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# Stationary Solution to the Overlapping Generations Model of Fiat Money: Experimental Evidence[1]

SUK S. LIM

City University of Seoul, Seoul, Korea

EDWARD C. PRESCOTT

Department of Economics, University of Minnesota, Minneapolis MN 55455, USA

SHYAM SUNDER

Graduate School of Industrial Administration, Carnegie Mellon University, Schenley Park, Pittsburgh PA 15213, USA

*Abstract:* Overlapping generations model of fiat money yields an infinity of competitive equilibrium solutions, only one of which is stationary. Economies reported in this paper involved a sequence of overlapping generations of three or four individuals; each individual lived for two periods. In their young age individuals were endowed with "chips" that could be traded for fiat money with the individuals of the old generation. In their old age, individuals could exchange their units of fiat money for the consumption good. Results of the experiments exhibit some support for the stationary solution. The results are robust to two designs of exchange institutions (double oral auction and supply schedule auction) and to two different endogenous ways of converting money into "chips" at the end of the game (average price prevailing during the last period the game is actually played and the average price forecast made during the last period the game is actually played).

*JEL-Classification System-Numbers:* C62, C92, E40, E50

The overlapping generations economy of Samuelson (1958) has become a central construct in monetary economics.[2] Lucas (1972), adding informationally decentralized exchange, used it to construct a monetary shock theory of business cycles. Since then a problem with using this abstraction has been recognized. There typically are not only the equilibria considered by Lucas but many others as well. Calvo (1978) showed there typically are a continuum of deterministic nonstationary equilibria. Azariadis (1982) and Cass and Shell (1984) found a set of sunspot equilibria. Kehoe and Levine (1985) showed that the problem of multiplicity of equilibria increases with the number of goods. Spear and Srivastava (1985) have constructed overlapping generations models with a continuum of stationary equilibria.

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[2] Wallace (1980) has championed its use in addressing monetary issues.

The basic problem is that there are many consistent sets of expectations for the future price path. Competitive equilibrium theory alone cannot resolve the issue of which of the equilibrium paths is to be expected in a given economy. Lucas (1986) suggested the experimental approach to resolve this issue. If experimental economies converge to stationary nonsunspot equilibrium, such results would provide justification for focusing attention on this equilibrium. If the allocation obtained over experiments varies, the experimental results provide support for those who see policy as the choice of monetary arrangement (e.g., Grandmont, 1986). Often there are monetary institutions that can be adopted to eliminate the indeterminacy resulting in but one equilibrium with valued fiat money.

A key experimental innovation is overcoming the endpoint problem. For any finite-lived economy there are no monetary equilibria.[3] Money has no value at the last trading date because it cannot be traded for anything subsequently. If it has no value at the last trading date, it has no value at the date before. By induction, it has no value in any period. Consequently, there can be no last period in an economy designed to examine the equilibrium value of fiat money. But experimental economies necessarily have a last period. Our resolution of this problem is to add economic forecasters to the economy. The value of money in the last period of the experiment is the average value forecasted for that period in the period before by nonparticipating subjects who are rewarded for accuracy of their forecasts. For this environment, the same set of equilibria is obtained as for the infinitely lived economy in the sense that the paths are the same for the life of the infinite-lived economy.

## The Economy

Consider a sequence of generations, each consisting of an equal number, n, of agents. Each agent lives over two consecutive periods $\{t, t+1\}$ and consumes $y_t$ at the end of the first period (youth) and $z_{t+1}$ at the end of the second (old age). Each agent is endowed with $e_y$ units of a consumption good at the beginning of the youth period and $e_z$ units at the beginning of the old age period and $e_y$ exceeds $e_z$. The economy has $n \cdot m$ units of fiat money (i.e., $m$ units per person) which can be used by the old to buy the good from the young each period. If each individual's preferences are given by $u\,(y_t, z_{t+1})$, the utility maximization problem can be specified as:

$$\max_{y_t, z_{t+1}, m_t} \quad u(y_t, z_{t+1})$$

$$\text{subject to } m_t = (e_y - y_t)p_t$$

$$z_{t+1} = e_z + m_t/(p_{t+1})$$

[3] There is always a nonmonetary equilibrium in which there are no trades and fiat currency is not valued.

where $p_t$ and $p_{t+1}$ are the prices per unit of the good and $m_t$ is the amount of money the individual acquires in youth and spends in the old age.

Substituting for $y_t$ and $z_{t+1}$, the maximization problem can be written as:

$$\max_{m_t} u\left(e_y - \frac{m_t}{p_t}, e_z + \frac{m_t}{p_{t+1}}\right)$$

Assuming $u(y_t, z_{t+1}) = (y_t \cdot z_{t+1})$,

$$\max_{m_t} \left[\left(e_y - \frac{m_t}{p_t}\right)\left(e_z + \frac{m_t}{p_{t+1}}\right)\right].$$

First order condition is sufficient for optimization of this concave problem:

$$\left(e_z + \frac{m_t}{p_{t+1}}\right)\Big/ p_t = \left(e_y - \frac{m_t}{p_t}\right)\Big/ p_{t+1}$$

or

$$p_{t+1} = \frac{e_y}{e_z} \cdot p_t - \frac{2m_t}{e_z}. \tag{1}$$

The stationary solution to this difference equation is given by

$$p_{t+1} = p_t = p^s = \frac{2m_t}{e_y/e_z}. \tag{2}$$

This is the stationary competitive equilibrium price system. Difference equation (1) has other solutions with positive prices. As $e_y/e_z > 1$ by assumption, given any $p_o \geq p^s$, the price sequence generated by (1) is a competitive equilibrium price system. Note that except for $p_o = p^s$, the equilibrium price sequence increases geometrically towards infinity. This implies asymptotically that individuals will just consume their endowment as money becomes worthless.

## Design of Experiments

Four laboratory economies, numbered chronologically for reference in this paper, were conducted, Economies 1 and 2 involved double oral auctions.[4] In Economies 3 and 4, market clearing price and allocations each period were computed from the supply functions solicited from the members of the "young"

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[4] A double oral auction is conducted as follows: Any seller (buyer) is free to state a price at which he/she is willing to sell (buy) one chip. Any other seller (buyer) can offer to sell (buy) at a lower (higher) price than the current offer (bid). Any buyer (seller) can accept the current offer (bid). When an acceptance is made, the respective traders enter into a binding contract to buy-sell one chip.

generation.[5] We describe the design of Economy 1 before outlining how the three subsequent economies differed from the first. Instructions for Economies 3 and 4 are given in the Appendix. Other instructions are available from the authors on request.

