pairs successfully made transactions with price offer $p = 0$, the phase remains at C. Otherwise, the phase moves to phase D. Once players move to D, they remains at D forever. It is easy to see that this strategy can be a stationary equilibrium if δ is sufficiently close to one (for details, see the Appendix).

However, previous experimental studies found that this type of gift-giving equilibrium rarely occurs in experiments on monetary search models. Camera and Casari [2] found in Result 2 of their paper that successful trade decreased when money transfer was unfeasible. Furthermore, Camera, Casari and Bigoni [3] verified that the successful trade rate was much higher in monetary transactions than in gift-giving environments, when the population of the economy is 6. Therefore, we have the following hypothesis.

Hypothesis 4 *A gift-giving equilibrium rarely occurs.*

Each subject was initially endowed with 300 points as an initial endowment. Total points consisted of the initial 300 points plus the cumulative points he or she acquired in all the cycles. Total points were converted into cash at the end of the session at an exchange rate of 1 point = 10JPY. The summary of the experiments is described as in Table 2.

Session No.: Treatment	Subjects	Total Periods	Cycles	Ave. Duration
1: $u = 14$, $dis = 200$	6×4	49	7	7
2: $u = 14$, $dis = 100$	6×4	53	4	13.25
3: $u = 14$, $dis = 100$	6×4	57	6	9.5
4: $u = 14$, $dis = 200$	6×4	49	6	8.2
5: $u = 20$, $dis = 200$	6×4	44	4	11
6: $u = 20$, $dis = 200$	6×3	64	8	8
7: $u = 20$, $dis = 100$	6×4	46	2	23
8: $u = 20$, $dis = 100$	6×3	48	4	12

Table 2: Summary of Experimental Sessions

4 Experimental Results

4.1 No Gift-Giving

As a starting point of our experimental results, we show that gift-giving equilibria rarely occurred in our experiment. For that purpose, Figure 1 depicts the frequencies of the offer prices. The percentage of $p = 0$ is below 1% and thus we can conclude that gift-giving equilibria rarely occurred.

Result 1 *Gift-giving equilibria rarely occurred.*

This finding supports Hypothesis 4. Therefore, we hereafter suppose that our experimental data are generated from some behavior using a positive amount of money.

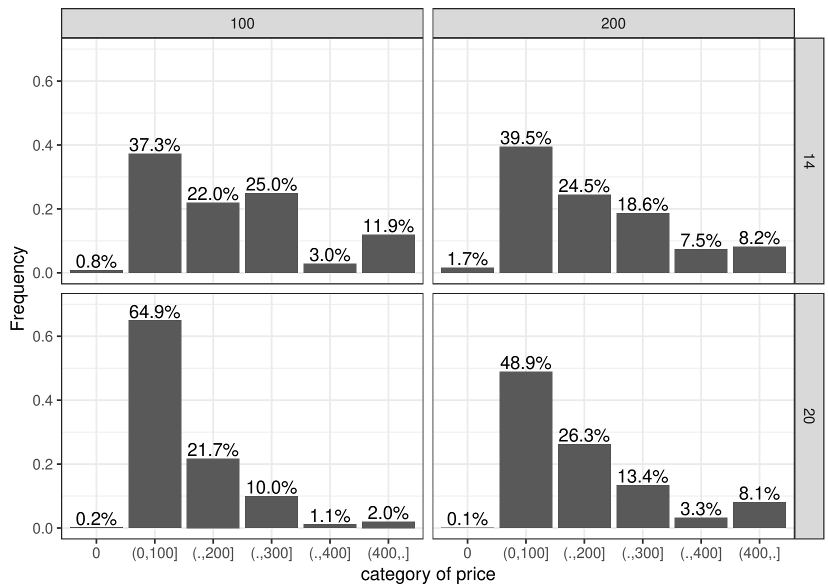

Figure 1: The Distributions of Offer Prices

In this figure, Category 0 means that the offer price level is equal to 0. Category $(0, 100]$ means that the offer price level is within the interval $(0, 100]$. Category $(\cdot, 200]$ means that the offer price level is within the interval $(100, 200]$. Category $(\cdot, 300]$ means that the offer price level is within the interval $(200, 300]$. Category $(\cdot, 400]$ means that the offer price level is within the interval $(300, 400]$. Category $(400, \cdot]$ means that the offer price level is higher than 400.

4.2 Successful Trade Rate

We first investigate how successful trade rates differ according to treatments. Figure 2 reports successful trade rates when averaging across all periods in all cycles for each treatment.

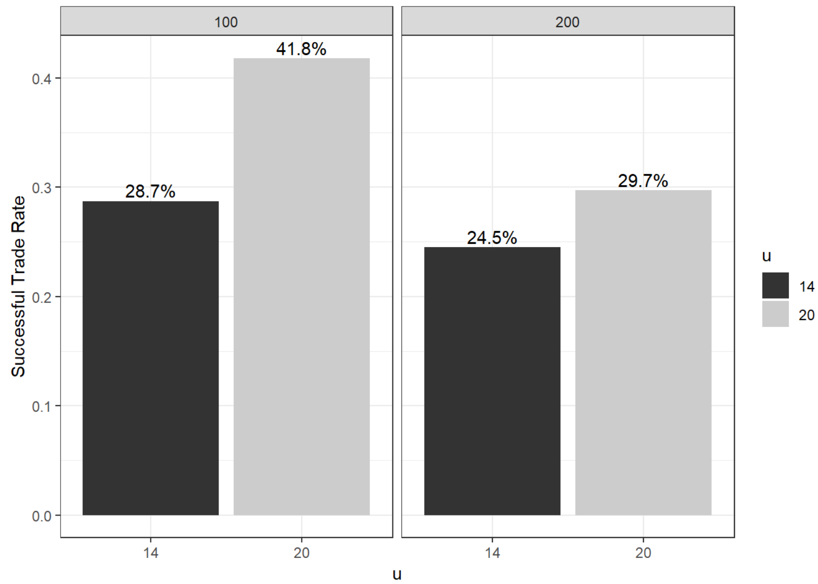

Figure 2: Successful Trade Rate

In the treatment of $u = 20$, the successful trade rate in $dis = 200$ is almost 30%, which corresponds to the most efficient theoretical successful trade rate, and the one in $dis = 100$ is more than 40%, which is beyond the most efficient theoretical successful trade. On the other hand, the successful trade rates in $u = 14$ are less than 30%, although they are not much smaller than 30%.

First, the subjects were not playing any SPEs in all treatments. Figure 3 reports the average ratios of subjects over all periods who had more than or equal to twice the transaction price, where the transaction price in each period is the average transaction price up to the period. More precisely, let the average transaction price up to period t be $\bar{p}_t$ and the ratio of subjects who have more than or equal to twice of $\bar{p}_t$ at period t be r_t.[8] (Note that, in Subsection 4.5, we statistically verify that the subjects recognized that $\bar{p}_t$ is a fair transaction price.) Figure 3 reports the average r_t over all periods.[9] The ratios were between 0.284 and 0.530. That is, a significant number of subjects had more than or equal to twice the transaction price, and thus, the opportunities for monetary exchange were larger than those in the SPEs. For example, when the role of a buyer was assigned to a subject with more than or equal to $2\bar{p}$ twice in a row, he or she could buy goods twice in a row, where $\bar{p}$ is the average transaction price up to the

[8] $\bar{p}_t = \frac{1}{t}\sum_{s=1}^{t} p_s$, where p_s is the average transaction price in period s.

[9] The average r_t is $\frac{1}{T}\sum_{s=1}^{T} r_t$, where T is the last period.

current period.[10] Indeed, in the treatment of $u = 20$ and $dis = 100$, the successful trade rate 0.418 was larger than that of the most efficient SPE. In the other treatments, the successful trade rates were almost equal to or slightly smaller than those of the most efficient SPE, because some subjects refused monetary exchange even when it was feasible. (See Figure 4.) In Section 4.5, we report individual behaviors that support the above results.

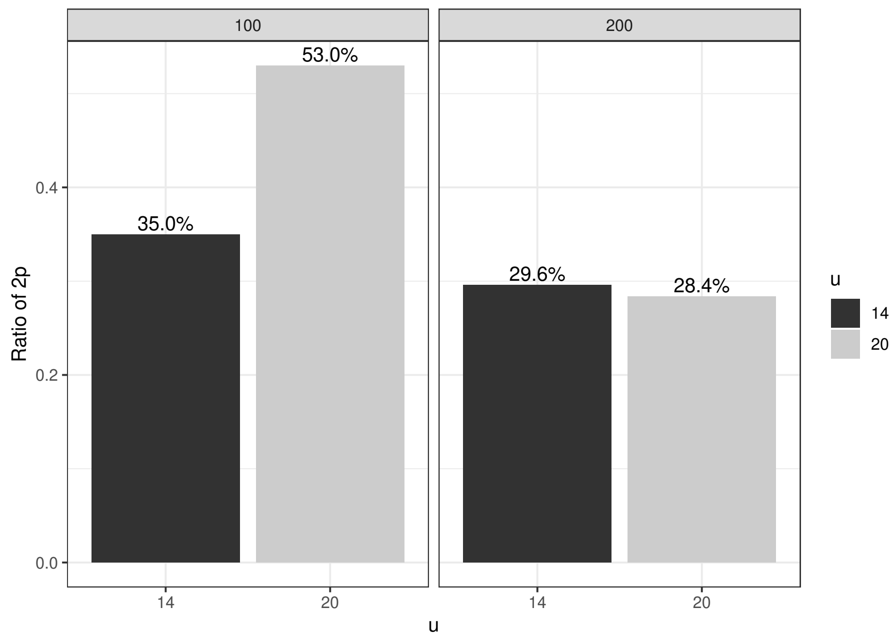

Figure 3: Subjects with Money More Than Twice the Average Price

Second, the differences in the efficiency of the treatments can also be checked in the statistical analysis. Table 3 reports the results of the random effect probit estimation whose dependent variable is binary: trade is successful or not. That is, if a trade is successful, the variable takes a value of 1 and zero otherwise. In Table 3, u20 and dis200 are the treatment variables. Specifically, the variable u20 (dis200) is a dummy variable that is equal to 1 if subject i is assigned to the treatment of $u = 20$ ($dis = 200$) and equal to zero otherwise. Additionally, the variables Cycle and PeriodInCycle are control variables. Cycle stands for the number of cycles in which subject i is involved, and PeriodInCycle specifies the period in a cycle that subject i faces. By looking at Table 3, we can verify that u20 is significantly positive, dis200 is significantly negative, and the cross-term of both variables is insignificant.

