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ASSET VALUATION IN AN EXPERIMENTAL MARKET

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The time path of asset prices is studied within a stationary experimental environment. After several replications prices converge to a perfect foresight equilibrium. A sequential market having an "informational trap" and a futures market are also studied.

1. INTRODUCTION

THEORIES OF ASSET PRICES have occupied a very special place in the history of economic doctrine as being both important and diverse. Importance is established with the key role of time in the analysis. Almost every economic commodity exists over time thereby manifesting one of the essential features of an asset. Diversity also follows from the incorporation of time because of the potential applicability of a host of subtheories which differ according to "motivational spirit" and rigor of development. Competing subtheories about the nature of choice over time, choice under uncertainty, learning and the informational content of prices can all lead to different theories of asset prices. In addition any theory of asset prices necessarily involves many parameters (information states, a priori expectations, preferences over time, etc.). As a result the discipline frequently has difficulty identifying a solid empirical base upon which to justify the acceptance or rejection of competing theories. This paper represents a first attempt to explore the potential of laboratory markets for adding to such base that exists.

The behavior of five different asset markets is reported. The markets were created in a laboratory environment and were very simple relative to the asset markets found in natural environments. The purpose of studying the simple markets is to find unambiguous answers to the following questions. (a) Do these asset markets exhibit any regularities relative to their organization and underlying parameters? (b) If regularities exist do they conform to the predictions of any of the standard mathematical models when the latter are applied in a natural way?

If the answer to either of these questions is "no" then one would be very suspicious of applications of the same models to more complicated markets. Models which are supposed to work in general should be expected to work in simple special cases. Obviously success of a model in simple special cases does not imply that the model will work in general and we make no such claim. Rather, we view the results reported here as simply a base upon which the study of more complicated situations can be conducted.

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In addition to the questions above some purely methodological questions are posed. The experiments themselves involved some experimental techniques that had not been used before. It was necessary to determine whether or not these techniques exerted an independent influence on market behavior before further studies could be conducted.

The theories we call upon can be divided into two broad classes. However, before discussing theories we should note the existence of *non*theories asserted in newspapers and social commentaries. These are in effect claims that asset prices are arbitrary. Such prices depend upon the idiosyncratic nature of individual behavior and convey little or no information at all about the states of the world or the magnitude of economic parameters. Some implications of this belief are that there are no reasons to study asset markets because there is nothing to learn and those who claim there is are confusing religion with science. Needless to say, most economists would disagree with this view and tend to dismiss it as "table talk" or "uninformed chatter" which is of no concern. It never appears in academic journals (at least we could find no good quotes). The fact is, however, that the profession has no simple way to disconfirm seemingly outlandish beliefs when held by skeptical students, colleagues in other disciplines, and decision-making politicians.

The first class of theories holds that asset prices are not arbitrary. Indeed the prices may exhibit a great deal of regularity. Those who accept theories of this first type would claim that the regularities may have very little, if anything, to do with underlying economics or the economy. Instead asset prices follow laws of random motion such as martingales. The only information that P_t conveys might be something about the probability of various prices in the past. The implication of this line of theory is that one might study charts, charting techniques, and various other models of stochastic processes.

Included in this class of theories, would be purely expectational equilibria similar to one put forth by Keynes. The essential idea is captured in the following selection from his *General Theory*:

> Or, to change the metaphor slightly, professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; so that each competitor has to pick, not those faces which he himself finds the prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view. It is not a case of choosing those which, to the best of one's judgement, are really the prettiest, nor even those which average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the fourth, fifth and higher degrees (Keynes [**10**, p. 156]).

While one may argue about what Keynes "really means" one natural conclusion from such a behavioral hypothesis is that for any set of vectors of returns to individuals virtually any price vector can be an equilibrium given the proper set of beliefs. This is possible because each individual bases his valuations, and hence his choices, *entirely* on the expected valuations of other individuals without stipulating any connection with an underlying stream of returns from holding the asset. In essence, all investors are viewed as short-run speculators who are not concerned with the stream of returns generated directly from holding the asset. Here the informational content of prices is, loosely speaking, a reflection of the "average" trader's expectations of future prices of the asset.

The second set of theories all hold that asset prices exhibit regularities that are systematically related to the underlying returns generated by the asset. All such models stipulate a consistency among expected individual returns, possible capital gains and individual choice behavior, but they differ on how these are related. Individual learning models, for example, have individuals forming expectations about price changes and the asset price being determined by choices based on both those expectations and the individual's expected stream of dividend returns from holding the asset (Easley [**2**], Jordan [**9**], and Townsend [**17**]). The rational expectations hypothesis and the related perfect foresight equilibrium concept stipulate a further direct consistency between expectations and the actual price behavior (see, for example, Harrison and Kreps [**8**]). The efficient market hypothesis extends the relationship to the speed with which economic events are translated into market prices by claiming that "prices at any time fully reflect all available information" (Fama [**3**, p. 383]).

These three categories (one class of nontheories and two classes of theories) are intended only as a means of organizing our thoughts and discussions. Clearly they do not capture the details of the wide variety and complexity of existing models. The formal development of specific models is contained in Section 4.

2. THE LABORATORY MARKETS

The economic properties of each of the five markets we studied are listed below. It is hoped that the study of such special cases will lead to clearly interpretable results despite the complexities of individual and market behavior that is observed in laboratory environments.

(a) Each market year had two periods, A and B. All period A's (in a market) were identical in terms of the underlying distribution of returns and all period B's in a market were identical. Thus each year was in a sense a replication of previous years.

(b) Each experiment consisted of a fixed group of subjects who participated in a sequence of six to eight market years. Each period A and each period B was seven minutes long.

(c) Assets had a one-year life. The supply of assets was constant for all periods of all years.

(d) Individual monetary returns from assets in any given period of a year were linear in the number of units of the asset held. That is, individual i received returns (dividends) d_A^i for each unit of the asset held at the end of any period A and d_B^i for each unit of the asset held at the end of any period B.

(e) Individuals were partitioned into trader "types." Individuals of a given trader type had identical returns but the returns differed across types.

(f) The markets were organized as oral double auctions.[2] All individuals were present for all periods. All bids, offers, and contracts were public and recorded publicly so the cost of gathering such information was minimal. Possibilities for explicit collusion did not exist.

(g) No short sales were permitted. This means that there was a fixed supply of the asset.

(h) Markets occurred sequentially except in Experiment 5.

(i) No futures markets existed with the exception of Experiment 5. In this market a period B futures market replaced the period B spot market.

Five markets were studied using subjects who were undergraduate male and female students at the California Institute of Technology. In three of the markets (Experiments 3, 4, and 5), only subjects who had been in one of the first two experiments were used and thus could be considered experienced.

In Experiments 1, 2, 3, and 5 there were nine traders; in Experiment 4 there were eight. At the beginning of a trading year each trader was endowed with two[3] "certificates" which had no face value but paid a "dividend" at the end of each of the two periods, A and B, during the year. The value of the dividend depended upon the individual and the period. That is, each certificate held by individual i at the end of a period could yield $\$X$ to individual i while each certificate held by individual j could yield $\$Y$ to individual j. Furthermore, a certificate could yield a different amount to a given individual in period A than it yielded to the same individual during period B. Because of these differences, there are gains from exchange with one individual selling the certificate to another.

The difference in individual returns was used only after considerable thought. The importance of the feature for the laboratory market is clear enough—it fosters the existence of gains from exchange. In addition, there are a number of reasons why streams of returns in naturally occurring markets might generally be different for different investors or for the same investor at different times. First of all, the evaluation of services of actual physical assets such as durable consumption goods might be greatest during early periods for some owners, while other owners might place a greater value in later periods. Secondly, for financial assets such as stocks for which the returns are dividends, different owners might be in different tax brackets or different risk classes. With the latter interpretation, (d_A^i, d_B^i) might be considered as a set of "certainty equivalent" dividends, different for each risk class. Third, the investors may all be risk neutral and simply have different expectations over the streams of returns, which in fact are random variables.

The parameters for the five markets are given in Table I. The currency used in the experiments was called *francs*. Value for francs was established by application of the theory of induced value (Smith [**15**], Plott [**12**]). In Experiments 1, 2, and 5 each franc was worth \$.002, in Experiment 3 each franc was worth \$.001

[2] See the Appendix for instructions with the exact trading rules.

[3] In Experiment 4 each trader was endowed with three certificates.

TABLE I
EXPERIMENTAL PARAMETERS

Experiment Number	Investor Type	Initial Francs on Hand	Initial Certificate Holdings	Dollar Value of Francs	Fixed Cost	Period A Dividend Value	Period B Dividend Value	Number of Investors
1 & 2	I	10,000	2	.002	10,000	300	50	3
	II	10,000	2	.002	10,000	50	300	3
	III	10,000	2	.002	10,000	150	250	3
3	I	20,000	2	.001	20,000	600	350	3
	II	20,000	2	.001	20,000	350	600	3
	III	20,000	2	.001	20,000	450	550	3
4	I	12,100	3	.01	13,000	150	50	4
	II	12,100	3	.01	13,000	100	250	4
5	I	15,000	2	.002	15,500	403	146	3
	II	15,000	2	.002	15,500	284	372	3
	III	15,000	2	.002	15,500	110	442	3

and in Experiment 4 each franc was worth \$.01. These conversion values may seem small at first but in fact the transaction prices in terms of francs were sufficiently high to make the dollar payoffs and values of decisions comparable to other experiments which have been successfully completed with subjects drawn from these subject pools. The average amount earned by a trader was about \$16 for two and one-half hours participation.