Economy 1 had 14 subjects of which four were randomly picked each period to form a generation. Each generation lived for two periods labelled entry and exit periods respectively. Thus during any given period, eight subjects were active participants in the economy while six sat idle. The next generation was formed by random selection from these six subjects. This procedure ensured that each subject sat idle for at least one period after exiting the game and before reentering it. The entry and exit plan in the Appendix shows the sequence of participation by individual subjects.

Each subject was endowed with seven chips at the beginning of the entry period and one chip at the beginning of the exit period. The entry period endowment of money (called francs in the experiment) was zero. Any money received from the sale of chips during the entry period was carried over by each subject to the exit period when it could be used to buy chips. Each subject for whom the first period itself was the exit period was given 1000 francs. No further money was injected into the economy.

Subjects were allowed a period of five minutes to engage in a double oral auction for purchase and sale of chips for francs. Entry subjects could only sell while exit subjects could only buy chips. The number of chips on hand with each subject was not allowed to go below one and the balance of francs was not allowed to go below zero during trading. If a buyer had insufficient cash to buy a whole chip at the prevailing price, he or she had the option to buy an appropriate fraction to use up the cash balance. Any francs left in the hands of the exit subjects at the end of the five-minute trading period were permanently lost from the economy.

At the end of trading during the exit period, traders of that generation calculated their "winning number" by multiplying the number of chips held at the end of entry period ($y_t$) and at the end of the exit period $z_{t+1}$. They received a fixed reward of $6.00 with probability proportional to the log of the "winning number" as follows:

$$\text{Prob. (reward} = \$6) = \log (y_t \cdot z_{t+1})/\log(30).$$

[5] These auctions were conducted as follows. Each seller (member of the young generation) was asked to offer a schedule of prices at which he/she was willing to sell up to 0, 1, 2, ..., 7 chips. Individual supply function was created by linear interpolation between discreet points specified by the seller. The market supply function was the sum of individual supply functions. All money in the hands of the buyers (members of the old generation in this experiment) was used to construct a hyperbolic (fixed revenue) demand function. Market clearing price and quantities were determined at the intersection of the supply and demand functions. The market clearing price and quantity were announced and each trader was informed individually about the number of chips bought or sold by him or her.

A prize wheel with log scale markings was used to determine if the subject received a \$6 or zero reward.[6] Subjects were given training to familiarize them with the probabilistic mechanism.

The subjects knew in advance that the game would last for approximately three hours. They were also informed that at the end of the game, francs in the hands of the subjects would be converted into chips at the mean transaction price of the last period actually played. The transaction price data was recorded on a blackboard during each period and a running summary of trading each period (number of transactions, opening, closing, highest, lowest and mean prices) was maintained in full view of the subjects on the blackboard.

Design of Economy 2 was similar to Economy 1 except that the francs given to "old" subjects in the first period were reduced to 250 from 1000 to change the initial stationary competitive equilibrium price from 333 to 83 francs. Nine of the subjects who participated in Economy 1 participated in Economy 2. Five new subjects were recruited for the study.

Economies 3 and 4 were designed as supply schedule auctions with some other innovations. First, we wished to test the robustness of the stationary equilibrium to a variety of auction mechanisms. Second, double oral auction required five minutes of hectic trading. Between trading and keeping their accounts, it was argued, the subjects had little time for reflection and to think about the future and to try to anticipate what might happen during the next period. Supply schedule auction simplifies the task of the subjects. It assigns a passive role to the buyers in our experiment. The role of sellers was limited to preparing a supply schedule specified at eight discreet points. This environment presumably places less severe demands on the cognitive resources of the subjects and thus permits more time for reflection. Third, it was difficult to prevent money from being permanently lost to the market in the double oral auctions because the exit subjects did not always use up all their cash balance to buy chips, due to accounting errors, misunderstanding or lack of time. The effect was a changing value of the price predicted by stationary competitive equilibrium. Five-minute trading time followed by accounting calculations allowed only about six periods to be run each hour which limited the total number of replications that could be carried out within the limited time available. Finally, in the heat of hectic trading, subjects made accounting errors that also resulted in either random loss or injection of money to the economy. Most of these problems could easily be handled through a supply schedule auction with the assistance of a personal computer and an appropriate monitoring program.

Two more changes were made between the first and the last two economies. The probabilistic reward mechanism was replaced by a deterministic one with rewards proportional to $(y_t \cdot z_{t+1})^{1/2}$. Also, at the beginning of each period, the nonparticipating subjects were asked to make a prediction of the market clear-

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6 The purpose of using the prize wheel and probabilistic reward scheme was to induce the subjects to be risk averse in consumption during each period. See Berg et al. (1986).

**Table 1.** Steps of experimental procedure

| |
|---|
| *Economies 1 and 2* |
| 1. Training (two periods of transaction examples and prize wheel). |
| 2. Experimenter announces entry subjects. |
| 3. Double oral auction between entry and exit subjects. |
| 4. Experimenter announces the end of the period. |
| 5. Participating subjects calculate ending balances of chips and money. |
| 6. Exit subjects spin prize wheels and record their profit. |
| 7. Go to step 2. |
| *Economies 3 and 4* |
| 1. Training (two periods of transaction examples). |
| 2. Experimenter announces entry subjects. |
| 3. Non-participating subjects record market price prediction. |
| 4. Experimenter collects prediction sheets, and keys predictions into the computer. |
| 5. Entry subjects record supply schedules on offer sheets. |
| 6. Experimenter collects offer sheets and enters them into the computer. |
| 7. Experimenter announces market clearing price, trading volume, average prediction, and the winner of the price prediction contest, and distributes individual allocations. |
| 8. All subjects record market outcome and exit subjects record their profit. |
| 9. Go to step 2. |

ing price of the period. After the market clearing price was announced, the subject with the closest prediction was given a reward of $2.00. Subjects were also informed that at the end of the game (approximately three hours from the start) money balances in the hands of the subjects would be converted into chips at the exchange rate determined by the average prediction made for that period. Thus in all economies, the price of "chips" at the end of the game was determined endogenously and not dictated by the experimenter. Moreover, the procedure for ending the game was clearly explained to the subjects at the outset.