In summary, we obtain the following results.

Result 2 *(i) The subjects are not playing any SPEs, and in some treatment the allocation is more efficient than those of the SPEs.*

[10]For simplicity, we denote $\bar{p}$ instead of $\bar{p}_t$.

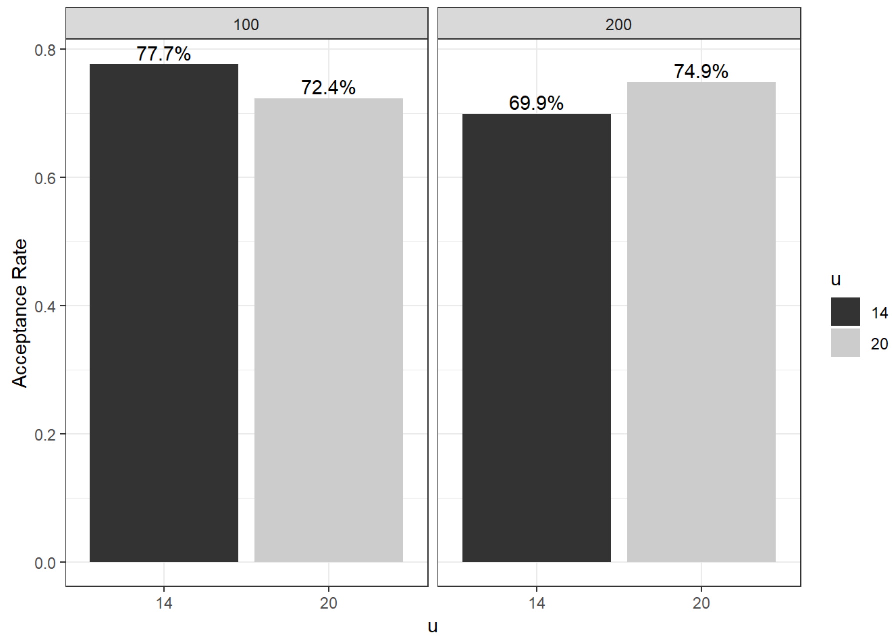

Figure 4: Average Rate of Buyers who Accept an Offer

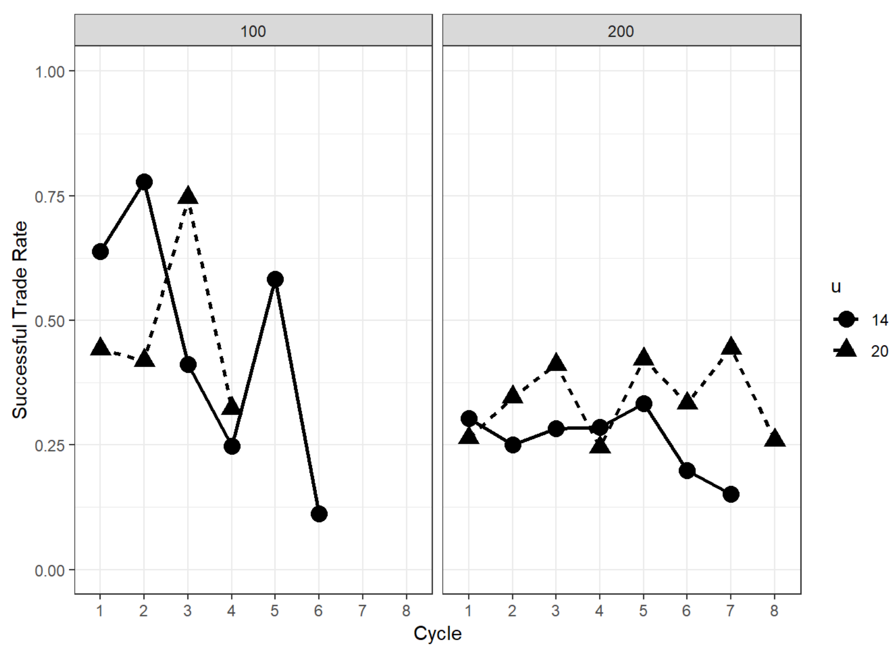

Figure 5: Successful Trade Rate over Cycles

VARIABLES	Successful Trade
PeriodInCycle	-0.0599***
	(0.00464)
Cycle	-0.102***
	(0.0275)
u20	0.450**
	(0.216)
dis200	-0.515***
	(0.173)
u20 × dis200	-0.147
	(0.271)
Constant	1.512***
	(0.219)
Observations	1,528

Session-clustered robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Random Effects Probit Estimation of Successful Trades

(ii) The successful trade rate is enhanced as the gain from trade grows, irrespective of the initial money distributions.

(iii) When the initial money holding distribution is dis=200, the successful trade rate is significantly lower than dis=100.

Note that (iii) contradicts Hypothesis 3, which could be an indirect evidence that the subjects are not playing any SPE.

4.3 Transaction Prices

Next, we explore how transaction prices differ according to the treatments. Figure 6 reports transaction prices in each treatment when averaging across all periods in all cycles. In Figure 6, we find that the average transaction prices in all treatments were less than the theoretical equilibrium prices in any SPE. We also examine transaction prices in each cycle and find that they were less than any SPE prices except the last cycles in $u = 14$. Figure 7 shows the results.

Based on the above observation, we implement the random effects linear regression estimation in order to investigate treatment effect on transaction prices. The first column of Table 4 reports the estimation result of the basic model. It does not show any significant treatment effects on the transaction prices, while transaction prices significantly increase over cycles. However, if we add the treatment effects at each cycle to the basic model, we can verify the following results as in the second column of Table 4. Both u20 and dis200 have a significantly positive effect on

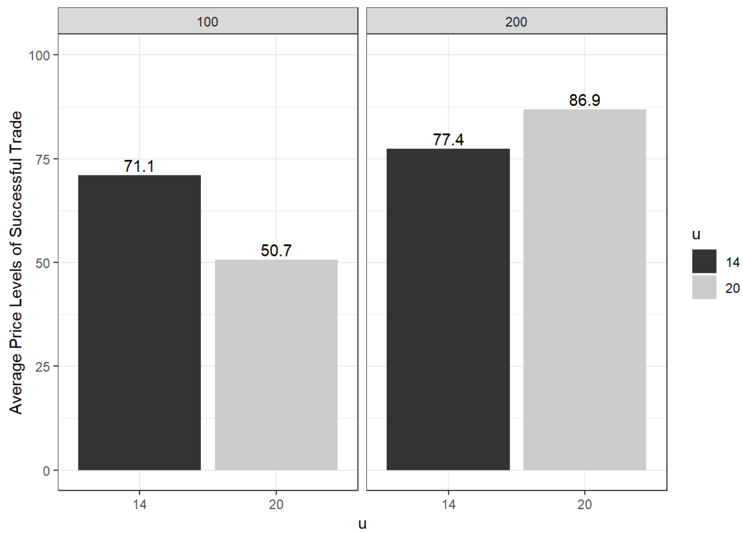

Figure 6: Transaction Price

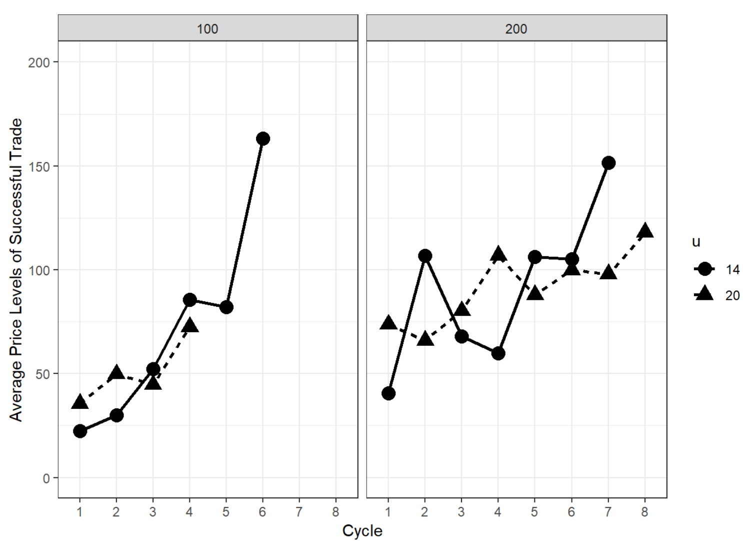

Figure 7: Transaction Prices over Cycles

VARIABLES	(1) Transaction Price	(2) Transaction Price
PeriodInCycle	2.184***	1.894***
	(0.398)	(0.308)
Cycle	13.67***	25.81***
	(2.546)	(0.869)
u20	-11.86	32.98***
	(13.51)	(10.49)
dis200	8.012	47.91***
	(11.98)	(11.17)
u20 $\times$ dis200	31.51	2.678
	(19.27)	(13.82)
u20 $\times$ Cycle		-13.25***
		(0.538)
dis200 $\times$ Cycle		-11.72***
		(1.267)
u20 $\times$ dis200 $\times$Cycle		8.099***
		(1.367)
Constant	15.27	-24.30***
	(13.09)	(8.851)
Observations	1,406	1,406

Session-clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Random Effect Linear Regression on Transaction Price

the transaction price at the initial point, and their marginal effects decreases over cycles. In summary, we obtain the following results.