Table I is read as follows. Consider Experiment 1 where there were three different types of investors with three individuals of each type. Each of the three was given 10,000 francs and two certificates at the beginning of each year. They were then allowed to trade freely according to their wishes subject to well-established rules during the year. Each certificate held at the end of period A yielded 300 francs and each held at the end of period B yielded 50 francs. They could also add to their franc holdings by selling certificates either from their endowments or from the ones they had purchased for potentially profitable resale. All francs held in excess of 10,000 francs were translated into dollars at the rate of \$.002 per franc and this was the amount of money the individual was allowed to keep. The payoff for all other groups and all other experiments should be interpreted similarly.

As will be discussed below several models can be applied to predict what will evolve from these simple markets. Looking ahead, however, will enable the reader to understand the structure and interrelations among the experiments. The first three experiments can be explained rather well by a perfect foresight equilibrium model (to be described below). The remaining two experiments were then designed to explore some slightly different markets using the insights gained from the first three. Once a positive result has been established it is only natural to initiate an inquiry which seeks deeper reasons about why the model works and if it will continue to work under other parameters, institutions, and complications. Experiment 4 represents an attempt to create a market by simple parameter adjustments which would equilibrate to an inefficient allocation. Experiment 5 involves an institutional perturbation—a futures market.

3. EXPERIMENTAL PROCEDURES

The instructions contained in the Appendix are an extension of those used in other studies. Two major exceptions to traditional procedures were used, however, and should be emphasized because of their importance in assessing the methodological contribution of the experiments.

The first involves the use of francs. With the exception of Friedman's [**4**] study of cooperative duopoly, other experiments have used dollars directly as a medium of exchange. For these experiments, in which initial endowments of certificates were distributed costlessly, and in which separation of theoretical predictions required the use of relatively high nominal prices, the cost of using dollars directly would have been prohibitive. Thus payoffs here for a given year are of the form $\$ = a + bx$ where $b > 0$, $a < 0$, and x is the quantity of francs held at the end of a trading year. While this theoretically should have no influence on behavior, it does involve a change in procedures relative to other experiments and is thus a candidate explanation for any problems which might occur.

The second break with tradition involves the nonpayment of commissions. It is known that the absence of trading commissions can cause slight divergences from demand and supply predictions (Plott and Smith [**13**]). Current theory holds that trading involves a slight cost which is overcome by a commission. Thus the lack of a trading commission can induce some small inaccuracies in models. On the other hand, the existence of a commission, since individuals can be on both sides of the market simultaneously, can lead to an infinite number of trades. The latter possibility was considered to be a greater problem than the former so commissions were omitted.

4. HYPOTHESES AND SPECIFIC MODELS

Our formal analysis will be concentrated upon models motivated by the second class of theories. If the models fail to work, then we would look to opinions in the first two classes of ideas (the "nontheory" class and the first theory class) for structuring future research priorities. On the other hand, if the models work, then we know the market behavior predicted by the first two views is not pervasive. The next steps would then involve attempts to understand why such models work and isolate the range of circumstances in which they can be relied upon. Perhaps ideas in the first classes are relevant when the situation becomes sufficiently rich but that can only be established by building up results from the simple cases which can (potentially) be thoroughly understood.

A two-period model for a discrete homogeneous asset seems to be the natural one to apply. There are n types of investors, each of whom "knows" his/her stream of returns, (d_A^i, d_B^i) for $i = 1, 2, \ldots,$ from owning a unit of the asset in periods A and B. The investors have no effective wealth limitations, but they possess a finite amount of the asset and there are no short sales. Furthermore, except for Experiment 5, the markets are sequential. The market for period B holdings occurs after the market for period A holdings has closed.

Price predictions for period B are the same for almost all models. Direct application of a demand and supply model yields

$$P_B = \max_i d_B^i.$$

This follows from the constant per unit yields and the fixed supply. For experiments 1, 2, 3, and 4 the predicted period B prices in francs are (300, 300, 600, 250) respectively. As shown in Figure 1 the demand function is perfectly elastic up to the wealth limitation of those who have the highest period B yields. The wealth limitation was sufficiently large in the experiment that it was never binding. Presumably the limit prices for such individuals are the per unit yield and the maximum quantity demanded is constrained only by the initial allocation of francs. The supply of certificates is fixed.

This model yields our first hypothesis. It is known that experimental markets do not attain equilibrium immediately. Instead they tend to converge. Assuming traders impute zero costs to making transactions, there is a natural prediction about the average price during period B of the final year, $\bar{P}_B^T$.

HYPOTHESIS 1: For experiments 1, 2, 3, and 4

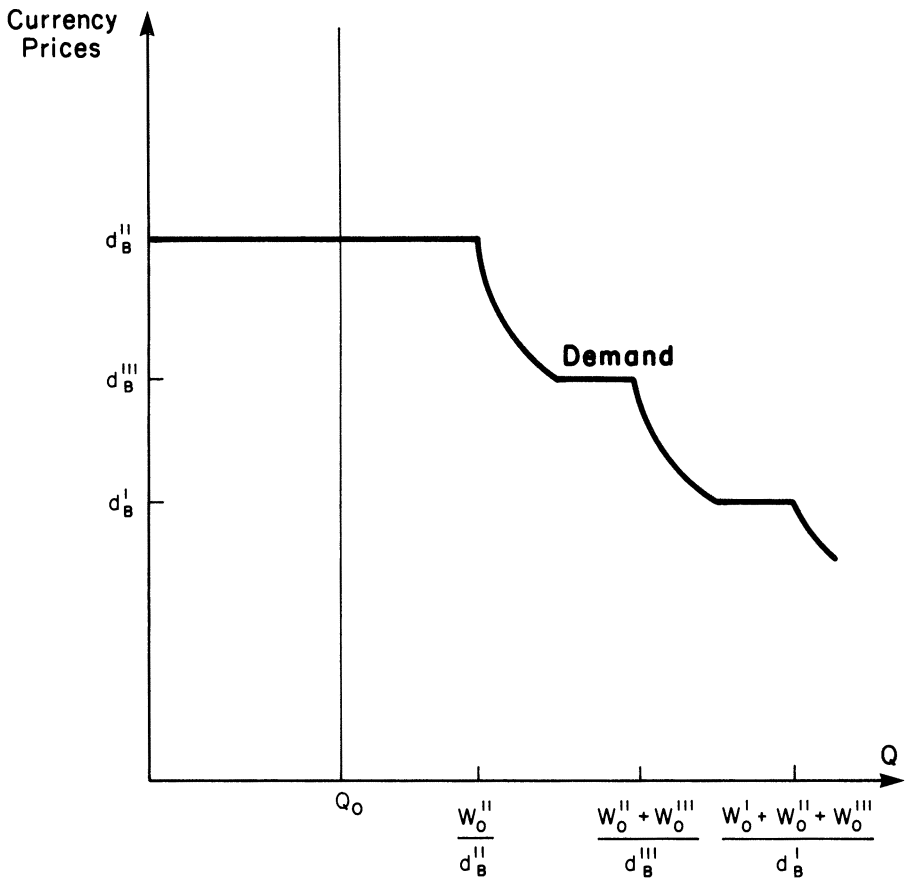
$$\bar{P}_B^T = \max_i d_B^i.$$

In light of the results obtained by Plott and Smith **[13]** and Smith **[15]** about transaction costs and the role of commissions in experimental double-auction markets, the assumption that traders impute zero costs to making transactions is not realistic. Therefore, we also state a more general version of the above hypothesis which takes account of these costs. Denoting the transaction cost by c, we have:

HYPOTHESIS 1′: For experiments 1, 2, 3, and 4

$$\bar{P}_B^T = \max_i \left(d_B^i - c\right).$$

Prediction of period A prices is more involved. In the sequential market



d_B^i: dividend of type i investor. Refer to Table I.
Q_O: total supply of certificates in period B.
W_O^i: holding of currency at the beginning of period B by investor i.

FIGURE 1—Period B theoretical demand and supply schedules.

structure informational assumptions are crucial for determining the nature of competing models of period A prices. Three different models will be considered.

First, it might be assumed that investors bring only their private information to bear on their market decisions and invest accordingly. Under this hypothesis, they take no account of potential speculative gains to be made in period B. The period A equilibrium price which results from the appropriate demand and supply model is

$$P_A^N = \max_i \left(d_A^i + d_B^i \right).$$

This will be referred to as the naive price equilibrium.[4] For experiments 1, 2, 3, and 4 these period A prices in francs are 400, 400, 1000, and 250 respectively. Assuming zero transaction costs, this leads to our alternative prediction about the average period A contract price in the final year.

