THE INFORMATIONAL ROLE OF FUTURES MARKETS AND LEARNING BEHAVIOUR: SOME EXPERIMENTAL EVIDENCE

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Section 1

INTRODUCTION

We have recently undertaken a series of experiments that examine the behaviour of futures markets. We are particularly concerned with the informational role of futures prices in allowing traders to achieve efficient outcomes, and with the learning process that takes place in such markets. In the present paper we lay out our basic approach and present the results of our first set of experiments.

Generally speaking, our experiments so far confirm the belief that the existence of active futures markets promotes a more efficient operation of spot markets. We find that prices tend to converge to more informationally efficient equilibria when futures markets operate and when traders are experienced (Hypotheses H1-H7 of Section 4). We also find that spot prices tend to be less volatile under these circumstances (H9, H10, and H12). The significance of learning behaviour, both within and across market experiments, is evident in our results (H11; experience variable). The informational content of futures prices appears to have a systematic effect in shifting spot prices (H8). On the other hand, our results do <u>not</u> confirm the value of futures markets in helping traders to achieve more efficient allocations of assets (H13 and H14). The observed combination of price efficiency and allocational inefficiency points up the inadequacy of traditional theoretical ("Walrasian") approaches to equilibrium (see discussions in Section 3 and at the end of Section 4).

The paper is organized as follows. In the next Section we review the salient features of experimental methodology in economics as it has emerged in recent years. We then describe the design of our current experiments.

In Section 3 we extract a few basic concepts from the theoretical literature on asset markets, and provide a detailed numerical example to familiarize the reader with the operation of our experimental markets. We then derive theoretically the equilibrium properties of our experimental markets, and review some aspects of the learning process. From the theory presented we isolate a set of testable hypotheses.

In Section 4 we present our experimental data descriptively, and then test our hypotheses. In the final section we describe our agenda for further work in experimental futures markets.

Section 2

EXPERIMENTAL DESIGN

2.1 ESTABLISHED EXPERIMENTAL METHODOLOGY

Experimental auction markets involve recruited subjects who are induced (by means of controlled market trading schedules and standard incentive structures) to display real-time market behaviour. Experimental control of market conditions (the "treatment variables") allows one to design groups of such experiments to gauge the effects of those variables on observed behaviour (e.g., the strength of equilibrium tendencies, efficiency of market outcomes, and the variability of price movements). Each of the hypotheses to be studied involve the specification of well-defined, and hence replicable, sets of trading rules, informational imperfections, and other institutional features.

The first methodological point to note is that the experimental method does provide evidence on "real-world" markets. The fact that these experiments typically involve small numbers of traders, that we deal with homogeneous commodities, and that the experimenter can control the notional trading schedules, does not render these markets irrelevant. They are indeed special, but so are the institutional realities of most organized exchanges. The main point, however, is the purpose for which these markets are conducted: to provide evidence on general theories. If a theory or economic principle is general it should cover special cases.

The second methodological point follows from the first -- if we cannot confirm or reject general theories in the context of controlled environments designed for the purpose of testing the theory, then the theory cannot be regarded as operational in any useful respect. Moreover, it is often difficult to "control" for all conceivably relevant influences on market behaviour with econometric methods and actual market data; see Leamer [1978] for a comprehensive statement of the methodological weaknesses of standard econometric method here.

A final methodological point relates more particularly to our use of the experimental technique to analyse the role of information in market behaviour. One common difficulty in analytic models of the informational aspects of markets is the precise definition of "the information sets" of traders. Our experiments allow very detailed knowledge of that set, for instance, the ability to control which traders know what information[1].

Since the pioneering work of Vernon Smith [1962] applications of experimental methodology have grown quite rapidly, but such studies of asset markets have emerged only recently and can be quickly enumerated. In the tradition of Samuelson's inter-temporal pricing model [1957], Miller, Plott and Smith [1977], using a two-period stock/flow market model, experimentally examined the effect of carryover decisions on equilibrium intertemporal price and resource determination. The implied operational definition of speculation was limited to agents' potential inventory responses to percieved and repetitively stationary "seasonal" differences in market supply and demand conditions. In the absence of "event" risk -- risk arising from uncertainty as to which state of supply/demand will occur next period -- the type of speculative behaviour analyzed by Miller, Plott and Smith might be called non-informative specula-

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[1] See Smith [1980] [1982] and Wilde [1980] for further discussion of the methodological contribution of experimental techniques.

tion[2]. The only datum that the agents are forced to learn about is the future period market clearing price that affect current and future excess demand decisions. Williams [1979] and Plott and Uhl [1981] essentially replicate this experimental design.

The study that most closely resembles our own is Forsythe, Palfrey and Plott [1981], hereafter FPP. FPP are concerned with inventory decisions and equilibrium price search. In particular, they address the following questions:

i) Do asset prices and inventories exhibit systematic temporal characteristics relative to the underlying market parameters?

ii) Which of several competing hypotheses concerning the nature of asset price determination does the experimental data evidence favor?

FPP are particularly concerned with the extent to which the formation of market clearing prices aggregates agents' diverse stock demand preferences. Although FPP is the first experimental study to model trading rules and induced stock demand valuations that reflect some of the salient aspects of organized futures markets, their futures market design was an incidental feature of their paper -- an "institutional perturbation" designed to check on the robustness of the striking results generated by their spot market experiments.

A primary purpose of our paper is to generalize the FPP experimental design of futures markets. In doing this we are able to:

i) check the robustness of the FPP futures market experiment;

ii) provide additional evidence on market clearing prices as aggregators of privately held 'information[3]

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[2] We are indebted to Jack Hirshleifer for bringing this point to our attention.

[3] ' Plott and Sunder [1981] present evidence on this issue using a <u>one-period</u> asset market (no carryover allowed between periods) with asymmetric private information sets experimentally induced (i.e., some traders were "insid-

iii) provide a more refined characterization of possible price/information equilibria and learning processes, and

iv) lay the foundation for further experiments designed to analyze the impact of event uncertainty on futures market trading performance.

2.2 DESIGN OF CURRENT EXPERIMENTS

The participants in our market experiments (referred to as "traders") were recruited primarily from MBA classes at the UCLA Graduate School of Management -- as likely a habitat for homo economus as we could think of. After distributing and reviewing the instruction sheets reproduced in the Appendices (which are adapted from FPP), we conducted double oral auction markets. Our traders could announce bid and offer prices and accept the bids or offers of others (providing they did not violate any budget constraint, as discussed below). Transacted prices were publicly recorded. The assets traded were called certificates; they yielded returns, called dividends, to traders who possessed them at the end of each trading period.

Each experiment consisted of a series of "Market Years", which can be thought of as Hicksian weeks. Within each Market Year there were three trading periods, referred to as periods A, B and C. Each trading period lasted for five minutes (real time) and each trader could buy or sell one certificate at a time. Lot sales and short sales were prohibited. At the beginning of each Market Year each trader was endowed with two certificates and $20.00 cash on hand. The endowments were sufficiently large that the implied wealth constraint was never an impediment to trade.

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ers").

TABLE 1

Induced Experimental Market Parameters

EXPERIMENT	MARKET INSTITUTION	AGENTS Type	ID #	DIVIDEND PROFILE A	B	C
1	Pure Stock	I	2,4,9	0.40	0.15	0.25
	No Futures	II	3,6,8	0.30	0.45	0.40
	Inexperienced	III	1,5,7	0.10	0.30	0.60
2	Pure Stock	I	1,3,6	0.40	0.25	0.15
	Futures	II	4,7,9	0.25	0.30	0.60
	Inexperienced	III	2,5,8	0.10	0.45	0.40
3	Pure Stock	I	1,3,6	0.45	0.45	0.45
	No Futures	II	4,7,9	0.70	0.30	0.10
	Experienced	III	2,5,8	0.10	0.30	0.70
4 *	Pure Stock	I	5,7,9	0.75	0.20	0.10
	Futures	II	1,3,6	0.40	0.45	0.45
	Experienced	III	2,4,8	0.15	0.30	0.80

Note: In Year 5 of Experiment 4 a random re-assignment of agents to trader type occurred; investor type I consisted of Agents 1, 3 and 5; type II of agents 4, 6 and 8; and type III of agents 2, 7 and 9. The parameters shown here pertain to all other Market Years.

Incentives for exchange among traders were provided by varying the per certificate dividends across individuals as well as across periods. There were three trader types, with individuals randomly assigned to each group; Table 1 provides details of the parameterizations for each experiment. The underlying period-specific certificate returns were identical across market years -- identical in the aggregate <u>and</u> for each individual[4]. Thus the markets were repetitively stationary from Year to Year. Note that traders were not in-

[4] A minor exception in Year 5 of Experiment 4 is noted in Table 1.

formed of this stationarity: they had to learn about it in "real time". Each individual was carefully monitored so that his/her private dividend profile was not observed by any other trader. Possibilities for explicit or implicit collusion were effectively nil.

To motivate an underlying story for the experimental set-up one can think of the traders as grain merchants trading in warehouse certificates which have a par value of zero but provide each trader with a finite time profile of convenience yields. Of course, in our experiments traders actually received a cash "dividend" for each certificate held at the end of each trading period, and the certificates expired after the Market Year ended.

In experiments 1 and 3 trading consisted of an immediate exchange of cash for certificates at accepted bid or offer prices (i.e., spot transactions only). In experiments 2 and 4 we permitted futures transactions as well. The futures contract consisted of the delivery of a certificate in period C, and futures contracts as well as spot contracts could be written in both period A and period B. In periods A and B dividends were paid as usual for each certificate held at the end of that period. No transactions were allowed in period C in experiments 2 and 4, but deliveries previously contracted for were performed. An individual with a net long (short) futures position was required to take (make) delivery of the certificates, and then period C dividends distributed. A natural interpretation of period C is that it corresponds to the day after the last trading day in the delivery month of a futures contract. Note that an agent had ample opportunity to offset futures positions during periods A and B, so offset procedures were fully operational in our design. However, because of the restriction on short sales, agents' short positions were limited to the quantity of inventoried spot certificates at any point in time. For a given net short position an agents spot sales were also constrained. Subject to this limitation, discretionary hedging positions were allowed.

In all experiments traders were given a small trading commission of one cent per transaction. Such commissions are a standard feature of most experimental market studies; the usual rationale for their inclusion is to overcome subjective transaction costs which might be especially relevant when transacted prices are very close to a market clearing price. At the end of each experiment we paid our traders in cash for all profits accrued from dividends and trading. See the Instruction Sheets in the Appendix for complete details.

Our experimental design differs from FPP in four respects. First, they had only two trading periods per market year. We included a third period, largely to create richer strategic opportunities and to provide greater flexibility in designing later experiments. Second, we employed trader experience as a treatment variable as part of our concern with learning behaviour; FPP did not do so. Third, FPP expressed their dividend schedules in terms of an arbitrary unit of account ("francs"); we used dollars and thus avoided what seems to us the needless complication (for traders) of converting francs to dollars. Finally, we followed the standard practice of employing small transactions commissions; FPP did not. Overall, then, our designs are quite similar; see Friedman, Harrison and Salmon [1982] for more detailed comments and comparison of results with FPP.

Section 3

LEARNING BEHAVIOUR, EQUILIBRIUM AND FUTURES MARKETS

3.1 THEORETICAL LITERATURE

In recent years, theorists have become increasingly interested in the informational role of prices in general and futures prices in particular; see, for instance, Grossman [1977(a)] [1977(b)] [1978], Bray [1981] and Grossman and Stiglitz [1976] [1980]. These theorists study a world in which information relevant to agents' intertemporal choices is dispersed throughout the economy. Under some conditions, they find that competitive equilibrium prices will reveal everything that rational agents need to know to make choices which result in an "efficient" allocation. That is, the economy may achieve an allocation which is the same as that which would arise in a fictitious but otherwise simiiliar economy in which each agent has access not only to his own personal information, but also the personal information of each other agent. In this case, prices are said to be <u>perfectly revealing</u> or <u>perfect aggregators</u> of information. For example, Grossman [1977(b)] models a case in which spot prices alone do not perfectly aggregate information, but spot prices together with futures prices do. He argues that such information aggregation is a major function of futures markets (although the aggregation will be less than perfect if information is costly).