Subjects were undergraduate business majors at the University of Minnesota. Nine out of fourteen subjects who participated in Economy 1 also participated in Economy 2. Five new subjects in Economy 2 were given instruction before participating. Fourteen new subjects were recruited for Economy 3, of which eight also participated in Economy 4. Three subjects from Economies 1 and 2 participated in Economy 4. Since only 11 subjects could attend Economy 4, each generation consisted of three instead of four subjects.

The sequence of main steps in the economies is given in Table 1 and the key design features of the four economies are given in Table 2.

**Table 2.** Design of experiments

| Expt. No. | Market Type | Location | Experience | Number of Subjects in the Experiment /in each Generation | Chip Endowment | | Money Endowment* (francs) | | (Expected) Payoff Function | Prize Wheel |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Entry | Exit | Entry | Exit | | |
| 1 | Double Oral | U. of Minnesota | Inexperienced | 14/4 | 7 | 1 | 1,000 | 0 | $\$6\,\frac{\log(y_t \cdot z_{t+1})}{\log 30}$ | Yes |
| 2 | Double Oral | " | Experienced (9/14) | 14/4 | 7 | 1 | 250 | 0 | $\$6\,\frac{\log(y_t \cdot z_{t+1})}{\log 30}$ | Yes |
| 3 | Supply Schedule | " | Inexperienced | 14/4 | 7 | 1 | 1,000 | 0 | $\$1.20(y_t \cdot z_{t+1})^{1/2}$ | No |
| 4 | Supply Schedule | " | Experienced | 11/3 | 7 | 1 | 250 | 0 | $\$0.75(y_t \cdot z_{t+1})^{1/2}$ | No |

* Money endowment was given only in the first period. No further money was injected into the economy.

**Equilibrium Predictions**

Two kinds of ideas can be applied to calculate the price and allocations predicted under a stationary equilibrium. In a competitive equilibrium where each trader acts as a price taker, the stationary equilibrium price is given by

$$p = 2m/(e_y - e_z)$$

where m is the amount of money per person, $e_y$ is the chip endowment per subject in the entry period and $e_z$ is the chip endowment per subject in the exit period. Under this equilibrium, each entry period subject will sell $(e_y - e_z)/2$ chips and each exit subject will buy the same number of chips and therefore hold $(e_y + e_z)/2$ chips at the end of each period. This equilibrium maximizes the payoff from the experimenter to the subjects. Parameters of the four economies, and the price, allocation, and (expected) profit predictions of the stationary competitive equilibrium model are given in the first few columns of Table 3.

While price-taking behavior may be a reasonable approximation when the number of traders is large, one may reasonably question if the predictions of the competitive model can describe the data well when the number of buyers and sellers is three or four each. Predictions of stationary Nash equilibrium can be derived under the assumption that traders choose their supply functions optimally, relative to their assumption about the behavior of the others and such assumptions are consistent with their own behavior. There is a continuum of symmetric stationary Nash equilibria of which stationary competitive equilibrium allocation represents one extreme case.

Suppose individual i sells $s_i$ units in youth and expects to buy goods at price $p^f$ in old age. Since the total amount of money in the economy is $m \cdot n$ units, individual i enters old age with cash $m \cdot n \cdot s_i \Big/ \left( \sum_{j=1}^{n} s_j \right)$ that can be used to buy $m \cdot n \cdot s_i \Big/ \left( p^f \cdot \sum_{j=1}^{n} s_j \right)$ units of good in old age. Therefore, i's maximization problem can be written as

$$\max_{s_i} (e_y - s_i) \left( e_z + m \cdot n \cdot s_i \Big/ \left( p^f \cdot \sum_{j=1}^{n} s_j \right) \right) .$$

The first order condition evaluated at $s_i = s$ is

$$m \left( \frac{n-1}{n} \right) \left( \frac{e_y - s}{p^f \cdot s} \right) = e_z + \frac{m}{p^f} .$$

Setting $p^f = p = m/s$ yields the extreme symmetric stationary Nash solution:

$$p^N = \frac{m(2n-1)}{(n-1)e_y - ne_z} , \tag{3}$$

which is greater than or equal to the stationary competitive price $p^s$ given in the equation (2). The range of symmetric stationary Nash equilibria is $p^N$ to $p^s$. This

**Table 3.** Equilibrium predictions

| Expt. No. | Competitive Equilibrium | | | Extreme Nash Equilibrium | | | Demonetized Economy | | |
|---|---|---|---|---|---|---|---|---|---|
| | Price | Number of chips Traded* | Profit[a] per person per 2-period life | Price | Number of chips Traded* | (Expected) Profit[a] per person per 2-period life | Price | Number of chips Traded | (Expected) Profit[a] of chips per 2-period life |
| 1 | 333 | 3 | \$4.89 | 412 | 2.43 | \$4.85 | | 0 | \$3.43 |
| 2 | 83 | 3 | \$4.89 | 103 | 2.43 | \$4.85 | | 0 | \$3.43 |
| 3 | 333 | 3 | \$4.80 | 412 | 2.43 | \$4.75 | | 0 | \$3.17 |
| 4 | 83 | 3 | \$3.00 | 114 | 2.19 | \$2.94 | | 0 | \$1.98 |

* Per capita
[a] Profit for each Entry-Exit pair

range is marked on Figures 1 through 4. As $n \to \infty$, $p^N \to p^s$ and the range converges to zero. Since we used $n = 4$ and 3, $p^N/p^s$ is 21/17 and 15/11 respectively. The price, allocation and profit predictions of the stationary Nash equilibrium of each of the four economies are given in Table 3.

From the continuum of nonstationary equilibria, it is worth mentioning at least one extreme case of a demonetized economy in which the price of chips in terms of money increases without bound and the money becomes worthless. In this equilibrium, all subjects stay with their endowment of chips and receive a relatively low level of payoff from the experimenter. The predictions of this model are also given in Table 3.