Result 3 *(i) The levels of transaction prices in each treatment are less than those of any SPE.*

(ii) Transaction prices increase over cycles in all treatments

(iii) Both u20 *and dis200 have a significantly positive effect on the transaction price at the initial point, and the marginal increase in the transaction price over the cycle is smaller in* u20 *than in* u14*.*

There are two reasons why transaction prices in each treatment are lower than those in any SPE. First, as shown in the previous subsection, a significant number of subjects have more than or equal to $2\bar{p}$. Thus, for a given amount of total money supply, the transaction price must be smaller than those in the case of the SPEs. Second, some amount of money is not used in monetary exchanges. Let M_{bt} be a level of money holdings of buyer b at the beginning of period t and p_{bt} be her transaction price at period t. Then, M_{bt} may not be an integer multiple of p_{bt} and the remainder of the division, called the remaining amount, is typically positive in our experiments. Because the total money supply is given, transaction prices must be smaller than the case without a remaining amount.

Note that the first part of Result 3(iii) contradicts Hypothesis 1. Recall that the hypothesis is supposed to hold under the assumption that the subjects are playing an SPE. As shown in Result 2 (i), they were not playing any SPE, and the assumption does not hold.

4.4 Money Holdings Distributions

As shown in Subsection 4.2, the trade rates were relatively large because the money holdings distributions in our experiments were very different from those of the SPEs. In this subsection, we more precisely investigate the money holdings distributions in our experiments, and find a cause of the efficiency found in Subsection 4.2.

First, Figure 3 shows that the ratio of subjects having more than or equal to $2\bar{p}$ is very large between 28.4% and 53.0%, where $\bar{p}$ is an average transaction price up to the current period. Note that the ratio must be zero in the SPEs. Moreover, Figure 8 shows that the ratio of subjects having more than or equal to $3\bar{p}$ is also large, between 12.5% and 32.0%. Note that the ratio must be zero in Camera and Casari [2], where a subject can hold at most twice of the given transaction price.

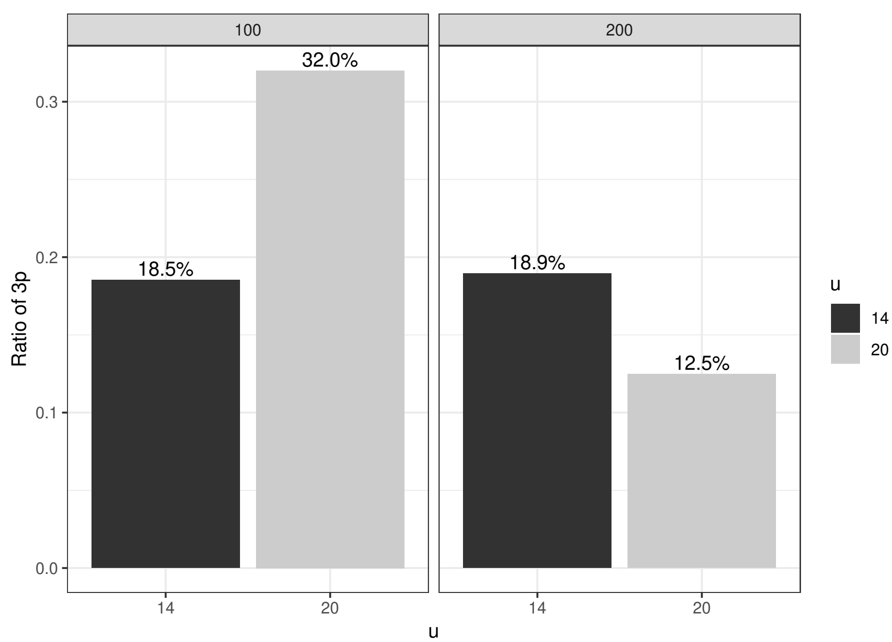

Figure 8: Subjects with More Money Than Three Times the Average Price

Result 4 *(i) A large proportion of the subjects have more than or equal to $2\bar{p}$, and thus, the money holdings distributions are different from those of the SPEs.*

(ii) A large proportion of the subjects have more than or equal to $3\bar{p}$, and thus, the money holdings distributions are different from those of Camera and Casari [2].

In the following subsection, we report that buyers' acceptance rates of offer prices were very high both in the cases with having more than or equal to $2\bar{p}$ and $3\bar{p}$. Together with the above results, we can conclude that buyers often bought goods more than or equal to twice in a row when the role of a buyer was assigned to his or her more than or equal to twice in a row. That is, the subjects endogenously chose the efficient allocations.

4.5 Individual Behaviors

In this subsection, we examine the mechanism by which the results in Sections 4.2, 4.3, and 4.4 are presented. Then we turn to the estimation of individual behaviors. Because the roles of seller and buyer are randomly determined in our experiment, we investigate each role separately.

4.5.1 Acceptance Decisions by Buyers

In Result 2 (i), we report that the subjects were not playing any SPE, and in a treatment, the allocation was more efficient than those of the SPEs. That is, buyers often bought goods more than or equal to twice in a row. Behind the result, a large proportion of subjects must have more than or equal to $2p$ and the acceptance rates of buyers must be high. The former has been shown in the previous subsection. Below, we show the latter.

As shown in Figure 4, the average acceptance rates are between 69.9% and 77.7%. Moreover, in the cases of money holding η satisfying $\eta < 2\bar{p}$, $2\bar{p} \leq \eta < 3\bar{p}$, and $3\bar{p} \leq \eta$ are between 75.6% and 84.4%, 67.7% and 79.1%, and 67.5% and 79.0%, respectively. (See Figures 9 to 11.) Therefore, we can conclude that subjects often bought goods twice or more in a row.

We defined $\bar{p}$ as the average transaction price up to the current period. Below, we show that it is the correct choice of a transaction price. First, Figure 12 shows that acceptance rates drastically decreased around $\bar{p}$, i.e., many subjects recognized that $\bar{p}$ was a fair price. Second, we also statistically verify that acceptance rates depend on whether an offer price is less than or equal to $\bar{p}$. That is, applying the strategy frequency estimation method by Dal Bo and Frechette [4], we tested the consistency of the strategy of buyers that they only accept an offer price less than or equal to $\bar{p}$. As in Table 5, the estimated rate of inconsistency is 0.247 that is significant at 1%. Therefore, we can conclude that almost 75% of subjects follow the above type of buyer's strategy.

Finally, we statistically investigate how the buyer's behavior differs across treatments. That is, we estimate the buyer's accept/reject pattern using the random effect probit model. Table 6 reports the estimation results. In Table 6, Price, Before_money, and Period are controls. Here, the variable Before_money stands for subject i's level of money holdings in the beginning of the period. The explanatory variable TheoAc is a dummy variable that a subject follows the acceptance strategy with $\bar{p}$, and it is significantly positive. This fact supports the conjecture