The models employed in this literature are stochastic, and information typically takes the form of samples drawn from some normal distribution whose parameters affect the outcomes of agents' decisions. The models all employ a "large" number of price-taking agents, or even a continuum of agents in Hellwig [1980]. Hence one cannot directly apply the conclusions reached in this literature to our market experiments in which the agents are permitted to set prices, are few in number, and in which (at least in the current round of experiments) the markets have no (exogenous) stochastic features. Nevertheless, our experiments involve dispersed personal information in the form of dividend schedules, and prices do provide useful, perhaps even perfectly revealing, information to our agents. Therefore, the literature is quite suggestive and will provide a helpful guide as we proceed in the next few sections to frame appropriate concepts of equilibrium and to extract testable hypotheses.

3.2 AN EXAMPLE

Before presenting a theoretical analysis of our experimental markets, an informal discussion of agents' behaviour, including numerical examples, may be in order. Consider the hypothetical dividend profile and agent assignment shown in Table 2.

TABLE 2

Hypothetical Experimental Market Parameters

EXPERIMENT	MARKET INSTITUTION	AGENTS Type	ID #	DIVIDEND PROFILE A	B	C
		I	1,2,3	0.45	0.45	0.45
HYPOTHETICAL		II	4,5,6	0.70	0.30	0.10
		III	7,8,9	0.10	0.30	0.70

Consider the strategic opportunities available to (say) Agent #9 in period C -- the last trading period of a market year with spot trading only. Since he has a dividend profile of type III, he will receive \$0.70 for each certificate he owns at the end of the period's trading, and the certificates have no further value to him or anyone else. Hence, \$0.70 represents his "reservation price": he will profit by any purchases he can make at a lower price and sales at any higher price. Agent #9 has no direct knowledge of the reservation prices of other agents. He will soon discover, however, that nobody can afford to outbid him, while he can't undersell anyone. Hence, he may find that if he actively bids and aggressively accepts offers, he will acquire certificates at prices below his reservation price -- but probably not much below and not for long. Agents #7 and #8 also have a reservation price of \$0.70, so if either one of them notices that #9 is snapping up certificates at (say) \$0.60, one or both are likely to begin to bid, say, \$0.62 or \$0.65, in an attempt to acquire the certificates. This process may be expected to raise the transacted price to \$0.70 in fairly short order (recall the one cent trading commission) as long as at least two of the type III traders actively attempt to buy up "cheap" certificates. Evidently, \$0.70, the highest reservation price[5], is the equilibrium price for period C, and the corresponding allocation involves all certificates being held by the type III agents. Presumably the most aggresive bidder among them gets the lion's share.

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[5] More specifically, the second highest reservation price among the nine traders, which in the current instance happens to equal the first and third highest since there are three agents of type III. See Vickrey [1961] for an explanation of the familiar pricing result that the winning bid is the second highest reservation price.

Let us now consider trading in the prior period B. At this point, our agent #9 knows a certificate will yield him at least \$0.30 (current dividend) + \$0.70 (period C dividend) = \$1.00, and possibly more if he were able to resell in the current period at a price above \$1.00 or in period C at a price above \$0.70. We are unable to determine his reservation price in this period without knowing his attitude to risk and the probabilities he assigns to these resale possibilities, but we do know that it is bounded below by his "security level" of \$1.00. Agent #1 is in a more interesting position: he has a lower security level (\$0.45 + \$0.45 = \$0.90), but if he has seen this market operate for several Market Years, he may become quite confident of his ability to resell in period C at \$0.70. In this case his reservation price will be approximately \$0.45 (current dividend) + \$0.70 (resale value in period C) = \$1.15, so he is likely, at least in later Market Years, to outbid #9 and the other type III agents. Once again, the price should be bid up to the highest reservation price among the agents of type I if the others (#2 and #3) also come to realize (either independently or through noticing #1's "windfall profits") that certificates might be worth more than \$1.00 to them in period B. Consequently, the period B price should settle somewhere between \$1.00 (the highest security level) and \$1.15 (highest "rational" reservation price), with the price rising towards the higher value as agents accumulate experience over the years. For closing prices in excess of \$1.00, all certificates should be held by type I traders.

Similiar considerations apply to period A trading. The highest security level belongs to type I traders (\$0.45 + \$0.45 + \$0.45 = \$1.35) but if type II traders begin to anticipate the ability to resell in period B at a price approaching \$1.15, their reservation price would be near \$0.70 + \$1.15 = \$1.85, and, over the years, learning may allow the closing period A price to rise from \$1.35 to nearly this value.

Suppose now that the data in Table 2 refer to an experiment in which futures trading is permitted, and consider the strategic possibilities available to agent #1 in Period B. He personally would be willing to bid at most \$0.45 for futures contracts (i.e., period C delivery of certificates), but for reasons discussed above it seems likely that agents of type III will bid up the price of this contract to \$0.70. With a currently quoted futures price of \$0.70, agent #1 now has a security level for spot transactions of \$1.15, not \$0.90 as before: for each certificate he acquires he can still earn his current period dividend of \$0.45, while "locking in" an additional \$0.70 return by selling a futures contract; he need not speculate, as was the case in the spot-only market, as to its future resale value. Hence a period B spot price of \$1.15 and a futures price of \$0.70 can arise from information directly available to the agents. Note that spot trading in period C would be redundant, given the operation of the futures market in prior periods.

The strategic opportunities in period A are quite rich. The opportunites discussed above still obtain, but the futures price provides additional information. Thus, if the futures price for period C delivery of certificates converges to \$0.70 in period A, then agents of type II will have a security level of \$1.70 (\$0.70 current dividends \$0.30 period B dividends + \$0.70 proceeds from the futures transaction). Hence we may anticipate that these agents (together with type I agents) will more quickly bid up spot prices when the futures market is active.

3.3 EQUILIBRIUM CONCEPTS

We now proceed to formalize our experimental market model. For purposes of equilibrium analysis, we may take time as discrete: $t = 0,1,2,3$, where 0 refers to the beginning of period A and 1,2,3 refer to the end of periods A, B and C respectively. The economy consists of agents $i = 1,\ldots,9$, each characterized by his dividend schedule $D(i,t)$, $t = 1,2,3$, and by his initial endowment of certificates and money: $w(i) = (c(i,0),m(i,0)) = (2,\$20.00)$. We assume that i's preferences depend positively on year-end wealth $m(i,3)$ and are independent of other variables[6].

We define agent i's private information reservation price in period t as:

$$R(i,t|PI) = \sum_{s=t}^{3} D(i,s),$$

the sum of his remaining per certificate dividend yields. Then the private information price is given by:

$$P(t|PI) = \max_{i} R(i,t|PI) \quad .$$

This price never exceeds the perfect foresight price given by:

$$P(t|PF) = \sum_{s=t}^{3} \max_{i} D(i,s).$$

In the above numerical example and in Experiment 3, P(.|PI) = (\$1.35, \$1.00, \$0.70) while P(.|PF) = (\$1.85, \$1.15, \$0.70). FPP, following Grossman [1978], refer to P(t|PI) as the Naive Equilibrium price and P(t|PF) as the Rational

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[6] Year-end wealth is expressed solely in terms of money, since certificates expire at the end of the Market Year.

Expectations Equilibrium price.

Note that there are really four "goods" in this economy: certificates held at t = 1,2,3 and money. Consider the case of complete markets (i.e., simultaneous trade in all three dated goods against money), which may be envisioned as a single round of trading in Period A in spot and two futures contracts: a fictitious one for delivery in period B, as well as the period C contract we actually employed in some experiments. Consideration of this economy is suggested by the fictitious economy of full information mentioned in Section 3.1 above. It provides a benchmark for efficiency considerations; although competitive equilibrium in any economy is *ex ante* Pareto-efficient given informational constraints, these equilibria *ex post* will generally be less efficient than that of our complete markets economy, in the sense that gains from trade would have been possible in other economies if agents had access to all information.

It is not hard to verify for our complete markets economy that $P(.|PF)$ are the unique competitive equilibrium (C.E.) prices, and that in any corresponding allocation, $c(.,.)$, we have $c(j,t) = 0$ unless $D(j,t) = \max D(i,t)$; i.e., in each period certificates are all held by traders of the type receiving the highest dividends in that period.

Another way of formalizing our market experiments, perhaps more appropriate in view of traders' ability to set prices ("price searchers"), is as a game in either extensive or normal form. The complete markets version in normal form may be regarded as a case of the market game in Dubey [1982], wherein agents' strategies consist of price-quantity pairs of both bids and offers. It appears that his Theorem 1 applies, so we may conclude that the Competitive Equilibria in the previous paragraph coincide with Active Nash Equilibria (A.N.E.) of our fictitious complete markets game. "Active" for our purposes means that at least two agents of each type participate in exchange[7].

However, our actual experiments do not employ complete markets. In the experiments without futures markets, agents must (at least implicitly) make forecasts of prices to obtain in later periods. Let $R(i,t|f(i))$ be agent i's reservation price given his forecasts of these prices, $f(i)$, and his risk preferences. A simple argument, illustrated in the previous subsection, shows that

$$P^{*}(t) = \max_{i} R(i,t|f(i))$$

where $P^{*}(.)$ are equilibrium prices,

if agents of the same type have the same reservation prices, and that in any case

$$P^{*}(t) \geq P(t|PI) \quad .$$

If agents are so risk averse and uncertain as to employ maximin strategies, then

$$P^{*}(t) = P(t|PI) \quad .$$

We refer to this case as the <u>private information equilibrium</u>. Of course no uncertainty remains in the last period, so things are more clear-cut:

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[7] See Smith, Williams, Bratton, and Vannoni [1982; p.65/66] for an explanation of NE in this context.

$P^*(3) = P(3|PI) = P(3|PF)$. The corresponding allocations c(.,.) still should satisfy $c(i,t) = 0$ if $R(i,t|f(i)) < P(t)$ in every case.

Without restrictions on agents' probabilistic beliefs or risk preferences, little more can be said about period 1 and 2 equilibrium prices and allocations. Under the extreme assumption of rational expectations, however, only the equilibria of the complete markets economy remain; we refer to this case as the *perfect foresight equilibrium*.

In our experiments with (period C) futures trading, we can make somewhat sharper statements. Equilibrium (C.E. or A.N.E.) prices are now determinate at t = 2 (period B) as well as at t = 3 (period C). The argument again was suggested in the numerical example, and we now make it explicit. Let P(3,t) be the futures price , and define

$$R(i,t|MI) = \sum_{s=t}^{2} D(i,s) + P(3,t)$$

as the *market information reservation price*, and define the *market information price* as

$$P(t|MI) = \max_i R(i,t|MI) \geq P(t|PI) \quad .$$

The last inequality will usually be strict; it is a consequence of the additional information provided by the futures market. In the numerical example

$$P(.|MI) = (1.70,\ 1.15,\ 0.70) \text{ for } P(3,t) = P^*(3) = \$0.70 \quad .$$

Note that in an equilibrium

$$P(3,t) = P^*(3) = \max_i D(i,3)$$

for each t (=1,2). In this case

$$P(2|MI) = \max_i R(i,2|MI) = P(2|PF) = P^*(2).$$

where $P^*(2)$ denotes the equilibrium Period B price.

Thus equilibrium prices are indeed determinate at t=2. Equilibrium prices are not determinate at t = 1, but as long as agents incorporate the information in the futures price and it reaches its equilibrium level, we can raise the lower bound on

$$P^*(1) \quad \text{to} \quad P(1|MI) .$$

The usual statements about equilibrium allocations still apply.

3.4 LEARNING BEHAVIOUR IN PREVIOUS EXPERIMENTAL MARKETS

In a real-time trading process such as that of our experiments, equilibrium can only be achieved as agents learn about their opportunities for gain through trade. In our experiments this learning can take place within each period as traders observe bids, offers and transactions (intraperiod learning); across periods and Market Years as traders observe trends in prices and the outcomes of their activities (interperiod learning); and across experiments as traders gain a better idea of what information is relevant and refine their strategies (experience). Traders presumably base their bids, offers, and acceptances on some sort of reservation prices that they modify as they learn.

We will not attempt to model this process formally here, despite its great theoretical and practical importance[8]. Instead we will content ourselves with a brief review with comments on discussions of (mostly interperiod) learning in the experimental markets literature.

A crucial experimental design feature introduced in the classic paper by Smith [1962] -- sequential replication -- is fundamental to interperiod learning across Market Years. Discussing an early experimental market[9] that was closed after only one trading period, Smith [1962; p. 114] notes that:

> There is therefore less opportunity for traders to gain experience and to modify their subsequent behaviour in the light of such experience. It is only through some learning mechanism of this kind that I can imagine the possibility of equilibrium being approached in any real market.

