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RATIONAL EXPECTATIONS AND THE AGGREGATION OF DIVERSE INFORMATION IN LABORATORY SECURITY MARKETS

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ABSTRACT

The study explores the information aggregation properties of experimental markets in which a fully revealing rational expectations equilibrium exists. In single securities markets in which traders have different preferences information aggregation seems to be minimal and rational expectations equilibria are not attained. If the market has a complete set of contingent claims securities or if preferences are identical the rational expectations equilibrium model works well.

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I. INTRODUCTION

In this paper we explore the information aggregation properties of market organization that recent mathematical theorizing suggests might exist. Economists have long recognized that markets, if properly organized, can be an efficient conflict resolution device for a given pattern of attitudes. In addition, the idea that market processes may involve value formation (the endogenous formation of limit prices and demand functions), thereby departing from an assumption of fixed attitudes, was introduced many years ago. However, the idea that value formation, to the extent it reflects expectations formation, may involve aspects of efficiency and that organizations might aggregate and disseminate information while also resolving conflicts is a product of the modern mathematical literature on decentralization (Hurwicz 1972) and on rational expectations (Lucas 1972).

That markets might reasonably be expected to efficiently resolve conflicts has been demonstrated many times in the experimental economics literature. Recent experiments (Forsythe, Palfrey, and Plott 1982; and Plott and Sunder 1982) have demonstrated that markets can also disseminate information efficiently. In this paper we address the more complicated and subtle issue of information aggregation when different traders have diverse information about an underlying state of nature. The situation is one in which no trader knows the state of nature but if traders pool their information, the state can be identified and, subject to the usual caveats about side-payments, the welfare of all improved. Rational expectations models suggest that markets might be used to accomplish this result even though traders are unable to communicate information directly and even though traders have no obvious incentive to unilaterally reveal what they know. The experiments reported below explore the possibility.

The information aggregation in the markets described later is of the following form. Rewards to traders depended upon purchases and sales of single-period securities and an unobserved state parameter. The state parameter could take three values {x,y, and z} and all traders had some information about the underlying state prior to any trading activity, but no one knew the state with certainty. For example, if the state was x, then some traders knew for certain that the state was not y and other traders knew for certain the state was not z; but no one was informed that it was x. Thus the state could be identified with certainty through a proper aggregation of all available information in the market. The question posed is how

markets might foster this aggregation.

Previous experiments have demonstrated the power of the rational expectations (RE) model, so we began with the working (null) hypothesis that with replication the predictions of the rational expectations model would be reasonably accurate. The first experiments (series A) led us to reject this idea and forced us to proceed on the opposite presumption that aggregation as suggested by the model will never occur. With this perspective a second set of experimental markets (series B) in which a complete set of state-contingent securities were traded was designed. Our discovery that this second series of markets behave substantially as predicted by the RE model led us to design a third series (series C) of single compound security markets in which payoffs of a security in a state were identical across all holders. The fact that both the second and third series performed as forecast by the RE model leads us to suspect that the existence of instruments which introduce some ability of traders to attribute the actions of others to a source of motivation is important to the information aggregation function of markets.

In the next, second, section the experimental design, parameters, and procedures are introduced. The third section outlines a rational expectations model and two competing models which will help us organize the data. The data from all series are presented in the fourth section and analyzed in terms of the major predictions of the models about prices, allocations, profits and efficiency. It also contains a discussion of aspects of behavior which may help in the development of a fully appropriate model. A fifth section contains a discussion of several parameters which may vary across experiments and our attempts to explain why the complete markets for state contingent securities seem better able to aggregate diverse information. The final section is a summary of conclusions.

II. MARKET DESIGN

A total of eleven markets (plus one pilot) were studied. Nine of the markets (1, 2, 3, 6 through 11) involved a single asset. Some of these markets had diverse dividends (1, 2, 3, 6, 10, 11) and are referenced as series A. Some of the markets had uniform dividends (7, 8, 9) and are referenced as series C. The other two markets (4 and 5) had a complete set of contingent claims during the first nine periods (indexed 4-CC and 5-CC) followed by several periods in which only a single compound security could be traded (indexed 4-S and 5-S). The contingent claims portions of these markets are referenced as series B and the single security portions are grouped in series A. The numerical indexing of the markets reflects the sequence in which the markets were conducted and to some extent the experience of subjects, but for purposes of analysis the markets will be rearranged as series A, B, and C.

Each market was conducted for several periods and in each period securities with one-period lives were traded. Each security paid a single dividend to the holder at the end of the period. These dividends differed across traders (except in markets 7, 8, and 9) and depended upon the state of nature. The differences in dividends and

in expectations about the underlying state of nature led to the existence of gains from trade similar to those induced by the differences in attitudes towards risk, wealth, and/or portfolio positions. The markets were organized as oral double auctions.

Subjects were students at the Graduate School of Business at the University of Chicago, the Indian Institute of Management in Ahmedabad, and graduate and undergraduate students at the California Institute of Technology. Experience varied across markets. As shown in Table 1, participants in market 1 had no previous experience. In market 2 subjects had participated in either market 1 or the pilot. Similarly, subjects in markets 5 and 6 had the experience gained from participating in one of markets 3 or 4. Inexperienced subjects in market 7 became the experienced subjects who participated in markets 8 and 11. Subjects in market 9 had experience from unrelated laboratory markets and in market 10 the subjects were those who participated in market 9.

II.1 <u>Preferences and Assets</u>

Instructions, procedures for training subjects, the method of inducing preferences, and other details of experimental procedure were like those used in Plott and Sunder (1982). Each trader, i, was

TABLE 1: DESIGN OF MARKETS

Market	Series	Location[a] & Subject Experience	Trader Type	Number of Traders	Initial Endowment Certificates	Initial Endowment Francs	Fixed Cost (Francs)	Dollar per Franc	Dividends x	Dividends y	Dividends z	Probabilities x	Probabilities y	Probabilities z	Expected Dividends No Information	Expected Dividends Not x	Expected Dividends Not y	Expected Dividends Not z
1	A	UC (inexperienced)	I	4	2	10,000	10,000	0.003	70	160	300	0.35	0.20	0.45	191.5	257	199	103
			II	4	2	10,000	10,000	0.003	230	90	60				125.5	69	134	179
2	A	UC (experienced in market 1 or pilot)	I	4	2	10,000	10,000	0.003	100	330	190	0.35	0.45	0.20	221.5	287	133	229
			II	4	2	10,000	10,000	0.003	260	90	120				155.5	99	209	164
3	A	CIT (inexperienced)	I	4	2	10,000	10,000	0.003	70	160	300	0.35	0.20	0.45	191.5	257	199	103
			II	4	2	10,000	10,000	0.003	230	90	60				125.5	69	134	179
4 (contingent claims periods 1-9) (single security periods 10-13)	B / A	CIT (inexperienced)	I	4	2	10,000	10,000	0.003	70	130	300	0.35	0.20	0.45	185.5	248	199	92
			II	4	2	10,000	10,000	0.003	230	90	60				125.5	69	134	179
			III	4	2	10,000	10,000	0.003	100	160	200				157.0	188	156	122
5 (contingent claims periods 1-9) (single security periods 10-16)	B / A	CIT (experienced in Market 3 or 4)	I	4	2(4)[b]	15,000	15,000	0.0025	140	260	600	1/3	1/3	1/3	333	430	370	200
			II	4	2(4)[b]	15,000	15,000	0.0025	460	180	120				253	150	290	320
			III	4	2(4)[b]	15,000	15,000	0.0025	200	320	400				307	360	300	260
6	A	CIT (experienced in Market 3 or 4)	I	4	4	16,000	16,000	0.00125	50	240	590	1/3	1/3	1/3	293	415	320	145
			II	4	4	16,000	16,000	0.00125	170	450	110				243	280	140	310
			III	4	4	16,000	16,000	0.00125	310	190	390				297	290	350	250
7	C	IIM (inexperienced)	I	12	4	25,000	25,000	0.0015[c]	50	240	490	1/3	1/3	1/3	260	365	270	145
8	C	IIM (experienced in market 7)	I	12	2	25,000	25,000	0.0015[c]	125	375	525	1/3	1/3	1/3	342	450	325	250
9	C	CIT (inexperienced)	I	12	4	25,000	25,000	0.0015	50	240	490	0.35	0.45	0.20	223.5	317	210	157
10	A	CIT (experienced in market 9)	I	4	4	16,000	16,000	0.00125	240	50	590	1/3	1/3	1/3	293	320	415	145
			II	4	4	16,000	16,000	0.00125	450	170	110				243	140	280	310
			III	4	4	16,000	16,000	0.00125	190	310	390				297	350	290	250
11	A	IIM (experienced in market 7 & 8)	I	4	2	16,000	16,000	0.00125[c]	50	240	590	1/3	1/3	1/3	293	415	320	145
			II	4	2	16,000	16,000	0.00125[c]	170	450	110				243	280	140	310
			III	4	2	16,000	16,000	0.00125[c]	310	190	390				297	290	350	250

a. UC = University of Chicago; CIT = California Institute of Technology; IIM = Indian Institute of Management.
b. 2 in complete markets (periods 1-9), 4 in single-security markets (periods 10-16).
c. Rupee per franc for markets 7, 8, and 11.

assigned a dollar redemption function of the form:

$$R_i^t = \gamma_i[a_i + \sum_\alpha d_{\alpha i}(\theta_t)x_{\alpha i}^t + \sum_s P_s^{it} - \sum_p P_p^{it} + C_i^t],$$

$$a_i < 0,\ d_{\alpha i}(\theta_t) > 0,\ \gamma_i > 0,\ x_{\alpha i}^t \geq 0.$$

$i \in \mathcal{I}$ = the set of traders.

$\alpha \in \mathcal{A}$ = set of types of securities.

$\theta \in \Omega$ = set of states of nature.

R_i^t = dollar earnings of trader i in period t.

$x_{\alpha i}^t$ = units of security of type α held by trader i at the end of period t (end of period short sales were prohibited so $x_i^t \geq 0$), is the initial endowment of securities plus purchases less sales in period t.

$d_{\alpha i}(\theta_t)$ = the dividend rate of type α security in francs for trader i expressed as a function of the state of nature θ.

$\sum_s P_s^{it}$ = revenue from sales of securities during period t.

$\sum_p P_p^{it}$ = cost of securities purchased during period t.

C_i^t = initial endowment of cash in francs.

a_i = fixed cost in francs. In general $a_i < 0$ because initial endowments of securities and francs were of substantial value.

γ_i = conversion rate of francs (experimental currency) into U.S. dollars.

If a trader has a positive utility for money, (s)he would like R_i^t as large as possible. Derived demand induces values on securities which, in turn, can be used as parameters in the models of market behavior.

Constraints on decisions of traders were as follows. At the beginning of each period each trader was given an initial endowment of working capital (C_i^t) which was sufficiently large never to be binding. Each trader was also given an initial endowment of securities ($\bar{x}_{\alpha i}^t$) of each type α. Short positions were permissible (in markets 4 through 11 but not in markets 1, 2, or 3) during a trading period, but no one was allowed to remain short at the end of the period.[1] Thus the supply of each type of security was fixed at $\sum_i \bar{x}_{\alpha i}^t$.

II.2 Information

The information structure of the markets was the same across all markets. Traders were publicly told that the selection of the state each period depended upon a draw from a bingo cage and they were trained through preliminary draws to guess the events which were to have led to various states of nature (see Plott and Sunder 1982 for procedures and instructions). In fact, the state in all markets was picked from a predetermined sequence of draws made in advance of the experiment. Draws from the bingo cage were conducted each period and the proportions of states were the same as the stated probabilities but the announced states were those of the predetermined sequence. We have no evidence which leads us to suspect that subjects disbelieved the mechanism.

No subject knew the dividends of any other subject. The number of informed traders and the type of information were both public. The method of distributing information (based on a random number table) was public.

In all cases there were three states x, y, and z ($\Omega = \{x,y,z\}$). As outlined above we postulate that a probability distribution $P(\theta)$, $\theta \in \{x,y,z\}$ represents the beliefs of all traders about the chances of the occurrence of each state in any period. At the beginning of the period the state was drawn. Information given to traders was as follows: if the state was, say, x, then half of the traders knew with certainty that the state was not y and the others knew with certainty that the state was not z. Furthermore, all traders knew that the identity of the traders who received each clue was determined according to a random number table (see Appendix 1 for the method). The probability that any given trader receives the clue "not y," given that the state is x, is one-half, etc.

II.3 Parameters

The actual parameters for each experiment are contained in Table 1. In the first three markets traders were partitioned into two types (designated I and II) according to dividend payoffs and, in 4, 5, 6, 10, and 11, three types (designated I, II, and III). In all these markets there were four traders of each type. Thus in each of the first three markets there were eight traders and in all other

markets there were twelve. In markets 7, 8, and 9 there was only one type of trader but there were twelve traders of this type. Each period each trader had an initial endowment of two securities except in markets 5-S, 6, and 9 where each trader had four. The initial cash endowments given to traders each period, the fixed cost and dollar/franc (or rupee/franc) exchange, are all listed in the table. Many of these variations reflected what we had learned from the preceding experiments. For example, the initial endowment and therefore the total supply of securities was doubled from market 3 to market 6. Had market 6 converged to the RE equilibrium, we would have suspected that volume might be a critical variable and we would have pursued volume as a treatment variable in the later experiments.

The structure of dividends differed between the contingent claims and the single security organizations. Consider first the single security case in which $\mathcal{A}$, the set of types of securities, contains only a single element. The dividends paid at the end of a period on a single security differ according to the state of nature revealed for that period and the type of trader holding the security. Take, for example, period 10 of market 4 in which only a single security existed. Any security held by, say, a type II trader yielded a dividend to the holder of 230 francs if the state was x, 90 francs if the state was y, and 60 francs if the state was z. The dividend returns to other types can also be read from Table 1.