## Results

### *Price*

Figures 1 and 2 show the prices of individual transactions during each period of Economies 1 and 2 respectively. Figure 3 and 4 show the market clearing prices for each period of Economies 3 and 4 respectively. Stationary competitive equilibrium price is shown by a horizontal line at the lower edge of the hatched area in all figures. The horizontal line at the upper edge of the hatched area marks the upper extreme stationary Nash equilibrium price. Downward shifts in equilibrium prices in Economies 1 and 2 were caused mostly by loss of money in the economy due to the inability of the old generation to utilize all the money they had to purchase "chips." The loss of money to the economy was permanent, and was not recouped through redistribution. Most of this shift occurred in the early periods of each experiment. All the upward shifts in the equilibrium price and some downward shifts occurred due to accounting mistakes by subjects, and they remained undiscovered until the data sheets were tabulated and analyzed by the experimenters. Thus, stationary equilibrium in Economies 1 and 2 in fact constituted a moving, though well-defined, target over the periods. The switch to supply schedule auction in Economies 3 and 4 was motivated in part by our desire to test the market behavior under conditions where stationary equilibrium remained unchanged from period to period. The changing equilibrium price did, as we argue later in this section, allow us to test the robustness of the stationary equilibrium concept under conditions of "stochastically" changing money supply.

In all four economies, the price of "chips" in terms of francs is substantially different from the competitive stationary equilibrium (CSE) in the first period. In the first period of Economies 1 and 2, the average transaction price is 60