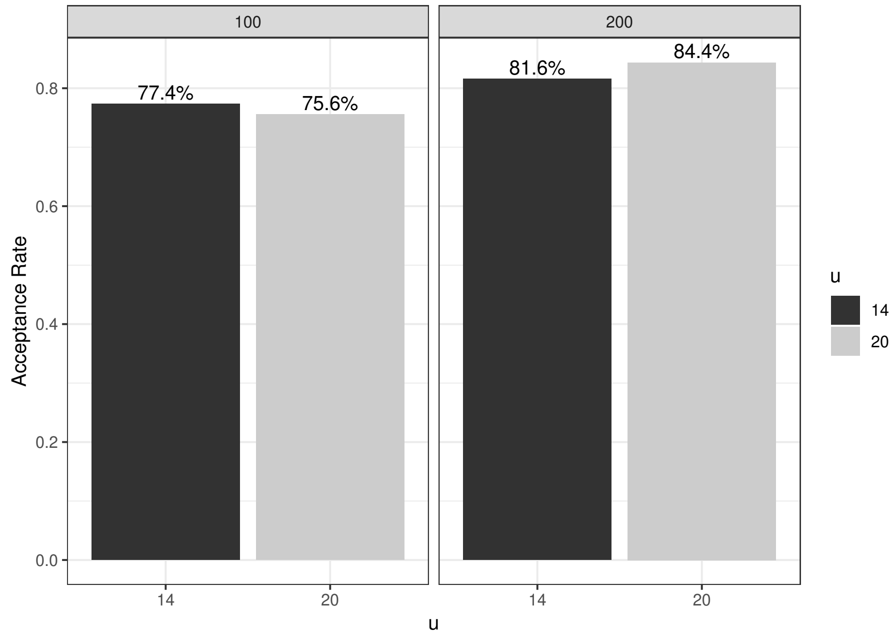

Figure 9: Buyers' Response When $\eta < 2\bar{p}$

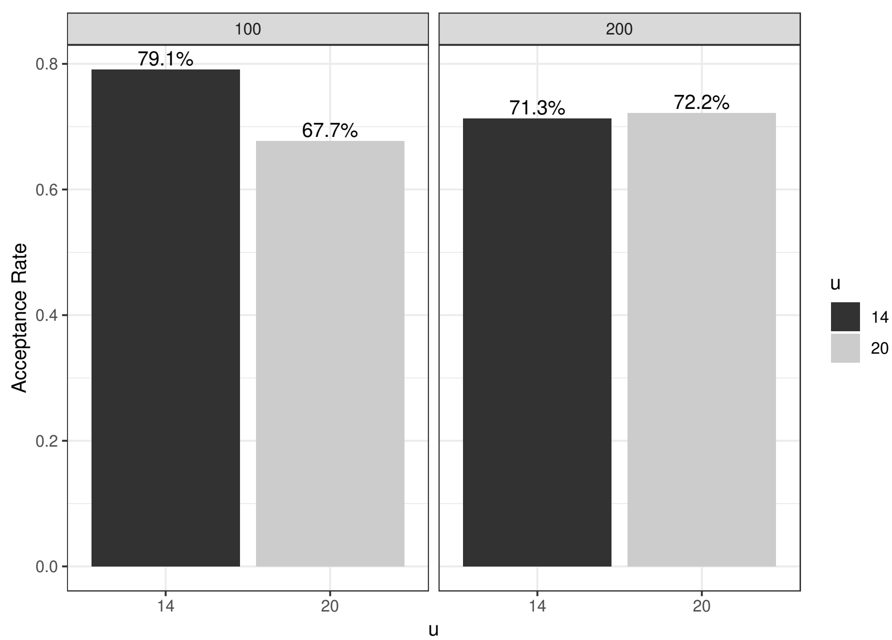

Figure 10: Buyers' Response When $2\bar{p} \leq \eta < 3\bar{p}$

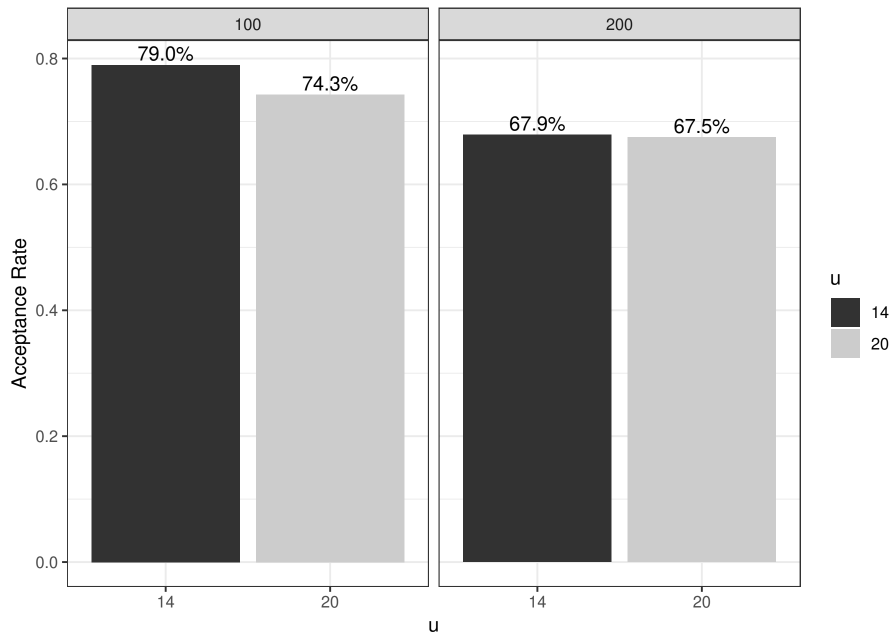

Figure 11: Buyers' Response When $\eta \geq 3\bar{p}$

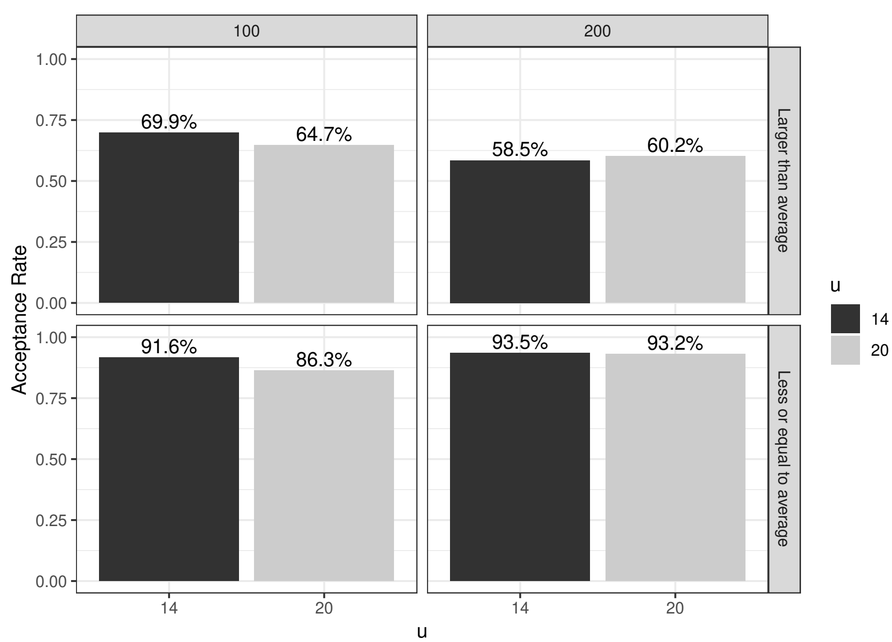

Figure 12: Buyers' Response to Average Offered Price

	Estimate
Inconsistency Rate	0.247***
	(0.026)
Log Likelihood	-2563.364

Session-clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Strategy Frequency Estimation

that buyers follow the above described strategy. Moreover, the cross terms of TheoAc and the treatment variables u20, and dis200 are all insignificant at the 5% level. Therefore, we can state that the above type of buyer's behavior is common across treatments.

In summary, we obtain the following results.

Result 5 *(i) The buyer's acceptance rates depend on whether an offer price is less than or equal to $\bar{p}$.*

(ii) The buyer's acceptance rates depend on his or her money holdings and are between 67.5% and 84.4%.

(iii) The gain from trade has a significant but small effect on the buyer's acceptance decision.

At the end of Subsection 2.2, we present a strategy with $N \geq 2$, where acceptance rates of buyers with money holdings $\eta \geq p$ are 100%. In the experiments, they are high but less than 100%. The reasons are (i) there are price offers larger than $\bar{p}$ and (ii) some subjects are inactive.

4.5.2 Price Offers by Sellers

Next, we investigate seller behavior. To estimate the seller's behavior, we must take into account the following problem associated with the seller's decision making. Although sellers only offer prices in our experiment, they might decide the following two things:

1. whether to offer an acceptable price or not, and

2. if a seller decides to offer an acceptable price, then he or she decides the price's level.

Thus, the seller's problem possibly contains an endogenous sample selection problem.

Before moving on to the estimation, we briefly show how unacceptable price offers differ according to the treatments. Here, we define unacceptable price offer to be a price levels that even the subject with the most money in the period cannot afford. It can be seen in Figure 13 that in both $dis = 100$ and $dis = 200$, the subjects with $u = 20$ offer an unacceptable price less often than those with $u = 14$. This finding means that, at least from the seller's point of view, the subjects with $u = 20$ did not offer unacceptable prices more often than those with $u = 14$. Therefore, this behavior contributes to a higher transaction success rate in the case of $u = 20$.