HYPOTHESIS 2: For experiments 1, 2, 3, and 4

$$\bar{P}_A^T = \max_i \left(d_A^i + d_B^i \right).$$

We have called this the "naive expectations hypothesis."

Taking account of transaction costs, we have:

HYPOTHESIS 2′: For experiments 1, 2, 3, and 4

$$\bar{P}_A^T = \max_i \left(d_A^i + d_B^i - c \right).$$

A second view of period A price formation is motivated by the insight that market behavior may be influenced by individuals who attempt to earn short-term capital gains in addition to dividend returns. This view would be consistent with observing a period A equilibrium price which exceeds the naive price. More specifically P_A^N is a reasonable lower bound for the period A price for the following reason. Let i^* satisfy

$$P_A^N = d_A^{i^*} + d_B^{i^*} \geq d_A^j + d_B^j \qquad \forall j \neq i^*.$$

Then any investor of type i^* is guaranteed P_A^N in dividend earnings from every certificate owned or purchased in period A. Another way of saying this is that i^* does not need to depend on capital gains in order to earn P_A^N. Thus such an investor is willing to purchase an infinite amount at prices below P_A^N even without information about P_B. Thus P_A^N provides one theoretical bound for P_A.

This line of reasoning yields a third prediction which is stated in a testable form in Hypothesis 3.

HYPOTHESIS 3: For experiments 1, 2, 3, and 4

$$\bar{P}_A^t \geq \max_i \left(d_A^i + d_B^i \right) \qquad (t = 1, 2, \ldots, T).$$

The next model is the rational expectations, or in this case, the perfect foresight equilibrium model. The demand in period A is augmented by the

[4] Katherine Echol suggests that this should be called the maximin equilibrium and that a true "naive" equilibrium would have traders determining values on the basis of one-period dividends alone. This type of myopic behavior was probably circumvented by question one of the practice calculations section of the instructions.

perfectly forecasted theoretical equilibrium price of period B. That is,

$$P_A^F = \max_i d_A^i + P_B = \max_i d_A^i + \max_j d_B^j.$$

For experiments 1, 2, 3, and 4 the numbers, P_A^F, in franc prices are 600, 600, 1200, and 400 respectively. Again assuming the traders in these experimental markets impute zero costs in making transactions, this model yields the next prediction.

HYPOTHESIS 4: For experiments 1, 2, 3, and 4

$$\bar{P}_A^T = P_A^F = \max_i d_A^i + \max_j d_B^j.$$

We call this the "perfect foresight hypothesis."

Taking transaction costs into account we have:

HYPOTHESIS 4′: For experiments 1, 2, 3, and 4

$$\bar{P}_A^T = P_A^F - 2c = \max_i (d_A^i - c) + \max_j (d_B^j - c).$$

Some controversy exists about the mechanism through which a rational expectations equilibrium might be achieved. Grossman [6] suggests that the key is *replication* and that with replication investors will acquire information about the joint distribution of prices which determines the equilibrium price function. With replication investors have the opportunity to observe period B prices and incorporate this information into their decisions in the period A market. Not only does this argument suggest something about the *necessity* of replication for the existence of a rational expectations equilibrium, it also suggests something about the time path of prices through which the equilibrium will be attained. The next hypothesis captures the idea about the nature of convergence motivated by the Grossman model.

HYPOTHESIS 5: For experiments 1, 2, 3, and 4

$$|\bar{P}_A^t - P_A^F| > |\bar{P}_B^t - P_B| \qquad \text{for all } t.$$

In other words, convergence in period A "follows" convergence in period B. We call this the "swing-back hypothesis."

In these markets investors enter in year one with no idea (or perhaps only a vague idea in the case of "experienced" investors) of the market price and they learn more about it in each subsequent year. Specifically in year one investors bring only their own private information to the market place. However, the perfect foresight equilibrium implicitly requires agents to possess information which they will normally receive by observing prices. Once prices are observed the lack of information which previously impeded attainment of a perfect foresight equilibrium no longer exists. Due to this, one would expect the trading to begin at the naive equilibrium price and monotonically converge to the perfect foresight equilibrium price as trading publicizes information that originally was private. In the absence of a period B futures market, investors will be unable to incorporate period B price information in their period A decisions until after the first year of trading. Implicit in this observation is Grossman's notion that in such markets replication is a necessary condition for convergence to a perfect foresight equilibrium when only sequential spot trading is allowed. This is the sixth hypothesis and only applies to a sequential market organization in which futures markets are absent.

HYPOTHESIS 6: For experiments 1, 2, 3, and 4

(a) $\bar{P}_A^1 = P_A^N$,

(b) $\bar{P}_A^t - \bar{P}_A^{t-1} > 0, \qquad \text{for } t > 1.$

Hypotheses 5 and 6 suggest that a very careful look at Experiment 4 is in order. This experiment represented an attempt to "trap" the market at an equilibrium other than that embodied in Hypothesis 4 by using the convergence path suggested by Hypotheses 5 and 6. The parameters of Experiment 4 are such that in the naive equilibrium no trade takes place in period B. As a result there would be no transacted price signals in period B and so P_B would not be known to the agents in subsequent years. Notice that for $j \in \text{I}$, $d_A^j + d_B^j = 200$ and for $i \in \text{II}$, $d_A^i + d_B^i = 350$ (see Table I). Thus under the naive hypothesis type II investors would purchase the entire supply in period A. Type II also has the higher return in period B so they are demanders in period B as well as in period A. Since the demanders in period B hold the entire supply, no trades would occur in B. However notice that for $i \in \text{II}$, $d_A^i + P_B = 100 + 250 = 350$ but for $j \in \text{I}$, $d_A^j + P_B = 150 + 250 = 400$. Thus according to the perfect foresight equilibrium model group I should hold all certificates in period A and sell to group II in period B. Experiment 4 was designed after the first three experiments and was intended as a check on the nature of the mechanisms which might motivate the perfect foresight equilibrium.

Experiment 5 involves a change in the market structure. A futures market is opened for period B holdings which is held concurrently (in time) with the period A spot market. From a static theoretical view this institutional perturbation makes no difference in the ultimate equilibrium values. The perfect foresight equilibrium values in francs are (845, 442) in periods A and B respectively. The natural conjecture is:

HYPOTHESIS 7: Hypotheses 1 through 6 apply to Experiment 5.

The more interesting aspects, however, are the implications about the necessity of replication for convergence to the perfect foresight equilibrium. Those who subscribe to the replication justification for the perfect foresight equilibrium, would argue that period A prices should converge more rapidly in the presence of a futures market. This is because simultaneous markets allow information about capital gains to be incorporated immediately into investor decisions. This hypothesis is formalized as (where S stands for any of the experiments involving sequential markets; P^F_{AS} is the period A perfect foresight price in sequential market experiment S, $S = 1, 2, 3, 4$):

HYPOTHESIS 8:

$$\frac{|P^F_{A5} - \bar{P}^t_{A5}|}{|P^F_{A5} - P^N_{A5}|} < \frac{|P^F_{AS} - \bar{P}^t_{AS}|}{|P^F_{AS} - P^N_{AS}|} \qquad (t = 1, 2, \ldots, T).$$

Of particular interest in this respect is $t = 1$ because immediate convergence

TABLE II

NUMBER OF UNITS HELD IN A THEORETICAL EQUILIBRIUM

EXPERIMENTS 1, 2, 3, 5

	Investor Type					
	I		II		III	
	Period A	Period B	Period A	Period B	Period A	Period B
Naive Equilibrium	0	0	0	9	9	0
Perfect Foresight Equilibrium	9	0	0	9	0	0

EXPERIMENT 4

	Investor Type			
	I		II	
	Period A	Period B	Period A	Period B
Naive Equilibrium	0	0	8	8
Perfect Foresight Equilibrium	8	0	0	8

would demonstrate that the futures market removes the necessity for any replication at all.

The final set of hypotheses deals with the distribution of certificates. Within these markets each theory makes a rather precise prediction about which individuals will hold certificates. As can be seen the naive expectations model and the perfect foresight model make very precise predictions. They yield two very different hypotheses about certificate holdings.

HYPOTHESIS 9F: Certificate holdings are the same as the holdings predicted by the perfect foresight model (see Table II).

HYPOTHESIS 9N: Certificate holdings are the same as the holdings predicted by the naive expectations model (see Table II).

5. EXPERIMENTAL RESULTS

Our analysis of the data is contained in three categories: price convergence, quantity convergence, and individual behavior. In dealing with the data we face some open problems that are being encountered in almost all experimental work where the cost of conducting experiments places a significant constraint on the number of observations. As will be obvious in the figures, the high degree of serial correlation of prices in a given experiment, both within a period and across periods, suggests the simultaneous interaction of the learning process by individuals and a convergence process by the market. Yet, without a theory about these processes, our statistical statements suffer from an inability to use all the data available to us. Furthermore, the statistical tests we report should be regarded more as measures than classical hypothesis tests. Fortunately, the data from these experiments show sufficient regularities so that this should cause no problems.

