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Rate-of-Return Dominance and Efficiency in an Experimental Economy

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Abstract

One of the main challenges for monetary economics is to explain the use of assets that are dominated in rate-of-return as media of exchange. In this paper, we use experimental methods to study how a fiat money might come to be used in transactions when an identically marketable, dividend-bearing asset, a consol, is also available. Our experimental economies, which have an overlapping generations structure, have the property that the only stationary rational expectations equilibria (SREE) require exclusive use of the consol as the medium of exchange. In a baseline treatment, agents use the consol exclusively, as would occur in an SREE. However, in other treatments, we observe episodes of rate-of-return dominance, as there is consistent use of fiat money as a medium of exchange. The results show that two properties of our economies are associated with the rate of return dominance anomaly. The first is a history of trading with fiat money, prior to the introduction of the consol. The second is the timing of the dividend payment; when the dividend payment follows the execution of trades between generations, hoarding of the consol occurs on the part of the old, who earn dividends by hoarding. In our economies, settling transactions with a dividend-bearing asset does not improve allocations over those resulting from trading with fiat money.

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1 Introduction

Fiat money, which is an intrinsically worthless and inconvertible object, is the generally accepted medium of exchange in most societies. Remarkably, this acceptance occurs despite the availability of other potential media of exchange that would yield their bearers a greater rate of return. For example, in the U.S. it is possible, at least in principle, to write contracts in terms of Treasury bills instead of cash. The T-bills would dominate cash because they are virtually default-free, interest-bearing assets.[1] The nature of the anomaly, known as the rate-of-return dominance of money, is clearly articulated by Hellwig (1993) who, in his presidential lecture to the European Economic Association, writes "Why does 'worthless' fiat money have a positive value in exchange against goods and services when there are other assets whose own rates of return in each period exceed the own rate-of-return on money?"

Monetary theorists have viewed the persistence of the use of assets that are dominated in rate-of-return as one of their main challenges at least since Hicks (1935) described it to be "the central issue in the pure theory of money". According to Hicks, "What has to be explained is the decision to hold assets in the form of barren money, rather than of interest- or profit-yielding securities."[2] The problem, however, is still largely unresolved. Hellwig (1993) writes, "If there is an asset whose own rate-of-return exceeds the own rate-of-return on money in each period with probability one, and if the asset has the same marketability properties as fiat money, then there exists no rational expectations equilibrium in which fiat money has positive real value." More recently, Wallace (1997) has referred to the coexistence of money and higher-return assets as

[1] We recognize of course, that the smallest denomination of T-bill available is greater than the value of many transactions. Wallace (1983) shows that coexistence of fiat money and T-bills can be consistent with a rational expectations equilibrium, by assuming a large denomination of the assets and the imposition of legal restrictions on private intermediation. Transactions smaller than the minimum denomination of T-bill must take place in terms of fiat money. There is evidence that the U.S. Liberty Bonds, issued during WWI in denominations as small as $50 (about $800 in today's value), circulated as currency at times.

[2] The mere existence of a valued fiat money, even in the absence of a dominating asset, poses challenges to theoretical modeling. Many authors, including Hahn (1965), Clower (1967), Brunner and Meltzer (1971), and Wallace (1980), have argued that the existence of fiat money can not be reconciled with Walrasian equilibrium. The monetary literature has seen the use of several alternative modeling choices to circumvent this problem. A popular approach has been the use of overlapping generations models based on Samuelson (1958), where fiat money is valued because of physical restrictions on intergenerational exchange (e.g. Wallace, 1980). Following Clower's view (1967) that "goods do not buy goods", others have used models where a demand for fiat money is generated by the imposition of restrictions on the way transactions are settled (e.g. Grandmont and Younes, 1972, Lucas, 1980, Diamond, 1990). Another alternative has been placing fiat money directly in the utility function, justifying it on the grounds of some transaction technology (e.g. Sidrauski, 1967, Feenstra, 1986). More recently models have been developed in which fiat money acquires value endogenously in decentralized trading environments with explicit exchange frictions (e.g. Townsend, 1980; Freeman, 1989; and Kiyotaki and Wright, 1989).

one of the two main challenges facing monetary economics.

Because rate-of-return dominance is so difficult to reconcile with theoretical models based on standard assumptions, it seems appropriate to search for starting points of alternative modeling strategies. One possibility might be to construct and identify classes of economies in which rate-of-return dominance occurs, and try to isolate the principles of behavior that seem to have caused it. These principles can then be used to help guide avenues of future theoretical modeling. In this paper we take the first step in such an approach. We use experimental methods to create conditions under which rate-of-return dominance does and does not occur. We then identify characteristics of the economies that appear to encourage the use of the dominated asset, which in our experiment, takes the form of a fiat money.

We take the view that the use of experimental methods can complement traditional empirical methods in studying questions in macroeconomics. Studies of field data can identify the characteristics of economies that exist in the field, but are restricted to studying economies that occur naturally. Thus, they can not be used to study other economic situations, that do not occur naturally, but that might be of interest to researchers and policymakers. These include economies with the exact structure of well-understood theoretical models or economies that isolate the effect of an exogenous shock or a policy change of interest, while holding other variables constant. Experimental methods allow the creation of controlled economies designed specifically to consider research questions. The economist can specify the structure of an experimental economy, including the levels of exogenous parameters generally unobservable in the field, and precisely measure the levels of the endogenous variables generated in the economy. Individual parameters can be manipulated to test comparative static or dynamic predictions of models, or the effect of shocks or policy changes. In addition, multiple experimental economies with an identical structure can be constructed. This serves to validate the effects observed, and to establish the degree of reliability of the results obtained. The research goals are to gain a thorough understanding of how the experimental economy operates and build intuition about how a broader class of economies might behave. This intuition can lead to assumptions, on which to base new theoretical models.

The experimental economies we construct have a simple structure, which is a modified version of the overlapping generations model of Samuelson (1958), and which draws on experimental methods introduced by Marimon and Sunder (1994), Lim, Prescott and Sunder (1994), and Aliprantis and Plott (1992). Our economies are populated by eight subjects who participate in a series of two-period trading sequences. The first (second) periods within a sequence correspond to the young (old) generations in the theoretical model. In each period the agents can trade two types of assets, a dividend-bearing consol and a fiat money, for a perishable good. Young agents, who are endowed with the good, can sell it for either one of the assets, which they may use to buy goods when they become old. There is only one injection of each asset into the economy. At the end of each period, any asset remaining in the old agent's inventory is permanently removed from the economy. Thus, the economy's stock of either asset may decrease from period to period, even to the extent that it exits the economy entirely. Monetary rational expectations equilibria do not exist in this environment. In any rational expectations equilibrium, the asset is the sole medium of exchange.

However, observed behavior may deviate from rational expectations equilibrium behavior, and it is possible that the fiat money come to be used as a medium of exchange either exclusively or along with the consol. The experiment explores the effects of two factors that might induce behavior that would lead to rate-of-return dominance. Both have to do with the timing of activity in the economy, and neither affects the property that the consol is the only medium of exchange possible in a rational expectations equilibrium. The first factor is a history of use of fiat money before the introduction of the consol. If fiat money has been previously accepted as a medium of exchange, agents might build confidence that it will continue to circulate even after the consol becomes available. It is natural to hypothesize that history influences choice of trading instrument. The idea dates back at least as far as Menger (1892) who writes "It is obvious how highly significant a factor is habit in the genesis of such generally serviceable means of exchange."

The second factor is the existence of an opportunity cost for using the consol in trade, stemming from intrinsic properties of the consol. We have created such an opportunity cost in some of our treatments by specifying the timing of activity so that the consol pays its dividend after the execution of commodity trades. This could encourage hoarding of the consol by the current old generation, and cause it to exit the economy, because unspent assets of old agents are lost. If trade occurs after the dividend is paid, no such opportunity cost exists.

The experiment consists of three treatments. The first is the *Simultaneous* (SIM) treatment in which both assets, consol and fiat, are introduced into the economy in the first period, and trade takes place prior to the payment of the dividend. The second treatment is called *Sequential Pre-dividend* (SEQP). In SEQP, old agents receive an endowment of fiat money in the first period of the experiment and the consol is introduced at the beginning of period five. Trade in this treatment also takes place pre-dividend, as in SIM. The final treatment is called *Sequential Ex-dividend* (SEQE). The timing of the introduction of the assets in SEQE is exactly the same as in SEQP, but trade occurs after the payment of dividends. In each of the treatments, there are *Equal Endowment* sessions, in which each old agent receives the same amount of consol, as well as *Unequal Endowment* sessions, in which endowment of the consol was provided to one-half of the old agents. In all treatments, the only stationary rational expectations equilibria involve the use of the consol as the sole medium of exchange, whenever the consol is present.

The data show that in the SIM treatment the incidence of use of consol and fiat money is consistent with a stationary rational expectations equilibrium. The fiat money quickly exits the economy and the consol remains in circulation. In the SEQP and SEQE treatments, however, the fiat money is widely used even after the introduction of the consol. This behavior is inconsistent with rational expectations and indicates rate-of-return dominance. The economies of the SEQP and SEQE treatments are characterized by greater realized gains from intergenerational trade than the SIM treatment.

The study demonstrates the following. In our economies, the consol will emerge as the sole medium of exchange, unless there is an opportunity for fiat money to establish a history of use prior to the introduction of the asset. The history appears to encourage the continued circulation of fiat money. A second feature that discourages the use of the consol is the payment of the dividend after trade. This promotes hoarding of the consol by old agents to earn dividends, and discourages its circulation. If both a history of use of fiat and pre-dividend trade are present, rate-of-return dominance will typically occur and lead to an outcome which is reminiscent of Gresham's Law, where "bad" money drives out "good" money. Surprisingly, the circulation of fiat money appears to be associated with greater intergenerational gains from trade because of a lack of liquidity engendered by excessive hoarding of the consol.

In section 2, previous experimental work in monetary economics is briefly surveyed. Section 3 describes the experimental environment. The stationary rational expectations equilibria for the economies are characterized in Section 4. The results of the study are presented in Section 5, and Section 6 contains a brief summary and concluding remarks.

2 Related Experimental Work

For over a decade, experimental methods have been used to investigate issues in monetary economics (see Duffy, 1998, for a comprehensive survey). McCabe (1989) was the first to study fiat money in the laboratory. He constructed a finite-horizon overlapping-generations economy, in which a group of subjects was divided in equal numbers into three types, each representing a generation, that could use fiat money for intergenerational trade. Due to a finite time horizon, there existed no equilibrium in which fiat money would be used. Since money had no value at the end of the time horizon, backward induction implied that it would not be accepted at any time. Subjects interacted repeatedly in a sequence of these finite-horizon economies. Inexperienced subjects consistently did use the fiat money for trade. However, as subjects gained more experience, they began to refuse to accept fiat money and the period of first refusal became earlier and earlier within the horizons.

Lim, Prescott, and Sunder (1994) investigated an economy with an infinite horizon overlapping generations structure in which fiat money was available for transactions.[3] Young agents were endowed with a non-durable good, which they could sell to old agents for money. There was a unique stationary rational expectations equilibrium (SREE) price path and a continuum of non-stationary equilibrium price paths. In the experiment, they observed that the fiat money was used and the gains from trade were close to the maximum possible level. Prices tended to converge to the SREE price, and explosive patterns were not observed.[4]

Aliprantis and Plott (1993) constructed an experimental overlapping generations economy, in which a real asset was used for intergenerational trade. They found that prices converged to the unique SREE level. They also observed that the dynamics resulting from unanticipated shocks to demand and supply were consistent with the SREE.

Brown (1996) conducted the first experimental study where different commodities, characterized by different holding costs, could be used as media of exchange. His experiment corresponded to the random matching environment of Kiyotaki and Wright (1989). For the parameters studied, two media of exchange with different holding costs circulated in the Nash equilibrium of the game. The results showed that the low-cost object was used more often than predicted. Duffy and Ochs (1999) conducted an experiment using a similar environment, but made more information available to subjects about the type of trader with whom they were randomly matched, and the type of object in his inventory. They also provided a history of use of the different objects. However, they still found that use of the commodity with the lowest holding cost was greater than predicted by the theoretical model.

Duffy and Ochs (1998) added a fiat object to the above economy. In one treatment the fiat object had no storage cost, and in another it had a storage cost greater than one of the commodities.[5] In their economies, the fiat object was frequently held by agents when they also had the option of holding a good with a higher storage cost, whether it was optimal to hold fiat or not. Thus fiat money was used, and tended to be held when it dominated the alternative in "rate of return" in the sense that had a lower storage cost.

The studies of McCabe (1989), Lim, Prescott and Sunder (1994) and Marimon and Sunder (1994) suggest

[3] See Ochs (1995) for a review of experimental studies of the role of money in overlapping generations environments.

[4] Marimon and Sunder (1994) studied a similar economy in which the stock of fiat currency was allowed to grow over time by government action. They found that the fiat money was used, and that prices converged toward a low-inflation steady state in a manner consistent with adaptive expectations (see Lucas, 1986). They also directly elicited expectations, and found that they were generally adaptive.