Organization of the contingent claims markets is a little different. In these cases there were three different securities, so *a* contained three elements. For convenience the securities were called x, y, and z, i.e., = {x,y,z}, as were the corresponding states. The x securities yielded a positive dividend if x occurred and zero otherwise. The y security yielded a positive dividend if y occurred and zero otherwise, etc. Again, reading from Table 1 the dividend structure for a type II trader during period 1 of market 4-CC when markets for a complete set of state contingent claims were operative, we get the following: for such a trader ($d_{xi}(x) = 230$, $d_{xi}(y) = 0$, $d_{xi}(z) = 0$); ($d_{yi}(x) = 0$, $d_{yi}(y) = 90$, $d_{yi}(z) = 0$); ($d_{zi}(x) = 0$, $d_{zi}(y) = 0$, $d_{zi}(z) = 60$). The dividend structure for all other traders can be determined similarly from Table 1.

III. COMPETING MODELS OF SECURITY BEHAVIOR

Three different models are examined as candidate explanations of the behavior of these security markets. Of course the entire project was motivated by the first model, the fully revealing rational expectations equilibrium (RE) in which beliefs are endogenously developed. The two other models, the prior information equilibrium (PI) and maximin (MM), utilize exogenously formed beliefs and both are known from other experiments (Plott and Sunder 1982) to be less reliable than RE. They are used here as alternatives against which to evaluate RE. In addition, both models could be used as starting points in dynamic models of formation of rational expectations; so both are of independent interest.

III.1 Rational Expectations (RE)

The central principle of this model is the fully revealing rational expectations hypothesis (RE): all traders choose in equilibrium as if they are aware of the pooled information of all traders in the system regarding the underlying state. This principle is supplemented with the standard principles of demand and supply as applied to competitive markets.

Under these assumptions an RE model can easily be derived for the markets described in the section above. In all states the pooled information will identify the state with certainty (half of the traders can eliminate one of three states with certainty and the other half can eliminate another). Under competitive conditions demands are perfectly elastic at the dividend rate (assuming no transaction cost). The supply is fixed.

The price and allocation predictions of this model for each market are listed in Table 2 in rows marked RE. In any given state the equilibrium price is the highest dividend in that state and the securities are held by the traders who have that high dividend potential. In market 1, for example, the rational expectations model predicts a price of 230 francs when the state is x and it also predicts that all securities will be held by type II traders. In market 4 the rational expectations model predicts, when the state is x, that the price of the x, y, and z securities will be 230, 0, and 0, respectively. All of the x securities would, according to this model, be held by type II traders and there should be no trades in the other

TABLE 2: PRICE AND ALLOCATION PREDICTIONS

		Diverse Information				Type of Trader Purchasing Assets			
			Diverse Information about the State				Diverse Information about the State		
Market	Model	No Information	x	y	z	No Information	x	y	z
1 and 3 (single security)	RE	191.5	230	160	300	I	II	I	I
	PI	191.5	199	257	257	I	I(not y)	I(not x)	I(not x)
	MM	70	90	160	160	I	II(not z)	I(not x)	I(not x)
2 (single security)	RE	221.5	260	330	190	I	II	I	I
	PI	221.5	229	287	287	I	I(not z)	I(not x)	I(not x)
	MM	100	120	190	190	I	II(not y)	I(not x)	I(not x)
4-CC (contingent claims)	RE								
	x-certificate	80.5	230	0	0	II	II	-	-
	y-certificate	32	0	160	0	III	-	III	-
	z-certificate	135	0	0	300	I	-	-	I
	PI								
	x-certificate	80.5	146	146	101	II	II(not z)	II(not z)	II(not y)
	y-certificate	32	58	58	49	III	III(not z)	III(not z)	III(not x)
	z-certificate	135	169	208	208	I	I(not y)	I(not x)	I(not x)
	MM								
	x-certificate	0	0	0	0				
	y-certificate	0	0	0	0	no predictions about allocations			
	z-certificate	0	0	0	0				
4-S (single security)	RE	185.5	230	160	300	I	II	III	I
	PI	185.5	199	248	248	I	I(not y)	I(not x)	I(not x)
	MM	100	100	160	160	III	III	III(not x)	III(not x)
5-CC (contingent claims)	RE								
	x-certificate	153	460	0	0	II	II	-	-
	y-certificate	107	0	320	0	III	-	III	-
	z-certificate	200	0	0	600	I	-	-	I
	PI								
	x-certificate	153	230	230	230	II	II	II(not z)	II(not y)
	y-certificate	107	160	160	160	III	III(not z)	III	III(not x)
	z-certificate	200	300	300	300	I	I(not y)	I(not x)	I
	MM								
	x-certificate	0	0	0	0				
	y-certificate	0	0	0	0	no prediction about allocations			
	z-certificate	0	0	0	0				
5-S (single security)	RE	333	460	320	600	I	II	III	I
	PI	333	370	430	430	I	I(not y)	I(not x)	I(not x)
	MM	200	200	320	320	III	III	III(not x)	III(not x)
6 and 11 (single security)	RE	297	310	450	590	III	III	II	I
	PI	297	350	415	415	III	III(not y)	I(not x)	I(not x)
	MM	190	310	240	310	III	III(not y)	I(not x)	III(not y)
7 (uniform dividends single security)	RE	260	50	240	490	<————all(no trade)————>			
	PI	260	270	365	365	all(no trade)	not y	not x	not x
	MM	50	50	240	240	<——all(no trade)——>		not x	not x
8 (uniform dividends single security)	RE	342	125	375	525	<————all(no trade)————>			
	PI	342	325	450	450	all(no trade)	not y	not x	not x
	MM	125	125	375	375	<——all(no trade)——>		not z	not x
9 (uniform dividends single security)	RE	223.5	50	240	490	<————all(no trade)————>			
	PI	223.5	210	317	317	all(no trade)	not y	not x	not x
	MM	50	50	240	240	<——all(no trade)——>		not x	not x
10 (single security)	RE	297	450	310	590	III	II	III	I
	PI	297	415	350	415	III	I(not y)	III(not x)	I(not y)
	MM	190	240	310	310	III	I(not y)	III(not x)	III(not x)

two securities.[2] In market 7, with all trades having identical dividends, RE implies x, y, and z prices of 50, 240, and 490 respectively and no trading, leaving final allocations of securities the same as the initial allocations.

III.2 Prior Information (PI)

The prior information model is based on three principles of individual action. The first is that traders apply Bayes law to the problem of ascertaining the likelihood of a state after having received their private prior information. The second principle is that traders act on the probability so derived. The third principle is that actions are taken in accord with the expected utility hypothesis. (Here we make a further and stronger assumption that traders are risk neutral.) The law of supply and demand is then applied. Aside from the parametric structure the model is that developed by Lintner (1969) and applied to the U.S. securities market.

For our experimental markets these axioms imply that the price of an asset will be equal to the expected value of the trader whose prior information about the state leads to the highest expected value across all traders. The model predicts that these highest expected value traders will hold all of the securities. These predictions for each period and each state are listed in Table 2 on rows labeled PI.

III.3 Maximin (MM)

The maximin model replaces the hypothesis regarding expectations formation of (PI) with the hypothesis that traders act

only on certainty.[3] This means that traders will not purchase a security unless the price is below the minimum (s)he could possibly receive given (her) his prior information. Thus the trader with the maximum (across all traders) of minimum (across all states) dividend will purchase the security and the competitive market hypothesis implies that the price will be at this dividend value. In market 1, for example, if the state is x, the model predicts a price of 90 francs. Type II traders who know the state is not z know that they will receive at least 90 francs in dividends. Since the minimum dividend of all other investors is lower, these traders have the maximum of such minimizers and will, according to the model, be the holders of all securities. The predictions for other markets and states are listed in Table 2 on rows labeled MM.

IV. RESULTS

Prices of the completed transactions in the eleven experimental markets are plotted chronologically in Figures 1 through 11. Complete data are given in Appendix 2 and 3. Horizontal lines in these figures indicate the predictions of the three models described above which can be compared to the actual results. Average transaction prices are also shown for each period.

The conclusions developed precisely below can be seen in the data presented in the figures. Market behavior relative to the predictions of the three models differs substantially depending upon treatment variables. The behaviors of the single security markets