A. Price Convergence

Figures 2–6 present the entire time series of transacted prices in the five experiments that were conducted. For every experiment, average price in each period of each year is given at the bottom of the corresponding figure. After repeated trials the period B price is accurately predicted by the simple supply and demand model in all experiments. Period B prices are always within the \$.02 of P_B in dollar terms by the final year. The observation that the observed prices stay consistently \$.01 or \$.02 below the predicted price is consistent with findings by Plott and Smith [13] that participants in these experimental markets impute a slight cost to trading.

Table III summarizes the data from Figures 2–6 and gives price predictions when the simple supply and demand model is modified to take account of transactions costs. Although the observed mean period B prices in the final year of the experiments are all significantly (at the 1 per cent level) less than the

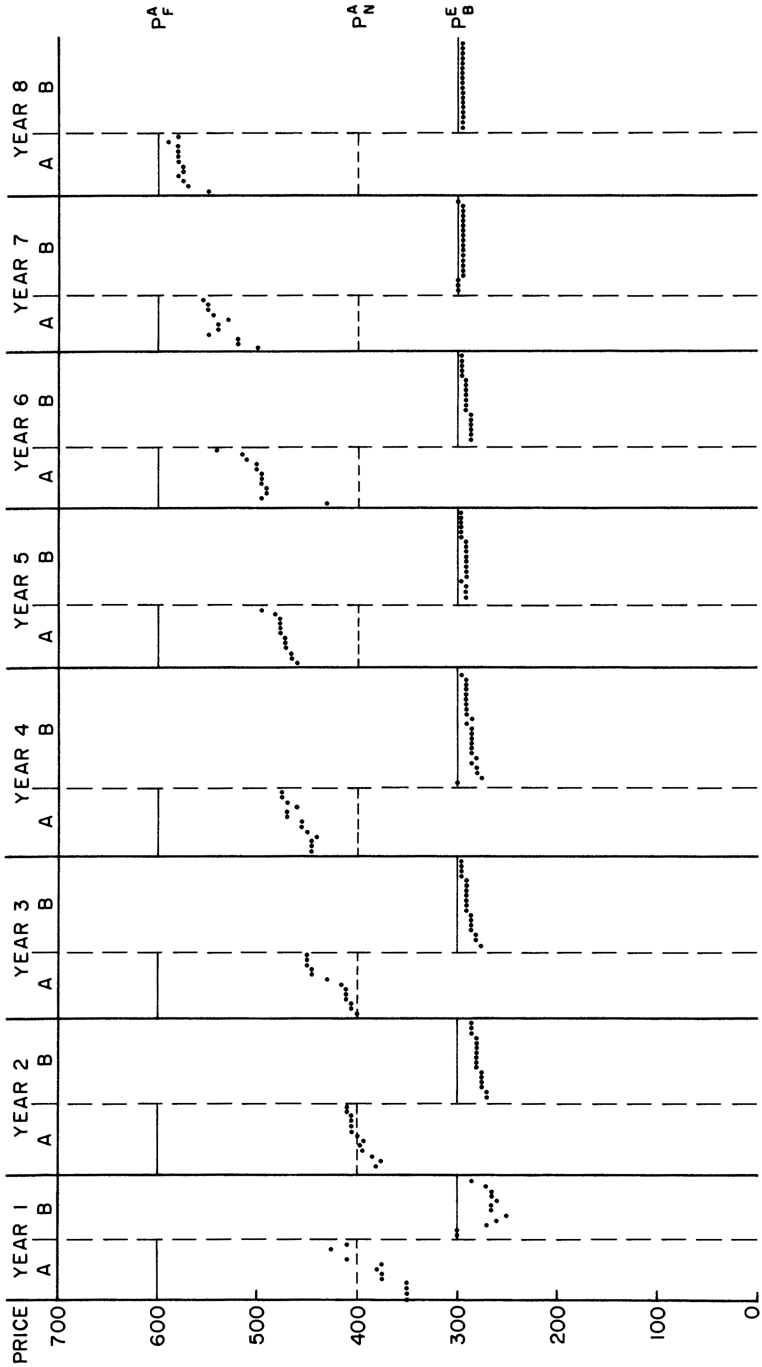


FIGURE 2—Experiment 1: Sequence of Contract Prices and Average Prices.

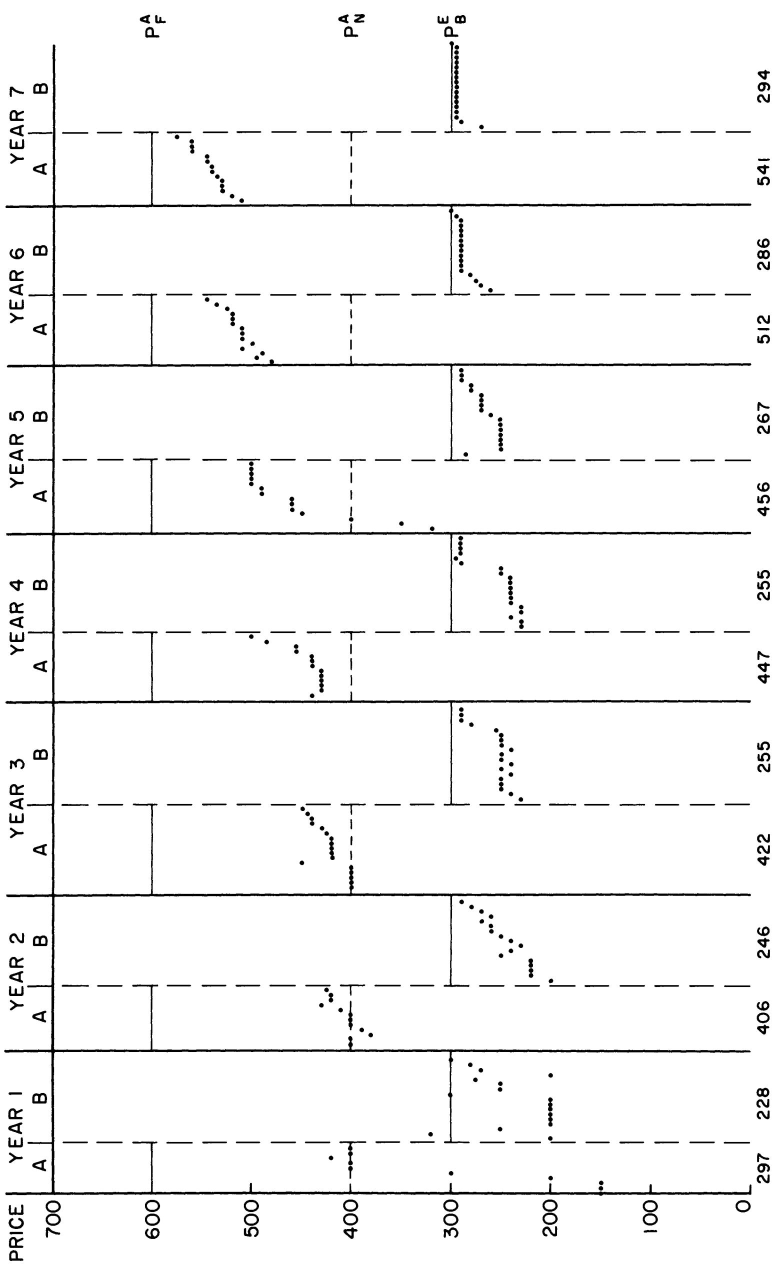


FIGURE 3—Experiment 2: Sequence of Contract Prices and Average Prices.