[5] Generally in these environments there are two pure strategy Nash equilibria. First, since fiat money has no intrinsic properties, it will not circulate if no one believes that it has value in exchange. Second, fiat money may be a medium of exchange if everyone believes all traders will accept it in exchange for some good. In this latter case it can be shown that fiat money does not need to have the lowest storage cost to have value in equilibrium.

that fiat money will be used when its use is essential to exploit potential gains from trade. This can occur even when the fiat money's sustained use is inconsistent with rational expectations on the part of agents. When multiple potential media of exchange are present, as in the setting of the Kiyotaki and Wright model, there is evidence that fiat money will be valued when its use is consistent with an equilibrium. There is some tendency for avoidance of rate-of-return dominance to manifest itself. In the experiments of Brown (1996) as well as in Duffy and Ochs (1998, 1999), the objects with low holding costs were generally somewhat more likely to be used than predicted by the theoretical model.

The experimental designs of Brown and Duffy and Ochs are specified to conform to the model of Kiyotaki and Wright, in which multiple currencies are predicted to emerge even when agents have rational expectations, because of absence of double coincidence of wants and trade frictions. In these studies, rate-of-return dominance can occur for reasons consistent with received monetary theory. However, in the current paper, our focus is not on testing theoretical models in which rate-of-return dominance can arise. Rather, we are interested in behavioral factors that might cause rate-of-return dominance when unanticipated by standard theory. To investigate this issue, we have chosen to extend the simple, elegant experimental design of Lim, Prescott and Sunder (1994) and Marimon and Sunder (1994). We construct an experimental economy similar to theirs, but in which in addition to the fiat money, a durable dividend-bearing asset is also available to use in trade. We have seen from previous studies that fiat money will be used when no alternative media of exchange are available. Our study considers whether fiat money will be used when it is dominated in rate of return by another asset, and what aspects of the experimental environment might lead to its use.

3 The Experimental Economies

There are many potential experimental economies that could have been constructed to study the issues that we are concerned with. We have chosen our particular design for several reasons. One reason is that stationary rational expectations equilibria can be easily characterized and compared to the data. A second reason is that the structure of the economy allows us to clearly identify an episode of rate-of-return dominance. Because an asset quickly exits the economy if it is not traded, it is obvious which, if any, of the assets have become media of exchange. A third reason is that since our design is largely based on previous experimental studies, it facilitates comparison with earlier work by other authors. A fourth reason is that the simplicity of the design makes us confident that confusion among the subjects about the decision situation was not a factor in determining the observed outcomes.

3.1 Economic Environment

In all sessions of the experiment, activity took place over a sequence of periods. The economies had an overlapping generations structure, and in each period one half of the participants were "young" and the other half were "old". In all communications with subjects, we use the term "entry period participant" to denote a young agent and the term "exit period participant" to denote an old agent. After completing a period as an exit (entry) period participant, the subject became an entry (exit) period participant for the next period. Thus the economy departed from the standard overlapping generations model by including "rebirth", the property that an old agent in period t was reborn as young in $t+1$. The implications of rebirth on the set of SREE are discussed in section four.

Young agents in each period were endowed with "chips", a perishable consumption good with identical consumption value for all agents. There were two potential media of exchange, "Red" and "Blue" tickets, that could be used to buy and sell chips. The Blue tickets were a fiat money and the Red tickets were a dividend bearing asset (consol) that paid a dividend equal to 1¢ per ticket, in every period. There were two markets, called Red and Blue, in which subjects had the opportunity to buy and sell chips. Trade in the Red (Blue) market had to occur in terms of Red (Blue) tickets. In all sessions, Blue tickets were given to all members of the initial old generation at the beginning of period 1. Red tickets were also given to the initial old in the *Simultaneous* (SIM) treatment. In the *Sequential* treatments, SEQE and SEQP, Red tickets were given to the current old generation at the beginning of period five.[6]

The incentive for exchange was due to the existence of gains from intergenerational trade. All subjects in the experiment received cash payments in $US based on the number of chips they consumed and the dividends they earned. Young agents, who were endowed with chips but no tickets, could increase their earnings by selling chips for tickets, and then could use the proceeds in the following period to purchase chips from the young of the next generation. Furthermore, if they sold their chips for Red tickets when young, they increased their earnings by receiving dividends on their Red ticket holdings. Members of the initial old generation, who were endowed with tickets but no chips, could increase their earnings by purchasing chips from the initial young.

The cash payments subjects received for consuming chips differed between sessions. The five payment schedules used are referred to as Utility Functions A-E and are given in Table 1. This table illustrates the $US value of chip consumption within a single period. The first column in the table, labeled *Unit*,

[6] In none of the Sequential sessions were subjects explicitly informed that consol would be introduced later in the second session. After the consol was introduced in period 5, the experimenter announced that there would be no more tickets introduced into the economy in the future.

corresponds to each chip consumed by the agent. u_i is the marginal dollar value from consuming an i^{th} unit. $u_1 + u_2$ is the total dollar value to the agent from consuming two units. No payments were received for consumption of any units beyond the second unit. The payment schedule of each subject remained the same in every period of a given experimental session.

[Place Table 1 Approximately Here]

The sequence of events within each period of the experiment is illustrated in Figure 1. At the beginning of each period, young agents received an endowment of chips, but no tickets. Once the market opened, they had the option of selling chips to old agents for either Red or Blue tickets. Old agents had the option of using Red or Blue tickets to try to buy chips. Under SEQE, old agents received a dividend for each Red ticket that they held prior to the opening of the market. Under SIM or SEQP, any agent, young or old, received the dividend corresponding to his holdings of Red tickets at the end of the period. Any tickets, Red or Blue, held by an old agent at the end of a period were permanently removed from the economy.

[Place Figure 1 Approximately Here]

Table 2 contains an outline of some characteristics of each of the 15 sessions. The first and second columns contain, respectively, the date and code name of each session conducted. The data in the *Red* and *Blue* columns are the per-agent quantities of the one time injection of Red and Blue tickets given to old agents. In the *Chips* column is the quantity of chips given to each young agent at the beginning of each period. The *Dist.* column describes the initial allocation of the Red tickets. In sessions in which the endowment was *Equal*, each old agent received an equal share, one-fourth of the total quantity shown in the column labeled Red under the heading Total MS. Under *Unequal* endowment, two of the four old agents received an equal share, 50 percent, of the total endowment of consol, except for sessions SIMSA and SIMSAx, in which a single agent received the entire endowment of Red tickets.[7] Otherwise, the SIMSA sessions followed all the same procedures as the SIM sessions. The *Total MS* columns provide the aggregate endowment of Red and Blue tickets in the economy. In the *Utility* column is the utility function (the payment schedule from table 1) used in each session. The *Period* column is the number of periods completed in each session. The *Exp.* column is the experience level of the subjects, which is defined as whether or not the subjects had participated in a previous session of the experiment. A suffix "x " on the session name indicates that subjects had participated in an economy previously. Prior participation was always in the same treatment.[8]

[7] A public roll of a die determined which agent(s) received the injection of currency.

[8] SIMSAx and SEQE4x, employed experienced subjects from sessions SIMSA and SEQE4, respectively. The "x" sessions took place immediately following the original sessions.

[Place Table 2 Approximately Here]

3.2 Procedures

The subjects were all recruited from undergraduate economics courses at Purdue University. Some of the subjects had participated in previous experiments. However, except for the SIMSAx and SEQE4x sessions, all of the subjects were inexperienced in this particular experiment, and participated in only a single session. A session lasted on average two hours, including initial training.

Sessions took place in a large classroom, where the chairs were arranged in two rows of four facing the front of the room. Each row corresponded to a generation of subjects so that all entry period participants were in the same row and all exit period participants were in the same row. The subjects were randomly assigned to these roles by their choice of seat as they entered the room. The experimenter read the instructions aloud at the beginning of the session. Thereafter, two periods of practice were conducted so that each subject would be allowed to practice in both roles, young and old, for one period. Earnings during these periods did not count toward their final payout. The purpose of the practice periods was to allow the subjects to become comfortable with the specific parameters of the session, the trading rules, and recording their earnings.

At the beginning of each period, the experimenter handed out two chips to each young agent. At the end of every period the experimenter collected all Red and Blue tickets remaining in the inventories of old agents, thereby removing them from the economy. He also collected all of the chips after the agents recorded their earnings and redistributed them to the next period's young. The subjects' records and calculations were also checked at the end of every period to ensure that they were correct.

All markets were conducted as continuous double auctions. The trading rules were as follows. In order to make an offer to the market, a subject would have to raise a cue card with her ID number written on it and wait to be recognized by the experimenter. The experimenter would call upon subjects to place offers in the order that they raised their cue cards. An improvement rule was imposed in all markets. Subjects would have to place an offer that was greater (less) than the standing market offer to buy (sell) in order to enter the market. To place an offer, the would-be buyer or seller was required to state the type of tickets he wanted to use for the trade, the type of offer (whether to buy or sell) the quantity of chips offered, and a price per chip. The experimenter recorded the information on the market record sheet, which was presented to the subjects on an overhead. A subject could submit only one offer each time that she was recognized by the experimenter. In order to accept a standing offer in the market, a subject had to call out, "Accept offer to buy/sell." If more than one subject simultaneously called out an acceptance, then the participant allowed to take part in the transaction were determined by the roll of a die. Once a transaction was agreed upon, the experimenter physically performed the transfer of chips and tickets between the traders. The accepted offer was cleared from the market and the next best offer became the new standing offer.[9]

The length of the period was determined by the volume of offers and transactions. If no agent indicated a willingness to submit a new offer or to accept a current standing offer, the experimenter announced aloud that the period would end in fifteen seconds, and continued to announce the time remaining in five second intervals until the time expired. A subject could stop the countdown at any time by submitting an offer to the market or accepting a standing offer. If again there was no new market activity, the fifteen second countdown began anew. This process ensured that the period would not end as long as any subject still wanted to participate in the market at the current price level.

A double auction market was used because previous studies have established that it tends to lead to competitive behavior on the part of agents, even when there is a small number of agents on each side of the market (see Smith, 1982), resulting in a competitive equilibrium outcome. This is a desired characteristic because the model we compare with our data contains the assumption of price taking behavior. In contrast, the laboratory evidence available suggests that a Walrasian tatonnement process results in less than the competitive equilibrium quantity transacted (Joyce, 1998), because of strategic under-revelation of quantities demanded and supplied. The sealed bid auction used by Lim, Prescott, and Sunder (1994), and Marimon and Sunder (1994), in which all bids are submitted simultaneously, presents difficulties of implementation here, because our economy requires the operation of two simultaneous markets, in which activity in one market would be expected to influence decisions in the other.

3.3 Rebirth and the Ending Rule

As indicated earlier, agents were "reborn" in future generations. This was done for practical and budgetary reasons, because far fewer subjects are required to construct each economy if each subject participates in multiple two-period sequences. This means that we are not reproducing the exact assumptions of the

[9] If a subject had an offer in the market and then made a new offer or accepted a transaction, the previous offer was cancelled by default so that the subject was not held accountable for buying or selling more units than they had intended. The previous offer could still remain in the market, but would have to be requested by the subject upon making his new offer or upon the completion of a transaction. This ensured that an agent would have the freedom to participate in both markets, and thus tender multiple bids, without the problem of negative inventories of chips or currency. At no point were agents allowed to attain negative inventories. At all times during the session, all of the offers and transactions made during a period remained on the experimenter record sheet overhead, and thus were common knowledge. The available supply of both fiat money and consol was recorded at the beginning of each period on the overhead next to the corresponding market and remained displayed throughout the period.

overlapping generations model of Samuelson, but rather a modified version.[10] However, the research questions we consider in this project, which is an exploratory study of the behavioral causes of rate-of-return dominance, rather than a test of a particular OLG model without rebirth, do not require reproduction of the standard theoretical model. As in the OLG model without rebirth, the only REE involve exclusive use of the consol as the medium of exchange in the actual economies we construct. This last feature is the crucial design feature we require.

We believe that rebirth creates more favorable conditions for the use of the consol, than an alternative design without subjects' repeated participation in a session. Repeated participation might encourage the forward-looking behavior embodied in the assumption of rational expectations. Repeated participation might also provide an individual incentive to keep the consol in circulation, because the possibility exists that agents will benefit from dividends in future periods.

To end a session we used the following procedure. At the beginning of a session, the subjects were not told how may periods they would be participating in. However, the following information was made common knowledge in the instructions. At the beginning of the next to last period of the session, the experimenter would publicly announce that the experiment would end in two periods. At the end of the last period, any tickets held by young agents would be converted into chips (and thus dollars) using the average prices in the *second-to-last* period.[11] Any tickets held by old agents at the end of the last period would become worthless and be removed from the economy just as in all proceeding periods. This ending procedure ensured that the classical backward induction problem of fiat money having a zero value in a finite overlapping generations model did not exist. It also ensured, as explained in section 4, that there were no rational expectations monetary equilibria.

The ending rule we use induces appropriate market incentives. Suppose that the session ends in period T and the tickets held by the young at the end of period T are converted to the dollar value of the chips they could purchase at the average prices of period $T-1$. These young agents of period T are old in period $T-1$ and the prices they negotiate become the prices in a hypothetical "period $T+1$", when they would also be old. Thus they have an incentive to purchase chips at low prices, while the young in $T-1$, have

[10] Rebirth was also used in the studies of Lim et al., Marimon and Sunder, and Aliprantis and Plott. They, like we, used techniques to implement rebirth that did not alter the REE predictions from corresponding economies without rebirth.