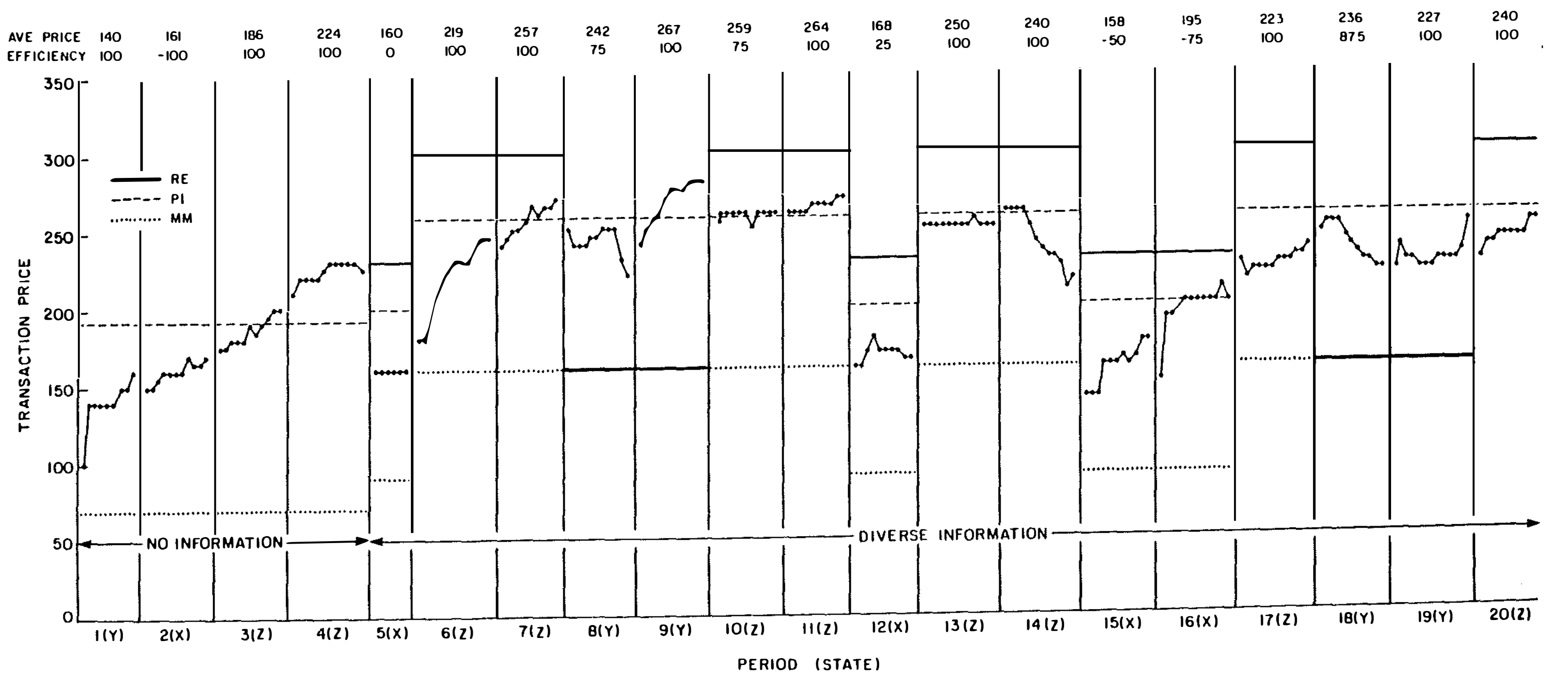

FIGURE 1 MARKET 1 TRANSACTION PRICES

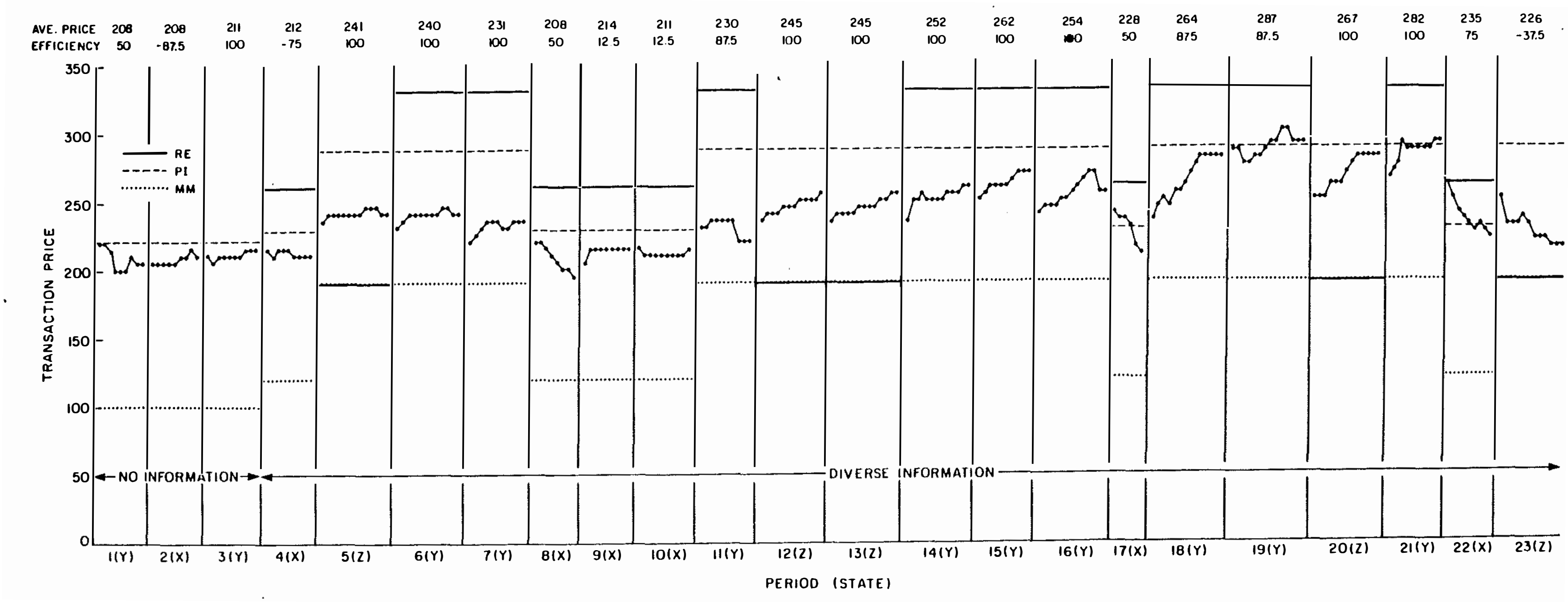

FIGURE 2 MARKET 2 TRANSACTION PRICES

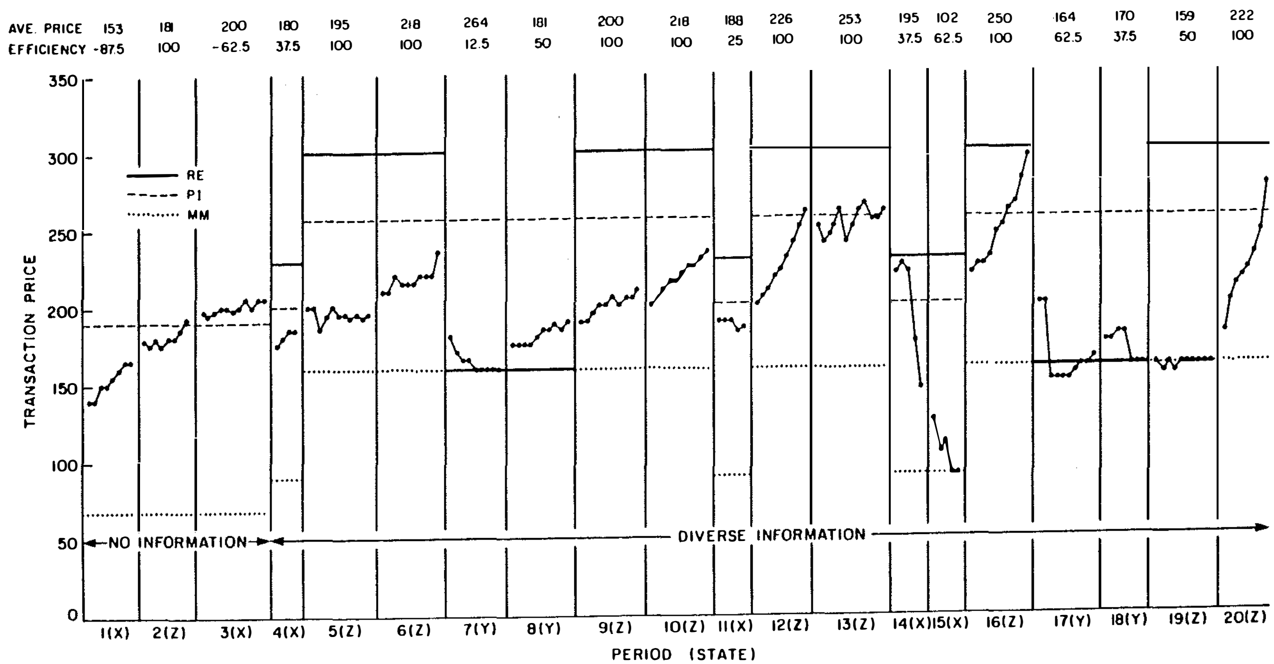

FIGURE 3 MARKET 3 TRANSACTION PRICES

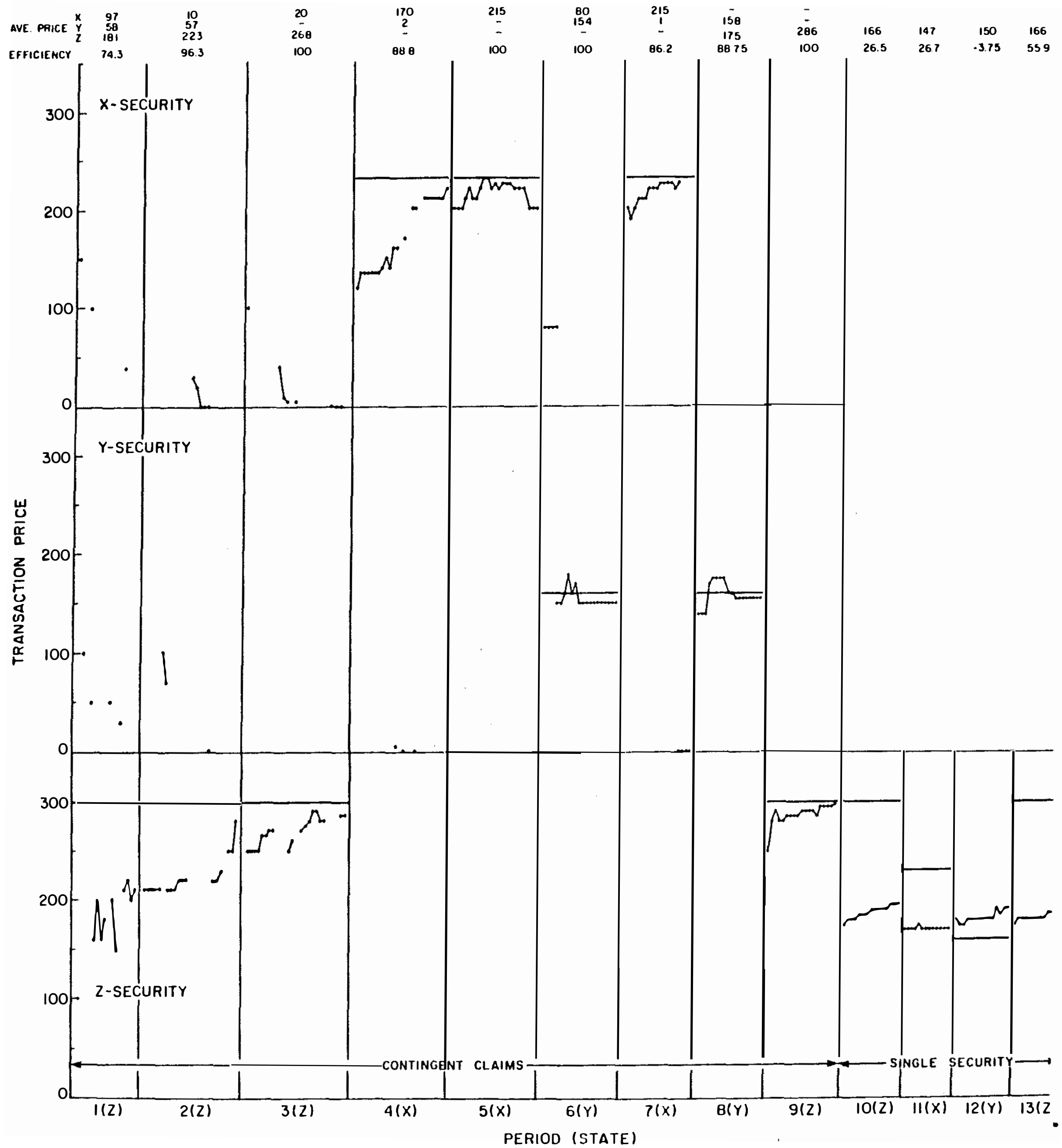

FIGURE 4 MARKET 4–CC AND 4–S TRANSACTION PRICES

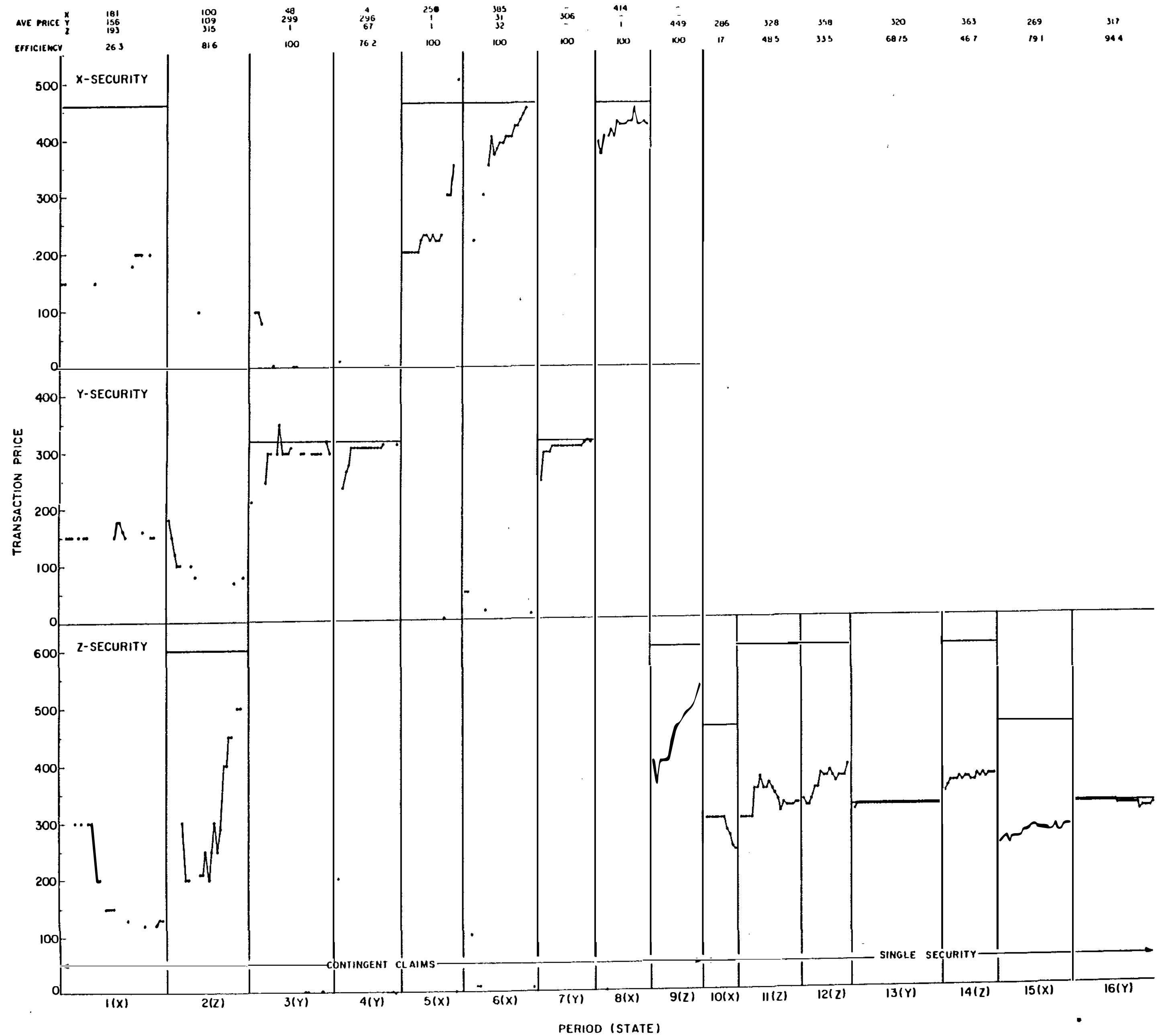

FIGURE 5 MARKET 5–CC AND 5–S TRANSACTION PRICES

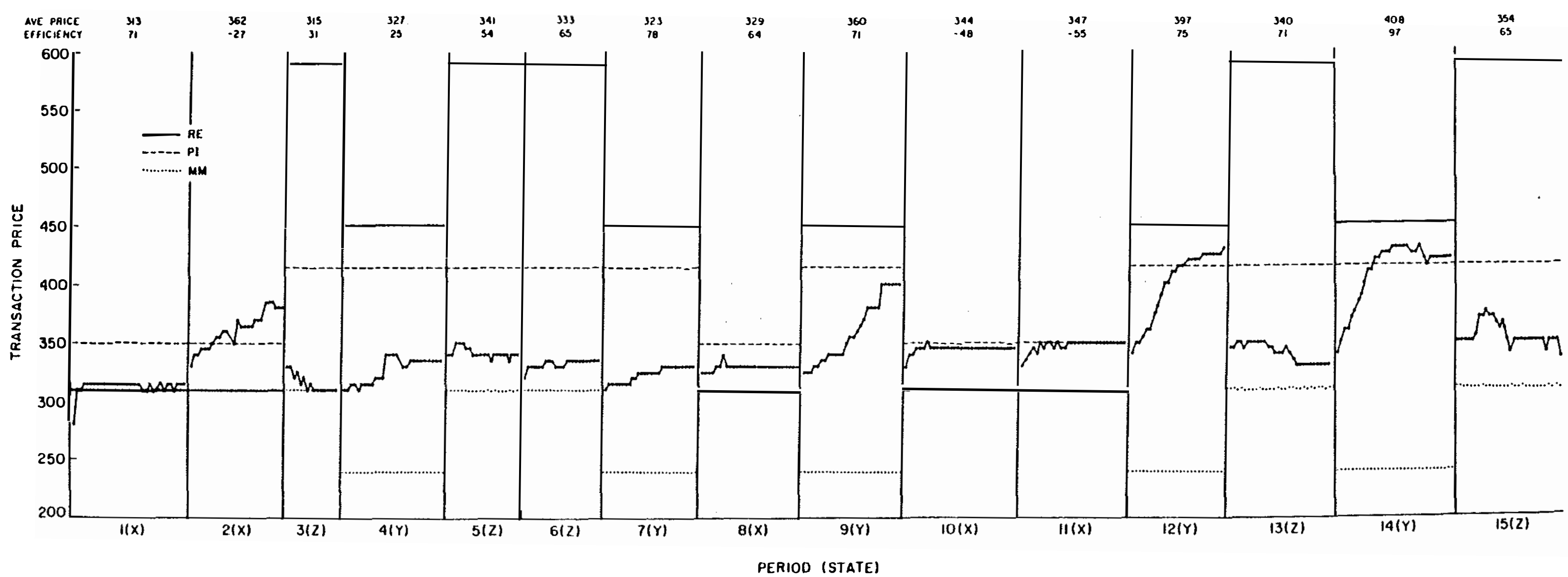

FIGURE 6 MARKET 6 TRANSACTION PRICES

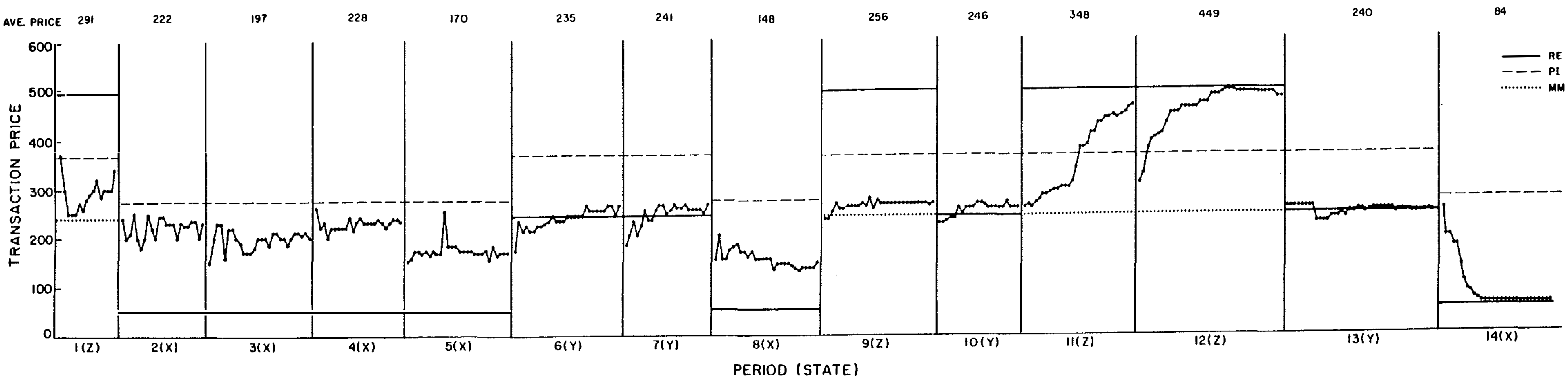

FIGURE 7 MARKET 7 TRANSACTION PRICES

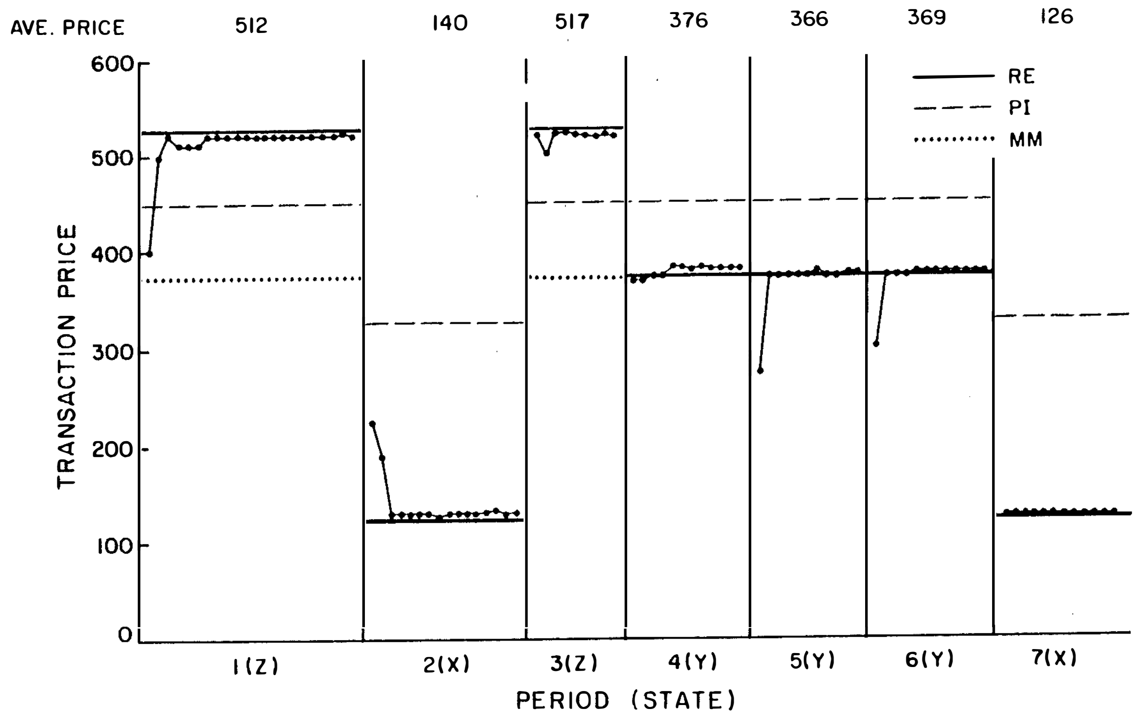

FIGURE 8 MARKET 8 TRANSACTION PRICES

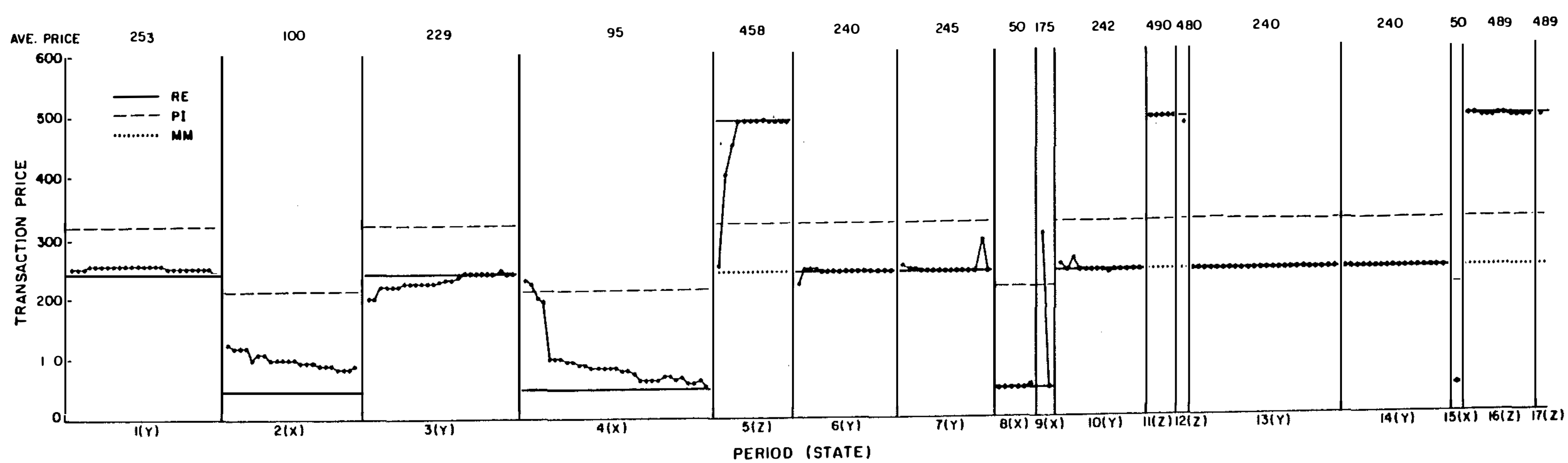

FIGURE 9 MARKET 9 TRANSACTION PRICES

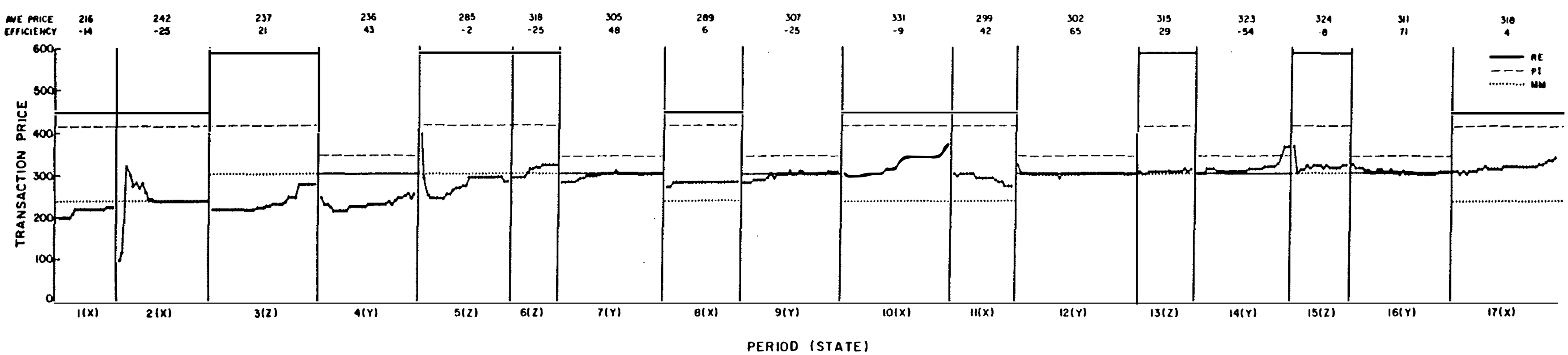

FIGURE 10 MARKET 10 TRANSACTION PRICES

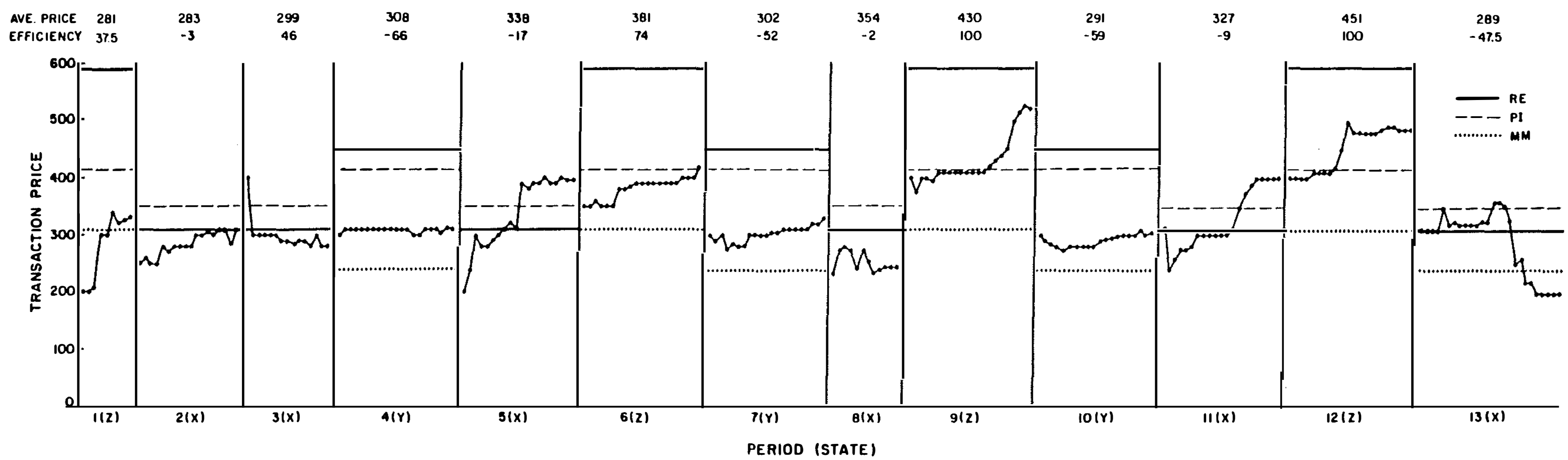

FIGURE 11 MARKET 11 TRANSACTION PRICES

with diverse preferences (series A) are only partially captured by the rational expectations model. The best example is market 10 in Figure 10. The early period prices are close to the MM predictions. Prices drift upward and remain about the same regardless of the state. If the markets are complete contingent claims markets as in series B or if preferences are identical (series C), the rational expectations model provides a reasonably accurate summary of market behaviors. Market 4-CC in Figure 4 is one of the two contingent claims markets. Notice that after the initial period or two the market corresponding to the realized state is near the RE price and the other two "not-state" markets have prices near zero. With uniform dividend, market 7 is slower to attain RE prices but by period 11 they are being attained and in the other two uniform dividend markets, 8 and 9, the RE levels are attained very quickly.

The discussion of results is divided into six subsections. Subsection IV.1 contains analysis relative to the equilibrium predictions of the three competing models. All models predict prices, allocations, and profits. Subsection IV.2 addresses the central issue of information aggregation as reflected in market efficiency. In a third subsection, IV.3, the dynamics of the possible equilibrating process receive some attention and IV.4 extends the investigation of dynamics to the bids and offers in the contingent claims markets. Subsection IV.5 analyzes the data relative to the fair game hypothesis of security markets. The sixth subsection, IV.6, addresses the possible effects of many variables which changed across the markets.

Though these variables are not central to the major thesis of this study, we analyze them in search for institutional variables that may assist in aggregation of information. We have labeled as conjectures those results which are either suggested by the data or are based on very little data. In either case more data are needed for testing these conjectures.

IV.1 Equilibrium Behavior

Only the last occurrence of each of the three states in each experimental market is used to evaluate the possible equilibrium behavior. Earlier experiments have demonstrated that replication of periods is necessary for the data to approach the levels predicted by equilibrium models but no convention has been established for the number of such replications that are necessary and in many cases it looks as though some adjustment always occurs. In the single security markets, each state occurs more than three times before the measurement is used for analysis in this section. Naturally the question about increased model accuracy upon even more replications remains open.