Hess [1972; p. 376] presents several suggestions about the learning process as a whole:

> As the participants in the market advance by learning from a situation of ignorance towards perfect information, observed prices should cluster more closely around their equilibrium value. Thus, as the market matures, the equilibrium price becomes both the expected and the observed price. In the limit, the supply-and-demand curves perfectly predict market behaviour. To be determined are the precision with which they predict the actual average price in less than perfect information conditions.

Although originally proposed by Hess in terms of the usual deviation about the sample mean, the conceptually correct calculation of course involves deviations around the (relevant) equilibrium price. For markets that are heavily damped there will be little or no difference between the two calculations, but for any study of convergence behaviour the difference is important.

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[8] See Easley and Ledyard [1981], Harrison [1982], and Harrison, Smith and Williams [1982] for recent efforts that concentrate on intraperiod learning behaviour.

[9] Presented in Chamberlin [1949].

In the context of experimental asset markets similar to ours, FPP examine Grossman's [1978] suggestion that sequential replication is necessary for convergence to a perfect foresight (or rational expectations) equilibrium. They note that:

> 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 [in our case, period C -- FHS], investors will be unable to incorporate period B price information in their period A decisions until after the first year of trading. [1981; p.18]

FPP call this their "swingback" hypothesis. In our three-period asset market, information about Period C must swingback to Period B before in turn influencing Period A prices. In short, there must be two such "swingbacks" for Period A prices to reflect the relevant private information pertaining to Periods B and C.

Harrison [1982] and Harrison, Smith and Williams [1982] formally model the Bayesian learning behaviour of traders in a sequentially stationary and non-stationary double oral auction for a perishable commodity. Traders begin in period 1 with appropriately diffuse priors about market price, and choose in each succeeding period how much weight to attach to the belief that the market equilibrium has shifted "fundamentally". If traders behave as if searching and bidding for "good" prices[10] from a fixed distribution in each period then con-

[10] Defined quite simply for sellers as those prices greater than the currently perceived equilibrium price, and conversely for buyers as those prices perceived to be below the current period equilibrium.

vergence in observed bids and offers follows a common public perception of the equilibrium price based on such learning behaviour[11]. The key to explaining convergence, then, is the increasing precision of this public (common) perception. In the present case of asset markets, this argument implies that the extent of any "swingback" depends as much on the attainment of equilibrium prices (in Period C) in the sense of absence of bias, as the precision of that perceived equilibrium.

3.5 TESTABLE HYPOTHESES

We now list the empirical hypotheses suggested by our discussion in the last two subsections of learning and equilibrium in stationary non-stochastic asset markets. All hypotheses will be presented as null hypotheses with the understanding that the implict alternative hypothesis in each case is a two tail, compound hypothesis; i.e., if a and b represent two parameters of interest then the null is of the form a = b and the alternative is a <> b. In this section we will use the convention that variables in uppercase represent a priori values given by theory and market parameters, while lowercase symbols represent the mean value (arithmetic average) of observed variables over the relevant time period.

In Section 3.3 we showed that several ways of deriving period C equilibrium all led to the same result, depicted in Figure 1. An implication of the discussion of learning is that equilibrium is not likely to be attained immediately; therefore hypotheses concerning prices will be defined in terms of the mean transacted price for each Year. We will also test the hypotheses using

[11] Moreover, there is strong experimental evidence that a competitive equilibrium solution in a double-oral auction constitutes a static Nash equilibrium -- see Smith, Williams, Bratton, and Vannoni [1982]. Thus such equilibria, once attained, will be self-reinforcing.

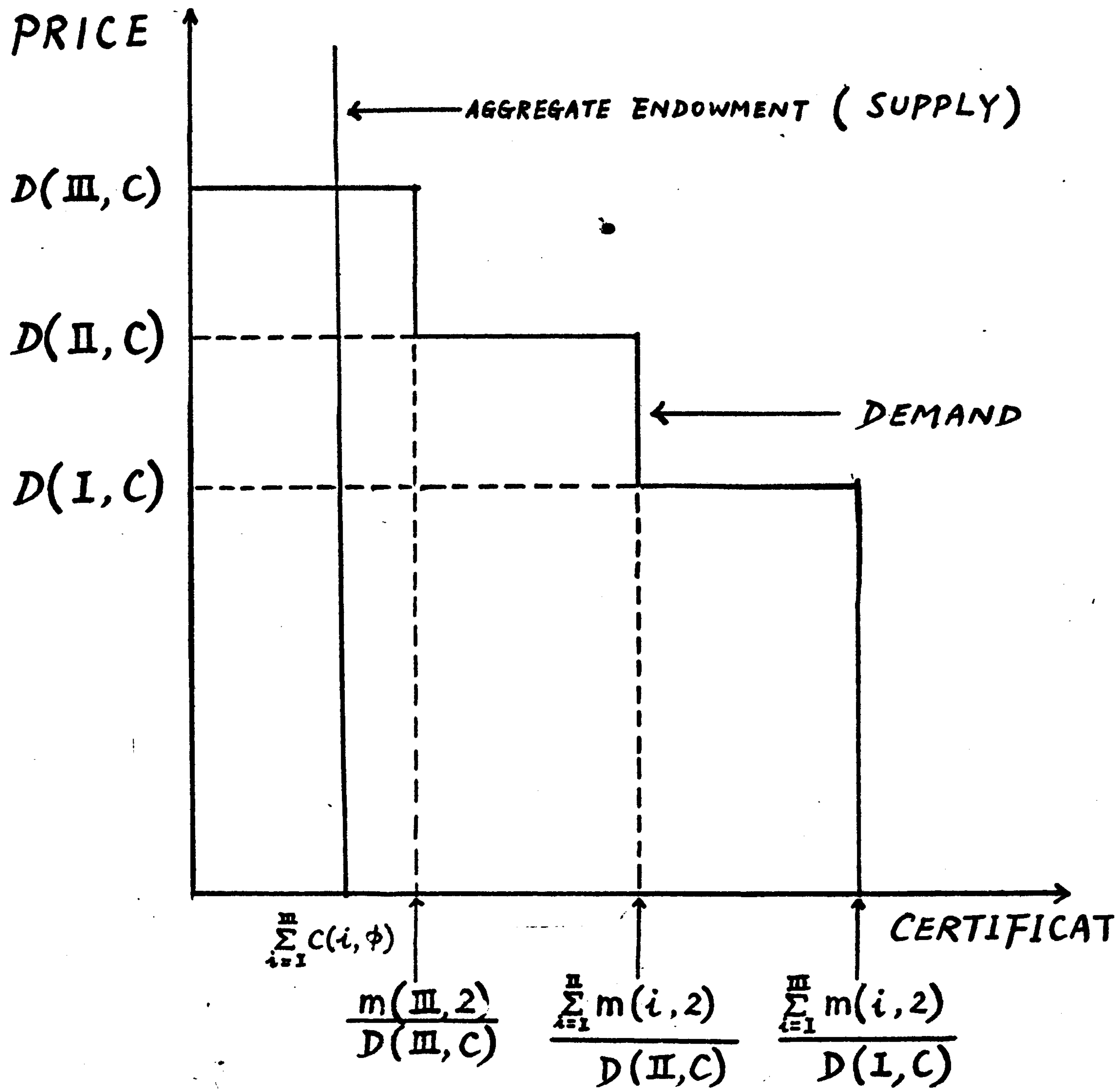

PRICE
AGGREGATE ENDOWMENT (SUPPLY)
D(III, C)
D(II, C)
DEMAND
D(I, C)
CERTIFICAT
$\sum_{i=I}^{III} c(i,\phi)$
$\frac{m(III,2)}{D(III,C)}$
$\frac{\sum_{i=I}^{II} m(i,2)}{D(II,C)}$
$\frac{\sum_{i=I}^{III} m(i,2)}{D(I,C)}$

FIGURE 1

closing price data. The first three hypotheses, then, concern period C:

H1: for experiments 1 and 3

$$p(C) = \max_i D(i,C) = P^*(C)$$

In words, the mean transacted period C spot price will equal the theoretical equilibrium price. Given our model parameters, the predicted prices are \$0.60 and \$0.70 for experiments 1 and 3 respectively. For a complete summary of all price predictions see Table 1; hereafter only the hypotheses and not the specific parameter values will be listed.

We may also apply H1 to the periods A and B futures price data (period C delivery) since the theoretical argument is the same. Therefore, for period A,

H2: For experiments 2 and 4

$$p(C,A) = \max_i D(i,C) = P^*(C)$$

and for the period C futures price transacted in period B,

H3: For experiments 2 and 4

$$p(C,B) = \max_i D(i,C) = P^*(C) .$$

The mean transacted futures price in periods A and B will converge to the notional Walrasian equilibrium price. By "converge" we mean that the average (resp. closing) price will be insignificantly different from the predicted price.

Private information price predictions for period B spot prices are captured by the following hypothesis:

H4: For experiments 1, 2, 3 and 4

$$p(B) = P(B|PI) = \max_i (D(i,B) + D(i,C))$$

The mean transacted period B spot price will converge to the private information equilibrium price. The competing hypothesis to H4 is the perfect foresight hypothesis given by:

H5: For experiments 1, 2, 3, and 4,

$$p(B) = P(B|PF) = \max_i D(i,B) + \max_i D(i,C)$$

$$= \max_i D(i,B) + P^{*}(C) .$$

The mean transacted period B spot price will converge to the perfect foresight equilibrium price.

Similarly, for period A spot prices:

H6: For experiments 1, 2, 3, and 4,

$$p(A) = P(A|PI) = \max_i (D(i,A) + D(i,B) + D(i,C)) .$$

H7: For experiments 1, 2, 3, and 4,

$$p(A) = P(A|PF) = \max_i D(i,A) + \max_i D(i,B) + \max_i D(i,C)$$

The relevance of our Market Information reservation price concept and the role of futures markets in conveying equilibrium price information is captured by our next hypothesis. Recall from the discussion in Section 3.3 that information incorporated in futures prices raises the reservation spot prices and the lower bound on the equilibrium prices. Taking $I = [P(.|MI) - P(.|PI)]$ as a proxy for this information, we hypothesize the following regression relationship:

$$(p(.|futures) - p(.|spot))_t = a + b (I)_t$$

p(.|futures) represents the transacted period A and B spot prices given an operating futures market (experiments 2 and 4); and p(.|spot) represents the transacted period A and B spot prices when only spot markets are operating (experiments 1 and 3). Given our model parameters, we would expect transacted spot prices to be higher when futures markets are active relative to when they are not. We have no sharp prior for the intercept term if the relationship is not linear; however assuming that it is our specific hypothesis is:

H8: Comparing experiments 1 and 2, or 3 and 4,

$a = 0$ and $b > 0$.

Other hypotheses regarding the informational role of futures markets implicit in our discussion in Section 3.4 may now be formulated explicitly:

H9: For all experiments, period A spot prices will converge in fewer market years to an equilibrium when there exists a market for futures trading relative to a spot-only regime.

H10: For all experiments, period B spot prices will converge in fewer market years to an equilibrium when there exists a market for futures trading relative to a spot-only regime.

The FPP "swingback" hypothesis was also discussed in Section 3.4, and is represented by:

H11: For experiments 1 and 3 and for each market year, convergence in period A occurs after convergence in period B, which in turn follows convergence in period C.

The impact of futures market trading on agents' ability to learn about market clearing prices can be operationalized by examining the standard deviation (or coefficient of variation) of transacted prices. The conjecture, stemming from our discussion in Section 3.4, is that the standard deviation of transacted prices is a proxy for (the reciprocal) of an agent's precision concerning the underlying market clearing price. Therefore, the hypothesis is:

> H12: The coefficient of variation of transacted spot prices will be smaller when futures trading opportunities exist.

We shall employ the coefficient of variation of transacted spot prices when testing this hypothesis, since the perfect foresight equilibrium prices vary from experiment to experiment.

Finally, we will examine two hypotheses stemming from the discussion in Section 3.3 about the final allocation of certificate holdings at the end of each trading period. These are:

> H13: The allocation of certificate holdings will be that of the private information equilibrium.

> H14: The allocation of certificate holdings will be that of the perfect foresight equilibrium.

In other words, all certificates will be held by agents of the type which has the highest reservation price, under the various assumptions of how these prices are formed.

Section 4

EXPERIMENTAL EVIDENCE

We discuss the results of our four experiments in two subsections. The first provides a descriptive account of the results, providing the reader with our application of Savage's renowned "Interocular Trauma Test"; the second section takes up the testable hypotheses introduced above in a somewhat more formal statistical manner.