[11] We explained to the subjects by means of detailed examples worked out on the blackboard, that they could receive fractions of units and the resulting $US cash payment in this final buyout. For example, if the average price of chips in period $T-1$ was 400 Red tickets, and a young agent held 500 Red tickets (and 0 Blue tickets) at the end of period T, he would obtain $u_1 + .25u_2$ for his Red ticket holdings. The amount of chips the young in period T could purchase with their final ticket holdings was cumulative in the sense that if a young agent held enough Red tickets to purchase y chips at $T-1$ consol prices, and enough Blue tickets to purchase z chips at $T-1$ fiat prices, the agent received a $US cash payment corresponding to $y+z$ chips.

an incentive to sell chips at high prices. In essence, the old in $T-1$ are negotiating prices for two identical periods, and thus have no distortion of their incentives by the ending rule. The young in $T-1$, who become the old in T, end their participation in the experiment at the end of T, and therefore the ending rule does not affect their incentives in $T-1$.

4 Rational Expectations Equilibria

In this section we characterize the stationary[12] rational expectations equilibria (SREE) of our economy. A rational expectations equilibrium consists of a time sequence of prices and consumption levels, such that all individuals' decisions are optimal when they take prices as given and all commodity and asset markets clear. We define an equilibrium as stationary from date t on if prices are constant from that date forward. A stationary equilibrium has the property that the optimization problem for each lifetime of an agent is identical.

The existence of rebirth does not affect the SREE. No inventories of agents are carried over from an old period to their following young period, and utility is time-separable. This means that there is no link between actions in one lifetime and outcomes in the next, except for possible effects of past actions on beliefs and behavior of other agents. However, in a competitive model, such as that presented here, agents act as non-strategic price takers, and do not try to manipulate future prices by their current actions, and thus we do not consider these effects.

In the theoretical environment corresponding to our experiment, time is discrete. In each period $t = 1, ..., T$, exactly N (= 4 in the experiment) agents, each of whom live for two periods, enter the economy.[13] We refer to them as *young* in their first period, and as *old* in their second period. In the initial period N *initial old* are also present. Each young agent comes to life with an endowment of two indivisible and perishable "chips" (as described in section 3). The initial old are endowed with two types of indivisible objects that can potentially serve as media of exchange: M_0 units of fiat money, and R_0 units of the consol. It follows that the initial net supply of the consol and money in the economy is, respectively, NR_0 and NM_0. During each period, each unit of the consol pays off a constant dividend stream of services d (=\$0.01 in the

[12] We focus on stationary equilibria for several reasons: a) analytical tractibility, b) previous research in similar environments has supported the notion that behavior converges toward stationary price equilibria (Lim, Prescott and Sunder, 1994; and Aliprantis and Plott, 1992) c) all treatments of our design have the feature that there exist stationary competitive equilibria supported by rational expectations. Stationarity requires that if the consumption of chips per period is constant, the dividends earned must also be constant, hence the price (in terms of red tickets) must be such that the total receipts of any young agent are equal to the total per capita supply of red tickets.

[13] $t = 1$ should be viewed as the first period in which both media of exchange are available, period 1 in the SIM treatment, and period 5 in the SEQE and SEQP treatments.

experiment).

The use of fiat money is inconsistent with the assumption of rational expectations in our environment, irrespective of the timing of the dividend payment. The argument is analogous to that for infinite-horizon economies given by Wallace (1980). At the beginning of the horizon, both money and consol exist in the economy. In a rational expectations equilibrium, young agents accept only the asset(s) that yield(s) the highest rate of return. Therefore, if money is held, a young agent must expect that its real rate-of-return from one period to the next will be at least as great as the real rate-of-return on the consol in every period. Thus, in all possible monetary equilibria, either the real price of money is rising or the real price of the consol is falling from period to period. However, the ending rule of the experiment, which was common knowledge, requires both consol and fiat prices to be identical in period $T-1$ and period $T+1$. The change in the price of the consol is the same as the change in the price of the fiat money over the final two periods. This means that the return on consol, which pays dividends, much exceed that of fiat over the last two periods. This implies that no agent would wish to hold fiat money over the last two periods. By backward induction, no agent would wish to hold fiat money at any time that the consol is also available.

4.1 Ex-Dividend Trade

In a stationary equilibrium we can represent preferences in terms of US dollars for young and old agents as follows,

$$U_y \equiv u_{1y} \cdot I_1 + u_{2y} \cdot I_2 + U_o$$

where

$$U_o \equiv u_{1o} \cdot I_1 + u_{2o} \cdot I_2 + dR,$$

where U_o is the cash payment that old agents in the experiment receive in the current period, and U_y is the lifetime payment that a young agent will receive during the next two periods. u_{ik} represents the marginal dollar payment from consumption of the i^{th} chip in age k (y for young, and o for old), I_i is an indicator function taking on the value 1 if consumption of the i^{th} chip has occurred (and zero otherwise), while R is the number of Red tickets the young has received in exchange for chips. In each session $u_{1k} > u_{2k}$, as indicated in table 1.

Since there is an identical number of young and old, and all agents of a generation are identical, we consider the representative transaction between one young and one old.[14] Because goods are indivisible, three possible patterns of intergenerational exchange are possible: (a) No-trade: two units consumed by the

[14] This analysis assumes each old agent has an equal endowment of tickets. This was true in all sessions with the designation"*Equal Endowment*" in table 2.

young and none by the old, (b) One-trade: one unit each consumed by young and old, (c) Two-trades: two units consumed by the old, and none by the young. Since the marginal utility of a third unit of consumption is always 0, consumption of more than two units can be ruled out as consistent with an equilibrium.

We show here that the only possible SREE involve each young agent selling one chip and each old agent purchasing one chip in each period. We let $p \in [1, R_0]$ denote the stationary *transaction price*, i.e. the consol units exchanged for one chip. The no-trade arrangement is inconsistent with a competitive equilibrium, for any p. The young always receive lower payoff if they do not trade than if they trade one unit because $u_{1y} + u_{2y} < u_{1y} + u_{1o} + dp$, $\forall p$. Since dividends are paid at the beginning of the period, the old receive lower payoff from no trade than from trading at least one unit.[15]

Two units can be traded in a competitive equilibrium only if the dollar value of a transaction to a young is greater than the marginal utility from consumption of the first unit. If young agents make two sales at price p, their payoff equals $u_{1o} + u_{2o} + 2dp$. A young agent who deviates and makes one sale at price instead, earns $u_{1y} + u_{1o} + dp$, which is greater than the payoff from two sales if $p < \frac{u_1 - u_2}{d}$. Since $p \leq R_0/2$, if two units are traded, then a sufficient condition for two trades not to take place is

$$dR_0/2 + u_2 < u_1,$$

an inequality always satisfied in every session of the experiment in which trade took place ex-dividend. Therefore, in a SREE exactly N units, one per member of each generation, must be traded.

An SREE exists at every price feasible in the experiment $p \in [1, R_0]$. The argument above shows that there exists no price at which any agent would wish not to trade at least one unit. However, no agent can deviate in a one-trade steady state equilibrium by trading two units, because the removal of unspent consol from the economy, requires the market price to equal to the entire per-capita supply of available Red tickets from time t on. It is therefore optimal for each agent to trade exactly one unit at price $p = R$ if all other agents also trade one unit at the same price, and any price $p \in [1, R_0]$ clears the market.

In a SREE the dollar earnings in a period for a young subject equal:

$$\text{dollar payment of young (any generation)} = \begin{cases} u_1, & \text{when young} \\ u_1 + dR & \text{when old} \end{cases}$$

We define welfare in each period by the sum of the utilities of a representative young and initial old, $W = U_o + U_y$, A social planner would want to set $p = R_0$ in all t to realize the maximum possible dividends and attain the highest welfare level possible.

[15] Under ex-dividend trade, the initial old have no loss from inelastically supplying their entire consol holdings in exchange for chips, so that any $p \leq R_0$ is consistent with a stationary one-trade equilibrium.

4.2 Pre-dividend Trade

In the pre-dividend case, all agents receive a dividend on any unit of the consol they hold at the end of the period. We can represent the steady state utility of a young individual as

$$U_y \equiv u_{1y} \cdot I_1 + u_{2y} \cdot I_2 + dR + U_o$$

In the absence of asset hoarding, $U_o \equiv u_{1o} \cdot I_1 + u_{2o} \cdot I_2$.

In any SREE each agent exchanges exactly one chip each period, as in the ex-dividend case. To see this, note that exchange of zero chips cannot be optimal because young and old can conclude a mutually beneficial exchange at any feasible price satisfying $dp < u_1$. The payoff for the young if they make one trade, $u_{1y} + u_{1o} + dp$, is greater that if they make no trades, $u_{1y} + u_{2y}, \forall p$. For the old holding R Red tickets, the payoff from one-trade, $u_1 + d(R - p)$, is greater than the payoff from no-trade, dR.

The exchange of two chips is inconsistent with an equilibrium, because of the following. The young are only willing to make a second sale if the price guarantees them a dollar value $dp + u_2 \geq u_1$. In a two-trade steady state $p = R/2$, and the value of an old's total disbursement, dR, cannot exceed the utility gain from her purchases, $u_1 + u_2$. It follows that a two-trade equilibrium can only be supported if $2(u_1 - u_2) \leq dR \leq u_1 + u_2$. However, $2(u_1 - u_2) < u_1 + u_2$ is only possible in parameterization E, adopted in one session (SEQP5) in which $dR_0 = 2(u_1 - u_2)$. Since at least some initial hoarding of Red tickets took place in every session, $R_t < R_0$ for all $t \geq 1$, ruling out a two-trade equilibrium from that point on in SEQP5.

To see that $dR \leq u_1 + u_2$, $\forall t > 1$, notice that an old agent would never purchase more than two chips (the marginal utility for the third chip is always zero), and would never pay more than his marginal utility for each unit, since her foregone dividend earnings would be greater than the value of the unit to her. Since the initial old will not agree to any set of transactions that do not satisfy $U_o \geq dR_0$, a lower bound on hoarding of Red tickets by the initial old must equal $dR_0 - (u_1 + u_2)$. Therefore, hoarding by the initial old occur whenever the inequality

$$u_1 + u_2 < dR_0$$

is satisfied. The inequality is satisfied in every pre-dividend session except for SEQP1 and SEQP3 in which the marginal values for the two chips were \$5 and \$1 and two of the four old agents received a supply of 500 units of the consol. Thus in an SREE there must be hoarding at the beginning of all sessions other than SEQP1 and SEQP3.

It is straightforward to show that an SREE exists at any price $p < u_1$. No party can benefit by deviating and making zero trades if the price is less than u_1, and it is not feasible to make two trades because p must equal R if one unit is traded.

Each potential SREE price $p = R$ corresponds to one particular division of the surplus from trade between young and old. If the gains from exchange are split equally, the resulting price will be $p = R = u_2/2d$. To see this, notice that in a steady state where there is no hoarding and the per-capita supply is R, $p = R$ must solve

$$u_{1o} - dR = u_{1y} + dR - u_{2y}.$$

If there is no trade, then the initial old receive dR_0, and the young receive $u_{1y} + u_{2y}$. If trade is concluded they receive, respectively, $u_{1o} + d(R_0 - p)$ and $u_{1y} + dp + u_{1o}$. Therefore the gains from trade equal

$$u_{1o} + d(R_0 - p) + u_{1y} + dp + u_{1o} - dR_0 - u_{1y} - u_{2y} = 2u_{1o} - u_{2y}.$$

Each agent receives surplus $u_{1o} - u_{2y}/2$. Both sides of the market then receive an equal increase in payoff, over the payoff guaranteed in autarchy. The chip price p that equates the gains from trade equals $u_2/2d$. If there is no hoarding, the cash holdings in the steady state equal the price and satisfy $p = R = u_2/2d$.

As under ex-dividend trade, all generations benefit from the circulation of the consol. Therefore, higher prices increase utility for all young generations over the life of the economy, and in the competitive equilibrium with the highest earnings to the subjects $dp = dR = u_1$. At these prices, the initial old receive zero surplus from exchange (they receive some surplus from the initial hoarding that takes place) and the young receive the entire gains from trade.

Note that under ex-dividend and pre-dividend trading, the ending rule we use does not change the set of SREE. Recall that both consol and fiat money held by young agents in the final period T is converted to chips at the average price of the previous period, which is compatible with stationarity. Therefore the final young generation has the exact same incentive as in the model described in this section, to behave as if the consol they hold can buy a chip in the following period at a price $p = R_{T-1}$.

4.3 Summary of Predictions

It follows from the discussion above that in the ex-dividend case, the theoretically predicted SREE has the following properties. Each agent consumes one chip per period. In each period, each old agent purchases one chip from a young agent using his entire current stock of Red tickets. Each young agent sells one chip per period. Blue tickets are not used in exchange and exit the economy immediately. Because subjects in SEQP and SEQE were not informed that Red tickets would be introduced in the future, Blue tickets may circulate until the introduction of Red tickets.[16] Upon the introduction of Red tickets, Blue tickets immediately exit the economy, and Red tickets are the only medium of exchange in any REE. In the ex-dividend case, any

[16] If fiat money is the only possible medium of exchange, an SREE exists in this environment (see Wallace, 1980).

positive price is consistent with a stationary equilibrium. The SREE for the pre-dividend case has the same properties except that only prices up to u_1/d are consistent with a stationary equilibrium.