Conclusion 1 (Price Level). In single security markets with diverse preferences (series A) the price predictions of the rational expectations model do not perform well relative to the performance of the price predictions of PI or MM. Neither PI nor MM is distinguished as an overall "best model."

Table 3 provides the supporting statistics. Three measurement criteria are presented. For series A the mean absolute deviations of actual prices from the price predictions of the PI model are less than those for either of the other models. The RE model is significantly worse than PI on this criterion since its predictions have a lower mean absolute deviation than PI in only one of the eight relevant experiments and the predictions of the RE model are marginally worse than MM. If log odds are used, RE is significantly worse than both PI and MM since the data are never the most likely under RE. The third measure is the percent of price changes in the direction of the predicted price. With this measure MM is significantly worse than RE while PI is marginally better than RE. In summary, RE is significantly worse than PI on two criteria and marginally worse on one, and has mixed results with respect to MM.

Conclusion 2 (Price Level). In markets with a complete set of state contingent securities (series B) and in markets with a single security with uniform dividends (series C) the RE model price predictions outperform both PI and MM. Furthermore the RE model is more accurate in series B and C than it is in series A.

Again, Table 3 contains the relevant measures. In the last periods of the contingent claims markets (series B) and in the last periods of the uniform dividends markets (series C) the price predictions of the RE model are significantly better than both PI and MM on two criteria (mean absolute deviation of price and log odds) and

marginally better on the third criterion (percent of converging price changes). The RE model is unambiguously the best.

The second part of the conclusion establishes the accuracy of the RE model in a sort of absolute sense by comparing its accuracy to the case in which it was performing badly relative to other models. The mean absolute deviations from the RE model in all markets in series B and series C, with the exception of market 5-CC, are less than all markets in series A, and in 5-CC the mean absolute deviation is better than all series A markets except markets 1 and 2. Log odds are always better in series B and series C than in series A. Percent of convergent price changes gives a less clear picture.

Each model predicts a flow of securities from some traders to others depending upon traders' dividends and the pattern of private information. The allocations predictions of the three models are in Table 2. Notice that the traders predicted to hold the securities by one model sometimes have a nonempty intersection with those predicted to hold by another model. On occasion the predictions by one are a subset of the predictions of another. In order to avoid some of the inherent problems associated with evaluating such models we chose to use the security flows predicted by the models as opposed to the final holdings alone. Table 4 reports the ratio:

$$\frac{\sum_{j \varepsilon C_m} (x_j - \bar{x}_j)}{\sum_{j \varepsilon C_m} (x_j^m - \bar{x}_j)} \times 100 .$$

TABLE 3: COMPARISON OF ACTUAL PRICES TO PRICES PREDICTED BY THREE MODELS AT THE END OF EACH MARKET*

Market Experiments		Criteria: Mean Absolute Deviation			Log Odds under Normality			Percentage of Convergent Price Changes		
Series	Number	PI	RE	MM	PI	RE	MM	PI	RE	MM
A	1	18	54	84	-55	-284	-455	82	71	18
	2	26	36	81	-85	-102	-373	69	57	62
	3	75	72	28	-146	-86	-17	50	50	50
	4-S	54	67	38	-2482	-7482	-5757	70	63	30
	5-S	94	144	38	-4719	-4509	-344	57	57	37
	6	27	105	83	-251	-3429	-652	61	54	37
	10	76	134	32	-1175	-2715	-547	57	66	45
	11	77	114	79	-511	-853	-160	56	61	39
Summary Statistics, Series A: Wilcoxon Signed Rank Sum Test T^+		35	27		31	31		25	33	
Level of Significance		.008(PI)	.125(MM)		.039(PI)	.039(MM)		.191(PI)	.02(RE)	
B	4-CC	82	13	220	-493	-33	-3853	35	65	35
	5-CC	159	71	389	-580	-72	-2801	25	75	25
C	7	133	27	83	-1530	-59	-189	28	81	57
	8	186	5	50	-281	-17	-1016	79	46	54
	9	136	0	83	-1	-1	-1	-	-	-
Summary Statistics, Series B and C: Wilcoxon Signed Rank Sum Test T^+		15	15		10	10		8	9	
Level of Significance		.031(RE)	.031(RE)		.062(RE)	.062(RE)		.188(RE)	.125(RE)	

*The model favored by the data in each paired comparison is shown in parentheses. The level of significance is the probability of incorrectly rejecting the null hypothesis that both models predict equally well.

TABLE 4

COMPARISON OF ACTUAL ALLOCATIONS WITH THE ALLOCATIONS PREDICTED BY THREE MODELS

CRITERION: PERCENT OF PREDICTED FLOW OF SECURITIES THAT ACTUALLY OCCURRED AT THE END OF EACH MARKET*

Market Experiments		Models		
Series	Number	PI	RE	MM
A	1	86	42	50
	2	19	46	47
	3	28	67	39
	4-S	17	17	5
	5-S	-8	59	18
	6	12	42	-2
	10	7	21	11
	11	-7	10	-7
Summary Statistics for Series A Wilcoxon Signed Rank Sum Test T^+		PI vs RE: 22	RE vs MM: 33	
Level of Significance		.109(RE)	.020(RE)	
B	4-CC	26	90	No Prediction
	5-CC	29	100	No Prediction
C	7	18	No Prediction	48
	8	0	No Prediction	4
	9	18	No Prediction	25
Summary Statistics for Series B and C Wilcoxon Signed Rank Sum Test T^+		PI vs RE: 13	RE vs MM: 9	
Level of Significance		.048(RE)	.100(RE)	

*The model favored by the data in each paired comparison is shown in parentheses. The level of significance is the probability of incorrectly rejecting the null hypothesis that both models predict equally well.

Where C_m is the set of traders who are predicted by model m to hold the securities in equilibrium, x_i^m is the predicted holding of trader i and x_i and $\bar{x}_i$ are as defined on page 6 with the α and t supressed. The measures are taken for the final occurrence of each state.

Conclusion 3 (Allocation Predictions). In all series, allocations aggregated over the final occurrence of each state are more accurately modeled by the RE model than either the PI or MM. The RE model is more accurate in series B (the RE makes no predictions in series C) than it is in series A.

Only in market 1 (series A) is the prediction of the RE model substantially dominated by either of the other two and in this case it is dominated by both. In market 2 the RE model is dominated by only MM and then only by 1 percent, and in 4-S it is tied for first with PI, but in all others it is the best. Rank sum tests indicate significantly better performance for RE than MM (latter rejected at .02) and marginally better than PI (latter rejected at .109). In series B the RE model accounts for from 90 percent to 100 percent of the flow. These predictions of the RE model are so overwhelmingly accurate that it seems safe to conclude its superiority is not due to chance. In the contingent claims markets the MM model predicts zero price of all securities so traders would be indifferent about holdings. Consequently we indicate no predictions for the model.

In series C in which all traders have the same preference the price should equal the state dividend according to the RE model and all traders should be indifferent between holding and not holding. Of the two remaining models MM seems marginally better. If, however, a slight transaction cost exists the RE model predicts zero trades. As can be seen in Figures 7 through 9 the volume is decreasing as periods replicate.

Predictions of the distribution of profits across individual traders for each model are obtained by assuming that the predicted holders of securities buy up all securities at the predicted equilibrium price. Applied to the final occurrence of each state in each experiment, the sums of the squared deviations from the mean are in Table 5.

Conclusion 4 (Profit Distribution). In all series the RE model is a significantly better predictor of the distribution of profits than either the PI model or the MM model.

In every market except 1, in which the PI model was the best, and 10, in which the MM model was best, the error of the RE model is less than the error of either competitor. In series B the error is very low and in series C the error of the RE model is near zero. Order statistics applied to the ranking of models can be used to significantly reject both PI and MM in favor of RE.

IV.2 Efficiency and Information Aggregation

Efficiency as the term is applied here is at 100 percent in a given period if and only if the total earnings of all traders are the

TABLE 5

COMPARISON OF ACTUAL DISTRIBUTION OF PROFITS TO DISTRIBUTION PREDICTED BY THE THREE MODELS. CRITERION: SQUARED SUM OF DEVIATION FROM THE MEAN ACROSS INVESTORS AT THE END OF EACH MARKET*

(in thousands)

Market Experiments		Models		
Series	Number	PI	RE	MM
A	1	37	132	277
	2	140	29	125
	3	124	37	217
	4-S	181	65	76
	5-S	3101	564	962
	6	3049	2356	2877
	10	2033	954	622
	11	1007	551	593

Summary Statistics for Series A	PI vs. RE	RE vs. MM
Wilcoxon Signed Rank Sum Test T^+	34	30
Level of Significance	.012(RE)	.055(RE)

Series	Number	PI	RE	MM
B	4-CC	907	6	242
	5-CC	2320	86	516
C	7	387	47	340
	8	70	0	313
	9	328	0	333

Summary Statistics for Series B and C	PI vs. RE	RE vs. MM
Wilcoxon Signed Rank Sum Test T^+	15	15
Level of Significance	.031(RE)	.031(RE)

*The model favored by the data in each paired comparison is shown in parentheses. The level of significance is the probability of incorrectly rejecting the null hypothesis that both models predict equally well.

TABLE 6: EFFICIENCY*

Series	Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean	Median
A	1	y 100	x -100	z 100	z 100	x 0	z 100	z 100	y 75	y 100	z 75	z 100	x 25	z 100	z 100	x -50	x -75	z 100	y 87.5	y 100	z 100				69	100.0
A	2	y 50	x -87.5	y 100	x -75	z 100	y 100	y 100	x 50	x 12.5	x 12.5	y 87.5	z 100	z 100	y 100	y 100	y 100	x 50	y 87.5	y 87.5	z 100	y 100	x 75	z -37.5	73	93.7
A	3	x -87.5	z 100	x -62.5	x 37.5	z 100	z 100	y 12.5	y 50	z 100	z 100	x 25	z 100	z 100	x 37.5	x 62.5	z 100	y 62.5	y 37.5	z 50	z 100				78	62.5
A	4-S										z 26.5	x 26.7	y -3.75	z 55.9											33	26.6
A	5-S										x 17	z 48.5	z 33.5	y 68.75	z 46.7	x 79.1	y 94.4								49	48.5
A	6	x 71	x -27	z 31	y 25	z 54	z 65	y 78	x 64	y 71	x -48	x -55	y 75	z 71	y 97	z 65									46	65.0
A	10	x -14	x -25	z 21	y 43	z -2	z -25	y 48	x 6	y -25	x -9	x 42	y 65	z 29	y -54	z -8	y 71	x 4							8	6.0
A	11	z 37.5	x -3	x 46	y -66	x -17	z 74	y -52	x -2	z 100	y -59	x -9	z 100	x -47.5											18	-3.0
B	4-CC	z 74.3	z 96.3	z 100	x 88.8	x 100	y 100	x 86.2	y 88.75	z 100															93	96.3
B	5-CC	x 26.3	z 81.6	y 100	y 76.2	x 100	x 100	y 100	x 100	z 100															87	100.0
C	7	Efficiency of uniform dividend markets is undefined.																								
C	8																									
C	9																									

$$\text{*Efficiency} = \frac{\text{Actual Dividends Paid} - \text{Zero-Trade Dividends}}{\text{RE Dividends} - \text{Zero-Trade Dividends}}$$

maximum possible given the particular states that occurred in that period. For example, in market 3, all securities should be held by type II traders during periods in which the state was x because during these periods, type II traders receive larger dividends than type I. As an example of contingent claims markets, consider market 4-CC. During periods when, say, state y occurred, type III traders should hold the y securities. In this way the total earning over all traders is maximized. For convenience the measure is truncated at no-trade earnings. That is, efficiency is zero if dividends paid equals the payment that would occur if no trades took place.

Efficiencies are presented in Table 6. Perhaps the most important features of the efficiency data are summarized by the following conclusion.

Conclusion 5. Efficiencies in the single security market are low relative to the non-diverse information experiments (Plott and Sunder 1982) and relative to the contingent claims markets.

Parametrically these markets are similar to those studied by Plott and Sunder (1982). The major difference is that in the 1982 study information aggregation was not necessary as the state was known with certainty by some traders. After a few periods those markets operated at near 100 percent efficiency for all states. On the other hand the efficiency of series A markets averages only 47 percent. Interestingly enough, the efficiency of single security markets is lower (markets 4-S, 5-S, 10, 11) when the experience of traders is

greater. Series B markets, with a complete set of contingent claims, have substantially higher (around 90 percent) efficiency levels.

Different models sometimes predict different levels of efficiency so efficiency can be used as a measure of model accuracy. Table 7 contains the mean square errors for all models in all markets. Only series A is useful because for series B PI and RE have identical predictions while MM makes no predictions.

Conclusion 6. The rational expectations model is the least accurate predictor for the efficiency of series A markets.

The rank test leads directly to a rejection of the RE model when compared to either PI or MM.

We have no measure of the degree to which information was successfully aggregated in these markets. However, information aggregation is related to efficiency even though the precise relationships is unclear. If information is perfectly aggregated, then an application of supply and demand suggests that the markets should operate at 100 percent efficiency. Those traders who have the highest dividends should acquire the security. If no information aggregation takes place, then resources should be allocated according to the prior information model in which each trader is risk neutral and acts on privately received information alone.

Conclusion 7. Information aggregation occurred in all markets in which the measurement can be made, except one. Furthermore, aggregation improved with replication of periods.

TABLE 7

ABSOLUTE DIFFERENCE BETWEEN THE EFFICIENCY PREDICTED BY EACH MODEL AND THE OBSERVED EFFICIENCY AT THE END OF EACH MARKET*

Market Experiments		Models		
Series	Number	PI	RE	MM
A	1	9	58	58
	2	46	21	21
	3	25	42	42
	4-S	74	74	22
	5-S	14	27	24
	6	19	64	10
	10	33	78	4
	11	61	106	32
Summary Statistics for Series A		PI vs. RE		RE vs. MM
Wilcoxon Signed Rank Sum Test T^+		25		15
Level of Significance		.039(PI)		.031(MM)
B	4-CC	8	8	-
	5-CC	0	0	-
C	7	Efficiency of uniform dividend markets is undefined.		
	8			
	9			

*The model favored by the data in each paired comparison is shown in parentheses. The level of significance is the probability of incorrectly rejecting the null hypothesis that both models predict equally well.