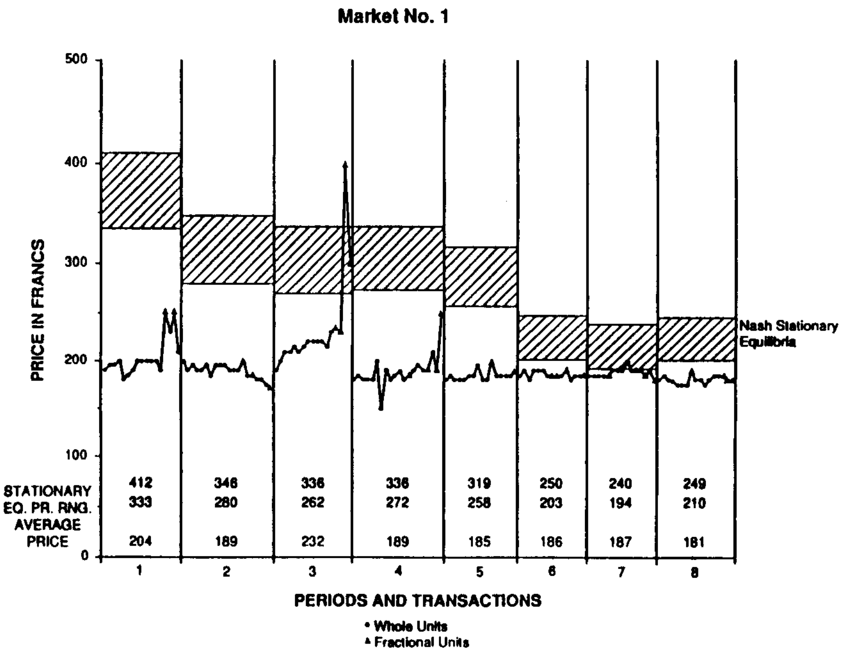


Fig. 1. Transaction prices

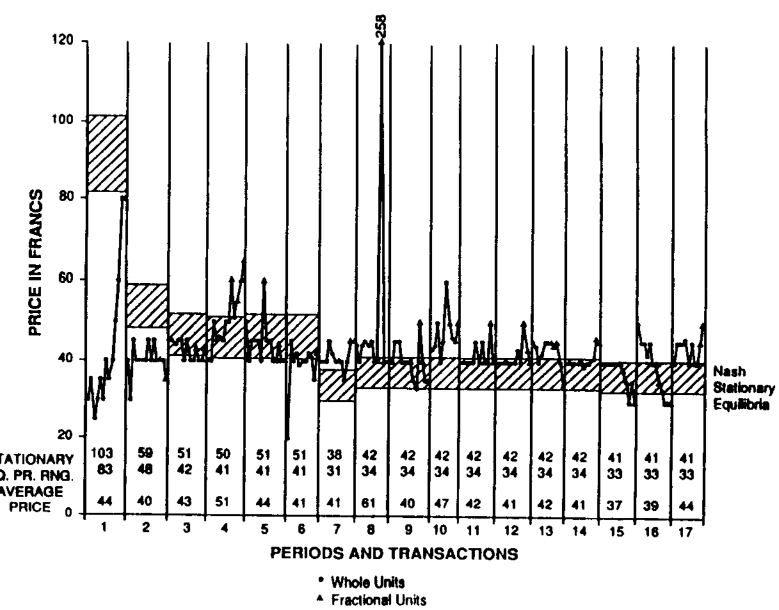


Fig. 2. Transaction prices

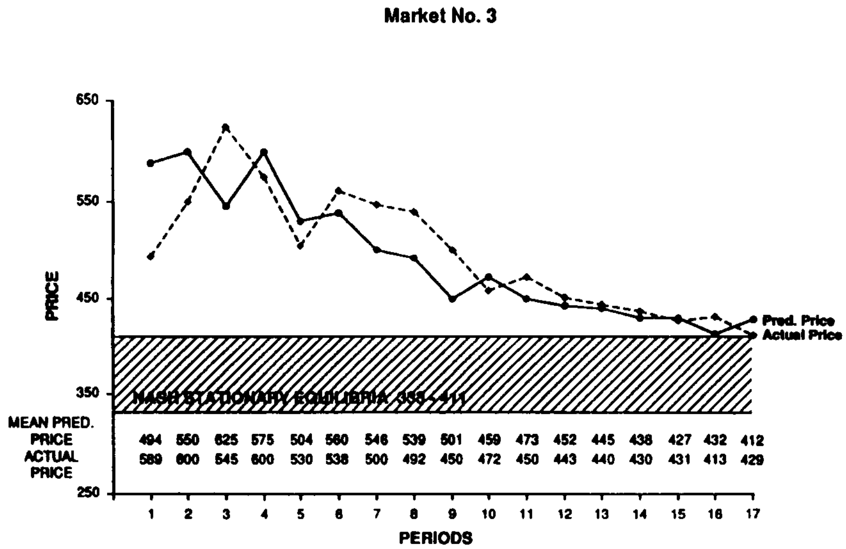


Fig. 3. Transaction prices

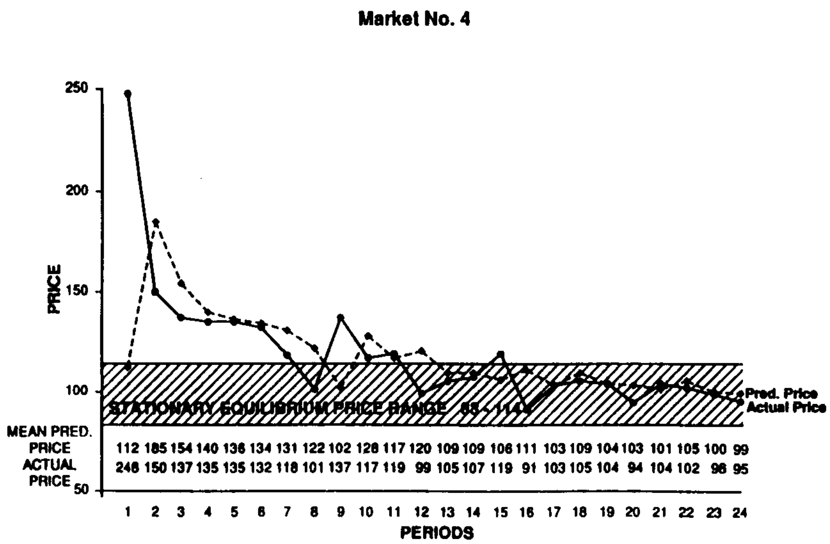


Fig. 4. Transaction prices

percent and 53 percent respectively of the CSE price. This percentage changes to 90 and 125 in the last period of the respective economies. In Economy 1, the change is more or less monotonic. In Economy 2, most of the change occurs in the first and second periods; and price is almost randomly distributed about 40 thereafter. In Economy 3, the market clearing price declines from 176 percent of CSE price in the first period to 129 percent in the last period. In Economy 4 the market clearing price declines from 300 percent of CSE to 112 percent. With replication there is a marked convergence towards stationary equilibrium though the convergence is not precise. To what extent further replications may affect the nature of convergence is an open question.

It is possible to interpret the evidence on price in support of the stationary equilibrium. Besides the observation of price in the neighborhood of the stationary equilibria, perhaps an even more striking aspect of the data is the rather stable nature of the price path. Even if the data cannot be said to support the stationary equilibrium, in no case can it be said to be consistent with demonetization of the economy. In both double oral auctions (Economies 1 and 2), some transactions occurred at very high prices and they could have provided a basis for the markets to take a path of exponential growth in prices. However, such high-price transactions seem not to have been followed by other high-price transactions and the markets continued on relatively stable paths.

As we discussed earlier, the loss of unutilized money in the hands of the old generation in Economies 1 and 2 amounted to a random demand shock to the economy in each period. The shock was random because none of the participants in the market that suffered such a demand shock knew about the fact of the extent of the loss of money in the economy. Recall that after exiting the game, each subject waited on the sidelines for at least one period before reentering. This random demand shock was another reason for the economy not to converge to the stationary equilibrium. The fact that the economy still seemed to converge in the neighborhood of the CSE is, to our eyes, evidence in the support of the robustness of the stationary equilibrium.

*Volume*

In Economies 3 and 4, volume is inversely proportional to the price of "chips" and therefore all information contained in volume is contained in the price variable. In all economies, CSE trading volume was 3 "chips" per capita and the extreme Nash Stationary Equilibrium (NSE) trading volume was 2.43 "chips" per person in Economies 1, 2 and 3, and 2.19 in Economy 4. In a demonetized economy, trading volume would be zero. The actual trading volume relative to these benchmarks is shown in the four panels of Figure 5. These results support the inference drawn in support of the stationary equilibrium.