VARIABLES	(1) Accept / Reject	(2) Accept / Reject	(3) Accept / Reject
Price	-0.0168***	-0.0169***	-0.0170***
	(0.00229)	(0.00231)	(0.00235)
Before_money	0.0116***	0.0116***	0.0116***
	(0.00287)	(0.00288)	(0.00290)
Period	0.0354***	0.0355***	0.0359***
	(0.00758)	(0.00768)	(0.00773)
TheoAc	0.428***	0.289***	0.285***
	(0.0966)	(0.109)	(0.109)
u20	-0.469**	-0.547**	-0.578**
	(0.195)	(0.250)	(0.258)
dis200	-0.590*	-0.576*	-0.577*
	(0.340)	(0.341)	(0.343)
u20 $\times$ dis200	0.725*	0.710*	0.784*
	(0.374)	(0.378)	(0.431)
TheoAc $\times$ u20		0.266	0.363*
		(0.207)	(0.206)
TheoAc $\times$ u20 $\times$ dis200			-0.233
			(0.313)
Constant	0.174	0.218	0.219
	(0.327)	(0.329)	(0.331)
Observations	1,721	1,721	1,721

Session-clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Buyer's Acceptance Decision

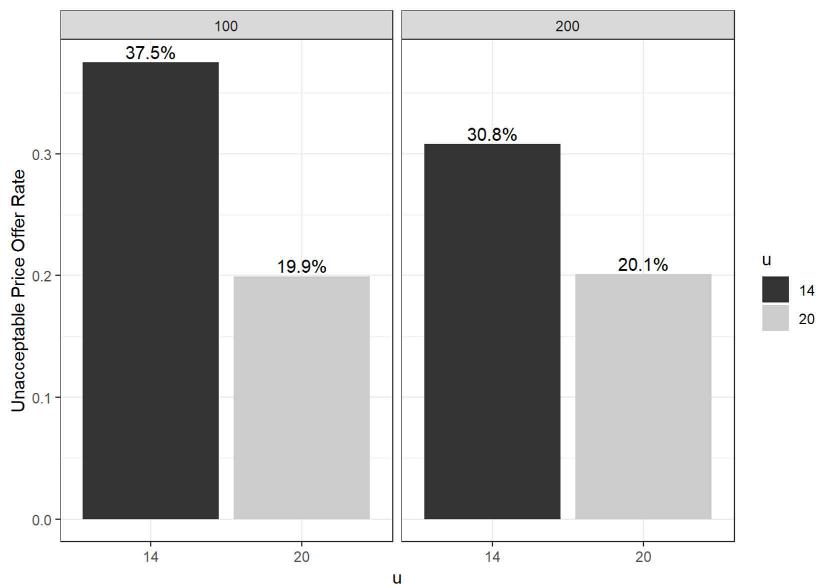

Figure 13: Unacceptable Offer Price Rate

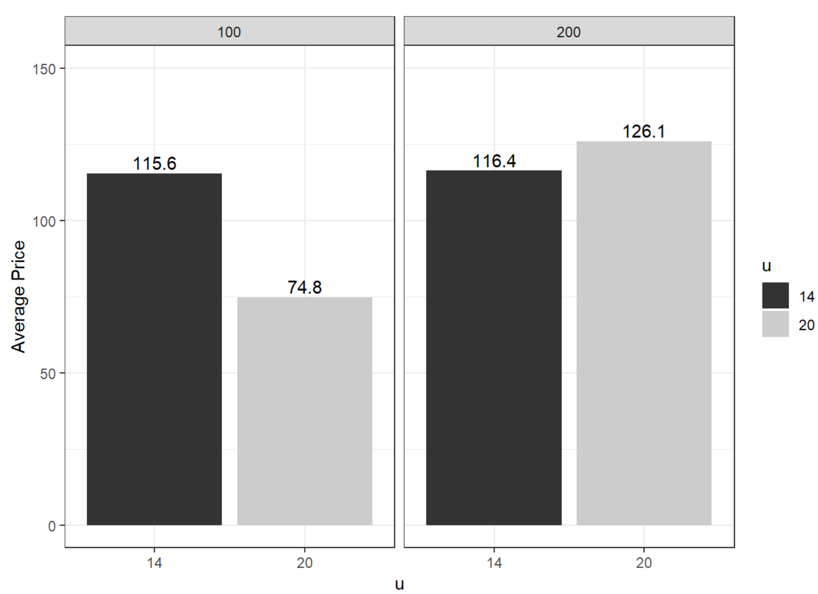

Figure 14: Acceptable Offer Price Levels

VARIABLES	Two Part (1st: Probit) SeriousOffer	Two Part (2nd: OLS) Price
Before_money	-0.00218***	-0.0455
	(0.000410)	(0.0458)
Period	-0.0319***	2.228***
	(0.00647)	(0.404)
u20	0.439*	-39.54*
	(0.249)	(18.43)
dis200	0.0895	1.026
	(0.441)	(19.71)
u20 × dis200	0.0268	38.72
	(0.574)	(25.51)
Constant	1.480***	70.58**
	(0.296)	(20.91)
Observations	4,584	3,309
R-squared		0.202

Session-clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Estimation of the Seller's Behavior Using Two-Part Estimation

Furthermore, in our model, it is difficult to build up the statistical model of seller's behavior that satisfies the exclusion restriction. Puhani [13] suggests that the two part model is less susceptible to bias than other models, such as a maximum likelihood estimation of the simultaneous equations. We implement the estimation of the seller's decision by following the suggestion.

The first column of Table 7 gives the estimation results for the first part of the two-part model by the probit model whose dependent variable is whether a seller seriously offers a price. Formally, we consider that a seller seriously offers a price if the seller offers an acceptable price. By looking at the estimation result, we find that u20 is significantly positive, although dis200 and the cross term of u20 and dis200 are insignificant. Furthermore, we find that sellers are less likely to seriously offer a price as the level of money holdings increases.

The second column of Table 7 gives the estimation results of the second part of the two-part model with the linear regression on the level of a serious offer price. We find that the treatment variable u20 is significantly negative but dis200 and that the cross term of u20 and dis200 are insignificant.

Result 6 *(i) The possibility of a serious offer increases as the gain from trade increases.*

(ii) The possibility of a serious offer increases as the level of money holdings increases.

(iii) The level of a serious price offer decreases as the gain from trade increases.

(iv) The level of a serious price offer increases over periods.

5 Discussion and Conclusion

In this paper, we conducted experiments using a monetary search model with multiple stationary SPE and gift-giving equilibria. We observed that gift-giving rarely occurred, the subjects did not play any SPE, and in a treatment, they chose a more efficient allocation than in any SPE. That is, the subjects endogenously reduced the friction of monetary exchanges.

In the case of divisible money and endogenously determined prices, any money holdings distribution can be endogenously chosen through monetary exchanges, while it is limited in the case of indivisible money. Therefore, the opportunity for monetary exchanges grows; that is, the set of feasible allocations is larger than that in the case of indivisible money. Of course, a very inefficient allocation, which is more inefficient than the case of indivisible money, can be endogenously chosen. In our experiments, such an inefficient money holdings distribution was not chosen, and a large proportion of the subjects had money equal to or more than three times of the average transaction price. Therefore, the transaction prices were much less than those in the SPEs. Note that the average transaction prices were between 50.7 and 86.9, while the offer prices were between 74.8 and 126.1 and larger than the transaction prices because relatively high price offers were often rejected. Indeed, as shown in the previous section, buyers recognized that $\bar{p}$ was a fair price and often rejected a price larger than $\bar{p}$.

Some experiments using monetary search models are closely related to ours. Camera and Casari [2] (hereafter, referred to as CC) investigated an equilibrium selection problem in an economy with indivisible fiat money.[11] In their model, the agents can hold at most two units of money and can use only one unit in monetary transactions; that is, a transaction price is exogenously given. They find that the subjects used both monetary transactions and gift-giving. The former was 61.4% when monetary exchange was feasible, and the latter was 12.5% when it was infeasible. There are some differences between their model and ours in addition to the divisibility of money. The main differences are (1) in their model, the buyer and seller know whether monetary exchange is feasible, while in our model, they know the money holdings distribution in the current period, and (2) in their model, the bargaining protocol is simultaneous offers of a buyer and a seller, while in our model, it is a take-it-or-leave-it offer from a seller. Below, we compare the rates of monetary transactions and of gift-giving with the counterparts in our experiments.

The acceptance rate of the buyers, when they have a sufficient amount of money to accept an offer price, can be considered as a counterpart of the rate of monetary exchange when it is feasible in CC because both are the rates of monetary exchange when it is feasible. As shown in Figure 4, the acceptance rates of the buyers are between 69.9% and 77.7% and are larger than the rate of monetary exchange in CC. In their experiments, the difference in payoffs of a buyer and a seller in the case of cooperation is 18, and it is larger than $u - c = 10$ or 4 in our experiments. Therefore, from the viewpoint of payoff, it can be considered that the subjects are likely to cooperate through monetary exchange in CC. However, the cooperation rate is higher in our case, which is a reason why, in our model, subjects focus more on monetary exchanges than on gift-giving. Indeed, in our model, a seller chooses gift-giving by offering a price of zero, while in CC, he or she can directly choose 'cooperation'.

In our experiments, the rates of a zero price offer were between 0.091% and 1.7%. (See Figure 1.) On the other hand, CC reported that the rate of gift-giving was 12.5% when monetary exchange was infeasible. It is not possible to directly compare these results, because the information on the subjects is different. That is, in their model, in each matching, the buyer and seller know whether monetary exchange is feasible. However, in our case, they do not have this information, but they know the money holding distribution in each period. That is, the devices for coordinating on gift-exchange equilibria are different. Therefore, there are several ways to compare these two results. First, the rate of cooperation, which means that a seller gives a good no matter what the buyer's choice is, may be a counterpart to a zero price offer. This rate is 12.6% and is much larger than our case. The second way is to compare the rates of successful gift-giving: the rate of an accepted zero price offer in our case and the rate of gift-giving when monetary exchange was infeasible in CC. The former was between 0% and 1.62%, and the latter was 12.5%. (See Figure 15.) In our experiments, subjects had positive amounts of money with high ratios between 68.5% and 94.2%, and thus a seller might think that a buyer almost always had a positive amount of money. Therefore, the third way is to compare the rate of accepted zero price offers in our case and the rate of gift-giving when monetary exchange was feasible in

[11] Duffy and Ochs [5] also conducted experiments using a model with indivisible fiat money, and reported that fiat money often served as a medium of exchange. However, their model is quite different from CC and our model. For example, in their model gift-giving is not allowed and goods can be circulated as media of exchange. Therefore, it is very difficult to compare their results with ours.

