INSIDER INFORMATION IN EXPERIMENTAL MARKETS

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Abstract

This thesis examines economic behavior in nine computerized, Double Auction asset markets. Different market environments are compared with regard to economic efficiency. Of primary interest is a comparison of the number of informed insiders. Of secondary interest is a comparison of continuous and discrete parameterization schedules. In both cases, price error and spread, and a time weighted version of each are the performance measures which are used to compare market environments. A fully revealing Rational Expectations price prediction model is used to compare price errors across market environments due to its somewhat universal acceptance and ease of computation. As a check on robustness, the above comparisons were done in different environments such as private value, common value, noisy, noiseless, early periods and late periods. The results indicate that with increasing numbers of insiders, there is greater competition and increased dissemination of insider information. In regards to the comparison of continuous and discrete parameterization schedules, the study results suggest that continuous markets may be more efficient than discrete markets.

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1. Introduction

This thesis examines economic behavior in nine computerized, Double Auction asset markets. In these markets, participants trade a single homogeneous asset, the worth of which is known initially only to insiders but is revealed to all at the end of the trading period. Each experiment is composed of roughly 40 trading periods. In Double Auction asset markets, all market participants can enter bids and asks as well as accept standing bids and asks over continuous time. The market is computerized as opposed to oral so that participants, who sit at terminals, do not know the identity of other traders. The computer keeps track of traders bids and asks and executes the transactions. In this way, economic behavior is recorded allowing for economic analysis of market efficiency. Globex, the Chicago Mercantile Exchange after hours trading system, is a real world example of a computerized Double Auction asset market. The structure of the nine computerized Double Auction asset markets are similar to that of Globex in that they embody the main characteristics, yet are experimental and simplified.

The different ways in which a given type of market is organized, commonly referred to as market environments, are compared with regard to economic efficiency. Here Double Auction markets are examined in different environments. Efficient markets are desired by economic actors. Market regulators and economic researchers are therefore particularly interested in comparisons of the number of informed insiders and the potential effects of insider activity. The fact that many forms of insider trading are, in most financial markets, illegal introduces noise to the observational process which restricts the ability of the observer to draw conclusions. It is of great importance to examine the effect on market efficiency. In an experimental setting, the effects of insider trading can be monitored in order to determine the extent of inefficiency of financial markets due to the presence of one or more insiders. As a result, we can determine how many insiders are necessary for a market to be strong form efficient.

Of secondary interest is a comparison of continuous and discrete parameterization schedules. Most experimental economics researchers to date include discrete parameterization schedules to test various hypotheses. In this paper a continuous parameterization schedule is tested against a discrete parameterization schedule in order to evaluate whether discrete parameterization leads to questionable conclusions. Certainly in the real world of financial markets a continuum of outcomes exist. Moreover, it is not known whether or not results from this type of oversimplified experimental technique extend to the proposed more complex, more realistic environment.

Conclusions are made using performance variables which measure the level of efficiency of a given market. In the analysis of varying numbers of insiders and continuous vs. discrete parameterization, price error and spread, as well as a time weighted version of each, are the performance variables used to compare environments. Price errors are determined by subtracting the equilibrium price from the actual price. The spread of a given market is the distance between the lowest offer to sell and the highest offer to buy. A time weighted version of each variable is possible since price error and spread are both defined over time intervals.

In this study I used a fully revealing Rational Expectations (RE) equilibrium price to compute price errors across market environments because it is well accepted and is easy to compute. A fully revealing rational expectations price prediction model is based upon the assumption that any private information is revealed to all market participants through market signals. As a check on robustness, the comparisons of market environments were conducted in different mediums such as private value, common value, noisy, noiseless, early periods and late periods.

The next section is an overview of the literature that is relevant to this thesis. This is followed by a presentation of the design of each of the nine experiments that constitute this study. Treatment, performance, and statistical variables are then discussed within the context of the experiments. Such variables can be used to show different levels of market efficiency across treatments. Next, the RE price prediction model is presented along with some environmental comparison predictions. In the results section I present some possible trader strategies, an interpretative look at some trading period graphs, and the results of statistical comparisons of various market environments. I conclude this paper with a discussion of what has been gained from this study, future analysis to be done with the data from this study, and other studies proposed by this research.