The dynamics of how the economy can converge to a stationary equilibrium are straightforward. Under ex-dividend trade with Equal Endowment, each initial old agent has an endowment of R_0 units of consol. Each old agent spending all R_0 for one chip, and each subsequent generation doing the same generates a stationary REE price path. Under pre-dividend trade with equal endowment the same is true if $dR_0 \leq u_1$. If $dR_0 > u_1$, the market must clear in the first period at a price $dp^* \leq u_1$, and the rest of the consol, $R_0 - p^*$, is hoarded. In subsequent periods $p_t = p^*$ is an SREE price path.

In the Unequal Endowment sessions, it is also the case that no monetary rational expectations equilibrium can exist. When half of the old agents receive Red tickets, it is straightforward to show that young agents will strictly prefer to sell for any quantity of the dividend-bearing Red tickets, rather than any amount of Blue tickets. When trades are ex-dividend (SEQE) the old offer $R_0/2$ per chip, as soon as the Red tickets are introduced. They acquire two chips by two different sellers, while the remaining two old consume nothing. Prices will be $R_0/2$ per chip from then on, and one chip is sold to every old agent each period. When trades are pre-dividend, and endowments are unequal, prices are equal to the un-hoarded supply of red tickets, $R/2$, where $dR/2 \in (0, u_2]$, since the initial old buy two units.

5 Results

5.1 Trading Regime Selection

Figures 2-4 below illustrate the number of transactions in terms of both consol and fiat money by period in each session, compared to the stationary REE characterized in section 4. Several general properties of the data are evident from the figures. The first is that in the SEQP and SEQE treatments, the total number of chips exchanged is typically close to four, which is consistent with the maximization of the total gains from chip consumption. In 50 percent of periods in SEQP and in 50 percent of periods of SEQE it is exactly equal to four. In the SIM treatment, the quantity traded is equal to four in only 9 percent of the sessions. The average absolute value of the difference between the actual and the REE quantities traded by period is 1.1 in SIM, and 0.5 in both SEQE and SEQP. The loss in cash payments from trading one extra or one too few units is between 8.33% and 10% of the total cash payment for the period, depending on the utility function in the session.

[Place Figures 2a-4 About Here]

The figures also show that almost all of the transactions are executed with consol exchanges in the SIM treatment, which is consistent with the REE prediction. Fiat money is used in the early periods of the SEQE and SEQP treatments, in which no consol is available. However, even after the introduction of the consol, the fiat money is used more frequently than predicted. The consol is more likely to be used under Equal Endowment, when it is given to each agent (79% and 55% of transactions in period 5 or later in SEQE and SEQP respectively) than under Unequal Endowment (43% and 26% of transactions in SEQE and SEQP).

Findings 1-4 below summarize our observations with regard to currency selection.

Finding 1: The incidence of the use of fiat money and consol is consistent with the REE in the SIM treatment. The consol is the exclusive medium of exchange.

Support for finding 1: As illustrated by figure 2a, in both economies of the SIM treatment, in which there is no prior history of use of either asset, all trades after period 2 were in terms of the consol. The same was true in the two SIMSA sessions, as shown in figure 2b. There was no fiat money remaining in the economy by period 3 in any of the four sessions. □

To explore the robustness of the ability of the consol to displace fiat money, sessions SIMSA and SIMSAx are of particular interest. In these two sessions only one of the four initial old agents was endowed with consol while all initial old agents were endowed with fiat money. If the initial young have rational expectations, they know that at some time in the future, only the consol will be accepted. Therefore, since initially there is only one old agent with the consol and she wishes to purchase at most two units, two subjects will not be able to sell when young, nor to consume when old. These agents earn $u_1 - u_2$ less than they would if fiat money successfully circulated in period 1. Despite this factor encouraging the use of fiat, it almost immediately disappears from the economy. The same pattern was observed again in SIMSAx, in which subjects were already experienced in a previous economy with an identical structure. These data suggest that the tendency for the dominant asset to become the medium of exchange is so strong that it is sufficient that only a small minority hold it initially.

In the SIM treatment, both available assets were placed on an equal footing in that neither had a previous history of use as a medium of exchange. The nearly-immediate exit of the fiat money and exclusive use of the consol is consistent with the stationary REE characterized in section 4. However, the data shown in figures 3-4 from the SEQE and SEQP treatments tell a different story. They show widespread continued use of fiat money in all of the sessions, well after the consol is introduced into the economy. This includes session SEQE4x, in which the same group had participated previously in the same treatment, indicating that the use of fiat money is not a transitory phenomenon that would occur only with inexperienced agents. Fiat money is also widely used in all of the *Equal Endowment* sessions except for SEQE5, illustrating that the continued use of fiat money is not due to the fact that only some of the members of the current old generation receive the initial injection of consol. Finding two characterizes the role of history in influencing the trading regime, controlling for dividend timing, by comparing the SIM and SEQP treatments.

Finding 2: A prior history of use of fiat money promotes its continued use as a medium of exchange, even after a dominant asset with equal marketability properties becomes available.

Support for finding 2: Periods 2-5 of the SIM sessions and periods 6-9 of the SEQP sessions are identical in all important respects except for the prior presence and use of fiat money (for four periods in the SEQP sessions). Trade occurred pre-dividend in both treatments, so that a comparison of the two treatments controls for the timing of the dividend payment. In both sets of data, the REE requires trade to occur in terms of the consol. In periods 2-5 of the SIM sessions 96 percent of the transactions were in terms of consol. In periods 6-9 of SEQP, the consol was used for only 31 percent of transactions. The t-statistic from a pooled-variance t-test comparing the percentage of the total trades that were in terms of consol between the SIM and the all SEQP sessions is 5.53. A comparison of the SIM data and the Equal Endowment sessions of SEQP yields a t-statistic of 6.02. Both of the differences between means are significant at the $p < 0.001$ level. □

Just as the use of fiat money can be promoted by a prior history of acceptance, the use of the consol can be inhibited by the existence of an opportunity cost to transacting with it. If trade takes place before dividends are paid, as in SEQP, the old have an incentive to try to use fiat money for purchases so that they can hoard the consol and earn dividends. If they find that they must use the consol for purchases, they can benefit by negotiating the lowest prices possible. These behaviors will cause a reduction in the available stock of consol. Under ex-dividend trade, the incentive to hoard the consol is not present, and one would not expect the available consol stock to decrease over time as sharply as under pre-dividend trading. The effect of the timing of the dividend payment on the supply of consol is described by finding 3, which compares the two treatments that differ in dividend timing, controlling for the timing of introduction of the two types of assets.

Finding 3: Hoarding of consol is greater and fewer trades occur in terms of the consol when exchange occurs pre-dividend than when it occurs ex-dividend.

Support for finding 3: The regression $R_t = \beta R_{t-1}$ where R_t denotes the stock of red tickets in period t of a session, was conducted for the SEQP as well as the SEQE data. The data from all sessions within a treatment is pooled. The estimate for β for the SEQE treatment is equal to .815 with a standard error of .023 The estimate for SEQP is equal to .459 with a standard error of .046. On average, about 19 percent of the current stock of consol was hoarded per period when trade occurred ex-dividend, and about 60 percent was hoarded per period in the pre-dividend case. An F-test comparing a restricted model where the β coefficients are common to the two treatments to an unrestricted model where the coefficients are allowed to differ is highly significant ($F = 56.39, p < .001$) $\square$

Thus we find that adding a history of fiat monetary trade (which promotes the use of fiat money), and by organizing trade pre-dividend (which promotes hoarding of the consol), will consistently result in the observation of rate-of-return dominance. In SEQP sessions, most trades are in fiat money and their proportion continues to increase over the session, indicating that it is more and more widely accepted over time. The data are summarized in finding 4.

Finding 4: An economy can be created in which the anomaly of rate-of-return dominance will be systematically observed.

Support for finding 4: Figure 4 shows the number of trades in terms of each asset over time in the SEQP treatment. 63 percent of all trades from period 5 on are in terms of fiat money. In the SEQP treatment, the fraction of trades in terms of fiat money is increasing over time and rises to 75 percent overall in the last period of the sessions. The ratio of the available stock of fiat money to stock of consol grows over time in every session of SEQP in the sense that the ratio is greater in the final period of every session than in period 5, when the consol is introduced. The average value of the variable (% of trades in consol in period t)/(% of agents endowed with consol in period 5) equals .55 and is significantly different from 1 at the $p < .001$ level of significance (t = 5.48).

The actual observed average rate of return on the consol exceeded that on fiat money in each session in which both circulated. The data are given in table 3. The (gross) rate of return on the consol is calculated as

$$r_C = \frac{P_{t+1} + d/u_1}{P_t}$$

where $P_t = 1/p_t$ is the average price of the consol in terms of chips in period t. The gross return r_C measures the sum of capital and dividend gains, in terms of chips. The capital gain is measured by the relative purchasing power of the consol across two periods, P_{t+1}/P_t. The value of the dividend earned, in terms of chips, is given by d/u_1, i.e. the dollar value of the dividend (one cent) relative to the dollar value of a chip (u_1 in an equilibrium where only one chip is consumed). This ratio is then compared to the initial consol's price P_t. Because fiat money bears no dividend, its (gross) rate of return is calculated as

$$r_F = \frac{Q_{t+1}}{Q_t}$$

where Q_t is the average price of fiat in terms of chips in period t. That is, r_F measures the change in the purchasing power of a unit of fiat money from period t to $t+1$. In every session, and indeed in 30 of 33 periods in which both fiat and consol were used in the current and the preceding period, the consol rate of return was higher. Thus, ex-post, a rate of return dominance occurs in the Sequential sessions. □

[Table 3: About Here]

The idea that the consol is hoarded while fiat money is used in exchange is reminiscent of a Gresham Law type of equilibrium where the "bad" money, the fiat money, drives out the "good" money, the consol. Rate-of-return dominance occurs here despite the equal marketability of the two potential media of exchange, the absence of legal restrictions, transaction costs, intermediation costs, or trading frictions that could lead to demand for the fiat money.[17]

5.2 Gains From Trade and Price Levels

There are at least two potential measures of welfare that are meaningful in our experiment. The measures are normalized with respect to the maximum welfare possible in an economy where the only available asset is fiat money, which equals $2Nu_1$ since in the most efficient trading scheme, each member of each generation

[17] Besides the imposition of marketability constraints, or legal restrictions (e.g. see Wallace, 1983, as well as Bryant and Wallace, 1984), a theoretical literature has studied how the presence of trading frictions can lead to coexistence of fiat money with a dominant asset. For example, Townsend (1987) studies the relationship between fiat money and interest-bearing securities within the context of a dynamic general equilibrium model. Ayagari et al. (1996) study a decentralized economy where fiat money and government issued securities coexist. In a similar random matching environment, Shi (1996) and Corbae and Ritter (1998) provide a rationale for the coexistence of money and credit. Kocherlakota, (2000) constructs a model in which nominal risk-free non-tradeable bonds serve as recordkeeping devices in a monetary economy.

consumes one chip per period. We will use the term *Consumption Efficiency* to denote the normalized realized payoff from consumption only. Consumption Efficiency is given by:

$$\frac{\sum_{j=1}^{2N}\left(u_{1y}\cdot I_1^j+u_{2y}\cdot I_2^j+u_{1o}\cdot I_1^j+u_{2o}\cdot I_2^j\right)}{2Nu_1}$$

and is calculated by period. Here $N=4$, $j=1,...,2N$ indexes the agent (four are young, the other four are old), and I_k^j equals 1 if agent j consumes at least k chips in the period. A level of Consumption Efficiency of 100 percent corresponds to the highest possible realization of gains from chip consumption possible. In autarky the young consume their entire endowment and the old do not consume at all, so that consumption efficiency equals $(u_1+u_2)/2u_1$, equal to either $60, 66.7$ or 70 percent, depending on the utility function used in the session.

A second measure of welfare, called *Total Efficiency*, includes the dividend on the available stock of consol. It equals:

$$\frac{\sum_{j=1}^{J}\left(u_{1y}\cdot I_1^j+u_{2y}\cdot I_2^j+u_{1o}\cdot I_1^j+u_{2o}\cdot I_2^j+dR_j\right)}{2Nu_1}$$

where dR_j is the dividend paid to agent j, and is also calculated by period. Because total efficiency includes the effect of the dividend on welfare, it may take on a value greater than 100 percent, if the consol is circulating.

Figures 5 and 6 show the values of the two welfare measures by period, averaged over all sessions, in each of the three treatments. Figure 5 depicts the *Consumption Efficiency.* The figure suggests a *positive* relationship between the use of fiat money and gains from trade. The first four periods of the SIM treatment, in which the consol was used almost exclusively, were characterized by lower gains from trade than the two sequential treatments. In period 5, when the consol was introduced, there was a drop in efficiency in the sequential treatments to the level attained in SIM. Lower gains from exchange were recorded in this instance, because generally too many trades were executed, suggestive of a type of "money illusion" generated by the introduction of an additional tradeable good. In periods 6 and later, the two sequential treatments, especially SEQP, where the consol was used the least, once again were characterized by higher efficiency than the SIM treatment. Perhaps the most striking comparison is from the data early in the experiment, which provides the supporting evidence for Finding 5 below.