CC. The former was between 0% and 1.62%, as in the above, and the latter was 0.1%. However, this might not be the correct way to compare the results because the money holdings for a buyer could be much smaller than $\bar{p}$ with some probability, and thus, a seller might think that a buyer does not have a sufficient amount of money to accept $\bar{p}$.

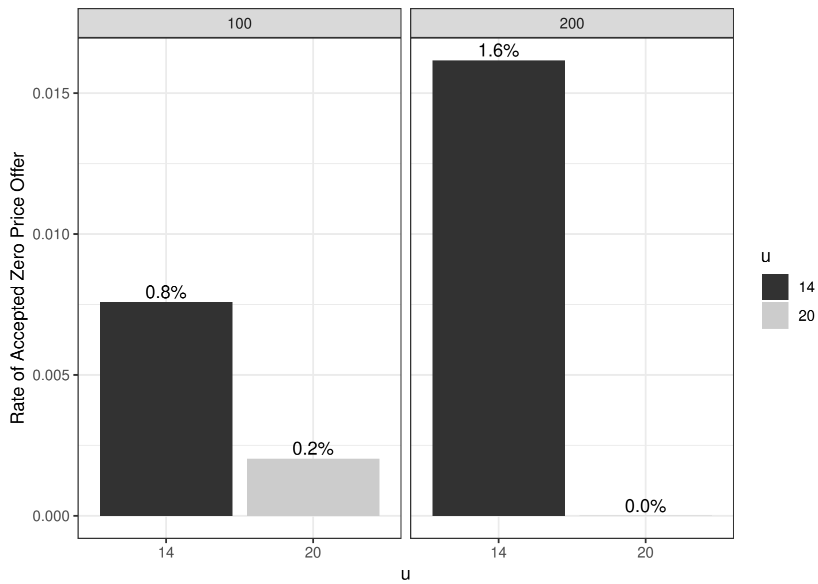

Figure 15: Rate of Accepted Zero Price Offer

Duffy and Puzzello [6] also investigate an equilibrium selection problem in an economy with divisible fiat money. Their model is a variant of Lagos and Wright's [12] model, where goods are traded in a search market and a Walrasian market, and there are a unique stationary monetary equilibrium and multiple non-monetary gift-exchange equilibria. One of their main concerns is whether subjects choose an efficient non-monetary gift-giving equilibrium. They find that the monetary equilibrium is selected in almost all cases, because more than 95% of the accepted offers include positive token (money) quantities. Their model is clearly very different from ours. First of all, the agents rebalance their money holdings in the Walrasian market, i.e., their money holdings become the same after trading in the market, and thus, their model is not an appropriate model for investigating the efficiency of money holdings distributions. In addition to the market institutions, the main differences are as follows. Goods are divisible and buyers have all the bargaining power in their case, while goods are indivisible and sellers have all the bargaining power in our case. Therefore, it is almost impossible to directly compare the results. However, slightly less than 5% of offers in their experiments have a zero price, which is much larger than our case. On the other hand, monetary offer acceptance rates are between 34.2% and 59.4%, and they are smaller than our case. Therefore, in Duffy and Puzzero [6], gift-giving occurred more frequently and monetary exchange occurred less frequently than those in our experiments.

In conclusion, the divisibility of money enhanced monetary exchanges and relatively efficient allocations were chosen through experiments, although inefficient allocation could be chosen. Moreover, gift-giving very rarely occurred. Finally, we compared the difference between our results and those in the literature.

References

[1] Matthias Blonski, Peter Ockenfels, and Giancarlo Spagnolo. Equilibrium selection in the repeated prisoner's dilemma: Axiomatic approach and experimental evidence. *American Economic Journal: Microeconomics*, 3(3):164–192, 2011.

[2] Gabriele Camera and Marco Casari. The coordination value of monetary exchange: Experimental evidence. *American Economic Journal: Microeconomics*, 6(1):290–314, 2014.

[3] Gabriele Camera, Marco Casari, and Maria Bigoni. Money and trust among strangers. *Proceedings of the National Academy of Sciences*, 110(37):14889–14893, 2013.

[4] Pedro Dal Bo and Guillaume Frechette. The evolution of cooperation in infinitely repeated games: Experimental evidence. *American Economic Review*, 101(1):411–429, 2011.

[5] John Duffy and Jack Ochs. Intrinsically worthless objects as media of exchange: Experimental evidence. *International Economic Review*, 43(3):637–673, 2002.

[6] John Duffy and Daniela Puzzello. Gift exchange versus monetary exchange: Theory and evidence. *American Economic Review*, 104(6):1735–1776, 2014.

[7] Urs Fischbacher. Z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, 10(2):171–178, 2007.

[8] Kazuya Kamiya, Noritsugu Morishita, and Takashi Shimizu. The existence of single-price equilibria in a matching model with divisible money and production cost. *International Journal of Economic Theory*, 1(3):219–231, 2005.

[9] Kazuya Kamiya and Takashi Shimizu. Real indeterminacy of stationary equilibria in matching models with divisible money. *Journal of Mathematical Economics*, 42(4):594–617, 2006.

[10] Kazuya Kamiya and Takashi Shimizu. On the role of the tax-subsidy scheme in money search models. *International Economic Review*, 48(2):575–606, 2007.

[11] Nobuhiro Kiyotaki and Randall Wright. A search-theoretic approach to monetary economics. *American Economic Review*, 83(1):63–77, 1993.

[12] Ricardo Lagos and Randall Wright. A unified framework for monetary theory and policy analysis. *Journal of Political Economy*, 113(3):463–484, 2005.

[13] Patrick Puhani. The Heckman correction for sample selection and its critique. *Journal of Economic Surveys*, 14(1):53–68, 2000.

[14] Ruilin Zhou. Individual and aggregate real balances in a random-matching model. *International Economic Review*, 40(4):1009–1038, 1999.

Appendix: Existence of Gift-Giving Equilibria

To analyze the strategy for the gift-giving equilibrium described in this paper, let us consider the incentive conditions for the seller and buyer in each phase. Suppose that the phase is C. First, consider the seller's incentives in Phase C. If the seller follows the prescription of the strategy, that is, the seller offers a zero price, then he or she obtains:

$$V_s^C = (1-\delta)(-c) + \delta[(1/2)V_s^C + (1/2)V_b^C]. \tag{6}$$

If the seller deviates to offer a positive price, then he or she obtains 0 in this period and the phases from the next periods on are D so that he or she obtains 0 forever. Therefore, we can verify that the seller has an incentive to follow the strategy in this situation if δ is sufficiently close to 1.

Second, consider the buyer's incentive in phase C. Suppose the situation in which the seller offers a zero price in phase C. If the buyer follows the prescription of the strategy, he or she obtains:

$$V_b^C = (1-\delta)u + \delta[(1/2)V_s^C + (1/2)V_b^C]. \tag{7}$$

If the buyer deviates and rejects the offer a zero price, then he or she obtains 0 in this period and the phases from the next periods on are D so that he or she obtains 0 forever. Because the condition (6) ≥ 0 implies (7) ≥ 0, the existence of δ that supports (6) ≥ 0 guarantees the buyer's incentive in this situation.

On the other hand, suppose that the seller offers a positive price in phase C. If the buyer has enough money to accept the offer and follows the prescription of the strategy, then the buyer obtains u in this period and obtains 0 from the next periods on. Therefore, the buyer obtains $(1-\delta)u + \delta \cdot 0 = (1-\delta)u$ If the buyer has enough money to accept the offer and deviates from the prescription of the strategy, the buyer obtains 0 in this period and obtains 0 from the next periods on. By the comparing payoffs, we can verify that buyers have an incentive to follow the strategy in this situation.

Next suppose that the phase is D. First, consider the seller's incentives in Phase D. If the seller follows the prescription of the strategy, he or she obtains 0 forever. Suppose that the seller deviates to offer a positive price that is less than the maximum amount of money in that period. If the buyer has enough money to accept the offer, then the seller pays the cost c in this period and obtains 0 from the next periods on. Therefore, the seller does not have incentives to deviate. On the other hand, if the buyer does not have enough money to accept the offer from the seller, then the seller obtains 0 forever. Therefore, the seller does not also have an incentive to deviate in this situation.

Second, consider the buyer's incentive in phase D. Suppose the situation in which the seller offers a price that is more than the maximum amount of money in that period. Because the buyer can not accept the offer, there is no incentive problem in this situation.

On the other hand, suppose that the seller offers a positive price in phase D. If the buyer has enough money to accept the offer and follows the prescription of the strategy, then the buyer obtains u in this period and obtains 0 from the next periods on. Therefore, the buyer obtains $(1-\delta)u + \delta \cdot 0 = (1-\delta)u$. If the buyer has enough money to accept the offer and deviates from the prescription of the strategy, the buyer obtains 0 in this period and obtains 0 from the next periods on. By the comparing payoffs, we can verify that buyers have an incentive to follow the strategy in this situation.

Appendix: Sample Instructions

The instructions were originally written in Japanese. Here, we provide a translated sample copy of the experimental instructions used in our treatment "$dis = 200$ & $u = 20$."[12] The instructions for the other treatments were adapted accordingly.