4.1 THE EXPERIMENTAL RESULTS

The complete set of experiments, again, is:

1. A pure stock market with three period-specific spot certificates, and with inexperienced subjects.
2. A pure stock market with two period-specific spot certificates and a third-period futures certificate tradeable simultaneously with the spot contracts. This experiment also uses inexperienced subjects.
3. The same institution as Experiment 1, but with experienced subjects.
4. The same institution as Experiment 2, but with experienced subjects.

It is convenient to consider Experiments 1 and 2 as a pair, and then likewise with Experiments 3 and 4.

4.1.1 Results With Inexperienced Subjects

Tables 3 and 4 summarize the observed price behaviour in our four experiments. For ease of comparison, we first list the numerical values of the theoretical spot equilibria introduced in Section 3.3 for each experiment, based on the parameters in Table 1. For each market year and trading period we then show the Closing Transaction Price (spot only for Experiments 1 and 3; Spot and Futures for Experiments 2 and 4), the Mean (and Standard Deviation in parentheses) of the Transacted Prices, and the same statistics for Non-Transacted Prices[12]. Figures 2 and 3 graphically display the time series data on transacted prices; **X** refers to spot prices and **O** to futures prices.

Consider first the Period C prices over the lives of the first two experiments. By Year 2 the mean price in Experiment 1 was only one cent short of the equilibrium level of $0.60, with a standard error of only 4 cents. In Experiment 2 the futures market in Period C certificates does not settle down to the equilibrium level of $0.60 until Period B of Year 3; note, with a standard deviation of only one cent or less it thereafter provides a very clear signal as to the value of a Period C certificate. Our Period C results with inexperienced subjects are therefore mixed -- although the price of futures contract settles down more quickly than that of the spot Period C contract, its bias in Year 1 is much greater[13].

---

[12] The term "Transacted Prices" refers to those prices at which a transaction occurred, as distinct from unnaccepted bids or offers.

[13] Root Mean Squared Deviation (RMSD) from the equilibrium value (not the sample average) provides a statistic that allows for both bias and variance. In Periods A and B the futures price RMSD is 0.076 and 0.175, respectively; the Period C spot price RMSD is 0.099 by comparison.

TABLE 3. OBSERVED AND PREDICTED PRICES IN EXPERIMENTS 1 AND 3

EXPERIMENT	YEAR	PERIOD	THEORETICAL SPOT EQUILIBRIUM PRICES Private	THEORETICAL SPOT EQUILIBRIUM PRICES Perfect	CLOSING TRANSACTED PRICES Spot	MEAN TRANSACTED PRICE (& STANDARD DEVIATION) Spot	MEAN NON-TRANSACTED PRICE (& STANDARD DEVIATION) Spot
1	1	A	$1.15	$1.45	$1.00	$0.93 (0.18)	$0.85 (0.15)
		B	0.90	1.05	0.90	0.91 (0.04)	0.87 (0.12)
		C	0.60	0.60	0.60	0.63 (0.10)	0.61 (0.17)
	2	A	1.15	1.45	1.10	1.02 (0.08)	1.01 (0.10)
		B	0.90	1.05	0.85	0.89 (0.02)	0.89 (0.07)
		C	0.60	0.60	0.58	0.59 (0.04)	0.59 (0.08)
	3	A	1.15	1.45	1.16	1.07 (0.08)	1.08 (0.09)
		B	0.90	1.05	0.90	0.90 (0.02)	0.90 (0.07)
		C	0.60	0.60	0.60	0.59 (0.02)	0.54 (0.13)
3	1	A	1.35	1.85	1.46	1.36 (0.09)	1.33 (0.15)
		B	1.00	1.15	1.00	0.99 (0.06)	1.00 (0.09)
		C	0.70	0.70	0.60	0.57 (0.10)	0.65 (0.12)
	2	A	1.35	1.85	1.50	1.44 (0.06)	1.50 (0.14)
		B	1.00	1.15	1.01	1.02 (0.02)	1.01 (0.03)
		C	0.70	0.70	0.68	0.62 (0.03)	0.67 (0.12)
	3	A	1.35	1.85	1.70	1.61 (0.05)	1.59 (0.12)
		B	1.00	1.15	1.05	1.03 (0.01)	1.03 (0.08)
		C	0.70	0.70	0.70	0.67 (0.02)	0.65 (0.12)
	4	A	1.35	1.85	1.72	1.70 (0.03)	1.67 (0.13)
		B	1.00	1.15	1.11	1.09 (0.03)	1.08 (0.04)
		C	0.70	0.70	0.70	0.68 (0.01)	0.70 (0.07)
	5	A	1.35	1.85	1.83	1.77 (0.04)	1.78 (0.04)
		B	1.00	1.15	1.14	1.15 (0.004)	1.11 (0.08)
		C	0.70	0.70	0.70	0.69 (0.003)	0.71 (0.05)

TABLE 4. OBSERVED AND PREDICTED PRICES IN EXPERIMENTS 2 AND 4

EXPERIMENT	YEAR	PERIOD	THEORETICAL SPOT EQUILIBRIUM PRICES			CLOSING TRANSACTED PRICES		MEAN TRANSACTED PRICE (& STANDARD DEVIATION)		MEAN NON-TRANSACTED PRICE (& STANDARD DEVIATION)	
			Private	Market	Perfect	Spot	Futures	Spot	Futures	Spot	Futures
2	1	A	$1.15	$1.25	$1.45	$1.15	$0.70	$1.01 (0.11)	$0.64 (0.07)	$1.03 (0.11,	$0.65 (0.13)
		B	0.90	1.05	1.05	0.97	0.75	1.02 (0.05)	0.77 (0.04)	1.00 (0.12)	0.78 (0.08)
	2	A	1.15	1.25	1.45	1.10	0.70	1.12 (0.06)	0.70 (0.03)	1.12 (0.07)	0.71 (0.07)
		B	0.90	1.05	1.05	1.00	0.56	1.00 (0.001)	0.57 (0.03)	0.91 (0.10)	0.67 (0.06)
	3	A	1.15	1.25	1.45	1.16	0.62	1.15 (0.02)	0.65 (0.02)	1.12 (0.15)	0.66 (0.06)
		B	0.90	1.05	1.05	0.90	0.62	0.89 (0.02)	0.60 (0.01)	0.84 (0.14)	0.60 (0.03)
	4	A	1.15	1.25	1.45	1.17	0.61	1.17 (0.004)	0.60 (0.01)	1.08 (0.18)	0.60 (0.04)
		B	0.90	1.05	1.05	0.90	0.60	0.90 (0.003)	0.60 (0.003)	0.92 (0.21)	0.61 (0.02)
	5	A	1.15	1.25	1.45	1.18	0.59	1.17 (0.003)	0.59 (0.001)	1.18 (0.11)	0.59 (0.001)
		B	0.90	1.05	1.05	0.89	0.59	0.90 (0.003)	0.60 (0.003)	0.90 (0.04)	0.59 (0.03)
4	1	A	1.30	1.75	2.00	1.60	0.75	1.49 (0.14)	0.75 (0.001)	1.34 (0.24)	0.69 (0.06)
		B	1.10	1.25	1.25	1.09	0.76	1.07 (0.10)	0.72 (0.09)	1.06 (0.09)	0.64 (0.12)
	2	A	1.30	1.75	2.00	1.72	0.77	1.67 (0.06)	0.76 (0.01)	1.67 (0.09)	0.75 (0.03)
		B	1.10	1.25	1.25	1.21	0.79	1.17 (0.02)	0.78 (0.01)	1.17 (0.06)	0.79 (0.02)
	3	A	1.30	1.75	2.00	1.95	0.75	1.85 (0.08)	0.75 (0.001)	1.83 (0.09)	0.75 (0.02)
		B	1.10	1.25	1.25	1.25	0.79	1.24 (0.01)	0.79 (0.004)	1.21 (0.04)	.79 (0.02)
	4	A	1.30	1.05	2.00	1.99	0.79	1.98 (0.01)	0.78 (0.01)	1.96 (0.06)	0.76 (0.04)
		B	1.10	1.25	1.25	1.25	0.80	1.25 (0.001)	0.80 (0.003)	1.25 (0.01)	0.80 (0.005)
	5	A	1.30	1.75	2.00	2.05	0.80	2.02 (0.03)	0.80 (0.01)	2.01 (0.05)	0.79 (0.01)
		B	1.10	1.25	1.25	1.24	0.80	1.23 (0.02)	0.81 (0.01)	1.20 (0.06)	0.81 (0.01)

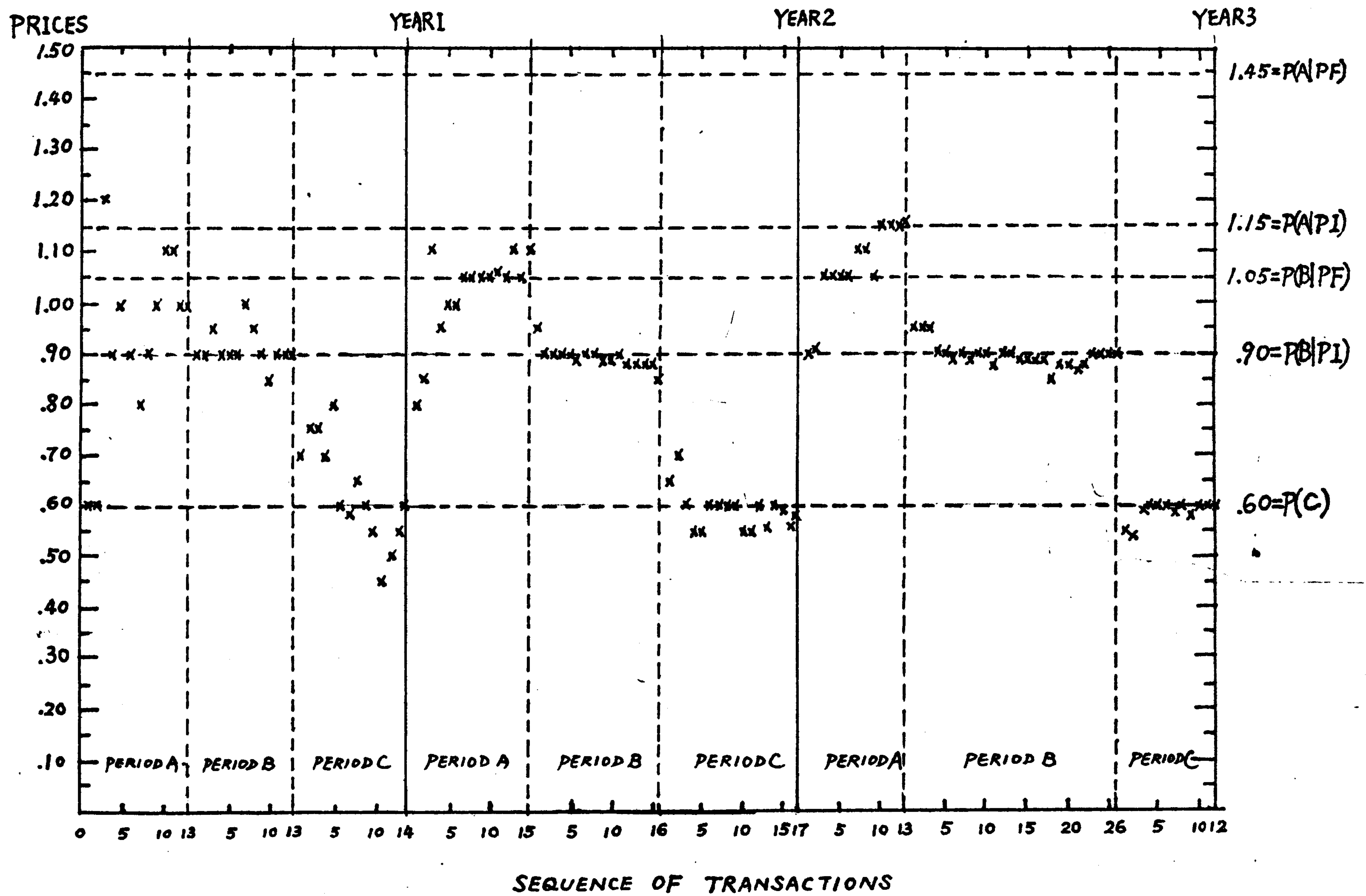
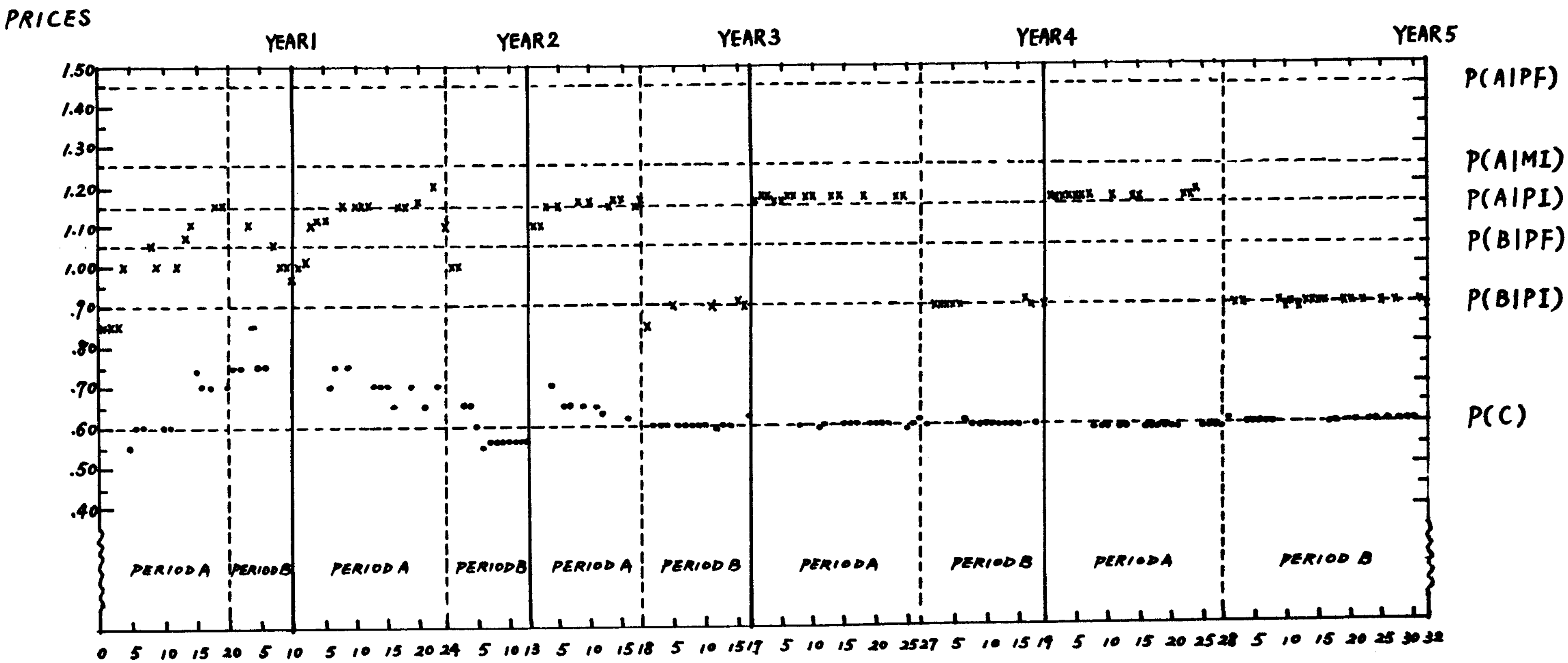