[Place figures 5 and 6 about here]

The average level of *Total Efficiency* is shown in figure 6. In the early periods total efficiency was higher in SIM than in the other two treatments, in which the consol was unavailable. However, in SIM, total efficiency fell over time. When the consol was introduced in period 5 in SEQE and SEQP, there was a brief increase in total efficiency due to the dividend payments. Late in the session, SEQE yielded the highest total efficiency. In the long run, the ex-dividend condition, in which there was no incentive to hoard the consol, appeared to create more favorable conditions for achieving high total efficiency.

A comparison between SIM, in which consol circulated, and SEQP, in which fiat money circulated, suggests that the benefits resulting from the availability of a dividend-bearing medium of exchange dissipate nearly entirely over time, if there is an opportunity cost of using the asset to facilitate the exchange of goods. In the long-run, the existence of the possibility to settle transactions with a dividend-bearing asset does not allow the economy to do appreciably better than trading with fiat money. A trade-off appears to exist. The consol yields a dividend that, relative to fiat money, increases welfare, though hoarding diminishes the advantage over time. However, fiat money, perhaps because of its lack of intrinsic properties, appears to permit the pricing mechanism to better allocate consumption goods. The SEQE economies appear to benefit both from the dividends paid on the consol, which add to total efficiency, as well as from the better allocations that the presence of the fiat money appears to make possible. These observations are summarized in finding 5.

Finding 5: The use of fiat money as a medium of exchange is associated with higher consumption efficiency. Ex-dividend trade is associated with higher total efficiency than pre-dividend trade.

Support for finding 5: A comparison between the efficiency in periods 1-4 of the three treatments illustrates the point. In the SIM treatment, the consol is used almost exclusively as the medium of exchange, and the average consumption efficiency is 84.3% (69.8% including sessions SIMSA and SIMSAx). In periods 1-4 of SEQP and SEQE, where only fiat money circulated, the average consumption efficiency across sessions is 94.0 and 93.5 percent, respectively. The mean efficiency is significantly different at the 1% level (t = 3.29) between SIM and SEQE as well as between SIM and SEQP (t = 3.79).

As Figure 6 shows, total efficiency in the first few periods of the sessions is higher in the SIM sessions, because of the presence of large quantities of consol in the economy. By the end of the sessions in period 9, however, total efficiency averages 97% in SIM, and 95% in SEQP, compared to 110% in SEQE. The mean efficiency in periods 6 - 9 in SEQE is greater than in SEQP at the 5% level of significance (t = 2.28). □

The next finding describes some properties of the behavior of prices over time. The average period price of chips in terms of both fiat money and consol units are given in figures 7 and 8 for all the SEQE and SEQP sessions.[18] Because there is a range of competitive equilibrium prices in each treatment, the consol-price is indeterminate. The CE consol-price ranges from 1 to u_1/d under pre-dividend and from 1 to R_0 under ex-dividend trade. The pre-dividend data show that the average consol-price in all periods was greater than $u_2/2d$, the price at which gains from trade are equal for the young and the old. The young receive additional surplus by charging higher consol-prices for sales of a chip, whereas the old receive additional surplus from hoarding their consol holdings.

[Place figures 7 and 8 about here]

Since fiat money does not circulate in an REE, the implied equilibrium exchange rate between money and consol is not defined. However, in many of our economies, fiat money does indeed circulate and the relative price of the two instruments can be calculated. This relative price can be viewed as an implied exchange rate. Noticeable patterns in implied exchange rate behavior have emerged in our data, and are summarized in finding 6.

Finding 6: Upon introduction of the consol the implied exchange rate of the consol in terms of fiat money tended to be close to 1 whenever previous fiat-prices did not exceed R_0, the maximum feasible consol-price. Under pre-dividend trade, consol-prices exhibited greater variability than fiat-prices.

Support for finding 6: Figure 7 shows chip prices in SEQP. In SEQP2, the implied exchange rate is not defined because the consol never circulates. In SEQP1, there is only one trade using the consol. In the other three sessions the average ratio of consol to fiat-price of chips is .988, .909, and 1.101. Figure 8 shows the analogous data for SEQE. There are two sessions, SEQE1 and SEQE4x, in which the fiat-price (prior to, as well as during, the introduction of the consol) is outside the feasible range of consol-prices. In session SEQE2, the first consol trade was executed at a price of 250, the same price as all four fiat trades in the same period. In the three remaining sessions, the implied exchange rates were 1.070, 1.057, and 0.964. Despite the large range of competitive equilibrium prices and the consequent implied exchange rate indeterminacy, it is obvious that the implied exchange rate of 1 has considerable drawing power.

The figures also show that in SEQE, consol-prices remain more stable than under SEQP. Average consol-prices did not fall by more than 60 percent between periods 5 and 9 in any of the sessions. The average absolute value of the price change from one period to the next, $|p_t - p_{t+1}|$ was 12.5% from period 5 on

[18] We refer to the number of Red tickets (Blue tickets) traded for one chip as the "consol-price" ("fiat-price").

and 4.9% between periods 8 and 9. In contrast, under pre-dividend, consol-prices fall by more than 60 percent in each of the three sessions in which it was used for more than one trade. The absolute value of the period-to-period price change averaged 32.5% between periods 5 and 9 and 33.6% between periods 8 and 9. In periods 6 - 9, the mean value of $|p_t - p_{t+1}|$ is significantly greater in SEQP than in SEQE at the 1% level of significance. □

One might have expected that upon its introduction the consol would be valued more highly relative to fiat money than what we have observed, even if the consol does not entirely displace fiat money. In principle, the consol should be as effective as fiat money in facilitating exchange. Furthermore, it yields a dividend. However, at the time of the introduction of the consol, fiat money already has a history of use, and the price of chips in terms of fiat money has already stabilized. Thus the young might be more willing to sell goods for fiat money than for the consol, because they can more accurately assess the probability that a given quantity of fiat money would be sufficient to purchase a chip in the following period. The benefits of relative price stability suggest a rationale for why the initial value of the consol (in terms of chips) is so close to that of fiat money. An initial (implied) exchange rate of 1 allows a better integration of the consol into the economy, without the need to re-coordinate on a different price.

Under pre-dividend trade, hoarding on the part of some agents reduces the stock of consol and consol-prices do not stabilize. The coefficient of variation of consol-prices is 0.858 in periods 5-9 of SEQP, compared to 0.484 for fiat-prices for the same periods. The higher variation of consol-prices provides a plausible explanation for the reluctance of many young agents to accept the consol in exchange for chips in SEQP. The changing consol-prices make it more difficult to form expectations of future consol-prices. Since the major source of income is from chip consumption, especially after hoarding has reduced the stock of consol, the assurance of the ability to make a chip purchase in the next generation appears to outweigh the benefit from the dividend.

6 Discussion

In this paper we have used experimental methods to study how rate-of-return dominance might arise. We have identified an economy, the SEQP treatment, in which rate-of-return dominance will occur in a natural and predictable manner. The SEQP treatment involves only a simple change in structure from the SIM treatment, an economy in which rate-of-return dominance does not occur. This allows isolation of the variables that are associated with the phenomenon.

The results suggest that a prior history of use is important in supporting fiat monetary exchange, even when it is suboptimal for the economy. Although departing sharply from the rational expectations theoretical prediction, the result that past outcomes influence current trading arrangements might not be surprising to some observers. However, we find it striking how resilient the use of fiat money can become after only a brief history of use (typically 15-20 minutes in the experiments), and the strength of the cash incentive to use the consol instead[19].

We also find that requiring trade to occur before the dividend payment is realized, further hinders the consol's selection as a medium of exchange, in a manner inconsistent with rational expectations. Pre-dividend trade creates an incentive for old agents to hoard the dividend-bearing asset. The hoarding creates repeated shocks to the consol supply, which translates into higher variability of consol-prices than fiat-prices. This reinforces the subjects' uncertainty about future consol-prices, and therefore the perceived ability to use the consol for future purchases. As the quantity of consol in circulation declines, the proportion of potential dividend earnings declines relative to those generated by chip consumption, further reducing its desirability as a medium of exchange. Many subjects appear to accept fiat money because, by the time the consol is introduced, fiat-prices have stabilized and the agents expect them to remain stable in the future.

Paradoxically, the establishment of a fiat money as a medium of exchange is positively correlated with the realized gains from trade. On average, consumption efficiency is over 10 percent higher when fiat money is valued, than when it is not. In our economies, fiat money seems to possess a subtle efficiency enhancing property. Because it pays no dividend, there is no incentive to hoard it, ensuring that its supply is steady, which in turn encourages stability of prices.

Furthermore, fiat money's lack of intrinsic value implies that there is no opportunity cost associated with its use in exchange. This may reduce the incentive to strategically misrepresent demand and supply functions in order to shift prices in one's favor. Such strategic behavior would reduce the volume of trade below the competitive equilibrium level, as was observed in the SIM sessions (see figure 2a). In other words, there is less incentive to engage in the hard bargaining that can cause foregone trade, when bargaining over fiat money prices. Economists have long pointed out that the use of fiat money in field economies can be explained by legal or operational restrictions on the use of dividend-bearing assets as media of exchange. None of the factors are present in our economies. The experiment raises the possibility that fiat monetary exchange might be desirable in itself for behavioral reasons. It may be the case that fiat money is more conducive to the efficient operation of some trading mechanisms than alternative trading instruments.

The persistence of fiat money transactions is our economies is all the more striking when one considers

[19] A group would earn \$50 - \$200 more in the last 5 periods of the experiment, about a 30 minute time interval, if they circulated all of the consol every period, than if they only used fiat money.

the fact that subjects reentered the economy repeatedly. In our view, this would create conditions more favorable to the use of the consol than a similar design without repeated participation. The use of the consol in purchases by old agents can benefit them later on if it recirculates to them. However, if they do not trust that the next generation will not hoard the consol, they will hoard it themselves.[20] In effect the consol has properties of a common pool resource (see Walker et al., 2000). When an agent hoards his holdings of consol, he reduces the total supply available to members of future generations. While the group would benefit if no hoarding took place, an individual can benefit by hoarding before future generations do so.

The experimental design used here could be modified in a straightforward way to study another fundamental issue in monetary economics. Consider an experimental economy with an identical structure to the economies constructed here, except in which two fiat moneys are available for use in exchange, rather than one fiat money and one real asset. In the economy with two fiat moneys, any exchange rate is consistent with an REE (Karaken and Wallace, 1981). The experiment can be employed to see if particular exchange rates will arise for behavioral reasons, and how the observed exchange rate is influenced by variables in the economy.

[20] Thus they are faced with a similar strategic situation to the investment game studied by Berg et al. (1995). This is a two-player game in which player 1 is endowed with $K. She can send any fraction of it to player 2. The amount sent to player 2 triples. Player 2 can then send back some of his cash back to player 1. The total earnings for the two players are maximized when player 1 sends her entire endowment to player 2.

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Table 1: Induced Utility for Chips

	A		B		C		D		E	
Unit	u_i	$u_1 + u_2$	u_i	$u_1 + u_2$	u_i	$u_1 + u_2$	u_i	$u_1 + u_2$	u_i	$u_1 + u_2$
1	\$3	\$3	\$5	\$5	\$4	\$4	\$2.5	\$2.5	\$2.5	\$2.5
2	\$1	\$4	\$1	\$6	\$0.8	\$4.8	\$0.5	\$3	\$1	\$3.5

Table 2: Experiment Parameters

Date	Session	Endowments				Total MS		Utility	Period	Exp.
		Blue	Red	Chips	Dist.	Blue	Red			
10/27/99	SIM1	1000	1000	2	Equal	4000	4000	A	5	No
2/8/00	SIM2	1000	1000	2	Equal	4000	4000	D	9	No
11/15/99	SIMSA	1000	1000	2	Uneq.	4000	1000	A	4	No
11/15/99	SIMSAx	1000	1000	2	Uneq.	4000	1000	A	4	Yes
12/10/99	SEQP1	1000	500	2	Uneq.	4000	1000	B	7	No
11/22/99	SEQP2	1000	500	2	Uneq.	4000	1000	C	8	No
11/18/99	SEQP3	1000	500	2	Uneq.	4000	1000	B	9	No
1/13/00	SEQP4	1000	500	2	Equal	4000	2000	D	9	No
4/6/00	SEQP5	1000	300	2	Equal	4000	1200	E	9	No
12/09/99	SEQE1	1000	500	2	Uneq.	4000	1000	C	9	No
12/06/99	SEQE2	1000	500	2	Uneq.	4000	1000	C	9	No
11/29/99	SEQE3	1000	500	2	Uneq.	4000	1000	B	9	No
1/19/00	SEQE4	1000	300	2	Equal	4000	1200	D	9	No
1/19/00	SEQE4x	1000	300	2	Equal	4000	1200	D	9	Yes
3/23/00	SEQE5	1000	300	2	Equal	4000	1200	D	9	No

Table 3: Actual Rate of Return

Session	Average Fiat Rate of Return	Average Consol Rate of Return
SIM1	n/a	2.08
SIM2	1.95	2.22
SIMSA	n/a	1.36
SIMSAx	n/a	1.43
SEQP1	1.02	n/a
SEQP2	1.05	n/a
SEQP3	1.13	1.69
SEQP4	1.13	2.13
SEQP5	1.36	2.05
SEQE1	1.07	1.83
SEQE2	1.15	1.75
SEQE3	1.18	1.61
SEQE4	1.15	1.94
SEQE4x	1.15	1.95
SEQE5	1.20	1.97