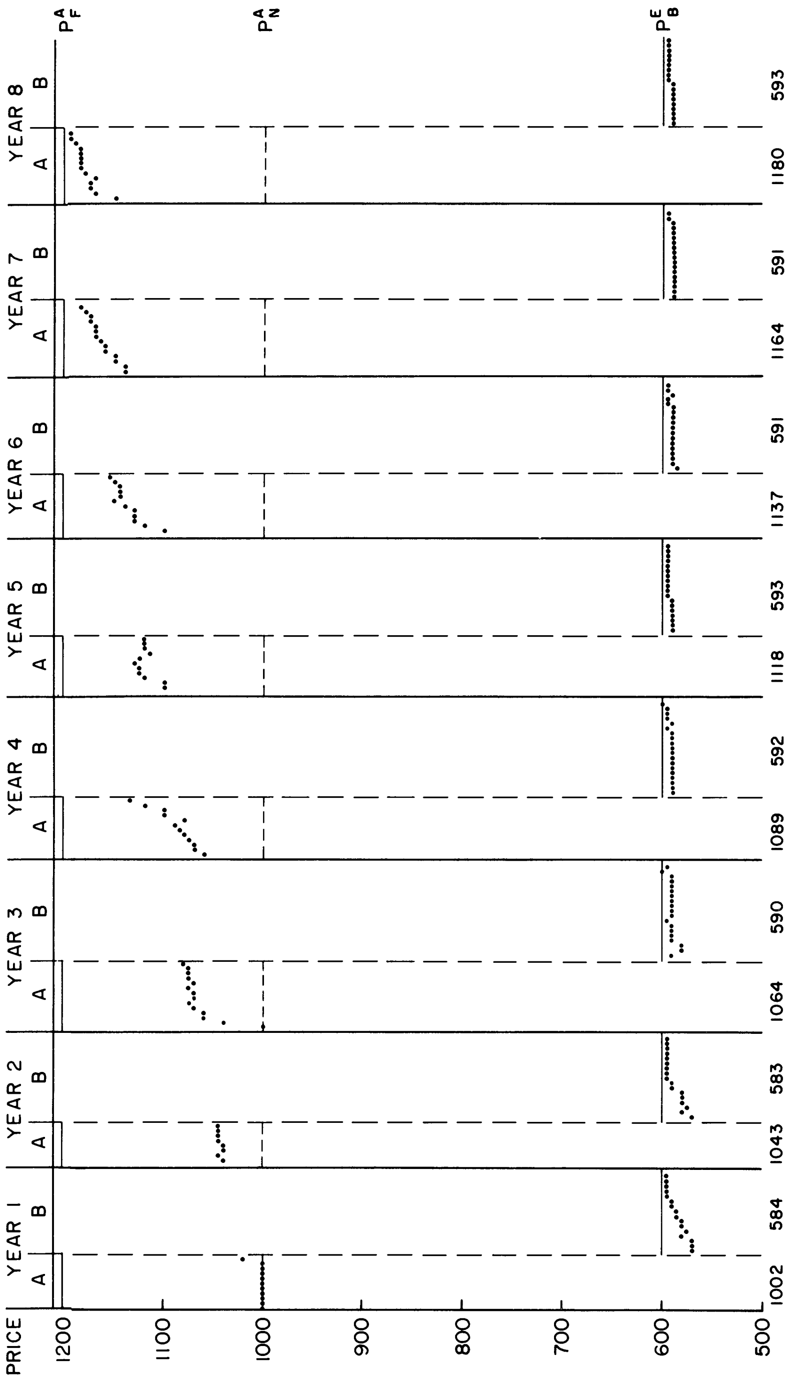


FIGURE 4—Experiment 3: Sequence of Contract Prices and Average Prices.

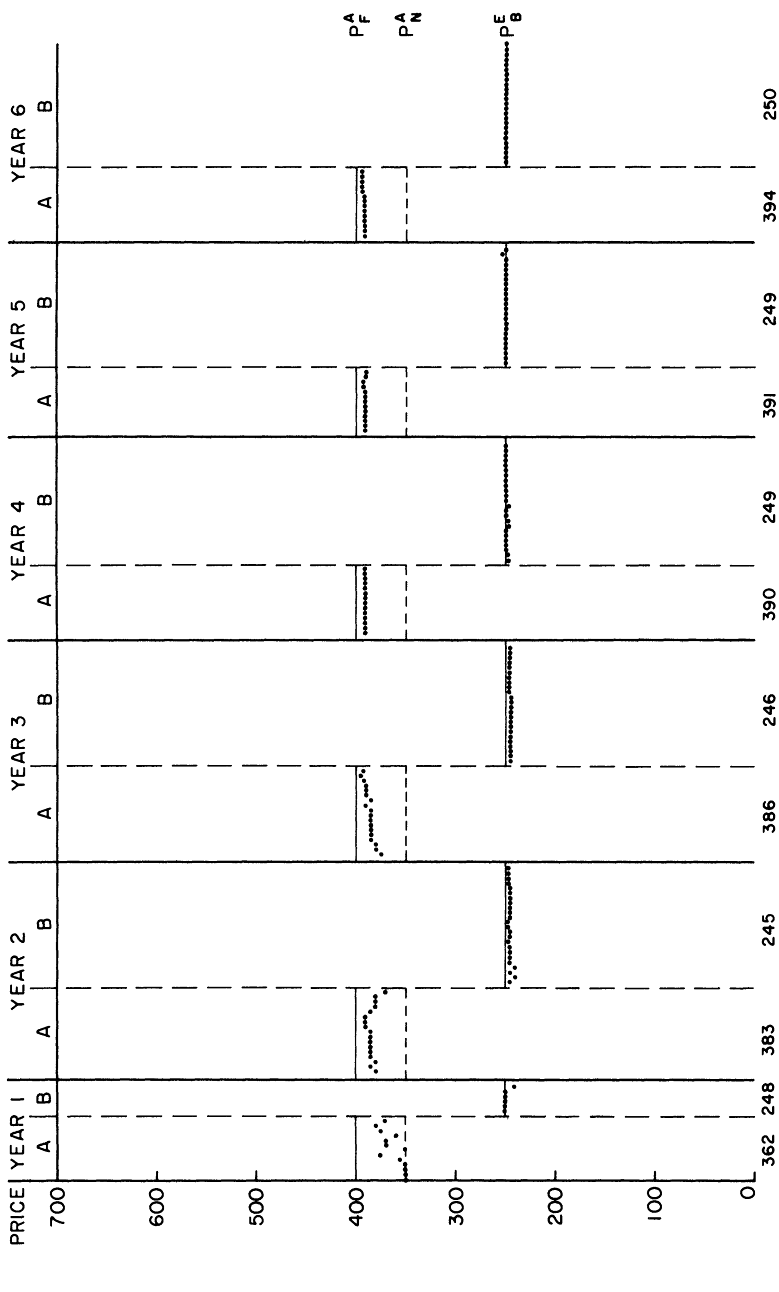


FIGURE 5—Experiment 4: Sequence of Contract Prices and Average Prices.

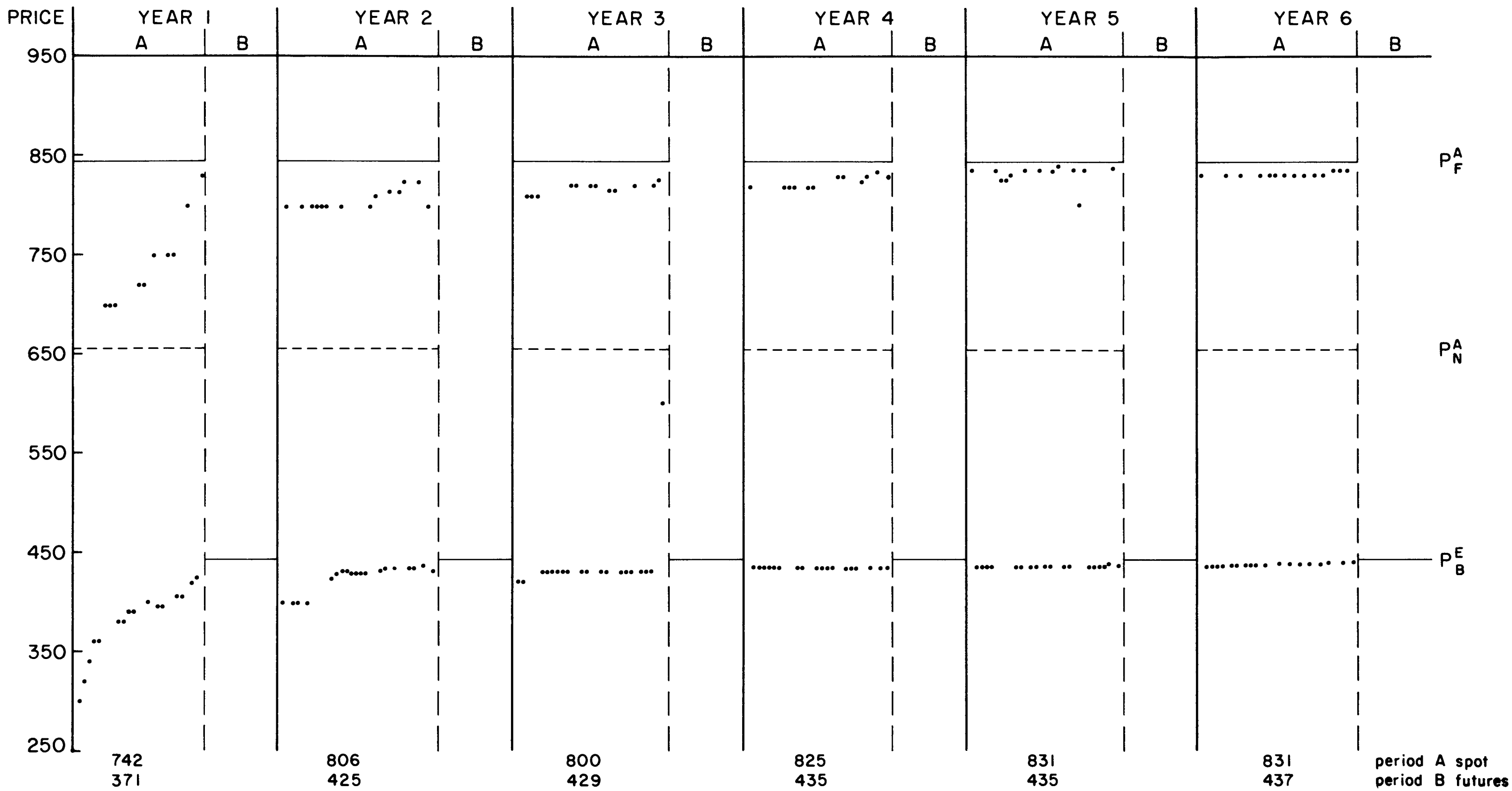


FIGURE 6—Experiment 5: Sequence of Contract Prices and Average Prices.