PRICES
YEAR1
YEAR2
YEAR3
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
1.45=P(A|PF)
1.15=P(A|PI)
1.05=P(B|PF)
.90=P(B|PI)
.60=P(C)
PERIOD A
PERIOD B
PERIOD C
PERIOD A
PERIOD B
PERIOD C
PERIOD A
PERIOD B
PERIOD C
0 5 10 13 5 10 13 5 10 14 5 10 15 5 10 16 5 10 15 17 5 10 13 5 10 15 20 26 5 10 12
SEQUENCE OF TRANSACTIONS

FIGURE 2



SEQUENCE OF TRANSACTIONS

FIGURE 3

Period B spot prices in both experiments eventually converge on the private information equilibrium and do not converge to the PF equilibrium. Convergence to the PI equilibrium in Period B is rapid in Experiment 1; again, in Experiment 2 we find the comparable price converging more closely but with a geater initial bias. We observe more rapid convergence to the Period A PI equilibrium in Experiment 2 (Year 2) than in Experiment 1 (Year 3). This is true with respect to both bias and precision.

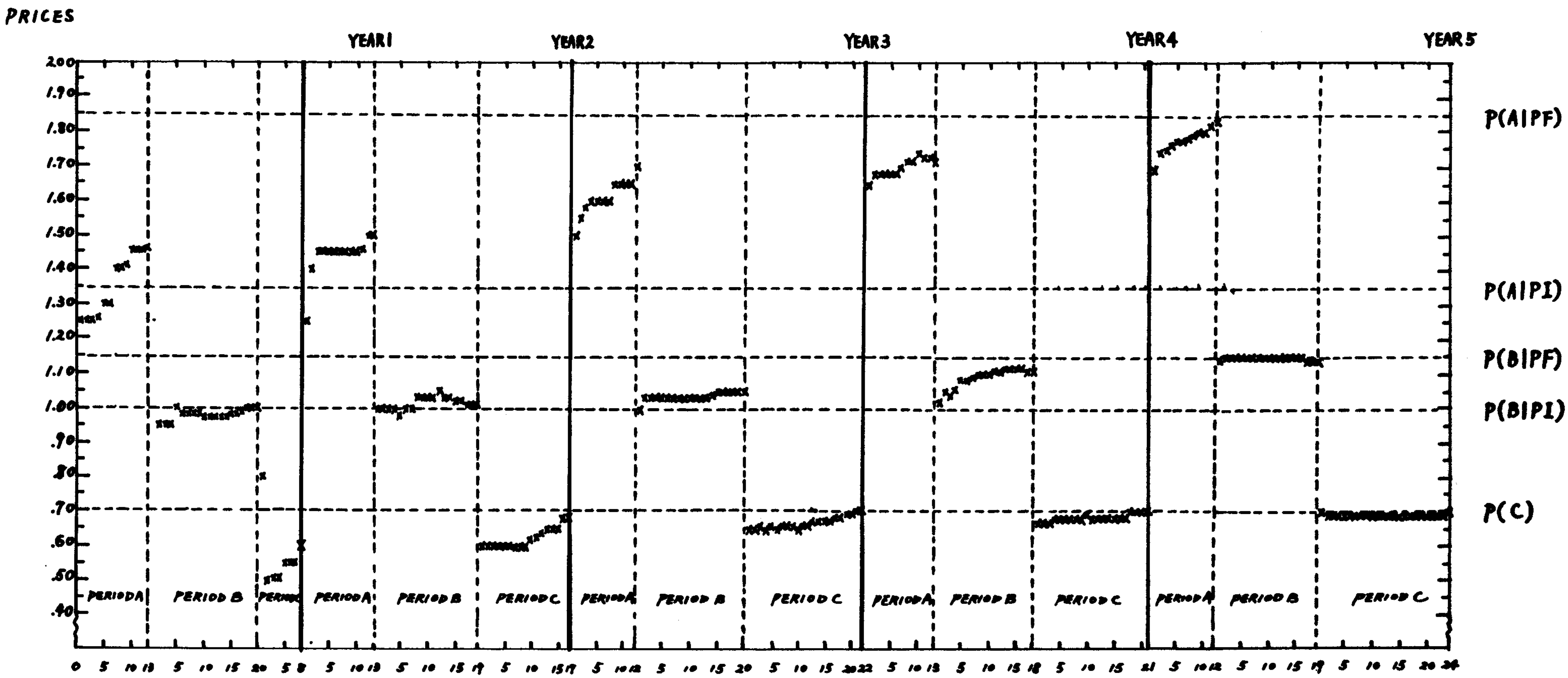
We attribute the failure to converge to a perfect foresight equilibrium or a market information equilibrium to the inability of inexperienced traders to employ more profitable strategies. Quite simply, they did not use the market signals available.

4.1.2 Results With Experienced Agents

Experiments 3 and 4 repeat the institutional design of Experiments 1 and 2, respectively, but with experienced subjects. Eight out of nine of our traders had previous experience with the experimental design in experiment 4, and all nine had such experience in experiment 3. The results are shown in Tables 3 and 4, and Figures 4 and 5.

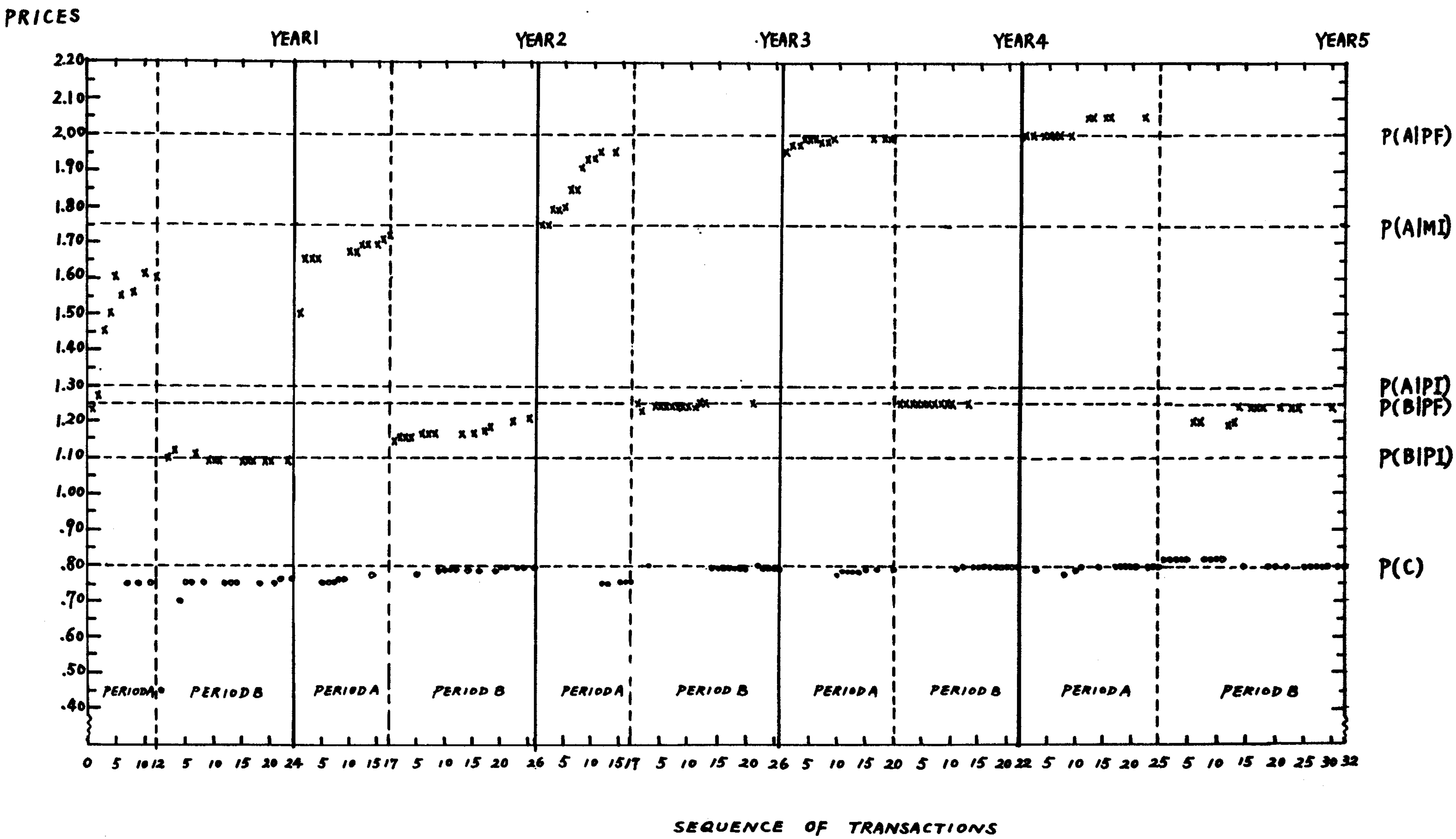
Period C prices[14] in Experiment 3 do not converge to the equilibrium value of $0.70 (using closing transacted prices) until Year 3, so it is not surprising that Period A and B mean prices are at the PI equilibrium in Year 1. Only when Period C prices do show repeated signs of converging (by Year 4, given the initial convergence in Year 3) do Period A and B prices significantly tend towards the PF equilibrium. This trend is not completed for Period A prices by Year 5, but Period A prices are strongly tending towards the PF equilibrium

[14] Unless otherwise stated, references to "prices" are to transaction prices.