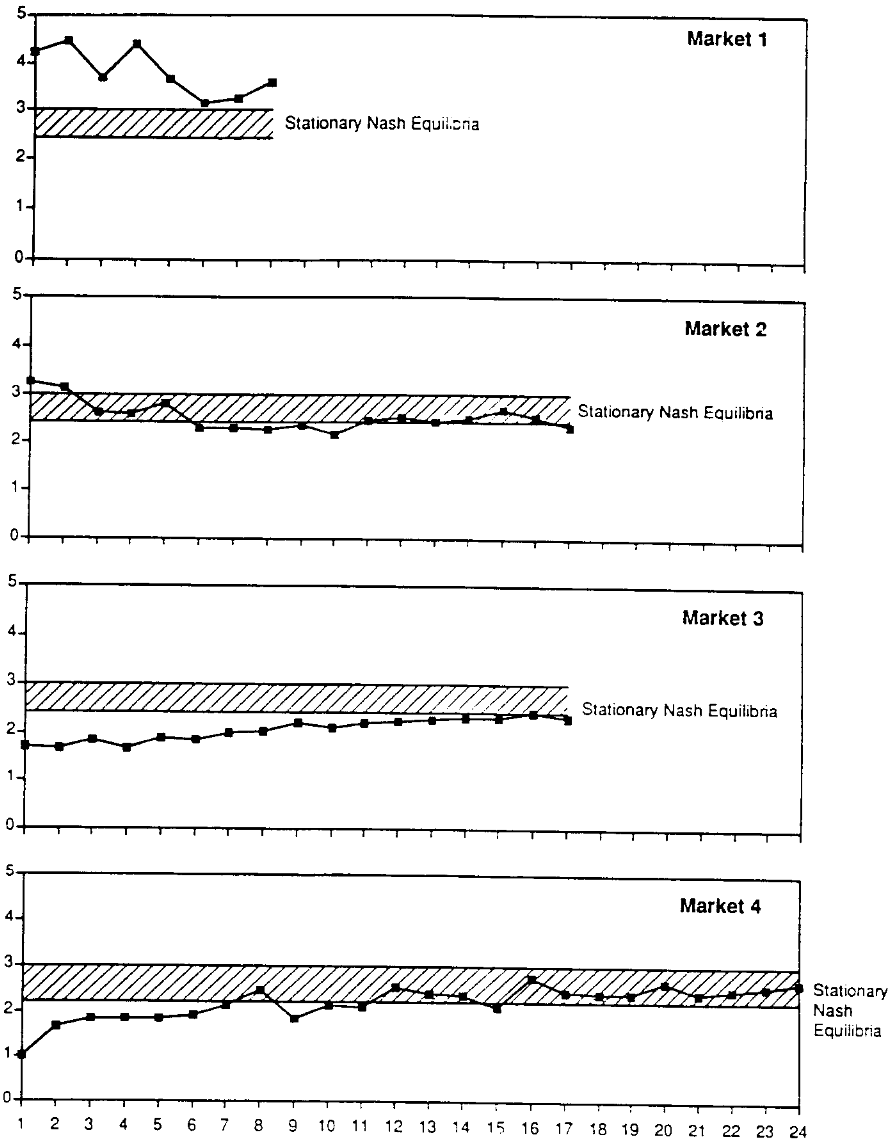


**Fig. 5.** Per capita trading volume

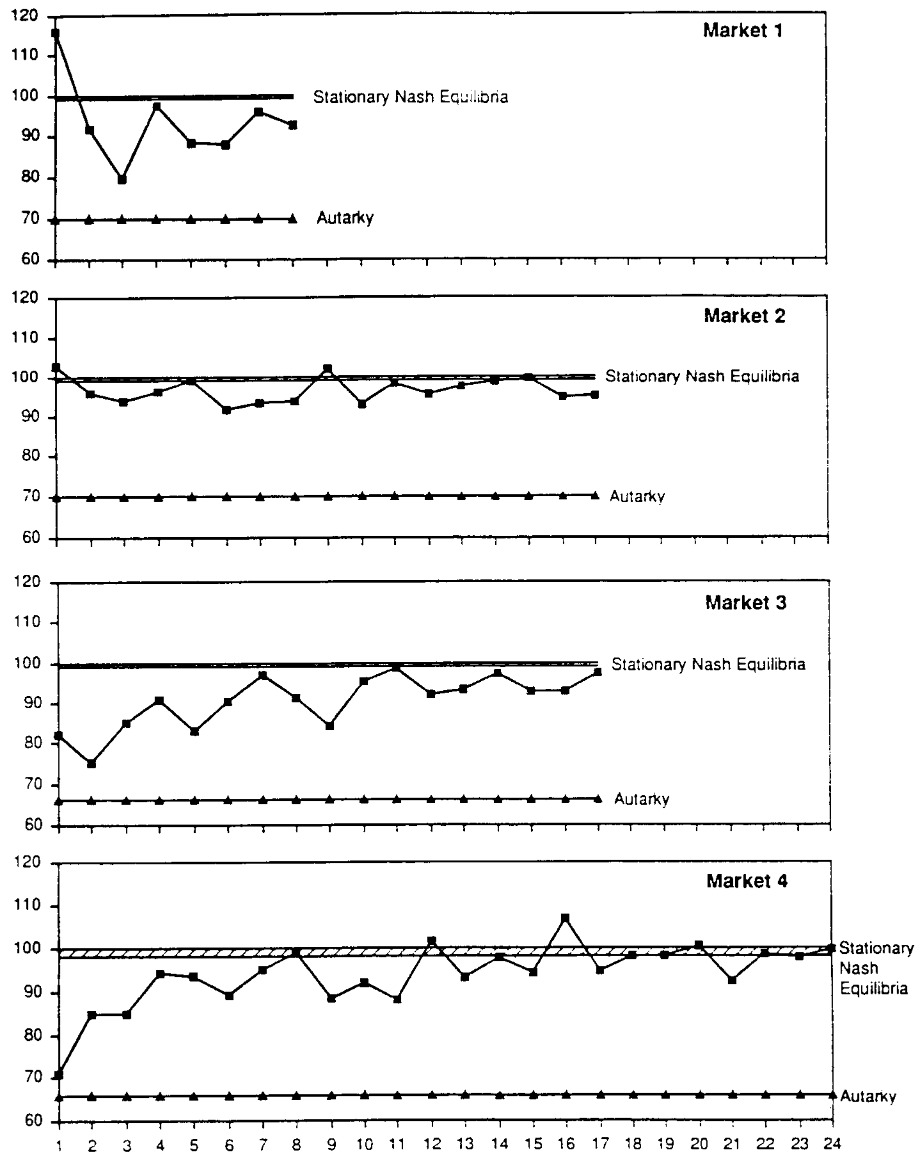


**Fig. 6.** Efficiency of markets

*Efficiency*

In Economies 1 and 2 which have probabilistic payoffs, we use the expected dollar payoff achieved by the exit subjects each period as a percentage of the maximum possible expected payoff achievable, as the measure of efficiency. In Economies 3 and 4 where the payoff is deterministic, efficiency is measured by the actual dollar payoff received by the exit subjects as a percentage of the maximum possible dollar payoff. The efficiency of all four markets is shown in Figure 6. The maximum payoff is attained for CSE and the 100 percent efficiency line corresponds to this equilibrium. A demonetized economy has no trades, and the efficiency corresponding to the endowment distribution of "chips" is the lower benchmark (autarky) in the efficiency charts.

All four markets can be seen to be highly efficient with the efficiency reaching as high as 98 percent. The average efficiency of Economies 1, 2, 3 and 4 is 93.7%, 96.5%, 90.5%, and 93.9% respectively. Compared to the 66–70 percent bench mark for demonetized economies, these data leave little doubt that the stationary equilibrium is a reasonable candidate to explain the behavior of these economies.

## Concluding Remarks

The substantive finding of our experiment is that the stationary solutions to the overlapping generations model of fiat money form the domain of attraction for the behavior of these experimental economies. Since the initial price in all experimental economies deviated significantly from the stationary solutions, there was every chance for these economies to follow nonstationary paths. The fact that all these economies stabilized close to the range of stationary solutions suggests that stationary solutions are better descriptors of behavior in such environments. Further, our conclusions are robust relative to two different institutions for organizing exchange transactions.