TABLE III

OBSERVED AVERAGE PRICES AND THEORETICAL PERFECT FORESIGHT PRICE PREDICTIONS WITH TRANSACTION COSTS

Experiment Number	Period	Observed Mean Transactions Price in Final Year (Standard Errors are in Parentheses)	Prices (in Francs) Predicted by Hypotheses 1′ and 4′, Corrected for Transaction Cost, c		
			$c = \$.01$	$c = \$.03$	$c = \$.05$
1	A	576.25[a] (2.76)	590	570	550
	B	295.00[a] (0.0)	295	285	275
2	A	541.43[c] (4.73)	590	570	550
	B	293.56[a] (1.43)	295	285	275
3	A	1180.36[a] (3.28)	1180	1140	1100
	B	592.50[a] (.61)	590	570	550
4	A	393.71[b] (.38)	398	394	390
	B	249.50[a] (.10)	249	247	245
5	A	831.07[b] (.57)	835	815	795
	B	437.06[a] (.34)	437	427	417

[a] At the 10 per cent significance level, one can reject the hypothesis that the observed mean transaction price is less than the predicted price, corrected for a transaction cost of $.01.

[b] At the 10 per cent significance level, one can reject the hypothesis that the observed mean transaction price is less than the predicted price, corrected for a transaction cost of $.03.

[c] At the 10 per cent significance level, one can reject the hypothesis that the observed mean transaction price is less than the predicted price, corrected for a transaction cost of $.05.

predicted prices under an assumption of zero transactions costs, none of these observed mean period B prices are significantly less than the predicted prices (even at a significance level as high as 10 per cent) if the participants of the markets impute a $.01 cost to trading.

The perfect foresight equilibrium model (hypotheses 4 and 4′) is very strongly supported by the period A price data. With one exception (Experiment 2), the average period A transacted price in the final year of each experiment was within $.05 at P_A^F. Experiment 2 lasted only seven years but the price in year seven was within $.12 of P_A^F and mirrored almost exactly the experience in Experiment 1 which was also about $.12 away from P_A^F in year seven. As was the case for period B prices, the period A prices also indicate that the imputed cost of trading is very low. In Experiments 1, 3, 4, and 5 the average prices in the period A of the final year are not significantly less (at the 1 per cent level) than the predictions of the perfect foresight model if the participants impute a trading cost of \$.03 (see Table III).

Hypothesis 3, which states that naive expectations provide a lower bound for prices, is almost a direct implication of Hypothesis 4; it is not particularly surprising that all five experiments support Hypothesis 3 for years beyond year two. Simple hypothesis testing allows us to reject the naive expectations Hypothesis 2 at any significance level. Note that Hypotheses 2 and 4 give mutually inconsistent price predictions for these markets and are sufficiently different that the strong support for Hypothesis 4 implies the rejection of Hypothesis 2.

The "swing-back" Hypothesis 5 that period B convergence precedes period A convergence was supported in all experiments. The relevant inequality was satisfied in every year. This reaffirms the crucial importance of price as a carrier of market information.

The experiments support Hypothesis 6, that convergence in experiments 1–4 will be from below beginning at the naive price. In three out of four experiments average price was at or below P_A^N in year one (Experiments 1, 2, and 3). In two out of four experiments prices were not significantly different from P_A^N (at the 5 per cent level) even during year two (Experiments 1 and 2).

Both Hypotheses 7 and 8 pertain to Experiment 5 alone. Hypothesis 7 (that the first six experiments extend to the case of futures markets) can be accepted on the basis of the above discussion with one important caveat. With a period B futures market (Experiment 5) the period A price in year one was much greater than P_A^N. In fact, it was halfway between the naive price and the perfect foresight price. We suggest that this was observed because individuals were able to obtain information about the period B price before making period A transactions. This theory, if ultimately supported, would also explain why Hypothesis 8 was supported. (Hypothesis 8 asserts that period A price will converge more rapidly with a futures market.) The relevant inequality, defined in Hypothesis 8, was satisfied in every case.

Our intuition that the existence of a no-trade equilibrium at naive prices would prevent or impede convergence to the Pareto optimal perfect foresight equilibrium was not supported. In Experiment 4 which was designed to explore this possibility, speculative investment by one investor (who had participated in an earlier experiment) drove the market away from the inefficient price in early years to an efficient, market-clearing (zero excess demand) price by the end of the final year. It appears that this phenomenon permitted the perfect foresight equilibrium to be reached in that experiment.

B. Quantity Convergence and Efficiency

The predictions about quantity convergence and efficiency of the experimental asset markets were very accurate. Predicted quantities (according to Hypothesis 9F) are 100 per cent accurate after the first year in Experiment 5, the second year

TABLE IV

NUMBER OF UNITS OF ASSET ON "WRONG SIDE OF MARKET" UNDER PERFECT FORESIGHT HYPOTHESIS

Experiment Number	Period	Year 1	2	3	4	5	6	7	8
1[a]	*A*	17	7	3	0	0	0	0	0
	B	2	2	0	0	0	0	0	0
2[a]	*A*	10	3	0	0	0	1	0	
	B	5	3	0	0	1	1	0	
3[a]	*A*	16	5	0	0	3	0	0	0
	B	2	1	0	0	0	0	0	0
4[b]	*A*	12	1	0	0	0	0		
	B	2	0	0	0	0	0		
5[a]	*A*	3	0	0	0	0	0		
	B	5	0	0	0	0	0		

[a] 18 units in the market.
[b] 24 units in the market.

in Experiment 4, and the third year in Experiment 1. Predicted quantities are 97 per cent accurate after the second year in Experiments 2 and 3. We conclude that Hypothesis 9F cannot be rejected and that Hypothesis 9N can be rejected after the first year. Note that quantity convergence is faster when the period *B* futures market exists in Experiment 5 (especially as compared with Experiment 3 where subjects were also experienced).

Percentage of maximum possible total payout is used as a measure of efficiency in a market year (as opposed to a period) of an experiment. There is only one source of inefficiency in these markets. Inefficiency occurs if and only if a "wrong type" of investor is holding assets at the end of a period. One can easily see the relationship between quantity convergence and efficiency in these experiments. Complete efficiency occurs if and only if quantities are allocated according to Table II. That is, complete efficiency occurs if and only if quantities are allocated according to the rational expectations theory. In each of the experiments, type II investors should be holding all units of the asset in period *B*, and type I investors should be holding all the units at the end of period *A*.

Table IV shows the number of units of the asset which are "on the wrong side of the market." When this number is 0 in periods *A* and *B*, that means that type I investors are the only holders at the end of period *A* and type II investors are the only holders at the end of period *B*. If this is true, *no matter what the price is*, the allocation is efficient. Considering the first year only, of the first four experiments 66 units of 156 were on the wrong side of the market. Then in year three and later in the same experiments only nine out of a possible 804 units are held by investors on the wrong side of the market. Thus, after only three years the quantity predictions by the perfect foresight equilibrium model are almost

TABLE V

PAYOUT AS A PER CENT OF MAXIMUM POSSIBLE EFFICIENCY LEVELS PAYOUT[a]

Experiment Number	Year 1	2	3	4	5	6	7	8	Per Cent of Maximum Payment under Naive Hypothesis
1	21.19	66.67	89.05	100	100	100	100	100	33.32
2	50.01	99.28	100	100	98.82	94.99	100		33.32
3	54.74	76.19	100	100	89.25	100	100	100	59.53
4	60.17	98.17	100	100	100	100			60.00
5	77.06	100	100	100	100	100			26.58

[a] Per cent of maximum total payout was calculated *relative* to original endowments. That is, if all participants in the market make no trades and are just paid on the basis of their original endowments only, then according to our measure, the per cent of maximum total payout is 0.0.

100 per cent correct. In Experiment 5 the model is 100 per cent correct after only one period, thus adding support for the hypothesis that the futures market causes more rapid convergence of the spot market.

The efficiency levels in Table V mirror the quantity predictions. After the second year, efficiency levels remain at near 100 per cent in all experiments. Except for Experiment 5 the efficiency levels attained in the first year approximate those predicted under the naive hypothesis. With a futures market, however, the efficiency level in the first year (77 per cent) was well above that predicted under the naive hypothesis (27 per cent).

Both the quantity and efficiency data provide strong evidence that these markets began at the naive equilibrium but ultimately converged to a rational expectations equilibrium. Only when a futures market existed (Experiment 5) did the market appear to bypass the naive equilibrium and converge immediately to the more efficient perfect foresight equilibrium.