SEQUENCE OF TRANSACTIONS

FIGURE 4


PRICES
YEAR1
YEAR2
YEAR3
YEAR4
YEAR5
2.20
2.10
2.00
1.90
1.80
1.70
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1.50
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1.30
1.20
1.10
1.00
.90
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.70
.60
.50
.40
P(A|PF)
P(A|MI)
P(A|PI)
P(B|PF)
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PERIOD A
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PERIOD B
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PERIOD A
PERIOD B
0 5 10 12 5 10 15 20 24 5 10 15 17 5 10 15 20 26 5 10 15 17 5 10 15 20 26 5 10 15 20 5 10 15 20 22 5 10 15 20 25 5 10 15 20 25 30 32
SEQUENCE OF TRANSACTIONS

FIGURE 5

value.

Experiment 4 strikingly demonstrates the role of futures market for experienced traders who have become aware of the informational value of futures prices. The equilibrium value of a Period C futures certificate in this case is $0.80. By Year 2 the average price of the futures certificate reflects this value; moreover, Periods A and B of that year provide a clear repeated signal to this effect. By Year 3 Period B spot prices have converged on the MI or PF equilibria (which are identical here), and remain significantly above the PI equilibrium values. Similarly, mean Period A spot prices in Year 3 ($1.85) are roughly mid-way between the MI equilibrium ($1.75) and the PF equilibrium ($2.00). By Year 4 all spot prices have converged to the PF equilibrium.

In Year 5 of Experiment 4 we randomly re-assigned agents to different dividend profiles, without altering the aggregate market parameters. The issue here is the ability of agents to distinguish the market signal from their private signal (viz., their own dividend profile) -- the essence of our competing equilibrium notions. Despite a "technical reaction" of sorts, the results essentially repeat the behaviour of Year 4. The fact that we observe convergence to the PF price in Year 4 indeed tells us that agents had made the distinction in forming their trading strategies between private and market signals; our Year 5 results confirm this conclusion.

The Closing Transacted Prices shown for each experiment also reveal the presence of significant intra-period learning behaviour. They are typically higher than the corresponding average transacted prices, and closer to the average price behaviour in the succeeding comparable trading period.

4.2 EVALUATING THE TESTABLE HYPOTHESES

4.2.1 Price Convergence Hypotheses

Table 5 presents the results for hypotheses H1 through H7 using 95% confidence intervals for the mean transacted price in the final Market Year. When examining these results the reader should keep in mind the following comments and qualifications. That H1 is accepted for Experiment 1 and rejected for Experiment 3 can be explained by noting that experiments using inexperienced subjects (Experiments 1 and 2) displayed period C price convergence from above and that the dispersion of transacted prices within a Market Year (from which confidence intervals were computed) was consistently larger for inexperienced than for experienced traders[15]. The fact that the coefficient of variation was consistently smaller for experienced traders suggests that the inexperienced/experienced distinction is a meaningful one. As noted previously, one can characterize agents' reservation price behaviour by their subjective probability distribution. A smaller coefficient of variation, then, suggests that experienced traders behave as if they hold their probability beliefs with greater precision than inexperienced traders. Thus they will not accept bids or offers "too far away" from the expected value of the market clearing price. If we were to use closing transacted prices as the location parameter estimate for the the 95% confidence interval we would accept H1 for Experiment 3.

---

[15] Convergence-from-above and the larger standard deviation of transacted prices implied wider 95% cofidence intervals for Experiment 1 then for Experiment 3. Hence, there was a greater likelihood of accepting the null hypothesis (H1) for the Market Years in Experiment 1. Since experienced traders typically displayed a smaller standard deviation of transacted prices, being very close to the equilibrium price (only one cent off, for example) makes it difficult to formally accept the null hypothesis. This is the reason that t statistics were not reported in our analysis. For Experiment 1, period C, the coefficient of variation (relative to the equilibrium price) ranged from 0.167 in the first Year to 0.033 in the final Year. For Experiment 2, the range was 0.14 to 0.004.

TABLE 5

Summary of Confidence Intervals for H1 - H7

Intervals refer to final Market Year

EXPERIMENT	PERIOD Actual (Delivery)	95% CONFIDENCE INTERVAL on MEAN TRANSACT. PRICE	ACCEPT or REJECT HYPOTHESES
1	C	0.58 < 0.59 < 0.60	Accept H1
3	C	0.688 < 0.69 < 0.692	Reject H1
2	A (C)	0.59	Reject H2
4	A (C)	0.796 < 0.80 < 0.804	Accept H2
2	B (C)	0.598 < 0.60 < 0.602	Accept H3
4	B (C)	0.795 < 0.80 < 0.805	Accept H3
1	B	0.893 < 0.90 < 0.907	Accept H4 (PI) Reject H5 (PF)
2	B	0.898 < 0.90 < 0.902	Accept H4 (PI) Reject H5 (PF)
3	B	1.148 < 1.15 < 1.152	Reject H4 (PI) Accept H5 (PF)
4	B	1.25	Reject H4 (PI) Accept H5 (PF)
1	A	1.03 < 1.07 < 1.11	Reject H6 (PI) Reject H7 (PF)
2	A	1.168 < 1.17 < 1.172	Reject H6 (PI) Reject H7 (PF)
3	A	1.760 < 1.78 < 1.80	Reject H6 (PI) Reject H7 (PF)
4	A	2.00 < 2.02 < 2.04	Reject H6 (PI) Accept H7 (PF)

Although H2 is rejected for Year 5 of Experiment 2, we cannot reject it for Year 4. The standard deviation in Year 5 was so small (effectively zero in this case) that being only one cent off the equilibrium price causes one to formally reject the null hypothesis. Given the above caveats, we conclude that H1 through H3 are favored by the experimental data evidence; that is, all market experiments displayed fairly rapid convergence to the Period C equilibrium price. However, the convergence-from-above phenomena for inexperienced traders remains to be explained.

The distinction between experienced and inexperienced traders also makes a difference when comparing H4 and H5 -- the private information and perfect foresight price equilibria hypotheses. We firmly reject H5 for inexperienced traders (Experiments 1 and 2), but just as firmly accept H5 for experienced traders (Experiments 3 and 4). Experience in market trading, then, significantly affects the transacted prices.

The reason we must reject H6 and H7 for Experiment 2 is that by the final Market Year the transacted prices had already passed PI (we cannot reject H6 for Market Years 2, 3 and 4) and were slowly approaching the PF equilibrium (see Figure 3). This is indirect evidence that the Market Information reservation price strategies were in operation (albeit imperfectly) and that some traders were using futures prices as signals for enlarged future period profit opportunities.

In Experiment 3, period A transacted prices began in Year 1 at the private information equilibrium price (we cannot reject H6 for Year 1) and then moved up towards the PF equilibrium price. If we use the Year 5 closing price, we cannot reject H7.

Turning now to H11, the "swing-back" hypothesis, we find that a comparison of the sequence of period specific price convergence statistics for Experiments 1 and 3 indicates that H11 is weakly supported (see Table 3). In Experiment 1, period C transacted prices converged by Year 1; period B prices converged to the PI equilibrium by Year 3 and period A prices never converged. Note that Experiment 1 only lasted for 3 Market Years. In Experiment 3 period C prices converged by Year 3 (using the closing transacted price as the criterion); period B prices converged to the PF equilibrium price by Year 5 and the period A prices, although clearly moving towards PF, did not quite converge. Given the extra trading period and fewer Market Years relative to the FPP study, it is not too surprising that our results for H11 are not as strong as those presented by FPP. We may nonetheless conclude that our results provide evidence in favor of a swing-back effect for repetitive, stationary markets.

We now evaluate H8; Table 6 presents our regression tests concerning the possible relevance of market information reservation price strategies. The form of the regression equation, again, is as follows:

$$Y_t = a + b(I_t) + e_t$$

where Y is defined as the difference between the average transacted spot price (t refers to periods A and B) with futures trading and the average transacted spot price with spot trading only; I is the difference between the equilibrium MI and PI prices (this difference equals $0.10 in period A and $0.15 in period B); and e is the error disturbance term assumed to be an i.i.d. random variable. When implementing our test of H8 we were forced to use average price data since the individual data points were not comparable across experiments.

TABLE 6

Regression Results For H8: Market Information Price Behaviour

Experiment Number	a	b	d	R^2	t .05 level
1 and 2	0.12 (1.16)	-0.33 (-0.41)	1.13	0.04	2.57
1 and 2	0	0.59 (3.58)	1.14	0.72	2.78
3 and 4	0.09 (2.28)	0.30 (2.52)	0.65	0.44	2.30
3 and 4	0	0.54 (8.42)	1.39	0.88	2.26

The regression equation was run twice for each experiment pair: once using unconstrained OLS, and then constraining the intercept to zero. The intercept constraint was used to check whether the estimated coefficients were orthogonal; clearly they are not. We also report the Durbin-Watson "d" statistic, critical 95% values of the Student's t distribution, and the R-squared.

The results in Table 6 must be interpreted with some caution. An inspection of the relevant upper and lower cut-off points for the "d" distribution reveals that one cannot reject the hypothesis of positive first order correlation for the unconstrained OLS estimates concerning Experiments 3 and 4. Hence, the t statistics for this case are biased upwards. This does no harm in rejecting the hypothesis that the intercept term is significantly different from zero. However, the significance of the slope coefficient is somewhat suspect. The fact that the sign of the slope coefficient is positive and that the constrained estimate is positive, large, and significantly different from zero leads us to conclude that the data from experiments 3 and 4 does support H8. However, the evidence from the first two experiements does not support H8. This is not unexpected since the PF equilibrium was not attained in these experiments. Although our results are mixed on this issue, they are suggestive that Market Information price strategic behaviour was in evidence -- at least for the experienced traders. Indirect evidence in favor of H8 is indicated by the fact that in Experiment 4 the PI equilibrium was surpassed in the very first Market Year.

Hypotheses H9 and H10 concern the possible role futures markets may have in speeding spot price convergence to <u>an</u> equilibrium value. When evaluating these conjectures, we consider both PI and PF equilibrium predictions. For the sake of H9 and H10 we consider convergence completed when either the average transacted price or the closing price is insignificantly different from the relevant equilibrium price. Consider the evidence pertaining to period A spot price convergence. Experiment 1 converged to the PI equilibrium by Year 3 and never converged to the the PF price. Experiment 2 converged to PI by <u>Year 2</u> and also never converged to the PF price. This comparison suggests that the presence of futures transacted prices did aid in convergence, but to an inefficient equilibrium. The evidence from Experiments 3 and 4 is more forceful. In Experiment 3 prices converged to the PF price by Year 5 but in Experiment 4 prices converged by <u>Year 4</u>. Thus we accept H9.

The convergence price patterns for period B spot prices are very similiar and imply an even stronger "speed-up" effect of futures markets on spot price convergence. We claim that the data evidence very strongly supports H10.

Finally, we consider the evidence on H12 -- the conjecture that the information content of futures prices is reflected by lower standard deviations of transacted prices when futures markets are active. Table 7 shows the coefficient of variation (calculated relative to the average transacted price) by Year and period for each of the four experiments.

TABLE 7

Coefficient of Variation Comparison: H12

YR.	Per.	EXP. #1 CV	EXP. #2 CV	EXP. #3 CV	EXP. #4 CV
1	A	0.193	0.113	0.065	0.096
1	B	0.040	0.050	0.064	0.009
2	A	0.087	0.050	0.043	0.035
2	B	0.023	0.0	0.017	0.017
3	A	0.079	0.020	0.033	0.042
3	B	0.025	0.026	0.012	0.005
4	A	N/A	0.003	0.016	0.006
4	B	N/A	0.004	0.028	0.0
5	A	N/A	0.003	0.020	0.012
5	B	N/A	0.004	0.003	0.017

For Experiments 1 and 2, we see that in 5 out of 6 instances spot prices displayed less (or equal) variability when futures markets were active. For Experiments 3 and 4, the same comparison indicates less (or equal) variability in 7 out of 10 instances. An F test of significance supports the hypothesis that the standard deviations of transacted prices were different between the two market regimes for both experienced and inexperienced traders. This difference favored a smaller standard deviation of transacted prices when futures markets were in operation. Thus we accept H12.

4.2.2 Allocation Hypotheses

The PI and PF equilibrium concepts each imply a particular final allocation of certificates at the end of trading in Periods A and B of each market year. They do not differ in their respective predictions for Period C. Table 8 shows the alternative predicted allocations by trader type for each experiment. It also shows the deviation of observed holdings (at the end of each period) from the respective predictions. Zero deviations represent correctly predicted allocations. Note that these deviations must sum to zero across agents for each period[16].