With the exception of Economy 1, all economies converged towards the upper end of the range of stationary Nash solutions as opposed to the lower end defined by the competitive stationary solution. The data therefore suggest that the young did exploit some of their monopsony power. Experiments with more subjects would reduce this power.

In Economies 3 and 4, as subjects gained experience, and as the economy stabilized close to the stationary equilibrium, the quality of forecasts improved. Forecasts appear to be adaptive though we have not carried out a formal analysis.

Finally, we experimented with two different techniques of bringing laboratory experiments of indefinitely lived economies to an end. Converting end-of-the-game money balances into goods at (1) price observed in the last period and at (2) price forecast made during the last period, seem to be satisfactorily neutral devices for terminating such economies.

## Appendix

### *Instructions and Experimental Procedures*

In Economies 1 and 2, markets were conducted in three steps: (1) training for the payoff mechanism with prize wheels; (2) training with two periods of sample transactions; and (3) main markets. At the beginning, subjects were randomly assigned their subject numbers and seated on prearranged seats with tables. On each table, a packet of instructions and forms was placed in advance. Subjects were not allowed to talk to one another.

*Step 1*: First instruction set (not included here) was read aloud. All subjects were asked to decide the number of chips to be purchased and then were asked to spin a prize wheel. The profit (prize won minus the cost of chips bought) was paid. This process was repeated about 10 to 15 times.

*Step 2*: Second instruction set (not included here) was read aloud. Two trial periods were conducted. In the first period, half the subjects played entry-period players and the other half exit-period players. In the second period, the roles were reversed to give all the subjects equal experience. Chip endowment for entry-period subjects was four chips and money endowment for initial exit-period subjects was 10,000 francs. All other parameters were the same as shown in Table 1. A set of transaction examples was shown on the projection screen. Subjects were asked to speak out their respective bids and offers in the examples shown. At the end of each period, they were asked to spin Prize Wheel 2. Individual record sheets were checked for possible errors.

*Step 3*: Actual overlapping generations economy was conducted. At the beginning of each five-minute period, the experimenter asked for bids and offers. A "one minute left" warning was issued before the market ended. At the end of each period, the experimenter checked the accuracy of record sheets and watched subjects spin prize wheels.

In Economies 3 and 4, markets were conducted in two steps: (1) training with two periods of example transactions; (2) actual experiment.

*Step 1*: The instruction set (see the following pages) was read aloud and explained. Transaction examples were shown on the screen. Half the subjects played entry subjects and the others exit subjects in the first example period, and the roles were reversed in the second. Subjects were asked to fill in their individual record sheets, including price prediction sheets, so each subject would understand how the market was to proceed and his/her profit would be calculated. The experimenter distributed pre-processed individual computer outputs. All the subjects were asked to record the market outcome from the computer outputs. The same process was repeated in the second period.

*Step 2*: Main markets were preceded by the procedure explained in the Design of Experiments section. At the beginning of each period, the experimenter showed entry and exit subjects of the period on the screen and asked the subjects not participating in that period to submit market price predictions and the entry subjects to submit their supply schedules. Supply schedules were entered into the computer and the experimenter announced the resultant market clearing price, the market clearing quantity, the average prediction price and the winner of the price prediction contest on the blackboard. Then the experimenter distributed computer-printed slips of paper indicating price and quantity bought/sold by them to the subjects and to the winner of the prediction contest. This process was repeated each period.

*Instructions*

This is an experiment in decision-making. Various research foundations have provided funds for this research. 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.

In this experiment, we are going to have a market in which you will buy and sell chips in a sequence of market periods. Attached to these instructions you will find sheets labelled Information and Record Sheet, Selling Offer Sheet and Market Price Prediction Sheet which help you record your decisions and determine their value to you.

The type of currency used in this market is francs. The only use of this currency is to buy and sell chips. It has no other use. The money you take home with you is in dollars. The procedures for determining the number of dollars you take home with you is explained later in these instructions.

You will participate in the market for two consecutive periods at a time. Let us 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 in the market). Different individuals may have different entry and exit periods and the experimenter will inform you about when you will enter and exit the market. You may be asked to enter and exit more than once depending on the number of periods for which the market is operated.

At the beginning of your entry period, you will receive 7 chips from the experimenter and at the beginning of your exit period you will receive 1 chip. In your entry period, you may keep these chips or sell chips to others. In your exit period, you can buy more chips from others but you cannot sell. Buying and selling of chips will occur in francs according to the rules to be explained later.

The product of the number of chips you hold at the end of trading each period determines the amount of money you earn for that pair of entry-exit periods. The experimenter will calculate the square root of the product and multiply it by $1.20 to calculate the amount of dollars you earn. Thus, suppose you hold 5 chips at the end of your entry period and 3.5 chips at the end of your exit period. The product of these two numbers is $5 \times 3.5 = 17.5$. The square root of 17.5 is 4.18 which is multiplied by $1.20 to yield $5.02 as your earning in these two periods. Note that the higher the product of the numbers of chips held by you at the end of entry and exit periods, the higher is the profit you earn. Also note that if you hold zero chips at the end of either period, your profits will be zero because the product of zero with any other finite number is zero. All chips are returned to the experimenter at the end of each period.

The first period of the market will be an entry period for some of you (as described above). For some of you, however, this first period itself will be an exit period and you will receive the exit period endowment of 1 chip at the beginning of this period. In addition, each of you for whom the first period is an exit period will receive 1,000 francs from the experimenter at the beginning of this period. You have to use all these francs to buy chips during the exit period because the francs you hold at the end of an exit period are worthless; they cannot be converted into dollars directly.

When you sell chips, your holding of chips decreases and your holding of francs increases by the amount of the price of the chips. Similarly, when you buy chips, your holding of chips increases and your holding of francs vanishes.

At the end of each period, all your chips on hand are used up to earn profits in dollars and thus returned to the experimenter. The francs you have on hand at the end of the entry period are carried over to the exit period and used to buy chips in this latter period.