C. Individual Behavior

In simple markets like these one might think that individual behavior is simple or "mechanical" and that the resulting market behavior is therefore "obvious." There are three observations about individual behavior which seemed particularly interesting in this respect and suggest that individual behavior is complicated. Both types of behavior are difficult to explain. One such observed action we will refer to as "overlapping." That is, investors do not always treat transacted price signals as bounds on willingness to pay. Sufficient information exists in the instructions to deduce that each individual has a dividend structure such that each individual's total dividend earnings are linear in the number of certificates held. Such a return structure suggests that in the absence of speculative purchases each transacted price indicates a lower bound on the buyer's willingness to pay. For example, it is hard to understand why subject one would sell subject two an asset for twenty francs if one just sold an asset to two for thirty francs in the previous year and one knows that two has a perfectly flat return structure (but doesn't know two's limit price). From the previous transactions individual one has reason to suspect (especially in period *B* where there is less opportunity to speculate) that he/she could hold out for thirty. In the experiments one observes trades transacted at p_1 and then observes subsequent trades in the same period and in later periods transacted at p_2, where $p_2 < p_1$. This frequency of overlapping can be seen in Figures 2–6.

A second observation which seems surprising is the lack of willingness of most individuals to attempt to earn short-term capital gains. Because much of the trading was out of equilibrium and an upward trend in period *A* prices was fairly well established in the early years, intratemporal arbitrage opportunities abounded. Even in period *B* the typical pattern of prices within a period started low and increased at the end of the period. Yet such arbitrage rarely occurred. This makes us suspicious of theories of the first type which suggest that equilibria are the result of short-term risky speculation.

A third observation is related to learning. We originally had thought that experience might be an important factor since it seemed likely that inexperienced subjects required several market years to become completely comfortable with trading rules, recording methods, etc. For this reason experienced subjects were used in Experiments 3, 4, and 5. Although convergence with experienced subjects seems to occur somewhat faster than with inexperienced subjects, the same general patterns of convergence to equilibrium are present in the data with both sets of subject pools. Thus, even though experienced subjects were used, the necessity for having done this is not at all evident.

6. CONCLUSIONS

Our conclusions are discussed in three sections. The first section deals with the technical models and what has been empirically established (subject, of course, to further replication). The second section concerns itself with the methodological questions alone. The final section deals with conclusions of a more general nature.

It is clear that the rational expectations equilibrium (i.e., the perfect foresight equilibrium) model is an excellent predictor of the behavior in these simple markets. The role of replication is also clear in the markets. In particular, for sequential markets such as those studied here without a futures market, replication is both a necessary and sufficient condition for the applicability of the perfect foresight equilibrium model. Necessity is established because the markets do not converge in the first period. Sufficiency is established by convergence of all markets after replication. Of course, exactly how this result extends to more complicated situations remains to be determined.

With these findings the results of Miller, Plott, and Smith [11] and Plott and

Uhl [14] can be reinterpreted as having provided some experience with the behavior of asset markets. Units in those experiments can be viewed as assets which yield zero dividend returns to the traders[5] and the equilibria can correspondingly be viewed as rational expectations equilibria. Of course the absence of intraperiod trading possibilities (which prevents the intraperiod speculation) and the adjustments on the supply side to aid the equating of market prices over time remove some of the important structural features of asset markets but the application of theory to explain the data is clear.

The convergence pattern in these markets is reminiscent of a dynamic programming algorithm. We have called it the "swingback hypothesis." The last period converges first and the convergence works back from this to earlier periods as the years replicate. Thus, information about prices seems to be the critical variable as the theory suggests. This conclusion is reinforced with the addition of a futures market. It is reasonable to conjecture that the transmission of information about future prices speeds the convergence of the period A spot market.

The observed price convergence has a pattern which supports another theoretical interpretation. The appropriate model may have the markets converging to a temporary (naive) equilibrium *first* and then adjusting to the perfect foresight equilibrium after "sufficient" information has accumulated (Grandmont [5]). Other experimental evidence suggests that a market has converged to an equilibrium when there is "low variance" of transacted prices around the average. This evidence may be used to support a conjecture that Experiments 1 and 2 converged to the naive equilibrium in year 2, and Experiment 3 converged in year 1 (see Figures 2–4).

Several new experimental features were introduced in these experiments. The use of special currency seems to cause no problems. And, the truncation of profits seems to leave behavior unperturbed. For example, a comparison of the behavior of these markets with those reported in Smith [16], which also had rectangular demands and supplies, yields few differences. The lack of a trading commission is thought to prevent "full convergence" (Plott and Smith [13]) but almost all experiments reported here were within \$.03 of predicted perfect foresight equilibrium prices in dollar terms.

There are several general implications which follow from the results above. (a) Any theory which advocates the *general* absence of regularities related to the underlying economic parameters of asset markets is demonstrably wrong. Thus, those who accept such a position must begin to adopt qualifications. (b) Because these markets never converged to the perfect foresight equilibrium during the first period, a *strict* rational expectations theory which does not require replication is inconsistent with the data. Similarly, the efficient market hypothesis can be rejected to the extent that it postulates immediate and instantaneous adjustments. Replication necessarily plays an important role in determining the appli-

[5] In these experiments traders had the exclusive right to purchase units in period A for resale in period B, but they could not sell units in period A or purchase units in period B.

cability of these models, and theories which address the question of how rational expectations are formed should be given serious consideration. (c) The study of futures market institutions can be supplemented by experimental techniques. Danthine [1] and Grossman [7] suggest that futures markets can play an important role in publicizing the private information which exists in an economy. Our initial probe with a single experiment establishes the feasibility of creating a controlled-environment futures market which has some of the properties they suggest will exist. A comparison of the observations from the first four markets with the fifth leads us to conjecture that the existence of a futures market affects the spot market. A futures market may increase the speed with which information is made public through price transactions. We suspect that this increases the speed of convergence to equilibrium, perhaps removes the necessity of replication, and might increase market efficiency. All of these conjectures were supported in the single futures market we studied.

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APPENDIX

INSTRUCTIONS FOR EXPERIMENTS 1–4

GENERAL

This is an experiment in the economics of market 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 simulate a market in which you will buy and sell certificates in a sequence of market years. Each year consists of two periods, the first of which will be called *A*, and the second *B*. Attached to the instructions you will find a sheet, labeled information and record sheet, which helps determine the value to you of any decisions you might make. You are not to reveal this information to anyone. It is your own private information.

The type of currency used in this market is francs. All trading and earnings will be in terms of francs. Each franc is worth ____ dollars to you. Do not reveal this number to anyone. At the end of the experiment your francs will be converted to dollars at this rate, and you will be paid in dollars. Notice that the more francs you earn, the more dollars you earn.

SPECIFIC INSTRUCTIONS

Your profits come from two sources—from collecting certificate earnings on all certificates you hold at the end of a period *and* from buying and selling certificates. During each market year you are free to purchase or sell as many certificates as you wish provided you follow the rules below. For each certificate you hold at the end of the period you will be given the number of francs listed on row 19 of your information and record sheet. Notice that this amount may differ from period to period.

Compute your total certificate earnings for a period by multiplying the earnings per certificate by the number of certificates held. That is,

(number of certificates held) × (earnings per certificate) = total certificate earnings.

Suppose for example that you hold 5 certificates at the end of period A of year 1. If for that period your earnings are 100 francs per certificate (that is, the number listed on row 19 is 100) then your total certificate earnings in period A would be $5 \times 100 = 500$ francs. This number should be recorded on row 19 at the end of the period.

Sales from your certificate holdings increase your francs on hand by the amount of the sale price. Similarly, purchases reduce your francs on hand by the amount of the purchase price. Thus you can gain *or* lose money on the purchase and resale of certificates. At the end of period B of each year all your holdings are automatically sold to the experimenter at a price of 0.

At the beginning of each year you are provided with an initial holding of certificates. This is recorded on row 0 of period A in each year's information and record sheet. You may sell these if you wish or you may hold them. If you hold a certificate throughout both periods, then you receive "earnings per certificate" twice—once at the end of period A, and again at the end of period B. Notice therefore that for each certificate you hold initially you can earn during the year *at least* the *sum* of the two "earnings per certificate" you receive at the end of periods A and B. You earn this amount if you do not sell that certificate during the entire year.

In addition at the beginning of each year you are provided with an initial amount of francs on hand. This is also recorded on row 0 of period A on each year's information and record sheet. You may keep this if you wish or you may use it to purchase certificates.

Thus at the beginning of each year you are endowed with holdings of certificates and francs on hand. You are free to buy and sell certificates as you wish according to the rules below. Your francs on hand at the end of a year are determined by your initial amount of francs on hand, earnings on certificate holdings at the end of each period and by gains and losses from purchases and sales of certificates. All francs on hand at the end of a year in excess of ____ francs are yours to keep. These are your profits for the year.

TRADING AND RECORDING RULES

(1) All transactions are for one certificate at a time. After each of your sales or purchases you must record the nature of the transaction, a sale (S) or purchase (P), and the transaction price. The first transaction is recorded on row (1) and succeeding transactions are recorded on subsequent rows.

(2) After each transaction you must calculate and record your new holdings of certificates and your new francs on hand. Your holdings of certificates may never go below zero. Your francs on hand may never go below zero.

(3) At the end of the period record your total certificate earnings on row 19. Compute your end of period totals on row 20 by listing certificate holdings and adding total certificate earnings to your francs on hand.

(4) The totals on row 20 at the end of period A should carry forward to row 0 of the next period.