The observed results for Experiments 1 and 2 do not agree with either predicted allocation. Allocations observed in Experiment 2 generally came closer to the PF than the PI allocation after Year 3, but we are unable to discriminate between the two alternative predictions for Experiment 1. This is really not too surprising, given that our inexperienced traders evidently had not yet learned effective strategies.

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[16] Considerable care was taken to ensure that the transactions data did not violate any individual's budget constraints (e.g., no short sales in Experiments 2 and 4). A small number of such errors were discovered ex post the corresponding experiment, and the relevant transactions judiciously deleted. Full details of the data, and the nature of these corrections, are available from the authors on request.

TABLE 8 OBSERVED AND PREDICTED CERTIFICATE ALLOCATIONS

EXPERIMENT	YEAR	PERIOD	PRIVATE INFORMATION EQUILIBRIUM Theoretical			PRIVATE INFORMATION EQUILIBRIUM (Actual-Theoretical)			PERFECT INFORMATION EQUILIBRIUM Theoretical			PERFECT INFORMATION EQUILIBRIUM (Actual-Theoretical)		
			I	II	III	I	II	III	I	II	III	I	II	III
1	1	A	0	18	0	4	-11	7	18	0	0	-14	7	7
		B	0	0	18	5	5	-10	0	18	0	5	-13	8
		C	0	0	18	4	0	-4	0	0	18	4	0	-4
	2	A	0	18	0	7	-8	1	18	0	0	-11	10	1
		B	0	0	18	4	4	-8	0	18	0	4	-14	10
		C	0	0	18	0	1	-1	0	0	18	0	1	-1
	3	A	0	18	0	12	-12	0	18	0	0	-6	6	0
		B	0	0	18	0	6	-6	0	18	0	0	-12	12
		C	0	0	18	0	1	-1	0	0	18	0	1	-1
2	1	A	0	18	0	9	-9	0	18	0	0	-9	9	0
		B	0	18	0	11	-12	1	0	0	18	14	6	-17
		C	0	18	0	8	-12	4	0	18	0	8	-12	4
	2	A	0	18	0	12	-12	0	18	0	0	-6	6	0
		B	0	18	0	12	-13	1	0	0	18	12	5	-17
		C	0	18	0	2	-5	3	0	18	0	2	-5	3
	3	A	0	18	0	11	-11	0	18	0	0	-7	7	0
		B	0	18	0	8	-8	0	0	0	18	8	10	-18
		C	0	18	0	1	-4	3	0	18	0	1	-4	3
	4	A	0	18	0	17	-17	0	18	0	0	-1	1	0
		B	0	18	0	14	-14	0	0	0	18	14	4	-18
		C	0	18	0	1	-3	2	0	18	0	1	-3	2
	5	A	0	18	0	18	-18	0	18	0	0	0	0	0
		B	0	18	0	11	-11	0	0	0	18	11	7	-18
		C	0	18	0	4	-6	2	0	18	0	4	-6	2

TABLE 8. OBSERVED AND PREDICTED CERTIFICATE ALLOCATIONS (continued)

EXPERIMENT	YEAR	PERIOD	PRIVATE INFORMATION EQUILIBRIUM Theoretical I	II	III	(Actual-Theoretical) I	II	III	PERFECT INFORMATION EQUILIBRIUM Theoretical I	II	III	(Actual-Theoretical) I	II	III
3	1	A	18	0	0	-14	14	0	0	18	0	4	-4	0
		B	0	0	18	3	1	-4	18	0	0	-15	1	14
		C	0	0	18	4	0	-4	0	0	18	4	0	-4
	2	A	18	0	0	-18	18	0	0	18	0	0	0	0
		B	0	0	18	5	2	-17	18	0	0	-3	2	1
		C	0	0	18	0	0	0	0	0	18	0	0	0
	3	A	18	0	0	-18	18	0	0	18	0	0	0	0
		B	0	0	18	16	2	-18	18	0	0	-2	2	0
		C	0	0	18	0	2	-2	0	0	18	0	2	-2
	4	A	18	0	0	-18	18	0	0	18	0	0	0	0
		B	0	0	18	18	0	-18	18	0	0	0	0	0
		C	0	0	18	0	0	0	0	0	18	0	0	0
	5	A	18	0	0	-18	18	0	0	18	0	0	0	0
		B	0	0	18	18	0	-18	0	0	18	0	0	0
		C	0	0	18	0	0	0	0	0	18	0	0	0
4	1	A	0	18	0	13	-14	1	18	0	0	-5	4	1
		B	0	0	18	1	13	-14	0	18	0	1	-5	4
		C	0	0	18	0	0	0	0	0	18	0	0	0
	2	A	0	18	0	13	-13	0	18	0	0	-5	5	0
		B	0	0	18	0	18	-18	0	18	0	0	0	0
		C	0	0	18	0	0	0	0	0	18	0	0	0
	3	A	0	18	0	13	-13	0	18	0	0	-5	5	0
		B	0	0	18	0	18	-18	0	18	0	0	0	0
		C	0	0	18	0	0	0	0	0	18	0	0	0
	4	A	0	18	0	18	-18	0	18	0	0	0	0	0
		B	0	0	18	7	11	-18	0	18	0	7	-7	0
		C	0	0	18	5	0	-5	0	0	18	5	0	-5
	5	A	0	18	0	14	-14	0	18	0	0	-4	4	0
		B	0	0	18	2	16	-18	0	18	0	2	-2	0
		C	0	0	18	2	1	-3	0	0	18	2	1	-3

The allocations in Experiments 3 and 4 on the whole converge reasonably quickly on the PF prediction. We are able to accept that prediction, as against the PI alternative, with little difficulty. However, the existence of futures markets did not appear to help much; although deviations from PF allocations were less in Year 1 in Experiment 3 than in Experiment 4, and roughly the same magnitude in Years 2 and 3, the deviations in subsequent years were substantial in Experiment 4 while the efficient allocation was obtained precisely in Experiment 3.

An examination of realized aggregate profits sheds some light on the issues of allocational inefficiencies. In Table 9 we list the aggregate profits actually received from the purchase, sale, and redemption of certificates within each Market Year as a percentage of "maximum" profits[17]. Note that it is possible for a trader to earn profits in excess of the "maximum" if he transacts at a price more favourable to him than the PF equilibrium price, but come at the expense of the counter-party to the transaction. Trading is a positive-sum game for our traders if they move towards the efficient PF allocation, but excess trading profits due to trade at non-equilibrium prices are zero-sum. Hence the maximum profit is 100% in the aggregate, and the actual aggregate profits are a measure of allocational efficiency (but not price efficiency).

The data in Table 9 very clearly suggest that traders' experience promotes allocational efficiency. Aggregate profits earned in Experiments 3 and 4 by experienced traders are all higher than the corresponding profits in Experiments 1 and 2 of inexperienced traders. Also, in each experiment, profits are generally higher in later market years. The major exception to this pattern --

[17] Maximum profits are those that would be earned in PF equilibrium trade. Trading commissions and profits which would be earned without trade are excluded.

TABLE 9

Aggregate Profits as a Percent of Maximum

YEAR	EXPERIMENT 1	2	3	4
1	17.9	-1.7	64.6	80.2
2	50.0	36.2	96.3	87.9
3	69.1	40.2	87.5	87.9
4	N/A	49.4	100.0	63.5
5	N/A	37.4	100.0	74.7

in Year 4 of Experiment 4 -- seems attributable to a single trader (of type I) who enthusiastically followed the very unprofitable strategy of buying up contracts in Period B[18]. The informational noise created by this aberrant behaviour (together with the noise deliberately introduced by shuffling dividend profiles) may have reduced the allocational efficiency and trading profits in the following Market Year. In any case, the existence of futures markets in Experiment 4 evidently was not sufficient to restore the perfect allocational efficiency observed in the last two Market Years of Experiment 3.

It is very interesting to observe that these deviations from PF equilibrium allocations occurred despite the very rapid convergence of prices to their PF values. Indeed, the price convergence was more rapid with futures markets -- compare Figures 4 and 5. This result is clearly inconsistent with the "Walrasian auctioneer" conception of the market adjustment process, but seems quite reasonable in light of our discussion in Section 3 which suggested that the price adjustment process is rather robust to deviant behaviour by a few indi-

[18] Incidentally, this trader was the one who was not experienced!

vidual traders.

Section 5

IMPLICATIONS FOR FURTHER WORK

Our experimental results generally support the conclusion that active futures markets tend to be associated with spot prices that reflect more efficient informational equilibria. The role of experience in the formulation of trading strategies is clearly demonstrated in our results. Similarly, the role of sequential replication in aiding convergence to such equilibria is evident. Finally, an experimental design for the study of futures market behaviour is established and evaluated.

We intend to extend our market experiments in several directions. The first is to add to our asset demand schedules contemporaneous production and consumption trading schedules, as in the seasonal carryover markets studied by Miller, Plott and Smith [1976], Williams [1979], and Plott and Uhl [1981]. Such stock-flow experimental markets allow examination of explicit Walrasian theories of intra-period dynamics with unchanging trading schedules[19], as well as the emergence and role of middlemen traders. These market provide a richer background setting for futures markets than the pure stock markets studied in the present paper.

Another important extension to our present experimental design is the introduction of "event uncertainty". This can be accomplished by allowing traders' period-specific certificate returns to be determined by a state of nature

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[19] We refer here to convergence to full equilibrium in a sequence of temporary equilibria.

(an event) whose realization is a random variable[20]. Implementing this more "realistic" design feature in our controlled market environment allows us to address a wider range of pertinent controversies in the study of futures markets. For example, theoretical predictions of spot price variability associated with and without active futures markets can be made using the techniques proposed in Salmon [1981]. These market model predictions can then be straightforwardly compared with actual experimental evidence. This allows an evaluation of the often-expressed concerns about the possibly destabilizing role futures markets have with respect to spot price variability and intertemporal resource allocation. The introduction of exogenous stochastic market parameters also allows us to examine empirically the theoretical results on prices as aggregators of private information.

Combining elements of middleman storage behaviour and event uncertainty in a three-period market year can provide an environment sufficiently rich to test the "blurring hypothesis" advanced by Friedman [1981]. This hypothesis asserts that in such environments a specific futures price may not be a (risk-adjusted) market forecast of the corresponding subsequent spot price.

We believe that the experimental approach to the study of futures markets developed in this paper provides a solid basis to examine these and other issues in the relevant theoretical literature.

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[20] See Plott and Sunder [1981] for several experimental markets with similar design features.

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Appendix A

INSTRUCTIONS FOR PURE STOCK MARKET EXPERIMENT

A.1 GENERAL

This is an experiment in the economics of market decision-making. Various research foundations have provided funds for this research. The instruction 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 by check.

In this experiment we are going to simulate a market in which you will buy and sell assets called certificates in a sequence of "market years". Each market year consists of three periods, the first of which will be called A, the second B and the third C. 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.

A.2 SPECIFIC INSTRUCTIONS

Your profits come from two possible sources -- from collecting certificate earnings on all certificates you hold at the end of each 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 a period you will be given the dollar amount 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) x (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 $0.10 per certificate (that is, the number listed on row 31 is .10), then your total certificate earnings in period A would be (5) x ($0.10) = $0.50. This number should be recorded on row 31 at the end of the period.

Sales from your certificate holdings increase your dollars on hand by the amount of the sale price. Similarly, purchases reduce your dollars on hand by the amount of the purchase price. Thus you can gain <u>or</u> lose money on the purchase and resale of certificates. At the end of period C 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 and cash. This is recorded on row 0 of period A in each year's information and record sheet. You may sell your initial certificate holdings, you may hold them for 1, 2 or 3 periods or you may buy additional certificates to hold. If you hold a certificate throughout all three periods then you receive "earnings per certificate" three times -- once at the end of period A, again at the end of period B and finally at the end of period C. Notice therefore that for each certificate you hold initially you can earn during the year <u>at least</u> the <u>sum</u> of the three "earnings per certificate" you receive at the end of periods A, B and C. You earn this amount if you do not sell that certificate during the entire year.

You may purchase (or sell) a certificate to hold during that period and for the remainder of the "market year". Thus, in period A you may buy (sell) certificates to hold (transfer) for periods A, B and C -- receiving (transfering) certificate earnings for each period. Likewise, you may trade in periods B and C for certificates to hold (transfer) in periods B and C.