The data are in Table 8. Of the fifty-two periods in which the measurement can be made, all were positive except four. Three of the four periods of negative aggregation occurred in market 11 in which aggregation never occurred. A test on the changes in the aggregation index indicates that twenty out of thirty-two changes in aggregation index upon repetition of a state within the same market converged towards 100 percent. The probability of chance is 0.107.

Unfortunately this aggregation measure cannot be applied to either series B or series C because those who would hold the securities on the basis of private information form a subset of those who would hold after full aggregation. The price behavior in the series B and C markets suggests that the information in both series was almost perfectly aggregated. Otherwise, without aggregation, price would not have been so close to the rational expectations prices. Nevertheless, given our definitions and parameters, we are unable to provide an elegant demonstration of the degree of aggregation under the alternative institutional regimes.

IV.3 Initial Periods: Some Price Dynamics

Because learning is an important feature of experimental markets in general, it is possible that in these markets too the behavior of early periods is distinct from the behavior of later periods. Table 9 contains the measures of price prediction accuracy for the first periods at which a state occurred for all experiments. In the series A single security markets, with diverse preferences, the

TABLE 8 : AGGREGATION INDEX*

Market Experiment Series	Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean	Median	Convergent Changes Within State
A	1					x 69	z –	z –	y 93	y 100	z –	z –	x 77	z –	z –	x 54	x 46	z –	y 97	y 100	z –					87	3 out of 5
A	2				x 4	z –	y 100	y 100	x 73	x 52	x 52	y 90	z –	z –	y 100	y 100	y 100	x 73	y 90	y 90	z –	y 100	x 86	z –		90	5 out of 8
A	3				x 81	z –	z –	y 76	y 86	z –	z –	x 77	z –	z –	x 81	x 88	z –	y 90	y 83	z –	z –					82	4 out of 6
A	4-S										z –	x 56	y -15	z –												20	–
A	5-S										x 30	z –	z –	y 65	z –	x 87	y 94									76	2 out of 2
A	6	x –	x –	z –	y 44	z –	z –	y 83	x –	y 78	x –	x –	y 81	z –	y 98	z –										81	3 out of 4
A	10	x 15	x 7	z –	y –	z –	z –	y –	x 30	y –	x 19	x 57	y –	z –	y –	z –	y –	x 29								24	2 out of 5
A	11	z –	x –	x –	y -24	x –	z –	y -13	x –	z –	y -19	x –	z –	x –												-19	1 out of 2
																											20 out of 32 α = 0.107
B	4A, 4B	Aggregation Index is undefined for complete markets																									
C	7, 8, 9	Aggregation Index is undefined for uniform dividend markets																									

$$\text{*Aggregation Index} = \frac{\text{Actual Dividends Paid} - \text{Dividends under PI Allocation}}{\text{Dividends under RE Allocation} - \text{Dividends under PI Allocation}}$$

Note that the Aggregation Index is undefined whenever RE and PI allocations are identical. This is always the case for the uniform dividends and contingent claims markets and is true for at least one of the three states in the other markets.

TABLE 9: COMPARISON OF ACTUAL PRICES TO PRICES PREDICTED BY THREE MODELS AT THE BEGINNING OF EACH MARKET*

Market Experiments		Criteria								
		Mean Absolute Deviation			Log Odds under Normality			Percentage of Convergent Price Changes		
Series	Number	PI	RE	MM	PI	RE	MM	PI	RE	MM
A	1	31	78	70	–	–	–	–	–	–
	2	37	63	64	-964	-2275	-2891	58	47	42
	3	58	53	43	-687	-1215	-459	39	72	61
	4-S	52	65	40	-1646	-4901	-5698	70	63	30
	5-S	99	149	35	-18393	-675	-59	48	48	91
	6	75	134	32	-1118	-5040	-335	56	50	47
	10	164	220	57	-2258	-3510	-323	88	88	88
	11	103	159	47	-2997	-5249	-1235	66	65	60
Summary Statistics, Series A										
Wilcoxon Signed Rank Sum Test T^+		35	35		21	23		16	21	
Level of Significance		.008(PI)	.008(MM)		.148(PI)	.078(MM)		.406(PI)	.148(RE)	
B	4-CC	53	63	168	-372	-56	-1046	48	79	34
	5-CC	93	197	265	-88	-240	-412	42	75	54
C	7	84	128	79	-281	-424	-335	62	59	50
	8	109	10	52	-1403	-25	-129	53	59	48
	9	109	32	94	-1571	-136	-155	35	72	52
Summary Statistics, Series B and C										
Wilcoxon Signed Rank Sum Test T^+		8	13		12	13		14	15	
Level of Significance		0.5	.094(RE)		.156(RE)	.094(RE)		.062(RE)	.031(RE)	

*The model favored by the data in each paired comparison is shown in parentheses. The level of significance is the probability of incorrectly rejecting the null hypothesis that both models predict equally well.

RE model is worse than either of the other two. The PI model is marginally better than the other two at the beginning.

An examination of the improvement of a model between the first periods and the last periods indicates that the RE model shows the greatest improvement in series A. Thus a not implausible model such as the one suggested by Jordan (forthcoming) has the markets adjusting from a temporary PI equilibrium to an RE equilibrium after some replications.

Conjecture 1. The markets adjust along a Jordan path from a PI equilibrium to an RE equilibrium.

The conjecture suffers from one obvious flaw. The markets we observed in series A did not achieve an RE equilibrium. Nevertheless the view that the markets are adjusting through a dynamic path beginning with the PI equilibrium seems to have some merit.

Insufficient data exist in series B and C to perform nonparametric tests on the series individually. In series B the average price prediction of the PI model and the RE model are almost equally close. In series C average price predictions of the MM model and the RE model are almost equally close. The pooled data show RE to be a significantly more accurate price predictor on two criteria (for mean absolute deviation, RE and PI tied). Percent of convergent price changes favor the RE model in both series B and series C. The fact that the RE model receives competition from the other models during the first period lends some support to the conjecture or at least the

spirit of the conjecture that it might be useful to study the adjustment process as though it operated on an equilibrium path from PI towards RE.

IV.4 Contingent Claims Price Dynamics and the Role of Bids

In contingent claims markets with diverse information structure traders who know, say, that state x has not occurred, know not only that the value of x-contingent security is zero to them, but they also know that its value is zero to all those who acquire this information. Making an offer to sell a security contingent upon the state that a trader knows has not occurred is a no-loss proposition if the trader expects the price to move toward zero. Buying any security on initial information involves some risk. It is reasonable to hypothesize that the first market action will be an offer (to sell) by a trader who knows the security is worth nothing.

Hypothesis 1. The opening action in a market period is an offer to sell a contingent claim corresponding to one of the two states that has not occurred and is made by a trader who has prior information that the corresponding state has not occurred.

Under the null hypothesis the opening action could occur in any of the three contingent claims markets, could be a bid or an offer, and could be made by any trader with the exception that the traders informed "not x" will not bid for x-contingent security and similarly for the other states. Thus, there is a two-out-of-ten or 20 percent probability that the events in Hypothesis 1 will occur by random chance. As shown in Table 10, the event occurred in 12 of the 18 opportunities. The null hypothesis is strongly rejected in favor of Hypothesis 1.

If the substance of Hypothesis 1 is true, then opening offers made in a contingent claims market corresponding to a state that has not occurred can, by a process of elimination, inform half the traders which state has occurred. Such newly informed traders will wish to buy the corresponding contingent security. Thus, the opening action in the contingent claims market corresponding to the realized state should be a bid (to buy).

Hypothesis 2: The first action in the "state" market is a bid (to buy).

Because the first action can be either a bid or an offer, probability that the first action in this market will be a bid by random chance is 50 percent. Again, Table 10 contains the results. The alternative is rejected in favor of Hypothesis 2.

Assume that state x has occurred and the first action is an offer to sell y-contingent security. If this offer is interpreted by traders whose private information is "not z" to mean that the state is not y either, they would know that the state is x and will therefore be inclined to buy the x-contingent security. This reasoning leads to the third hypothesis about the behavior of bids and offers:

TABLE 10

ANALYSIS OF BIDS AND OFFERS IN CONTINGENT CLAIMS MARKETS

Hypothesis	Market	Number of Occurrences and Sample Size	Probability of Occurrences under Null Hypothesis	α-Level*
	4-CC	7 out of 9	0.2	0.0004
1	4-CC	5 out of 9	0.2	0.0210
	Combined	12 out of 18	0.2	0.0000
	4-CC	8 out of 9	0.5	0.0200
2	5-CC	7 out of 9	0.5	0.0700
	Combined	15 out of 18	0.5	0.0008
	4-CC	2 out of 3	0.5	0.5000
3	5-S	3 out of 4	0.5	0.3100
	Combined	5 out of 7	0.5	0.2300

*Probability that the realized sample or a more extreme result will be obtained by random chance under the null hypothesis.

<u>Hypothesis 3</u>: When the first action in the "state" market is preceded by action in only one of the two "not" markets, this first action (a bid by Hypothesis 2) will be by a trader whose private information is that the state corresponding to the second of the two "not" markets has not occurred.

Because this action could be taken by traders with either of the two pieces of information and the number of traders with each piece of information is equal, the condition in Hypothesis 3 will be fulfilled by random chance 50 percent of the time. The tests summarized in Table 10 indicate that the evidence favors Hypothesis 3 as well as the first two hypotheses, but it is much weaker, perhaps due to a much smaller sample size.

IV.5 <u>Fair Game Tests</u>

In the single security markets of series A, the trading occurred at prices far from the RE equilibrium prices. However, such trading did not offer traders opportunity to make profits by using mechanical trading rules. Table 11 shows the average amount of capital gains that could be obtained in the single security markets by following five trading rules: (1) buy-and-hold, (2) trend filter, (3) 1-franc filter, (4) 5-franc filter, and (5) 25-franc filter.[4] For the single-period securities traded in these markets, equilibrium return over time is zero. None of the four filter rules is able to beat a naive buy-and-hold strategy more often than it is beaten by such a strategy. These markets are similar to the New York Stock Exchange in

TABLE 11

PROFIT FROM MECHANICAL TRADING RULES: TESTS OF FAIR GAME HYPOTHESIS

(Mean Profits and Rank)

Series	Market	Buy and Hold	Trend Filter	1-Franc Filter	5-Franc Filter	25-Franc Filter	RE Price Perfect Information
A	1	9.0 (2)	4.0 (3)	-14.0 (5.5)	-14.0 (5.5)	-3.0 (4)	33.0 (1)
	2	2.8 (4)	3.0 (3)	3.5 (1.5)	3.5 (1.5)	-0.8 (5)	-2.5 (6)
	3	1.0 (5)	4.0 (4)	5.0 (2.5)	5.0 (2.5)	0.6 (6)	6.0 (1)
	4-S	10.0 (1)	0.0 (5.5)	3.0 (2.5)	3.0 (2.5)	0.0 (5.5)	1.0 (4)
	5-S	14.9 (1)	9.0 (3)	2.0 (4.5)	2.0 (4.5)	-1.0 (6)	12.0 (2)
	6	25.0 (1)	20.0 (2)	7.0 (4)	7.0 (5)	0.0 (6)	11.0 (3)
	10	16.0 (5)	20.0 (4)	22.0 (3)	23.0 (2)	-1.0 (6)	24.0 (1)
	11	51.0 (1)	47.0 (2)	15.0 (5.5)	15.0 (5.5)	22.0 (4)	45.0 (3)
Sum of Ranks for Series A		(20.0)	(26.5)	(29.0)	(29.0)	(42.5)	(21.0)
B	4-CC	45.0 (1)	22.0 (3)	-6.0 (4.5)	-6.0 (4.5)	0.3 (6)	44.0 (2)
	5-CC	101.0 (2)	24.0 (3)	21.0 (4.5)	21.0 (4.5)	18.0 (6)	118.0 (1)
C	7	-7.0 (2)	-10.0 (3)	-38.0 (6)	-36.0 (5)	-35.0 (4)	90.0 (1)
	8	30.0 (1)	8.0 (4)	5.0 (5.5)	5.0 (5.5)	11.0 (3)	16.2 (2)
	9	-11.0 (2)	-51.0 (4)	-55.0 (5.5)	-55.0 (5.5)	-49.0 (3)	83.0 (1)
Sum of Ranks for Series B and C		(8.0)	(17.0)	(26.0)	(25.0)	(22.0)	(7.0)
Sum of Ranks for all Markets		(28.0)	(43.5)	(55.0)	(54.0)	(64.5)	(28.0)

that it is difficult to discover mechanical trading rules that statistically beat the naive buy-and-hold strategy. In addition, in the single security markets of series A, a rule based on perfect knowledge of the RE equilibrium price in these markets does not beat the naive strategy.

Markets in series B and series C converge to near the rational expectations prices. Buy and hold beats the filter rules in series B and C but it is not as good as knowledge of the RE equilibrium price. We can conclude:

Conclusion 8. The fair game property of security markets is a necessary but not a sufficient condition for the existence of RE prices.

The calculations assume, of course, that purchases in accord with the rules applied above would not affect price or otherwise lead to a transmission of the information. The results given in Table 11 and the results of filter tests on market data in general, assume that the marginal effect of such strategies on the behavior of the market is negligible. This assumption is unlikely to hold, especially for perfect knowledge of rational expectations equilibrium price because such knowledge can alter the behavior of the market as was shown in Plott and Sunder (1982).