Instructions

This is an experiment in economic decision-making. If you understand these instructions well, and make the appropriate decisions, you can earn a reasonable amount of money. The points that are acquired during the course of this experiment will be converted into monetary funds and paid out in cash once the experiment is over. At the start of the experiment, you will be given 300 points, and this amount will fluctuate in accordance with your decision-making thereafter. In this experiment, 1 point will be converted to 10 yen.

1. In this experiment, you will engage in multiple periods of decision-making. You are to randomly gather with other subjects in one group consisting of six people, and make multiple decisions. The sequence of periods in which the same six people form the group will be called a "cycle."

2. The length of the cycle will be randomly determined. After each decision-making in a period, there is a 90% probability that the cycle will continue. In other words, there is a 10% probability that the cycle will end.

3. Once the cycle ends, six new people will form a group at random, and a new cycle will begin.

4. During each cycle, six people form one group and engage in decision-making. These six people will not change (groups) until that cycle is over.

5. In this experiment, besides points, a substitute currency will be used. At the start of each cycle, three members from each group selected at random will be assigned 0 units of the substitute currency, while the remaining three members will be assigned 200 units of the substitute currency.

   Figure 1 shows a summary of the above flow.

   Each period will proceed according to the following format.

[12] In the main part of this paper, we use the term "cycle" to refer to a cycle of the stage games until the period when play is randomly terminated. However, we used the term "cycle" to refer the same concept in our instruction. This is because the term "cycle" better fits this context in Japanese.

1. In each period, among the six people who created the same group at the beginning of the cycle, you will randomly form a group of two with subjects other than you and engage in decision-making.
2. Although you are allowed to know the distribution of the substitute currencies among the six members of your group, you will not know the amount held by your paired subject.
3. At random, one of the people in the pair will be assigned the role of the "buyer," while the other will be assigned the role of the "seller".
4. The seller will always have the opportunity to sell one unit of goods to the buyer. When doing so, the seller will present the amount of substitute currency requested to the buyer in exchange for the goods.
5. Upon examining the amount of substitute currency that has been requested, the buyer decides whether to "make a deal" or to "not make a deal." However, when the amount of substitute currency requested by the seller is more than the amount held by the buyer, "do not make a deal" is automatically selected.
6. If the buyer chooses to "make a deal" and a deal is established, the buyer acquires 20 points; at the same time, the buyer loses the requested amount of substitute currency. On the other hand, when a deal is established, the seller loses 10 points to represent the cost of producing the goods; at the same time, the seller acquires the requested substitute currency.
7. If the buyer does not make a trade, both the buyer and seller will earn 0 points. In other words, there will be no increase or decrease in terms of points. Furthermore, there will be no increase or decrease in the substitute currency.
8. Here, it is worth noting that the buyer will lose the requested amount of substitute currency instead of being able to earn points by trading and acquiring goods, and the seller will lose points because the deal is made and the goods are handed over to the buyer. In particular, points are not acquired by holding a substitute currency.
9. The following three pieces of information about the group will be displayed at the end of each period: (1) Success or failure in regard to deals made among the three pairs in the group, (2) the amount of substitute currency requested by the seller for groups in which deals are made, (3) the distribution of the substitute currency held by the six members of the same group after these deals have been made.

   Figure 2 shows a summary of the aforementioned flow.

Notes:

(1) At the beginning of the cycle, the assignment of the substitute currency is determined randomly, regardless of the amount of substitute currency held in the prior cycle. In other words, at the end of the cycle, all substitute money held will be set to zero, and will be newly assigned randomly at the start of the next cycle.

(2) One hour after the start of the experiment, the experiment will end at the completion of the current cycle.

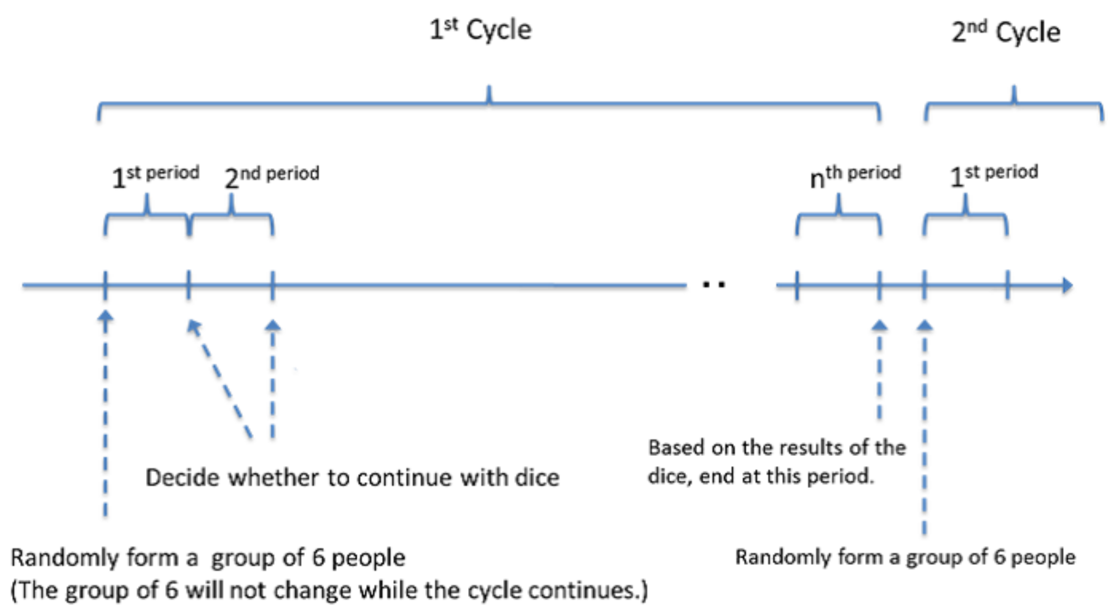

Figure 1. Relationship Between Each Period and Cycle

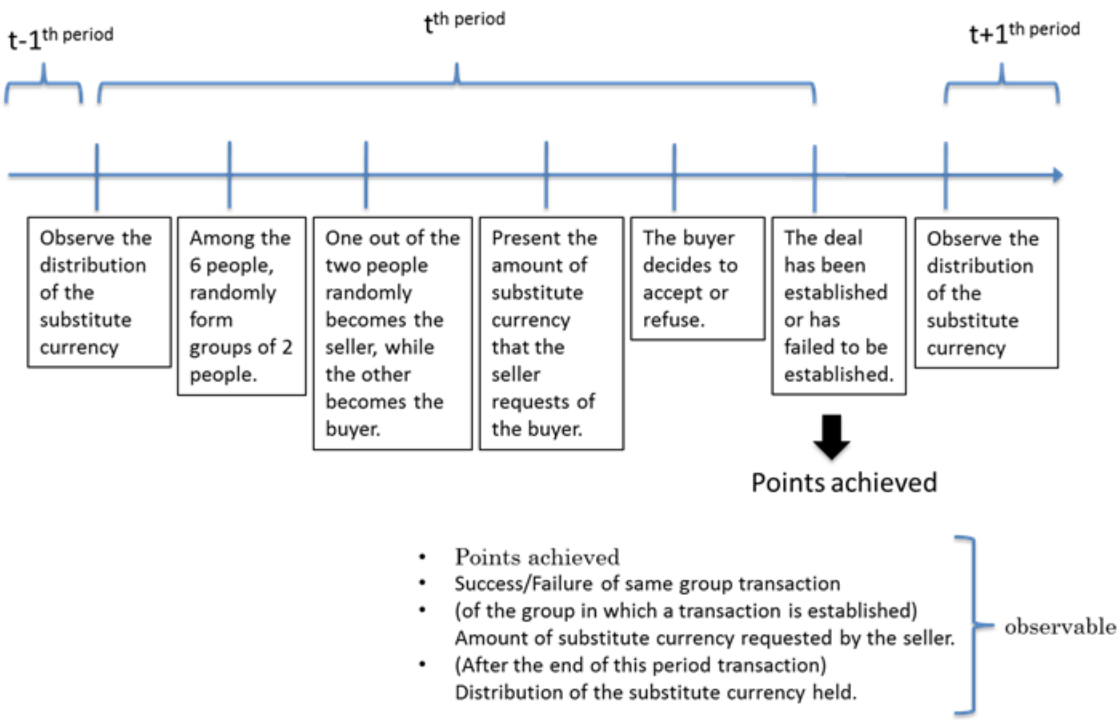

Figure 2. Decision-Making Flow for Each Period

Appendix: Screen shots

The screen shots of the program are illustrated in Figures 16-19.