In addition, at the beginning of each year you are provided twenty ($20.00) dollars 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 dollars on hand. You are free to buy and sell certificates as you wish according to the rules below. Your dollars on hand at the end of a year are determined by your initial amount of dollars on hand, earnings on certificate holdings at the end of each period and by gains and losses from purchases and sales of certificates. All dollars on hand at the end of a year in excess of the initial $20.00 endowment are yours to keep. These are your profits for the year.

A.3 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 certificate transaction in each period you must calculate and record your new holdings of certificates and dollars on hand. <u>Your</u>

holdings of certificates and dollars on hand may never go below zero. You must also enter the identification number of the buyer (seller).

3. At the end of each period (A, B and C) record your total certificate holdings and earnings on row 31. Record your end-of-period totals of "Number of Certificates" and "Dollars on Hand" on row 32. On row 33 compute your total end of period dollars on hand by adding your certificate earnings to your row 32 "Dollars on Hand".
4. The number of total certificates on row 32 and the total dollars on hand on row 33 should be carried forward to row 0 of period B.
5. At the end of period B, your computed total dollars on hand (certificate earnings plus dollars on hand) should be carried forward to row 0 of period C. Note at the end of period C no more transactions take place.
6. At the end of period C, compute your period C certificate earnings. Add this amount to your last "Dollars on Hand" entry and record on row 33. Count the total number of transactions in periods A, B and C and enter this number on row 34. Multiply this number by 0.01 and record the result on row 34 under the "Dollars on Hand" column. These are your transaction profits. Add the transaction profits to the total dollars on hand entry on row 33 and record the amount on row 35. From the row 35 total subtract $20.00 - your initial endowment. This is your profit for the market year. At the end of the 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. If this is a positive number, the experimenter will pay you this amount of money

plus $5.00 by check. If this entry is a negative number, then you will only receive $5.00.

A.4 MARKET ORGANIZATION

The market for these certificates is organized as follows. The market will be conducted in a series of "market years" each consisting of three periods lasting for between 5 and 7 minutes. The experimenter will warn when you when the period is about to close. Anyone wishing to purchase a unit is free to raise his hand and make a verbal bid to buy <u>one</u> certificate at a specified price, and anyone with units to sell is free to accept or not accept the bid. Likewise, anyone wishing to sell a unit is free to raise his hand and make a verbal offer to sell <u>one</u> at a specified price. If a bid or offer is accepted, a binding contract has been closed for a single unit, and the contracting parties will record the contract price to be included in their record sheet. When making a bid or offer, you must specify whether you wish to buy or sell a certificate. In the space provided on your sheet, record the identification number of the person you contracted with. Any ties in bids or acceptance will be resolved by random choice by the experimenter. <u>Except for the bids and their acceptance, you are not to speak to any other trader</u>. There are likely to be many bids or offers that are not accepted, but you are free to keep trying. You are free to make as much cash as you can.

A.5 RECORD SHEETS

YEAR ____ NAME: ____ I.D. #: ____

PERIOD A						PERIOD B						PERIOD C					
ROW				# OF CERT.	$ ON HAND	ROW				# OF CERT.	$ ON HAND	ROW				# OF CERT.	$ ON HAND
0						0						0					
	S or B	I.D. NUMBER	TRANSACTION PRICE				S or B	I.D. NUMBER	TRANSACTION PRICE				S or B	I.D. NUMBER	TRANSACTION PRICE		
1						1						1					
2						2						2					
3						3						3					
4						4						4					
5						5						5					
6						6						6					
7						7						7					
8						8						8					
9						9						9					
10						10						10					
11						11						11					
12						12						12					
13						13						13					
14						14						14					
15						15						15					
31	PER CERTIFICATE					31	PER CERTIFICATE					31	PER CERTIFICATE				
32						32						32	PER TRANSACTION				
33						33						33					

	S or B	I.D. NUMBER	TRANSACTION PRICE	# OF CERT.	$ ON HAND		S or B	I.D. NUMBER	TRANSACTION PRICE	# OF CERT.	$ ON HAND		S or B	I.D. NUMBER	TRANSACTION PRICE	# OF CERT.	$ ON HAND
16						16						16					
17						17						17					
18						18						18					
19						19						19					
20						20						20					
21						21						21					
22						22						22					
23						23						23					
24						24						24					
25						25						25					
26						26						26					
27						27						27					
28						28						28					
29						29						29					
30						30						30					
31		PER CERTIFICATE				31		PER CERTIFICATE				31		PER CERTIFICATE			
32						32						32		PER TRANSACTION			
33						33						33					
34						34						34					
35																	

Appendix B

INSTRUCTIONS FOR PURE STOCK/FUTURES MARKET EXPERIMENT

B.1 GENERAL

This is an experiment in the economics of market decision-making. Various research foundations have provided funds for this research. The instruction 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 by check.

In this experiment we are going to simulate a market in which you will buy and sell assets called <u>certificates</u> in a sequence of "market years". Each market year consists of three periods, the first of which will be called A, the second B and the third C. 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. <u>You are not to reveal this information to anyone</u>. It is your own private information.

B.2 SPECIFIC INSTRUCTIONS

Your profits come from two possible sources -- from collecting certificate earnings on all certificates you hold at the end of each period <u>and</u> 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 a period you will be given the dollar amount 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) x (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 $0.10 per certificate (that is, the number listed on row 31 is .10), then your total certificate earnings in period A would be (5) x ($0.10) = $0.50. This number should be recorded on row 31 at the end of the period.

Sales from your certificate holdings increase your dollars on hand by the amount of the sale price. Similarly, purchases reduce your dollars on hand by the amount of the purchase price. Thus you can gain <u>or</u> lose money on the purchase and resale of certificates. At the end of period C 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 and cash. This is recorded on row 0 of period A in each year's information and record sheet. You may sell your initial certificate holdings, you may hold them for 1, 2 or 3 periods or you may buy additional certificates to hold. If you hold a certificate throughout all three periods then you receive "earnings per certificate" three times -- once at the end of period A, again at the end of period B and finally at the end of period C. Notice therefore that for each certificate you hold initially you can earn during the year <u>at least</u> the <u>sum</u> of the three "earnings per certificate" you receive at the end of periods A, B and C. You earn this amount if you do not sell that certificate during the entire year.

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

1. You may purchase (or sell) a certificate to hold during that period and for the remainder of the "market year". Thus, in period A you may buy (sell) ordinary certificates to hold (transfer) for periods A, B and C -- receiving (transfering) certificate earnings for each period. Likewise, you may trade in period B for certificates to hold (transfer)in periods B and C.

2. You may purchase (or sell) certificates to hold only in period C (if you are a purchaser) or to hold in periods A and B (if you are a seller). These are called Period C Certificates. If you purchase it, you hold it only during period C. If you sell a Period C Certificate you hold it only during periods A and B; the trader you sell it to holds it during period C. Note that you may not sell a Period C Certificate if you do not currently hold any certificates. Remember that you are allowed to buy and sell Period C certificates (as well as, of course, ordinary certificates).

In addition at the beginning of each year you are provided twenty ($20.00) dollars 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 dollars on hand. You are free to buy and sell certificates as you wish according to the rules below. Your dollars on hand at the end of a year are determined by your initial amount of dollars on hand, earnings on certificate holdings at the end of each period and by gains and losses from purchases and sales of certificates. All dollars on hand at the end of a year in excess of the initial $20.00 endowment are yours to keep. These are your profits for the year.

B.3 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. In period A you may make ordinary certificate transactions and/or Period C Certificate transactions. After each transaction for a ordinary certificate you must calculate and record your new holdings of certificates and dollars on hand. Your holdings of certificates and dollars on hand may never go below zero. You must also enter the identification number of the buyer (seller). For each Period C Certificate transaction in each period, you must record the transaction information under the Period C column following the last certificate transaction.
3. After each transaction for a Period C Certificate during period A, you must record the net purchases of Period C Certificates in the "Net Purchases" column of period C. Record a +1 for a purchase and a -1 for a sale. Each purchase of a Period C Certificate requires a decrease in the period A "Cash on Hand". Likewise, each sale of a Period C Certificate during period A requires an increase in the period A "Cash on Hand". The above recording rules also apply to Period C Certificate

transactions that take place during period B. <u>Note that a negative number in the "Net Purchases" column of period C must never exceed the number in the current "Certificate Holdings"</u>.

4. At the end of each period (A and B) record your total certificate holdings and earnings on row 31. Record your end-of- period totals of "Number of Certificates" and "Dollars on Hand" on row 32. On row 33 compute your total end of period dollars on hand by adding your certificate earnings to your row 32 "Dollars on Hand".
5. The number of total certificates on row 32 and the total dollars on hand on row 33 should be carried forward to row 0 of period B.
6. At the end of period B, your computed total dollars on hand (certificate earnings plus dollars on hand) should be carried forward to row 0 of period C. Note at the end of period B no more transactions take place.
7. At the end of period C your total certificate holdings is equal to your total certificate holdings at the end of period B plus your "Net Purchases" of Period C Certificates. Record this number on row 31 under the "Net Purchases" column of period C.
8. Under the period C heading compute your Period C Certificate earnings. Add this number to the dollars on hand in row 0 and record on row 33. Count the total number of transactions in periods A and B and enter this number on row 34. Multiply this number by 0.01 and record the result on row 34 under the "Dollars on Hand" column. These are your transaction profits. Add the transaction profits to the total dollars on hand entry on row 33 and record the amount on row 35. From the row 35 total subtract $20.00 - your initial endowment. This is your profit

for the market year. At the end of the market year record this number on your profit sheet.

9. 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. If this is a positive number, the experimenter will pay you this amount of money plus $5.00 in cash. If this entry is a negative number, then you will only receive $5.00.

B.4 MARKET ORGANIZATION

The market for these certificates is organized as follows. The market will be conducted in a series of "market years" each consisting of three periods lasting for between 5 and 7 minutes. The experimenter will warn when you when the period is about to close. There will be no trading in period C. Anyone wishing to purchase a unit is free to raise his hand and make a verbal bid to buy one certificate at a specified price, and anyone with units to sell is free to accept or not accept the bid. Likewise, anyone wishing to sell a unit is free to raise his hand and make a verbal offer to sell one at a specified price. If a bid or offer is accepted, a binding contract has been closed for a single unit, and the contracting parties will record the contract price to be included in their record sheet. When making a bid or offer, you must specify whether you wish to buy or sell an ordinary certificate or a Period C Certificate. In the space provided on your sheet, record the identification number of the person you contracted with. Any ties in bids or acceptance will be resolved by random choice by the experimenter. Except for the bids and their acceptance, you are not to speak to any other trader. There are likely to be many bids or offers that are not accepted, but you are free to keep trying. You are free to make as much cash as you can.

FIGURE 7 (CONTINUED)

	S or B	I.D. NUMBER	TRANSACTION PRICE	# OF CERT.	$ ON HAND		S or B	I.D. NUMBER	TRANSACTION PRICE	# OF CERT.	$ ON HAND		S or B	I.D. NUMBER	TRANSACTION PRICE	NET BUY (+/-)	$ ON HAND
16						16						16					
17						17						17					
18						18						18					
19						19						19					
20						20						20					
21						21						21					
22						22						22					
23						23						23					
24						24						24					
25						25						25					
26						26						26					
27						27						27					
28						28						28					
29						29						29					
30						30						30					
31		PER CERTIFICATE				31		PER CERTIFICATE				31		PERIOD B CERT. PLUS NET BUY			
32						32						32		PER CERTIFICATE			
33						33						33		PER TRANSACTION			
34						34						34					
35						35						35					

FIGURE 7: TYPICAL RECORD SHEET FOR PURE STOCK & FUTURES MARKET TRADER (EXPERIMENTS 2 & 4)

YEAR ______ NAME: ______________________ I.D. #: __________

PERIOD A						PERIOD B						PERIOD C					
ROW				# OF CERT.	$ ON HAND	ROW				# OF CERT.	$ ON HAND	ROW				NET BUY (+/-)	$ ON HAND
0						0						0					
	S or B	I.D. NUMBER	TRANSACTION PRICE				S or B	I.D. NUMBER	TRANSACTION PRICE				S or B	I.D. NUMBER	TRANSACTION PRICE		
1						1						1					
2						2						2					
3						3						3					
4						4						4					
5						5						5					
6						6						6					
7						7						7					
8						8						8					
9						9						9					
10						10						10					
11						11						11					
12						12						12					
13						13						13					
14						14						14					
15						15						15					
31	PER CERTIFICATE					31	PER CERTIFICATE					31	PER. B CERT. +NET BUY				
32						32						32	PER CERTIFICATE				
33						33						33	PER TRANSACTION				
34						34						34					

B.5 RECORD SHEETS