IV.6 OTHER VARIABLES

Several variables were changed during these experiments. The first few markets of series A yielded a negative result regarding the ability of markets to aggregate information. The changes in variables in later markets represent probes into the possibility that some aspects of the structure or the procedure might be responsible. Had any of these changes yielded immediate and strong differences in behavior, the research would have focused in the indicated direction. Consequently the discussion in this section represents an ex post examination of variables that were dropped as having a low probability of being of substantial importance.

During the course of some markets traders learned the actual rational expectations prices and/or that markets can aggregate information. Does such experience make a difference? In markets 4-S, 5-S, 10, and 11 subjects had all participated in a market in which the RE information phenomenon existed. If market efficiency is used as the measure of the importance of this experience, the data suggests that experience was no help at all and it might even hurt. The data are in Table 12.

Conjecture 2. Prior experience of traders with the RE phenomena is not a sufficient condition for the single security market to arrive at the RE equilibrium.

Traders may have difficulty developing trading rules relative to private information. By allowing traders to specialize in

TABLE 12

COMPARISON OF MEAN EFFICIENCY OF SINGLE SECURITY, DIVERSE DIVIDEND MARKETS (SERIES A) WITH AND WITHOUT RE EXPERIENCE

	Experiment Number	Mean Efficiency	Rank
Without Experience	1	69	6
	2	73	7
	3	78	8
	6	46	4
Rank Sum			25
With Experience	4-S	33	3
	5-S	49	5
	10	8	1
	11	18	2
Rank Sum			11
Level of Significance*			.029

*Wilcoxon Rank Sum Test

H_0: Efficiency is unchanged with experience

H_1: Efficiency decreases with experience

Upper tail probability given.

Source: Myles Hollander and Douglas A. Wolfe, Nonparametric Statistical Methods. New York: Wiley, 1972, Chap. 4.1 and Table A.5.

functions, we thought "noise" in the single security markets might be identified and the formation of RE behavior speeded. With market 4 the number of investor types was increased from two to three. With three types a different set of "buyers" occurs with each state so given the state the composition of demand and supply should have more stability. If average efficiency is the measure of RE formation the results in Table 13 show that efficiency is higher with two types than with three.

Conjecture 3. The increase in the number of trader types did not improve the RE formation process.

Note that with the exception of market 6, all markets with two trader types are those without experienced traders and all markets with three trader types have experienced traders. Thus, it is difficult to disentangle the effects of these two treatment variables, number of types and experience, with our data.

Of course if the number of types is reduced to one type as in series C, the RE model works well. We suspect, however, that the key is not the number of types but knowledge of preferences, as will be discussed later.

The RE model depends upon the state revelation through price and other observable market phenomena. If larger samples existed, the strength of the signal might be improved. In order to check this possibility the volume was increased by increasing the endowments of all traders in market 6 and some of the later markets, from two units

TABLE 13

COMPARISON OF MEAN EFFICIENCY

OF SINGLE SECURITY, DIVERSE DIVIDEND MARKETS

(SERIES A) WITH TWO AND THREE DIFFERENT TYPES OF INVESTORS

Number of Investor Types	Market	Mean Efficiency	Rank
2	1	69	6
2	2	73	7
2	3	78	8
Rank Sum			21
3	4-S	33	3
3	5-S	49	5
3	6	46	4
3	10	8	1
	11	18	2
Rank Sum			15
Level of Significance*			.018

*Wilcoxon Rank Sum Test
H_0: Number of investor types makes no difference to efficiency
H_1: Efficiency decreases as the number of investor types increases.

Upper tail probability given.

Source: Myles Hollander and Douglas A. Wolfe, Nonparametric Statistical Methods. New York: Wiley, 1972, Chap. 4.1 and Table A.5.

to four units. The results in Table 14 indicate efficiencies are always higher in the low volume markets.

Conjecture 4. Volume increases do not facilitate RE price formation.

Collinearity of the three treatment variables would have to be handled more carefully, especially if the effect of experience, number of investor types, and volume on efficiency of these markets were positive. Given the negative results our conjectures merely suggest that these treatment variables are unlikely to be of independent significance.

V. WHY DO THE CONTINGENT CLAIMS MARKETS AGGREGATE INFORMATION BETTER?

The title of this section states the overriding question that has emerged from the research. Four different types of explanations have occurred to us. In this section we will review them.

The first potential explanation is that the single security markets are slow to adjust and that, given more time, these markets too will behave as predicted by the RE model. Indeed data exists that suggests the single security markets might ultimately attain a rational expectations equilibrium. In market 3 the price in state z seems to be separating in spite of the remarkable counter-example provided by period 19 (see Figure 3). In market 6 and 1 the price in state y appears to be separating near the end of these experiments. In market 11 the z state appears to be separated. But of course these

TABLE 14

COMPARISON OF MEAN EFFICIENCY OF SINGLE SECURITY, DIVERSE DIVIDEND MARKETS WITH TWO AND FOUR SECURITIES PER INVESTOR

Number of Securities per Investor	Market	Mean Efficiency	Rank
2	1	69	6
2	2	73	7
2	3	78	8
2	4-S	33	3
2	11	18	2
Rank Sum			26
4	5-S	49	5
4	6	46	4
4	10	8	1
Rank Sum			10
Level of Significance*			.196

*Wilcoxon Rank Sum Test

H_0: Efficiency is unchanged when volume is higher.

H_1: Efficiency decreases when volume is higher.

Upper tail probability given.

Source: Myles Hollander and Douglas A. Wolfe, Nonparametric Statistical Methods. New York: Wiley, 1972, Chap. 4.1 and Table A.5.

signs that a willing eye can extract from the data must be considered with the seventeen periods of market 10 where there seem to be no signs of separation.

A second explanation rests on a comparison of the "size" of the message space. The message space of the contingent claims markets is larger than the message space of the single security markets in the sense that three sets of bids/offers/prices are available to the traders in the former. The larger message space, according to this view, allows traders to establish a one-to-one message-state correspondence. The problem with the idea is series C, for which the size of the message space was identical to that of series A. Series C performed substantially in accord with the RE models whereas series A did not. If message space size was the problem with series A it should have surfaced also with series C.

A third potential explanation involves the absence of a one-to-one relationship between the state and price along all points along the dynamic path taken by price on the way to a RE equilibrium. In market 4 for example, the two sets of equilibrium prices, PI and RE, are shown on the vertical lines along with the states that would induce those prices (see Figure 12).

Consider a dynamic model that has prices adjusting first to a PI equilibrium and then moving from there to a RE equilibrium along the indicated lines. Now notice that regardless of the state an instant exists in which it is impossible for all participants to infer the state from the price.

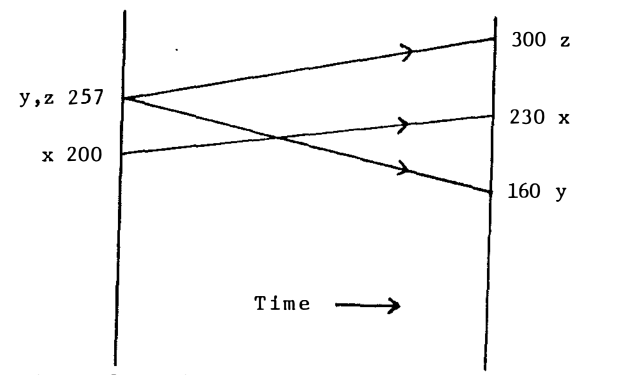

FIGURE 12

This third idea suffers on two counts. First, it is always possible for some subset of the traders to use the market price and their private information to identify the state. Secondly, from experiment 6 onward only the initial identification problem, the one at the PI equilibrium, existed. The parameters were adjusted so the paths did not cross. The remaining markets still did not adjust to the RE equilibrium.

The fourth explanation rests with the type of information implicit in the structure of the contingent claims used in these markets. A security paid a positive dividend only if a state occurred and paid zero otherwise, so strategic considerations aside, the purchase or sale of a security could be directly interpreted as a belief about the occurrence of a particular state. Thus traders in the contingent claims markets had a "natural" knowledge about the preferences of other traders that was not present in the single security markets.

The same type of information probably existed in the uniform dividend series C. If traders began with a presumption that other preferences are similar to their own, their initial assessment of others is correct in these markets. The knowledge bases of actions can then be inferred.

This idea, that one key to market performance is a knowledge of others' preferences, is further supported by the analysis of bids discussed above. Traders seemed to use their knowledge of others' preferences in determining their own actions. The offer to sell the x security, for example, at the opening of a market seemed to be interpreted as a signal that the seller knew the state was not x. If for example, the contingent claims were replaced by a "spanning" set of compound securities that were not "Arrow-Debreu" securities, then such an inference could not necessarily be made. On our belief about the behavior of these markets, information would not become perfectly aggregated with such a "spanning" set of securities.

These four ideas exhaust our current thinking on the subject. We are of the opinion that the key to understanding these markets rests in part with traders' beliefs of other traders' preferences. Some sort of knowledge of others' preferences appears to be a necessary condition for aggregation of diverse information. However our own understanding of the issue is so incomplete that we cannot even provide a precise conjecture.

VI. CONCLUSIONS

The results have both positive and negative elements. On the positive side, experiments in the contingent claims markets (series B) and in the uniform dividends markets (series C) demonstrate that markets can aggregate diverse information in a manner consistent with rational expectations models. The markets in series B and in series C are perhaps the very first demonstration that markets can simultaneously perform the independent functions of information aggregation, information dissemination and conflict resolution.

The negative results are of two forms. First, as demonstrated

by the markets in series A, not all markets can be depended upon to behave in accord with the rational expectations model. The second negative result is that fair game tests used to check for efficient market behavior are unreliable indicators about when a market is not operating efficiently. Even though the markets in series A were not operating efficiently in the rational expectations sense they were still "fair games." That is, filter rules for potentially profitable trades worked no better than "buy and hold." Markets that are "fair games" are not necessarily efficient.

A comparison of the single security markets in series A with the contingent claims markets of series B that had substantially the same economic parameters demonstrates the importance of market institutions and instruments. The introduction of a complete set of Arrow-Debreu securities transformed a market that was operating inefficiently into a market that rapidly achieved a rational expectations equilibrium.

Exactly why the contingent claims instruments produced such a dramatic effect is an open question. Series C demonstrates that a single security will perform according to the RE model if all traders have similar preferences. An analysis of the bids in the contingent claims markets suggests that traders used implicit information about others' preferences. These two series together suggest that some knowledge about other traders' preferences may be a necessary condition for the operation of rational expectations principles in markets.

APPENDIX 1

Markets were conducted in four steps: (1) training with the mechanism used to draw states of nature; (2) training with the mechanism to distribute diverse information; (3) explanation of procedures and rules of the market; (4) conduct of markets for several periods.

STEP 1: TRAINING WITH MECHANISMS USED TO DRAW THE STATES OF NATURE

Instruction Set 1 was distributed and read aloud. On the table between the subjects and the experimenters was kept a bingo cage with the appropriate number of balls. Subjects had the opportunity to observe the operations of the devices for many draws. Following this, subjects were asked to predict the outcome, with the incentive structure described in the instructions, for about 10-20 draws until most, though not all, subjects predicted the state with the highest relative frequency based on the bingo-cage numbers. No mention was made of probabilities.

<u>Instruction Set 1</u> [State Probability Training]

Each year we draw a ball from a bingo cage containing thirty-six balls number one through thirty-six. If the ball drawn is numbered one through twelve, outcome of the draw is called x; if the ball drawn is numbered thirteen through twenty-four, the outcome is y; if the ball drawn is numbered twenty-five through thirty-six, the outcome is z.[5]

You have to predict the outcome of each draw before it is announced. If your prediction is correct, you win \$0.25; if wrong, you lose \$0.10. Before the first draw is made, record your prediction by circling either x, y, or z in the first row of the enclosed sheet. After you have encircled one letter, the outcome will be announced and you should record the announced outcome in the blank space on the same row of the table. If your prediction is correct, circle the amount shown in the Win column, otherwise circle the amount shown in the Lose column.

Once you have recorded your prediction you must not make a change; any erasure will invalidate your prediction. At the end, add up your total winnings and losses and record the difference (net winnings or losses) at the bottom right corner of the sheet [see Figure 13].

STEP 2: TRAINING WITH MECHANISM TO DISTRIBUTE DIVERSE INFORMATION

Instruction set 2 was distributed and read aloud. Following the above procedures, the experimenter drew a ball from the bingo cage, recorded the state drawn, consulted the master clue sheet, and called out the row and column numbers of the cell on the subjects' clue sheet that contained each subject's clue.

In advance of the experiment, a complete list of all possible ways of dividing a group of an even number of investors into two equal groups (for n = 12, this number is $\frac{n!}{2[(n/2)!]^2} = 462$) was prepared. These combinations were randomly ordered. One combination beginning from the top of this list was used each period to distribute

PREDICTION SHEET

Subject No. ____

Number	Circle One Decision	Outcome x, y, or z	Circle One Win ($)	Lose ($)
1	x y z	____	0.25	-0.10
2	x y z	____	0.25	-0.10
.				
.				
.				

Total winnings ____________

Total losses ____________

Net winnings/losses ____________

FIGURE 13

information among the investors and none were repeated because the number of periods in any one experiment never exceeded 23. A coin toss determined which group received information about which of the two unrealized states. A separate clue sheet was designed for each investor [see Figure 14] along with a master clue sheet for the experimenter. After determining the realized state, the experimenter called out the row and column number of the clue sheet which contained the private information of each investor. This method provided quick but confidential yet open means of communicating diverse information to all market participants.

Training with this clue sheet was continued for eight to ten draws until all subjects were familiar with the mechanism.

Instruction Set 2 [State and Clue Training]

At the beginning of each year, the experimenter will provide you with a clue about whether x, y, or z dividend will be paid each period. After the experimenter has turned the bingo cage and determined the dividend outcome for the period, he will announce a row and column number of a cell on your clue sheet which will contain one of the following:

(i) not x

(ii) not y

(iii) not z

If the cell on your clue sheet contains "not x," the dividend paid for that period will not be x. Similarly, "not y" and "not z" inform you that the dividend paid will not be y and will not be z respectively.