Figure 1: Period Timeline

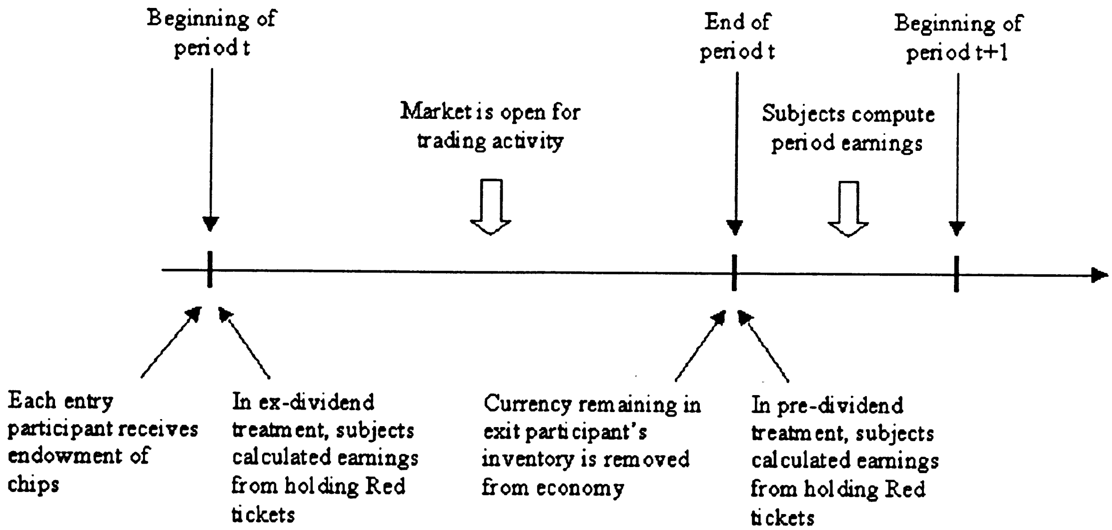


Figure 2a: Transactions in Terms of Fiat and Consol by Period in SIM

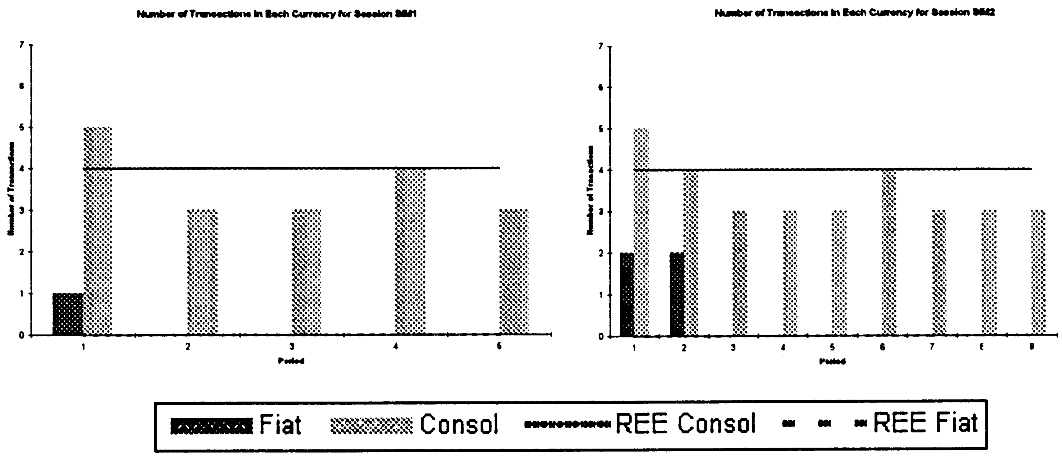


Figure 2b: Transactions in Terms of Fiat and Consol by Period in SIMSA

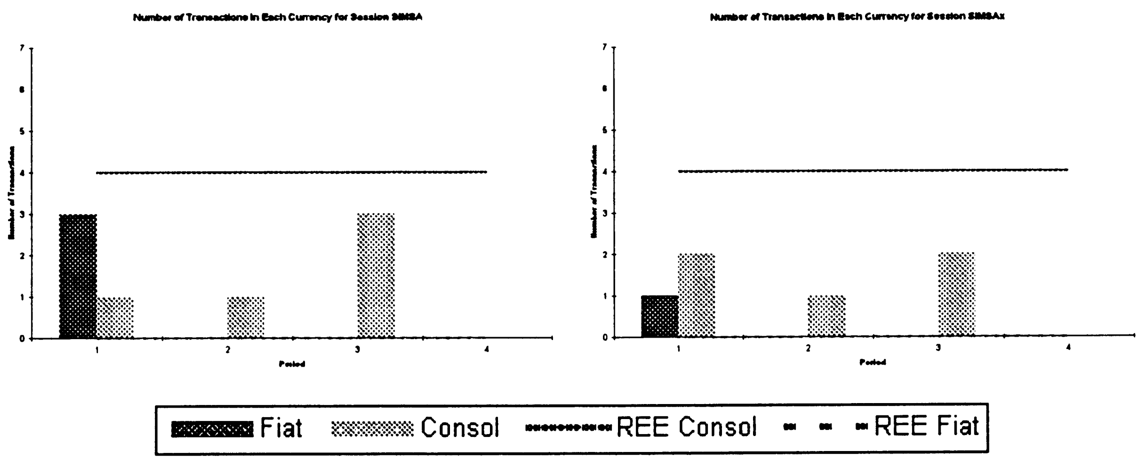


Figure 3: Transactions in Terms of Fiat and Consol by Period in SEQE

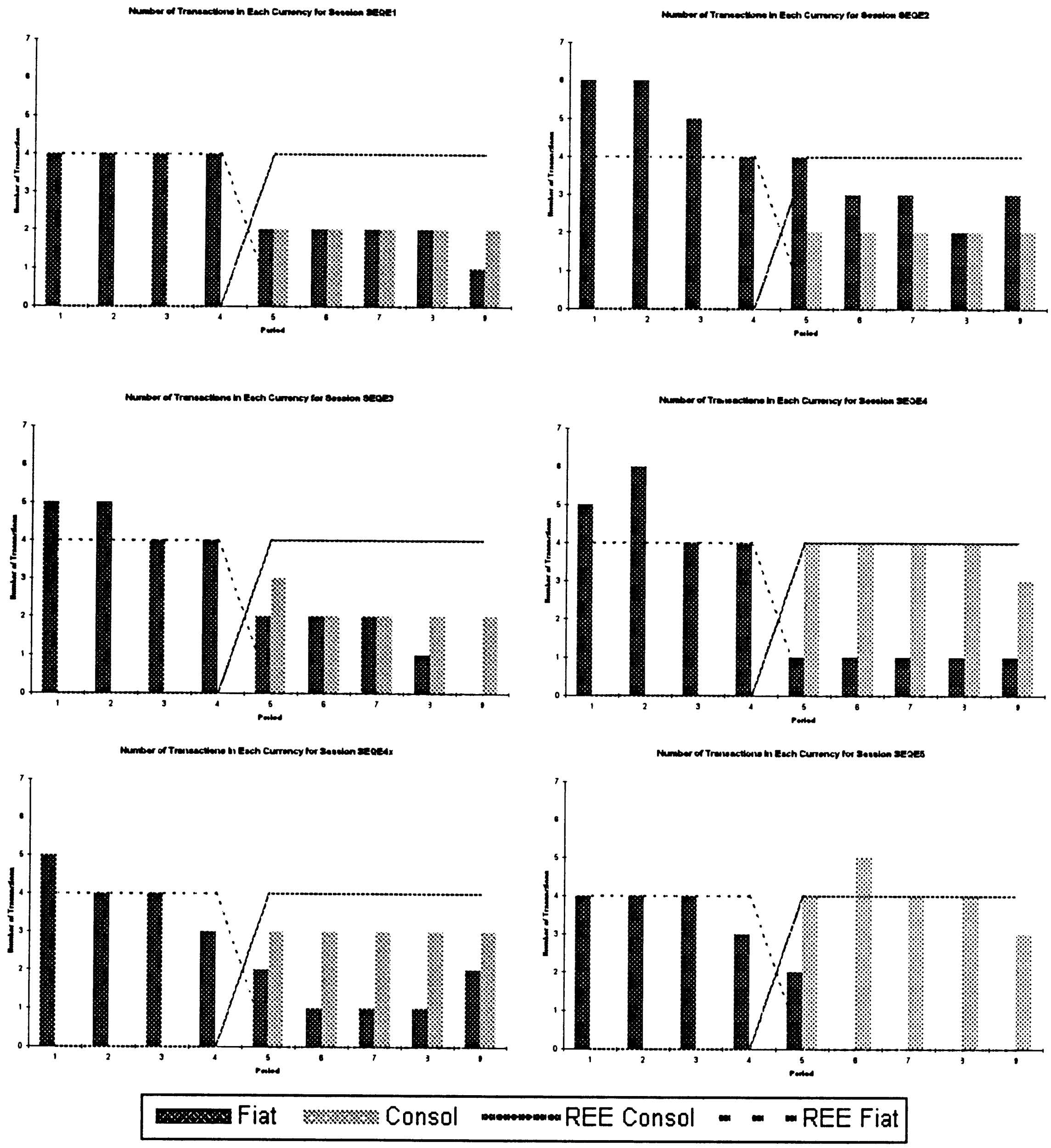


Figure 4: Transactions in Terms of Fiat and Consol by Period in SEQP

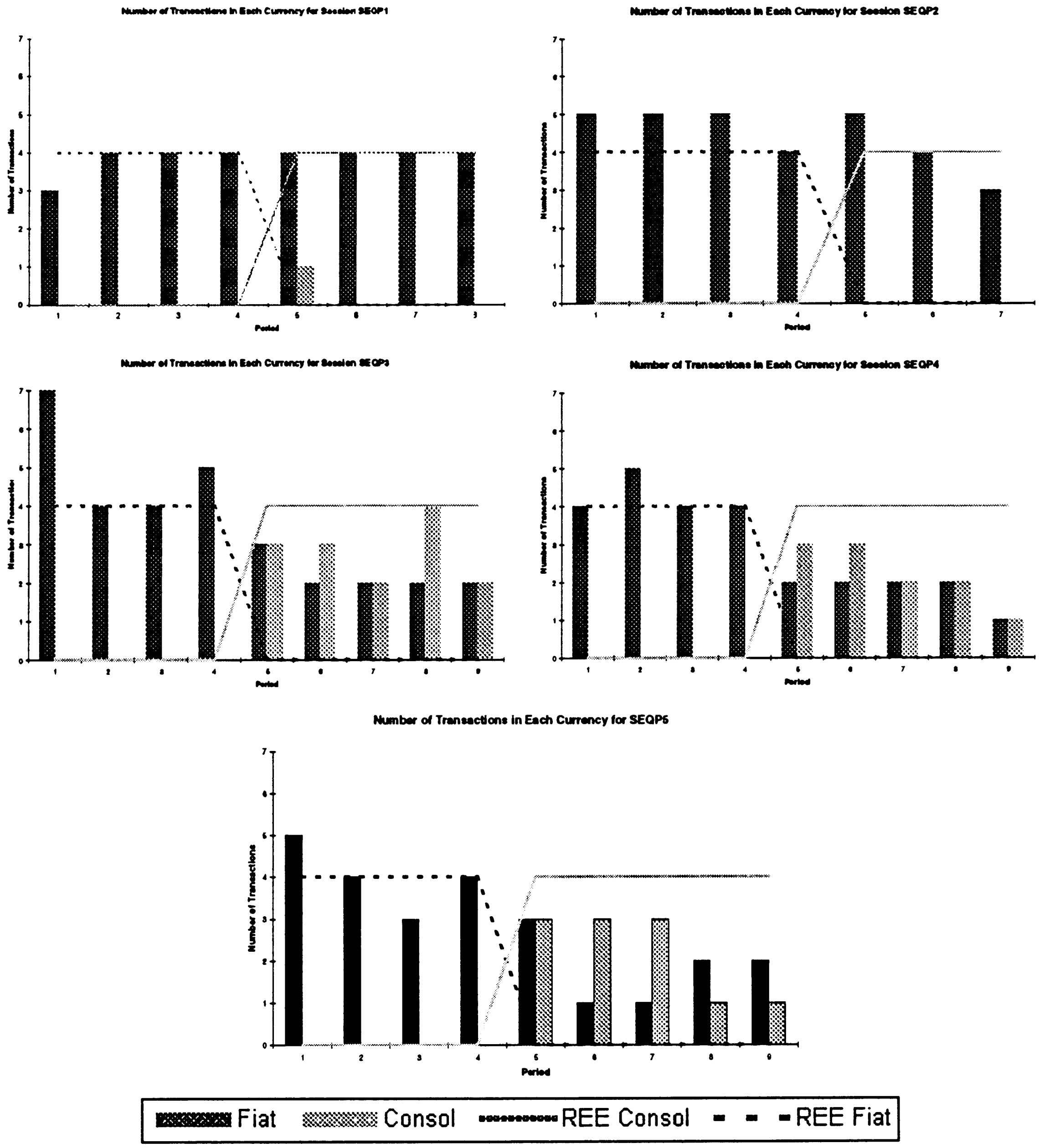


Figure 5: Consumption Efficiency Levels Each Period by Treatment

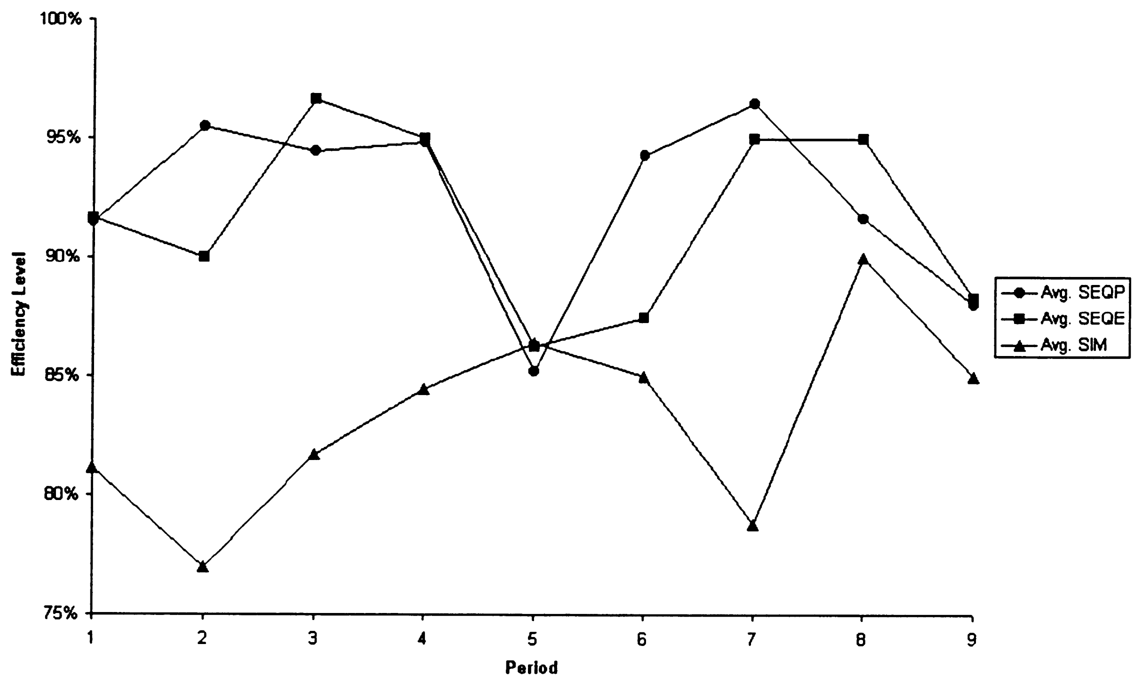


Figure 6: Total Efficiency Levels Each Period by Treatment

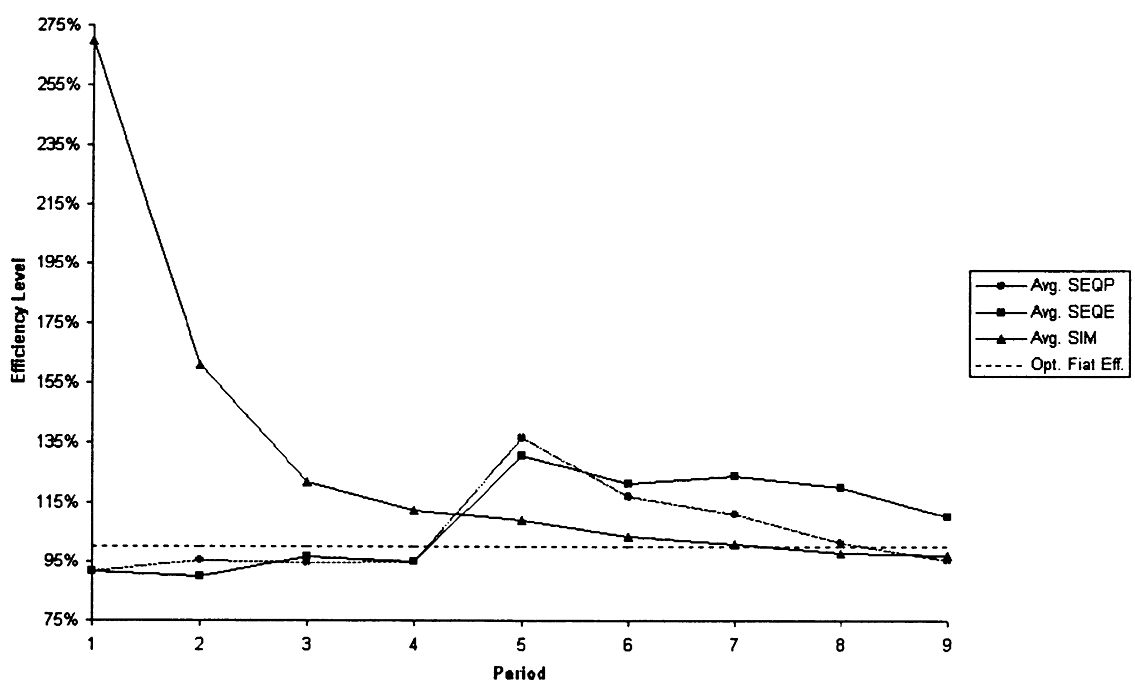


Figure 7: Average Prices in SEQP Treatment, Individual Sessions