All outside-market players participate in the market indirectly. At the beginning of each period, each outsider-market player predicts the market price of the period. The average of the predicted price will be used to convert the francs held by the entry-period players to chips at the end of the experiment. A $2.00 prize will be given to the player whose prediction is the closest to the actual market price. If there is a tie, the prize will be split.

*Trading and Recording Rules*

1) All entry-period players are sellers and all exit-period players are buyers.
2) Every exit-period player must pay all his francs to entry-period players in exchange for chips at a *market price* determined below.
3) At the beginning of each period, every entry-period player must state the following prices on the Selling Offer Sheet and submit it to the experimenter. If the prices you submit are not nondecreasing in the number of chips offered, we shall make them so.

   Price below which you don't want to sell any chips —— francs/chip;
   Price at which you are willing to sell up to 1 chip —— francs/chip;
   Price at which you are willing to sell up to 2 chips —— francs/chip;
   Price at which you are willing to sell up to 3 chips —— francs/chip;
   Price at which you are willing to sell up to 4 chips —— francs/chip;
   Price at which you are willing to sell up to 5 chips —— francs/chip;
   Price at which you are willing to sell up to 6 chips —— francs/chip;
   Price at which you are willing to sell up to 7 chips —— francs/chip;

4) The experimenter collects the Selling Offer Sheets from all entry period players, and after considering the amount of francs available from the exit-period players, computes and announces the market clearing price. Each entry-period player will be informed of the number of chips he/she has been able to sell at the market price, and each exit-period player will be told of the number of chips that he/she has been able to buy with his/her francs on hand.

   Note that if you (entry-period player) do not specify a price for zero chip, up to one chip of yours may be sold at zero francs. If you do not want to sell more than a specified number of chips under any circumstances, specify a very high price. This is the only way you have of not wanting to sell. The actual number of chips you sell will almost always be in fractions, depending on the market clearing price. The way the market clearing mechanism works, if you are willing to sell, say two units at unit price $x$ and 3 units at unit price $y$, you may end up selling, say 2.4 units at a price between $x$ and $y$.
5) At the beginning of each period, each outside-market player writes down a predicted market price on the Market Price Prediction Sheet which is collected by the experimenter. At the end of each period, the experimenter announces average predicted market price and the winner(s) – the outside-market players whose prediction was the closest to the actual market price. This player records *$2.00* prize on the Market Price Prediction Sheet. But, when there is more than one winner, the prize is split. All other outside-market players record *$0* prize on the sheet.
6) After the transaction information is received from the experimenter, each

entry-period player computes the chips remaining on hand and the francs received from sale and records them on the Information and Record Sheet.

7) Each exit-period player records the number of chips purchased on the Information and Record Sheet. Then the experimenter computes the product of the number of chips held by each exit-period player at the end of entry and exit periods respectively, takes the square root of the product and multiplies by *$1.20*. This amount is the profit of the exit-period player who records this profit on the Information and Record Sheet. At the conclusion of the experiment, the experimenter will pay each player the total amount of profits made.
8) The francs received by the entry-period players in the entry period will be used to buy chips in the exit period which follows immediately. So, carry your francs on hand forward to the exit period by entering them in the column Beginning-Francs on Hand on the Information and Record Sheet.
9) At the end of the experiment, francs held by *all entry-period* players are converted into chips using the average of predicted market prices by outside-market players.
10) At the end of the experiment, add up the profit column of your Information and Record Sheet. The experimenter will pay you this amount of money.

*Entry and Exit Plan for Economy 1*

(N = entry, X = exit)

| | *Subject Number* | | | | | | | | | | | | | (14 Subjects) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Period* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* |
| 1 | N | – | X | – | N | X | N | – | X | X | – | N | – | – |
| 2 | X | N | – | – | X | – | X | N | – | – | N | X | N | – |
| 3 | – | X | – | N | – | N | – | X | N | – | X | – | X | N |
| 4 | N | – | N | X | – | X | N | – | X | N | – | – | – | X |
| 5 | X | N | X | – | N | – | X | N | – | X | – | N | – | – |
| 6 | – | X | – | N | X | – | – | X | – | – | N | X | N | N |
| 7 | – | – | N | X | – | N | – | – | N | N | X | – | X | X |
| 8 | N | N | X | – | – | X | N | N | X | X | – | – | – | – |
| 9 | X | X | – | N | N | – | X | X | – | – | N | – | N | – |
| 10 | – | – | N | X | X | – | – | – | – | N | X | N | X | N |
| 11 | – | N | X | – | – | N | – | N | N | X | – | X | – | X |
| 12 | N | X | – | – | N | X | N | X | X | – | N | – | – | – |
| 13 | X | – | – | N | X | – | X | – | – | – | X | N | N | N |
| 14 | – | N | N | X | – | N | – | – | – | N | – | X | X | X |
| 15 | – | X | X | – | N | X | N | – | N | X | N | – | – | – |
| 16 | N | – | – | N | X | – | X | N | X | – | X | N | – | – |
| 17 | X | N | N | X | – | – | – | X | – | N | – | X | N | – |
| 18 | – | X | X | – | N | – | – | – | N | X | N | – | X | N |
| 19 | N | – | – | – | X | – | N | N | X | – | X | N | – | X |
| 20 | X | N | N | – | – | N | X | X | – | N | – | X | – | – |

### *Training Sheets*

Player No. __________

| Period No. | Entry / Exit | Beginning Francs on Hand | Beginning Chips on Hand | Chips Sold | Chips Purchased | Ending Francs on Hand | Ending Chips on Hand | Profit ($) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | Entry | 0 | 5 | | | | | |
| | Exit | | 1 | | | 0 | | |
| | Entry | 0 | 5 | | | | | |
| | Exit | | 1 | | | 0 | | |
| | Entry | 0 | 5 | | | | | |
| | Exit | | 1 | | | 0 | | |

| Period No. | Unit Selling-Offer Prices (francs) for: 0 Chip | 1 Chip | 2 Chips | 3 Chips | 4 Chips | 5 Chips | 6 Chips | 7 Chips | Market Price | Chips Sold |
|---|---|---|---|---|---|---|---|---|---|---|
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| Period No. | Predicted Market Price (francs) | Actual Market Price (francs) | Prize ($) |
|---|---|---|---|
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