Number _____

CLUE SHEET

Columns

	1	2	3	4	5	6
1	not y	not x	not z	not y	not x	not z
2	nox x	not y	not x	not z	not z	not y
3	not y	not y	not x	not z	not z	not x
4	not y	not y	not z	not x	not z	not x
5	not z	not z	not x	not y	not x	not y
6	not z	not z	not y	not x	not x	not y
7	not x	not z	not y	not y	not z	not x
8	not y	not z	not y	not x	not z	not x
9	not x	not y	not y	not z	not x	not z
10	not z	not y	not x	not z	not y	not x
11	not z	not z	not y	not x	not x	not y
12	not y	not x	not z	not y	not z	not x
13	not y	not y	not x	not x	not z	not z
14	not z	not z	not y	not x	not y	not x
15	not y	not z	not x	not y	not z	not x
16	not x	not z	not z	not y	not x	not y
17	not y	not z	not z	not x	not x	not y
18	not y	not z	not x	not x	not z	not y
19	not z	not y	not z	not y	not x	not x
20	not y	not x	not z	not x	not y	not z
21	not z	not z	not x	not x	not y	not y
22	not y	not z	not x	noy y	not x	not x
23	not x	not x	not y	not y	not z	not z
24	not z	not y	not x	not y	not z	not x
25	not y	not x	not y	not x	not z	not z
26	not x	not x	not y	not y	not z	not z
27	not z	not y	not y	not x	not z	not x
28	not z	not x	not z	not y	not x	not y
29	not z	not x	not z	not y	not y	not x
30	not x	not z	not x	not y	not y	not z
31	not z	not x	not x	not y	not y	not z
32	not z	not x	not y	not x	not z	not y
33	not y	not z	not x	not y	not x	not z
34	not z	not z	not x	not x	not y	not y
35	not z	not z	not x	not x	not y	not y

FIGURE 14

Each period, the experimenter randomly divides the investors into two groups of six each. When z dividend is paid, six investors will receive clue "not x" and six will receive clue "not y." Which group receives which clue is determined by a coin toss. Similar procedure is followed for other dividends.

Enclosed is a clue sheet and prediction sheet [see Figures 14 and 15]. After I announce the row and column, circle the appropriate cell on your clue sheet and the appropriate clue on your prediction sheet. Make your prediction of dividend for the period. After all investors have recorded the dividend prediction, the outcome will be announced. Record this outcome in the blank space. If your prediction is correct, circle the amount in the win column, otherwise circle the amount in the lose column.

Do not change your predictions after you have recorded them. At the end add up your total winnings and losses and record the difference at the bottom right hand corner of the sheet.

STEP 3: EXPLANATION OF PROCEDURES AND RULES OF THE MARKET

Instruction set 3 was distributed and read aloud. The experimenter illustrated a sequence of hypothetical transactions on the blackboard so each subject would understand how transactions were to be recorded on the record sheet and how his/her profit would be calculated. The example was designed to minimize its normative effect on subsequent bidding behavior. Importance of accurate records of all transactions was emphasized.

PREDICTION SHEET

Subject No. ______

Number	Clue (Circle One)	Prediction (Circle One)	Outcome	Win ($)	Lose ($)
1	not x not y not z	x y z	______	0.25	-0.10
2	not x not y not z	x y z	______	0.25	-0.10
.					
.					
.					

FIGURE 15

Instruction Set 3[6] [Single Security Markets]

General: This is an experiment in the economics of market decision making. Various research foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In this experiment we are going to simulate a market in which you will buy and sell certificates in a sequence of market years. Attached to the instructions you will find a sheet, labeled information and record sheet [see Figure 16] which helps determine the value to you of any decisions you might make. You are not to reveal this information to anyone. It is your own private information.

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

Specific Instructions: Your profits come from two sources--from collecting certificate earnings on all certificates you hold at the end of the year and from buying and selling certificates. During each market year you are free to purchase or sell as many certificates as you wish, provided you follow the rules below. For each certificate you hold at the end of the year you will be given one of the three numbers of francs listed in the margin of your information

Trader #_____

INFORMATION AND RECORD SHEET

YEAR ________

	Trans- action Number	Transaction Price Sale	Purchase	Certifi- cates on Hand	Francs on Hand
Beginning of the Year Holdings	0	//////////////////////////////	//////////////////////////////		
	1				
	2				
	. . .				
	18				
x-Dividend_____ y-Dividend_____	19	Total Certificate Earnings Dividend Rate on Hand at the End of the Year			
z-Dividend_____	20	Total Francs on Hand at the End of the Year			
	21	Less: Fixed Cost			
	22	End of Year Net Profit			

Transfer this amount to your Profit Sheet

FIGURE 16

and record sheet. Note that earnings may be different for different investors. The method by which one of the three numbers is selected each year is explained later in these instructions. 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 five certificates at the end of year one. If for that period your earnings are one hundred francs per certificate (that is, the number selected from the margin of your information and record sheet is 100) then your total certificate earnings in the year would be 5 X 100 = 500 francs. This number should be recorded on row 19 at the end of the year.

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

At the beginning of each year you are provided with an initial holding of certificates. This is recorded on row 0 of the year's information and record sheet. You may sell these if you wish or you may hold them. If you hold a certificate, then you receive "earnings per certificate" at the end of the year. Notice therefore that for each certificate you hold <u>at least</u> the amount shown as "earnings per certificate." You earn this amount if you do not sell that certificate during the year.

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

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

Information About Dividends: Whether the dividend you receive from the certificates you hold is the x dividend, the y dividend, or the z dividend, shown in the margin of your Information and Record Sheet, is determined by the experimenter at the beginning of the year by drawing a ball from a bingo cage containing forty balls numbered one through forty. If the ball drawn is numbered one through fourteen, x dividend is paid; if the ball drawn is numbered fifteen through thirty-two, y dividend is paid; if the ball drawn is numbered thirty-three through forty, z dividend is paid.

Each year you will receive a clue as to what state has not occurred. The procedure for providing you the clues is explained later.

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 TRANSACTION PRICE in the appropriate column depending on the nature of the transaction. The first transaction is recorded on row (1) and succeeding transactions are recorded on subsequent rows.

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

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

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

(5) 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 [see Figure 17]. To convert this number into dollars, multiply by the number on row 16 and record the product on row 17. The experimenter will pay you this amount of money.

Trader #______

PROFIT SHEET

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

NAME________________________________

FIGURE 17

Market Organization: The market for these certificates is organized as follows. The market will be conducted in a series of years. Each period lasts for _____ minutes. Anyone wishing to purchase a certificate is free to raise his or her hand and make a verbal bid to buy one certificate at a specified price, and anyone with certificates to sell is free to accept or not accept the bid. Likewise, anyone wishing to sell a certificate is free to raise his or her hand and make a verbal offer to sell one certificate at a specified price. If a bid or offer is accepted, a binding contract has been closed for a single certificate, and the contracting parties will record the transaction on their information and record sheets. Any ties in bids or acceptance will be resolved by random choice. Except for the bids and their acceptance, you are not to speak to any other subject. There are likely to be many bids that are not accepted, but you are free to keep trying. You are free to make as much profit as you can.

Instruction Set 4 [Contingent Claims Markets]

General: This is an experiment in the economics of market decision making. Various research foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In this experiment we are going to simulate a market in which you will buy and sell three types of certificates in a sequence of market years. Attached to the instructions you will find a sheet, labeled information and record sheet [see Figure 18], which helps determine the value to you of any decisions you might make. You are not to reveal this information to anyone. It is your own private information.

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

Specific Instructions: During each market year you are free to purchase or sell as many certificates as you wish, provided you follow the rules below. Three types of securities are: type x, type y, and type z. Your profits come from two sources--from collecting certificate earnings on all certificates you hold at the end of the year and from buying and selling certificates. During each market year you are free to purchase or sell as many certificates as you wish, provided you follow the rules below.

For each certificate you hold at the end of the year you will earn one of the three numbers of francs listed on row 26 of your information and record sheet. Compute your total certificate earnings for a period by multiplying the earnings per certificate by the number of each type of certificates held. The method by which one of the three numbers is selected each year is explained later in these instructions. Note that earnings are different for different types of certificates and may be different for different investors.

Suppose for example that you hold five certificates of type x at the end of year one and none of the other two. If for that period your earnings are one hundred francs per x-type certificate (that is, the number selected from row 26 is 100) then your total certificate earnings in the year would be 5 × 100 = 500 francs. This number should be recorded on row 7 at the end of the year.

(number of x certificates held) × (earnings per x certificate)
= earnings from x certificates

Sales from your certificate holdings increase your francs on hand by the amount of the sale price. Similarly, purchases reduce your francs on hand by the amount of the purchase price. Thus you can gain or lose money on the purchase and resale of certificates. At the end of 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 each type of certificate. This is recorded on

INFORMATION AND RECORD SHEET FOR CONTINGENT CLAIMS MARKETS, YEAR _____

Trader No. _____

Transaction Number	X-Certificates: Transaction Price – Sale	X-Certificates: Transaction Price – Purchase	X-Certificates: Certificates on Hand	Y-Certificates: Transaction Price – Sale	Y-Certificates: Transaction Price – Purchase	Y-Certificates: Certificates on Hand	Z-Certificates: Transaction Price – Sale	Z-Certificates: Transaction Price – Purchase	Z-Certificates: Certificates on Hand	Francs on Hand
Beginning of the Holdings → 0	///////	//////////		///////	//////////		///////	//////////		
1										
2										
3										
.										
.										
.										
25										
26	X-Dividend ___ Y-Dividend 0 Z-Dividend 0			X-Dividend 0 Y-Dividend ___ Z-Dividend 0			X-Dividend 0 Y-Dividend 0 Z-Dividend ___			
27	Total Certificate Earnings for X, Y, and Z Type Certificates = Sum of (dividend rate × Certificates of each type on hand at the end of the year)									
28	Total Francs on Hand at the End of the Year									
29	Less: Fixed Cost									
30	End of Year Net Profit									

Transfer this amount to your profit sheet

FIGURE 18

row 0 of the year's information and record sheet. You may sell these if you wish or you may hold them. If you hold a certificate, then you receive "earnings per certificate" at the end of the year. Notice therefore that for each certificate you hold initially you can earn this amount if you do not sell that certificate during the year.

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

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

Information about Dividends: Whether the dividend you receive from the certificates you hold is the x dividend, the y dividend or the z dividend shown on row 26 is determined by the experimenter at the beginning of the year by drawing a ball from a bingo cage containing thirty-six balls numbered one through

thirty-six. If the ball drawn is numbered one through twelve, x dividend is paid; if the ball drawn is numbered thirteen through twenty-four, y dividend is paid; if the ball drawn is numbered twenty-five through thirty-six, the z dividend is paid.

Each year you will receive a clue as to what state has not occurred. The procedure for providing you the clues is explained later.

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 TRANSACTION PRICE in the appropriate column depending on the nature of the transaction. The first transaction is recorded on row (1) and succeeding transactions are recorded on subsequent rows.

(2) After each transaction you must calculate and record your new holdings of certificates and your new francs on hand. Your holdings of any type of certificates must not be below zero at the end of the period. For every certificate "short," a fine must be paid equal to the highest price at which any unit is sold during the period, plus ______ francs.

(3) At the end of the year record your total certificate earnings in the last column of row 27. Compute your end of period total francs on row 28.

(4) Subtract from total francs (28) the amount listed in row 29

and enter this new amount on row 30. This is your profit for the market year and is yours to keep. At the end of each market year, record this number on your profit sheet.

(5) At the end of the experiment add up your total profit on your profit sheet and enter this sum on row 21 of your profit sheet. To convert this number into dollars, multiply by the number on row 22 and record the product on row 23. The experimenter will pay you this amount of money.

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

Instruction Set 4 - Supplement [Contingent Claims Market]

For the next several periods the three securities will be merged into a single compound security. This single security has for each of you, your dividend value of the previous x security should the state x occur. It has for each of you your dividend value of the y security should the state y occur, and it has the value of the z security should the state z occur. These dividend values are shown in row 19 of your information and record sheet.

As you can see this security is like the x security when x occurs, the y security when y occurs and the z security when z occurs. Thus one possibility is that the market price of this compound security in any given state will be similar to the price of the x security when x occurs, the y security when y occurs, and the z security when z occurs.

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FOOTNOTES

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1. A penalty of 300 francs plus the highest transaction price traded during the period was imposed for each short unit. Only once (market 4, period 9) did a trader end a period in a net short position.

2. Since the RE equilibrium price of y and z securities under state x is zero, the model actually makes no predictions about allocations. If we assume that the investors will not incur the pecuniary or psychological costs of conducting a transaction without expectation of gain from it, the zero trade prediction follows. Some evidence on reluctance of investors to enter trades which have zero expected benefit is available in the experimental literature (Plott and Smith 1978).

3. One could interpret this as an alternative to the expected utility hypothesis as opposed to a difference in belief structures between the models.

4. Buy-and-Hold: buy one certificate at opening transaction price of each period; liquidate at closing transaction price of each period.

   Trend Filter: observe transaction price trend from opening to current price; if positive, buy if necessary to hold one certificate; if negative, sell if necessary to maintain a short position of one certificate. Liquidate at closing transaction price.

   y-Franc Filter: if transaction price goes up by y or more francs, buy if necessary to hold one certificate until the price goes down by y or more francs at which time sell, if necessary to maintain a short position of one certificate until the price goes up again by y or more francs. Liquidate at closing price.

5. The numbers in this first paragraph were altered appropriately for each experiment.

6. Language of these instructions was suitably altered for contingent claims and for the uniform dividend markets. The design of information and record sheets for the single security and contingent claims markets was different as shown.