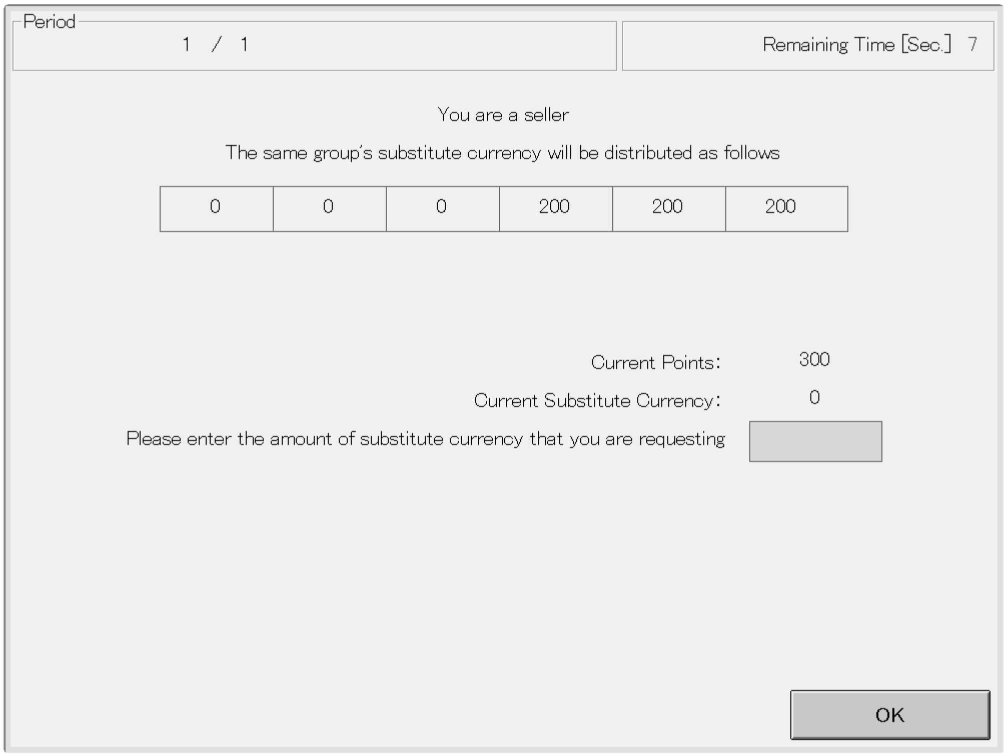

Figure 16: Seller's Decisions Screen

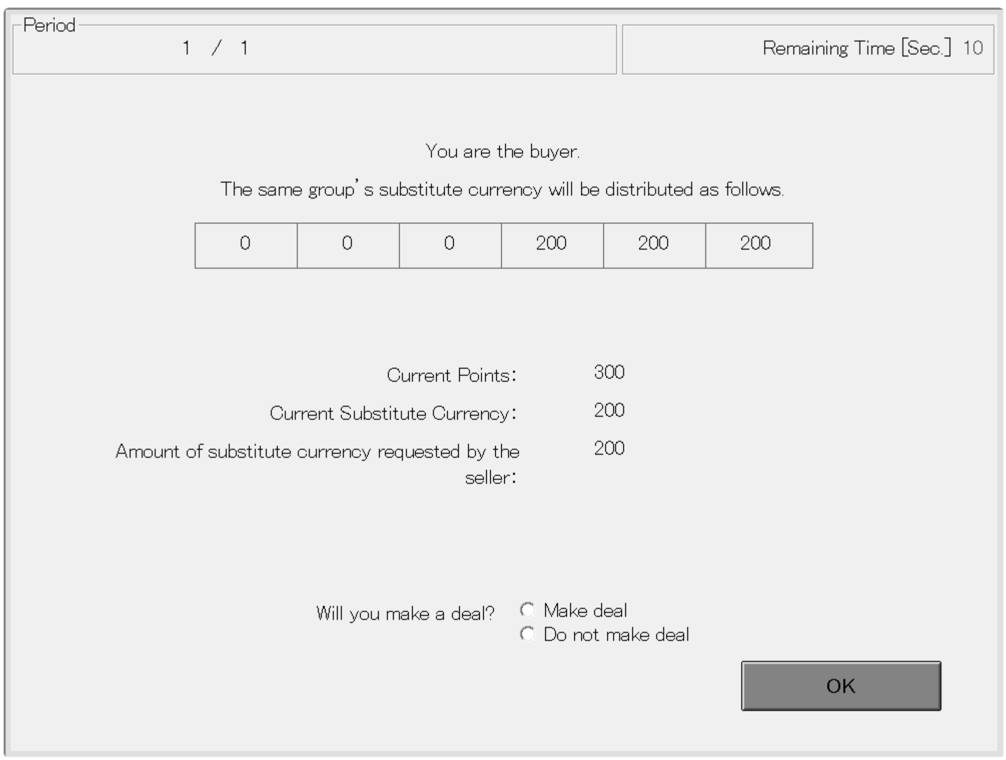

Figure 17: Buyer's Decisions Screen: Acceptable Offer

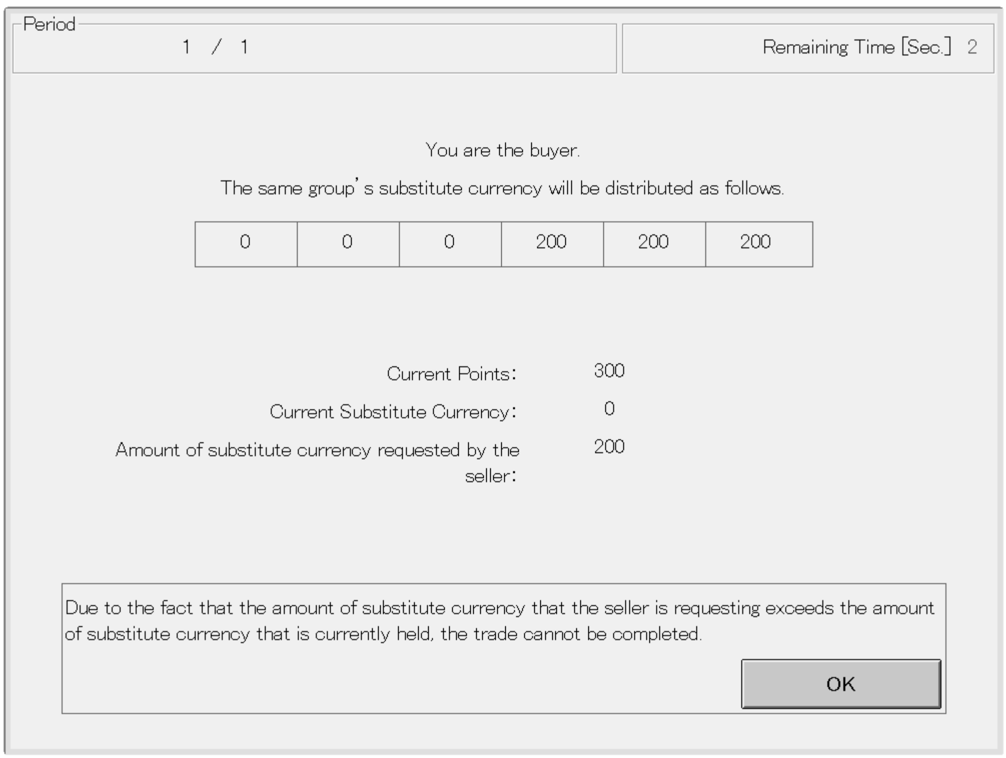

Figure 18: Buyer's Decisions Screen: Non-Acceptable Offer

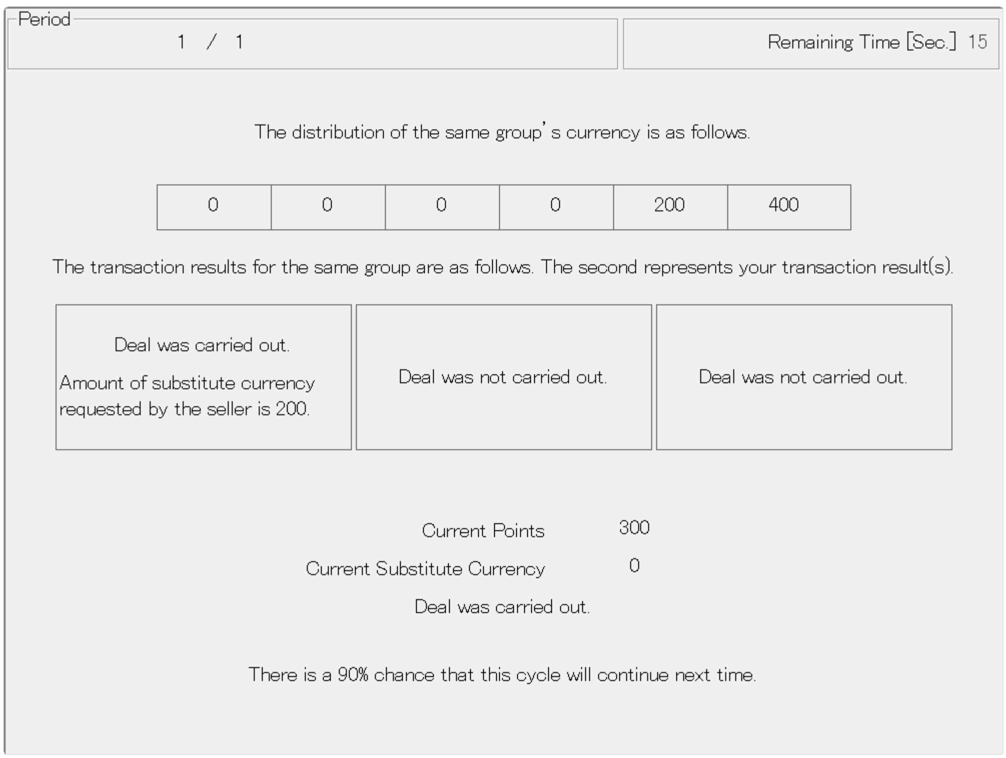

Figure 19: Transaction Result Screen