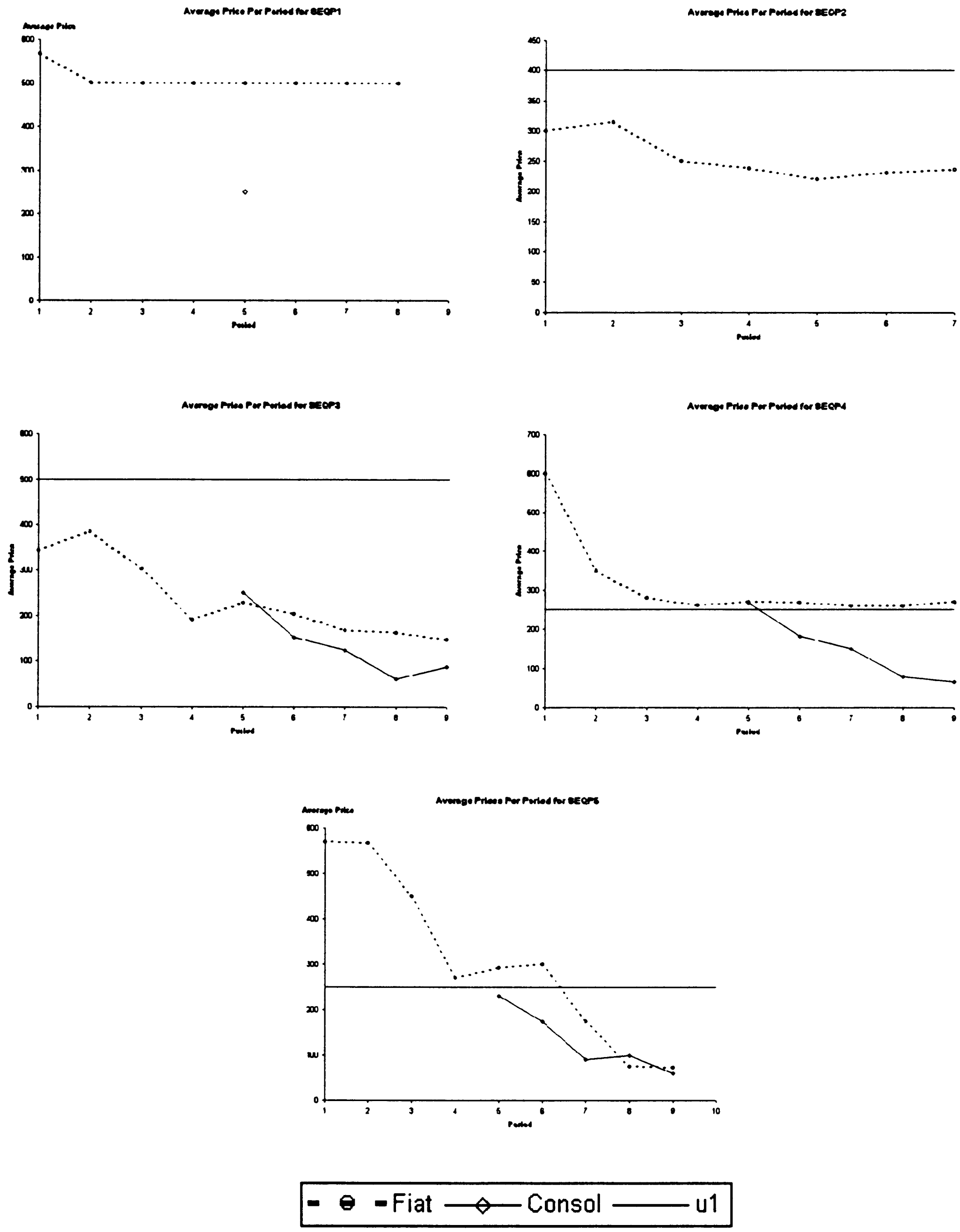
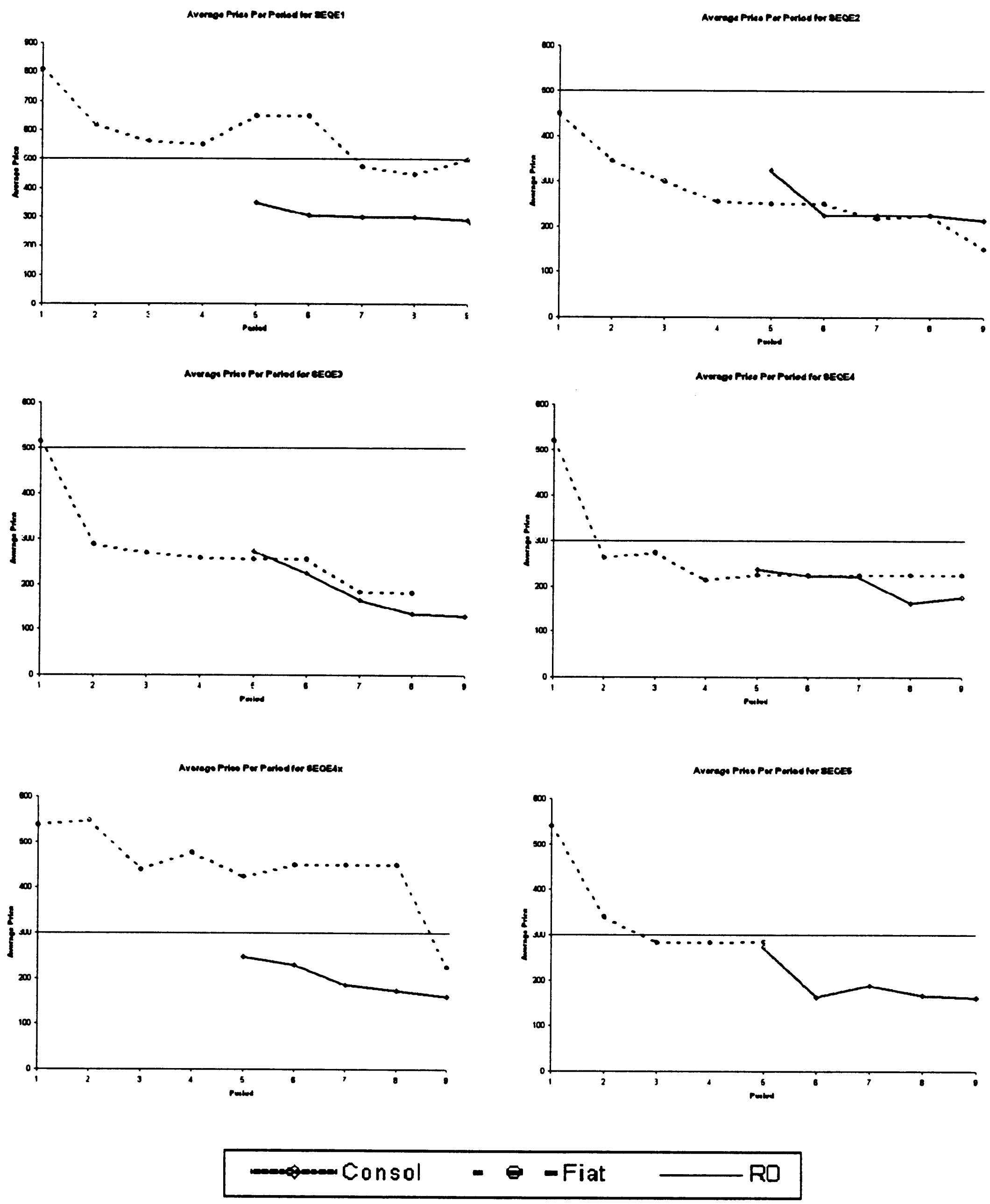


Figure 8: Average Prices in SEQE Treatment, Individual Sessions



Entry Participant in period 1.

Instructions for Experiment

1. General Instructions

This is an experiment in the economics of market decision making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money, which will be paid to you in cash at the end of the experiment.

In this experiment, we are going to conduct a market in which you can buy and sell chips in a sequence of market periods. Within these instructions you will find a Redemption Value Sheet and a series of Record Sheets. These sheets will help you determine the value to you of any decisions that you might make. YOU ARE NOT TO REVEAL THE INFORMATION ON THESE SHEETS TO ANYONE. They are your own private information.