(5) At the end of period B, subtract from your francs on hand the amount listed in row 21 and enter this new amount on row 22. This is your profit for the market year and is yours to keep. At the end of each market year, record this number on your profit sheet.

(6) At the end of the experiment add up your total profit on your profit sheet and enter this sum on row 15 of your profit sheet. To convert this number into dollars, multiply by the number on row 16 and record the product on row 17. The experimenter will pay you this amount of money.

MARKET ORGANIZATION

The market for these certificates is organized as follows. The market will be conducted in a series of years each consisting of two periods. Each period lasts for 7 minutes. Anyone wishing to purchase a certificate is free to raise his or her hand and make a verbal bid to buy one certificate at a specified price, and anyone with certificates to sell is free to accept or not accept the bid. Likewise, anyone

PROFIT SHEET

Row	Market Year	Profit
1	1	
2	2	
⋮	⋮	
14	14	
15	Total Profit (in Francs)	
16	Dollars Per Franc	
17	Total Dollar Profit	

NAME__________________

TRADER NUMBER_________

INFORMATION AND RECORD SHEET

YEAR_____

	Row	PERIOD *A*				PERIOD *B*			
				Certificate Holdings	Francs on Hand			Certificate Holdings	Francs on Hand
Beginning of Period Francs on Hand and Certificate Holdings	0								
		S or *P*	TRANSACTION PRICE			*S* or *P*	TRANSACTION PRICE		
	1								
	2								
	⋮								
	18								
Total Certificate Earnings	19	____ per certificate				____ per certificate			
End of Period Totals	20								
	21								
	22					End of Year Profit			

wishing to sell a certificate is free to raise his or her hand and make a verbal offer to sell one certificate at a specified price. If a bid or offer is accepted, a binding contract has been closed for a single certificate, and the contracting parties will record the transaction on their information and record sheets. Any ties in bids or acceptance will be resolved by random choice. Except for the bids and their acceptance, you are not to speak to any other subject. There are likely to be many bids that are not accepted, but you are free to keep trying. You are free to make as much profit as you can.

PRACTICE CALCULATIONS

(The substance and much of the wording has been preserved but the format of the practice calculations has been changed to conserve space.)

1. Suppose that at the beginning of period A your initial certificate holding is 1 and your initial francs on hand are 0. Suppose your earnings per certificate are 10 and 15 in periods A and B, respectively, and each year you are allowed to keep all francs on hand in excess of 0. If you hold onto your certificate for the entire year, that is, you do not make any transaction in period A or period B certificates, then calculate total certificate earnings in period A, end of period francs on hand in period A, total certificate earnings in period B, end of period francs on hand in period B, and profit for the year.

2. Suppose that at the beginning of period A your initial certificate holding is 1 and your initial francs on hand are 100. Your earnings per certificate are 10 in period A and 15 in period B. Each year you are allowed to keep all francs on hand in excess of 100. Listed below are seven possible series of trading activities which would be legal for you to do in any given year. In each case you are asked to compute your profit for the year. (i) Make no transactions in period A certificates or period B certificates; (ii) sell one period A certificate for 20, make no transaction in period B certificates; (iii) make no transaction in period A certificates, sell one period B certificate; (iv) purchase one period A certificate for 20, make no transaction in period B certificates; (v) make no transaction in period A certificates, purchase one period B certificate for 20; (vi) sell one period A certificate for 20, purchase one period B certificate for 20; (vii) purchase one period A certificate for 20, sell one period B certificate for 20.

INSTRUCTIONS FOR EXPERIMENT 5

GENERAL

This is an experiment in the economics of market 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 simulate a market in which you will buy and sell certificates in a sequence of market years. Each year consists of two periods, the first of which will be called A, and the second B. Attached to the instructions you will find a sheet, labeled information and record sheet, which helps determine the value to you of any decisions you might make. You are not to reveal this information to anyone. It is your own private information.

The type of currency used in this market is francs. All trading and earnings will be in terms of francs. Each franc is worth ____ dollars to you. Do not reveal this number to anyone. At the end of the experiment your francs will be converted to dollars at this rate, and you will be paid in dollars. Notice that the more francs you earn, the more dollars you earn.

SPECIFIC INSTRUCTIONS

Your profits come from two sources—from collecting certificate earnings on all certificates you hold at the end of a period *and* from buying and selling certificates. During each market year you are free to purchase or sell as many certificates as you wish provided you follow the rules below. For each certificate you hold at the end of the period you will be given the number of francs listed on row 31 of your information and record sheet. Notice that this amount may differ from period to period. Compute your total certificate earnings for a period by multiplying the earnings per certificate by the number of certificates held. That is,

(number of certificates held) × (earnings per certificate) = total certificate earnings.

Suppose for example that you hold 5 certificates at the end of period A of year 1. If for the period your earnings are 100 francs per certificate (that is, the number listed on row 31 is 100) then your total certificate earnings in period A would be $5 \times 100 = 500$ francs. This number should be recorded on row 31 at the end of the period.

Sales from your certificate holdings increase your francs on hand by the amount of the sale price. Similarly, purchases reduce your francs on hand by the amount of the purchase price. Thus you can gain *or* lose money on the purchase and resale of certificates. At the end of period B of each year all your holdings are automatically sold to the experimenter at a price of 0.

At the beginning of each year you are provided with an initial holding of certificates. This is recorded on row 0 of period A in each year's information and record sheet. You may sell these if you wish or you may hold them. If you hold a certificate throughout both periods, then you receive "earnings per certificate" twice—once at the end of period A, and again at the end of period B. Notice therefore that for each certificate you hold initially you can earn during the year *at least* the *sum* of the two "earnings per certificate" you receive at the end of periods A and B. You earn this amount if you do not sell that certificate during the entire year.

All trading for holdings of certificates in period B takes place in period A. Therefore, in period A, you may make the following two types of trades:

(1) You may purchase (or sell) a certificate to hold throughout *both* periods. These are called period A certificates.

(2) You may purchase (or sell) certificates to hold in only one period. These are called period B certificates since if you purchase it, you hold it only during period B. Note that if you sell a period B certificate you hold it only during period A and the trader you sell it to holds it during period B.

In addition at the beginning of each year you are provided with an initial amount of francs on hand. This is also recorded on row 0 of period A on each year's information and record sheet. You may keep this if you wish or you may use it to purchase certificates.

Thus at the beginning of each year you are endowed with holdings of certificates and francs on hand. You are free to buy and sell certificates as you wish according to the rules below. Your francs on hand at the end of a year are determined by your initial amount of francs on hand, earnings on certificate holdings at the end of each period and by gains and losses from purchases and sales of certificates. All francs on hand at the end of a year in excess of ____ francs are yours to keep. These are your profits for the year.

TRADING AND RECORDING RULES

(1) All transactions are for one certificate at a time. After each of your sales or purchases you must record the nature of the transaction, a sale (S) or purchase (P), and the transaction price. The first transaction is recorded on row (1) and succeeding transactions are recorded on subsequent rows.

(2) After each transaction for a period A certificate you must calculate and record your new holdings of certificates and your new francs on hand. Your holdings of certificates may never go below zero.

(3) After each transaction for a period B certificate, you must record the net sales of period B certificates in the "Net Sales" column of period B. The number in this column must never exceed the number in the "Certificate Holdings" column of period A.

(4) At the end of period B your total certificate holdings is equal to your total certificate holdings in period A *minus* your "net sales" of period B certificates.

(5) At the end of the period record your total certificate earnings on row 31 and list your total certificate holdings on row 32.

(6) At the end of period B, add your total certificate earnings in both periods to your francs on hand, and enter this amount on row 32. Subtract from your francs on hand the amount listed in row 33 and enter this new amount on row 34. This is your profit for the market year and is yours to keep. At the end of each market year, record this number on your profit sheet.

(7) At the end of the experiment add up your total profit on your profit sheet and enter this sum on row 15 of your profit sheet. To convert this number into dollars, multiply by the number on row 16 and record the product on row 17. The experimenter will pay you this amount of money.

MARKET ORGANIZATION

The market for these certificates is organized as follows. The market will be conducted in a series of years each consisting of two periods. Trading for both periods will be done in period A. This period will last ____ minutes. Anyone wishing to purchase a certificate is free to raise his or her hand and make a verbal bid to buy one certificate at a specified price, and anyone with certificates to sell is free to accept or not accept the bid. Likewise, anyone wishing to sell a certificate is free to raise his or her hand and make a verbal offer to sell one certificate at a specified price. When making a bid or offer, you must specify whether you wish to buy or sell a period A or period B certificate. If a bid or offer is accepted, a binding contract has been closed for a single certificate, and the contracting parties will record the transaction on their information and record sheets. Any ties in bids or acceptance will be resolved by random choice. Except for the bids and their acceptance, you are not to speak to any other subject. There are likely to be many bids that are not accepted, but you are free to keep trying. You are free to make as much profit as you can.

The profit sheet for Experiment 5 was the same as that for the other experiments. The information and record sheet for Experiment 5 differed in that the francs-on-hand inventory was carried in a single column on the right-hand side of the form as opposed to the two columns shown on the form above under period A and period B.

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