The experiment will consist of a series of trading periods in which you will have the opportunity to buy and sell chips. There are two types of currencies that can be used in this market: Red and Blue tickets. At the end of every period, participants with units of Red tickets in their inventories are provided a dividend of $0.01 US dollars per Red ticket. Blue tickets do not provide a dividend to participants holding Blue tickets in their inventory. The currencies can be used to buy and sell chips. All trading will be in terms of either Red and Blue tickets. The cash payment to you at the end of the experiment will be in dollars. The procedures for determining the number of dollars you take home with you are explained later in these instructions.

You will participate in the market for two consecutive periods at a time. We will call the first of these periods *your* entry period (because you begin your participation then) and the second of these periods *your* exit period (because you end your participation then). Different individuals may have different entry and exit periods. At the top of the instruction sheet, it states whether your first period (period 1) is an entry or exit period. You may be asked to participate in more than one two period sequence depending on the number of periods that the market is operated.

2. Specific instructions for entry period participants

At the beginning of your entry period, you will receive 2 chips in your inventory. During this period, you may consume these chips yourself or sell them to others for units of Red or Blue tickets. You cannot buy chips in your entry period. When you sell chips, your inventory of chips decreases by the number of chips sold and inventory of Red or Blue tickets increases by the amount of the price of chips. The tickets that you receive for selling chips will be carried over to your exit period, and can be used to buy chips in this latter period. Any chips that you hold in your inventory at the end of the period are considered to be consumed by you. The amount of US dollars you earn depends on how many chips you consume, as indicated on your Redemption Value Sheet. Note that if you do not sell chips for tickets in your entry period, you will be unable to purchase chips in your exit period, and thus unable to consume chips in your exit period.

3. Specific instructions for exit period participants

At the beginning of your exit period, you will receive 0 chips in your inventory. If you are an exit period participant in period 1, you will also receive 1000 units of Red tickets and 1000 units of Blue tickets that can be used to purchase chips. This is the only time that participants will be given tickets. The only way to receive tickets after period 1 in order to purchase chips for exit period consumption is to sell chips in your entry period. Any tickets remaining in your inventory at the end of an exit period will be taken away from you (after you receive the dividend on your Red tickets), so that they will be unavailable if you are to participate in another entry/exit period sequence. Any chips that you hold in your inventory at the end of the period are considered to be consumed by you.

4. Calculating you earnings

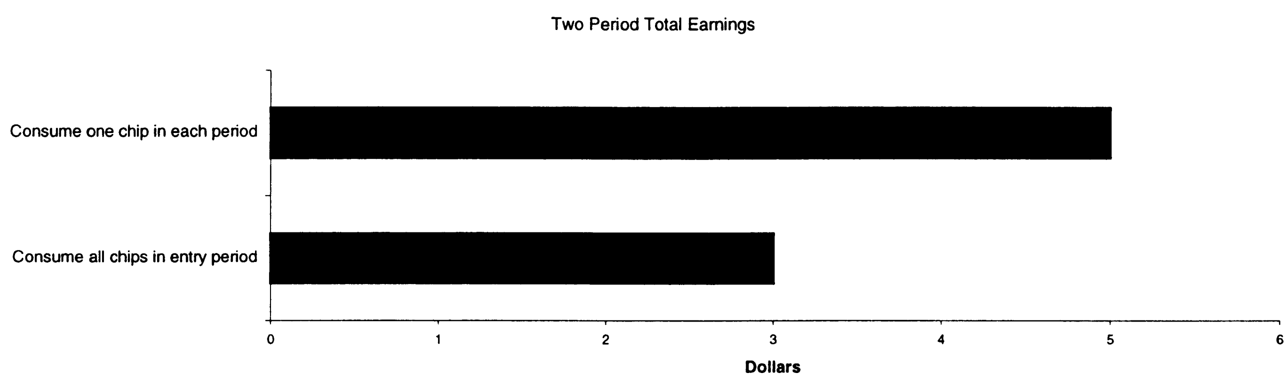
The amount of chips that you hold in your inventory at the end of the entry and exit periods determines your dollar earnings from consumption. The Redemption Value table will allow you to calculate your earnings in each period easily. The column labeled **Unit Value** gives the amount of earnings for each chip that you consume. The column labeled **Total Value** gives the total amount of earnings for all chips that you consume by adding up all the unit values for the total amount of chips consumed. The following example may be helpful to you.

Example: Suppose that you have the following Redemption Value Table and you consume a total of 3 chips for the period.

Unit	Unit Value	Total Value
1	$2.50	$2.50
2	$0.50	$3.00
3	$0.00	$3.00
4	$0.00	$3.00

The first chip that you consume will provide you $2.50 for consuming that chip. The second chip that you consume will provide you $0.50 for consuming that chip. The third chip that you consume will provide you $0.00 for consuming that chip. You total earnings for consuming the three chips is $3.00.

As stated earlier, if you do not sell chip(s) in your entry period for tickets, you cannot consume chips in your exit period. If you were to consume both chips in your entry period, then your dollar earnings from consuming chips for the two-period sequence would be $3.00. If you were to sell one chip in your entry period (consume only one chip in the entry period) and use the tickets from the sale to purchase and consume one chip in your exit period, then your earnings from consuming chips over the two period sequence would be $5.00.



5. Recording your earnings

At the end of every period, record your consumption of chips and period earnings in your record sheet. At the end of your entry period, complete your record sheet as follows. In line 1, enter the number of chips consumed during the period. In line 2, enter your dollar earnings from consuming those chips in your inventory, which is presented on your Redemption Value Sheet. In line 3, enter the number of Red tickets you have in your inventory at the end of the period. In line 4, calculate your dividend for holding units of Red Tickets by multiplying line 3 by $0.01.

Entry Participant in period 1.

At the end of your exit period, complete your record sheet as follows. In line 5, enter the number of chips consumed during the period. In line 6, enter your dollar earnings from consuming those chips in your inventory. In line 7, enter the number of Red tickets you have in your inventory at the end of the period. In line 8, calculate your dividend for holding units of Red tickets by multiplying line 7 by $0.01. In line 9, calculate your total earnings for the two period sequence by adding line 2, line 4, line 6 and line 8.

6. Ending the experiment

The experimenter will announce the end of the experiment at the beginning of the second-to-the-last period. All units of Red tickets held by participants at the end of the last period will also provide a dividend. All tickets that are held by entry period participants in the last period are converted into chips using the average market price of the second to the last period. Tickets that are held by exit period participants at the end of the period cannot be converted into chips.

Entry Participant in period 1.

6. Trading Rules

1) All entry period participants are sellers and all exit period participants are buyers.

2) Each participant receives a cue card with his or her ID number written on it. This cue card is used to propose an offer to the market to buy or sell chips.

3) There are two markets to trade chips. A market for trading chips using Red tickets and a market for trading using Blue tickets. Any trader is free to participate in either, both, or none of the two markets for trading chips.

4) To place an offer to either market to buy (sell) chips, raise cue card in the air and wait for the experimenter to call your ID number. When the experimenter calls upon you, state which market, price per unit and quantity that you want to buy (sell). The experimenter will then write this offer on the overhead in the appropriate market as the standing market price to buy (sell) chips.

5) If there is no standing offer at the market, a buyer (seller) can offer any per unit price they would like at which to buy (sell) chips. If there is a standing offer at the market to buy (sell) chips, a buyer (seller) must offer a higher (lower) price than the existing market price in order to enter the market.

6) To accept an offer to buy (sell), or in other words make a trade for chips, call out your ID number and state "Accept offer to buy (sell)." If more than one trader simultaneously accepts a standing market offer, a flip of a coin or rolling of a dice decides who will receive the chip(s). At that point, the actual trade of the chip and tickets takes place.

7) Once a transaction is completely fulfilled in a market, the accepted offer is cleared from the market and the offer prior to the accepted offer becomes the new standing offer in the market.

8) A period will end when there are no more offers made to the market and no standing offers accepted.

The following hypothetical market transactions may be helpful in understanding the trading rules:

Period open.
Trader ID#4 makes an offer to buy one chip for 50 tickets in the Red market.
Trader ID#5 makes an offer to sell one chip for 89 tickets in the Blue market.
Trader ID#8 makes an offer to sell two chips for 100 tickets in the Red market.
Trader ID#2 makes an offer to buy two chips for 75 tickets per chip in the Red market.
Trader ID#4 makes an offer to buy one chip for 48 tickets in the Blue market.
Trader ID#3 makes an offer to buy one chip for 60 tickets in the Blue market.
Trader ID#3 makes an offer to buy one chip for 82 tickets in the Red market.
Trader ID#7 accepts the offer by ID#3 and buys one chip for 82 Red tickets.

After the acceptance of the offer, the chips and tickets are then exchanged, and the new standing buy offer in the Red market is by trader ID#2 for two chips for 75 tickets since this is the next highest bid in that market.

The market transactions will be presented on the overhead as follows:

Red Market						Blue Market					
Purchase Offers			Sell Offers			Purchase Offers			Sell Offers		
Trader ID	# chips	Price	Trader ID	# chips	Price	Trader ID	# chips	Price	Trader ID	# chips	Price
4	1	50	8	2	100	4	1	48	5	1	89
2	2	75				3	1	60			
3	1	82									

Entry Participant in period 1.

Redemption Value Sheet

Unit	Unit Value	Total Value
1	$2.50	$2.50
2	0.50	3.00
3	0.00	3.00
4	0.00	3.00

Entry Participant in period 1.

Record Sheet

Practice Period 1 Entry Period

(1) Number of chips in inventory ________

(2) Dollar value from consumption ________

(3) Number of Red tickets in inventory ________

(4) Dividend from holding Red tickets x $0.01 = ________

Practice Period 2 Exit Period

(5) Number of chips in inventory ________

(6) Dollar value from consumption ________

(7) Number of Red tickets in inventory ________

(8) Dividend from holding Red tickets x $0.01 = ________

(9) Total earnings from Entry and Exit period sequence (2) + (4) + (6) + (8) = ________

Entry Participant in period 1.

Record Sheet

Period 1 Entry Period

(1) Number of chips in inventory ________

(2) Dollar value from consumption ________

(3) Number of Red tickets in inventory ________

(4) Dividend from holding Red tickets x $0.01 = ________

Period 2 Exit Period

(5) Number of chips in inventory ________

(6) Dollar value from consumption ________

(7) Number of Red tickets in inventory ________

(8) Dividend from holding Red tickets x $0.01 = ________

(9) Total earnings from Entry and Exit period sequence (2) + (4) + (6) + (8) = ________

Period 3 Entry Period

(1) Number of chips in inventory ________

(2) Dollar value from consumption ________

(3) Number of Red tickets in inventory ________

(4) Dividend from holding Red tickets x $0.01 = ________

Period 4 Exit Period

(5) Number of chips in inventory ________

(6) Dollar value from consumption ________

(7) Number of Red tickets in inventory ________

(8) Dividend from holding Red tickets x $0.01 = ________

(9) Total earnings from Entry and Exit period sequence (2) + (4) + (6) + (8) = ________

Entry Participant in period 1.

Record Sheet

Period 5 Entry Period

(1) Number of chips in inventory ________

(2) Dollar value from consumption ________

(3) Number of Red tickets in inventory ________

(4) Dividend from holding Red tickets x \$0.01 = ________

Period 6 Exit Period

(5) Number of chips in inventory ________

(6) Dollar value from consumption ________

(7) Number of Red tickets in inventory ________

(8) Dividend from holding Red tickets x \$0.01 = ________

(9) Total earnings from Entry and Exit period sequence (2) + (4) + (6) + (8) = ________

Period 7 Entry Period

(1) Number of chips in inventory ________

(2) Dollar value from consumption ________

(3) Number of Red tickets in inventory ________

(4) Dividend from holding Red tickets x \$0.01 = ________

Period 8 Exit Period

(5) Number of chips in inventory ________

(6) Dollar value from consumption ________

(7) Number of Red tickets in inventory ________

(8) Dividend from holding Red tickets x \$0.01 = ________

(9) Total earnings from Entry and Exit period sequence (2) + (4) + (6) + (8) = ________

Entry Participant in period 1.

Record Sheet

Period 9 Entry Period

(1) Number of chips in inventory ________

(2) Dollar value from consumption ________

(3) Number of Red tickets in inventory ________

(4) Dividend from holding Red tickets x $0.01 = ________

Period 10 Exit Period

(5) Number of chips in inventory ________

(6) Dollar value from consumption ________

(7) Number of Red tickets in inventory ________

(8) Dividend from holding Red tickets x $0.01 = ________

(9) Total earnings from Entry and Exit period sequence (2) + (4) + (6) + (8) = ________

Period 11 Entry Period

(1) Number of chips in inventory ________

(2) Dollar value from consumption ________

(3) Number of Red tickets in inventory ________

(4) Dividend from holding Red tickets x $0.01 = ________

Period 12 Exit Period

(5) Number of chips in inventory ________

(6) Dollar value from consumption ________

(7) Number of Red tickets in inventory ________

(8) Dividend from holding Red tickets x $0.01 = ________

(9) Total earnings from Entry and Exit period sequence (2) + (4) + (6) + (8) = ________

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