2. Literature Review

There seems to be a consensus among studies in experimental securities markets that these markets tend towards strong form efficiency over several trading days. Researchers have found this to be the case with both oral and computerized market mechanisms. It is commonly argued that prices, bids, and asks serve as market signals used by traders to reveal the state of the market. It is also commonly argued that market environments play a significant role in determining price and economic behavior.

Expectations of the traders regarding the environment of the market are seen to factor into economic behavior. For example, uninformed traders may be apprehensive of the presence of insiders, causing them to be mistrustful of market signals.

The study on the "Efficiency of Experimental Security Markets with Insider Information" conducted by Plott and Sunder (1982) deals with principles of rational expectations and the processes of "market information integration and dissemination to explain" economic behavior in experimental securities markets.(ibid., p. 663) Plott and Sunder see price as an indicator of the state of the market as well revealing the insider information. In a strong form efficient market model, price is believed to be fully revealing, making imperfect private information a secondary or less significant factor in affecting market efficiency. The strong version of the efficient markets hypothesis alleges that "prices adjust instantaneously to all available information."(ibid., p. 678) Plott and Sunder conclude that trading environments themselves ,not simply bids and asks, may be important in determining the applicability of the RE models. "Environments can dictate the type of information available to participants."(ibid., p. 690) Plott and Sunder close with the notion that "RE models must be taken seriously as not universally misleading about the nature of human capabilities and markets."(ibid., p. 692)

In their study of the presence of futures market as a market environment, using the experimental approach, Friedman, Harrison, and Salmon suggest that this environment itself promotes the dissemination of "inside information, with strong-form predictions outperforming semi-strong-form predictions."(Friedman et al, 1984, p. 349) Their experiments support using strong form RE as a bench mark for environmental comparisons. After several repetitions of the market, asset price reached RE predictions. Friedman, et al conclude that over time, "market outcomes tend to evolve toward strong-form informationally efficient equilibria."(ibid., p. 349) And that the environment of futures markets speeds the market towards RE, as well as promotes "the 'leakage' of insider information."(ibid., p. 349)

Unlike Friedman et al and Plott and Sunder, this study changes the identity of the insider agents after four periods, adding more noise to the experiments. Insiders were always picked randomly. In Jeffrey Banks' 1985 study titled "Price-conveyed Information versus Observed Insider Behavior: A Note on RE Convergence," he shows that varying the identity of the insider still creates market conditions of the RE model and that information is eventually disseminated over time. In regard to information dissemination, Banks remarks that the "fixed information structure of Plott and Sunder could well have overstated the revelation" (ibid., p. 814) that markets become more revealing over time. He adds that the 1984 Friedman et al conclusions concerning "informational efficiency in the presence of futures markets could have been driven, to some extent, by this same phenomenon"(ibid., p. 815) in reference to the fixed information structure. That is to say, the market may be less than strong form efficient.

In his thesis, "Market Efficiency and Insider Trading," von Borries (1988) looks at how the information structure of a market functions to disseminate insider information and thereby influence market efficiency and asset price. He does this in a computerized double auction setting, noting that the oral market mechanism "allows greater leakages of information."(1988, p. 4) He tests a fixed information structure with multiple insiders and finds that the strong form market efficiency model predominates and information is fully disseminated after several trading days. The same holds true when only an information monopolist is present. He also tests a random information structure and shows that the market under this structure is semi-strong form efficient. Von Borries concludes that uninformed traders are able to act upon market signals in some cases. But in other cases, uninformed traders are at the mercy of the information insiders. This leads von Borries to further suggest that markets are possibly less than strong form efficient. His thesis argues for the appropriateness of the semi-strong form efficient model in noisy environments.

In their findings on "Rational Expectations and the Aggreagation of diverse Information in Laboratory Security Markets," Plott and Sunder in 1988, were led to conclude that traders are perceptive of environments that disclose insider motivation. For their study, they use RE, PI (Private Information) and MM (Maximin) models. They find that the price predictions of the PI and MM models best suit the behavior of single security markets with private valuations. However, the RE model works best of the three in predicting the price in a market of common valuations. Plott and Sunder also looked at information aggregation where two or more traders possess less than perfect information that when aggregated becomes perfect information. In their experiments using the RE models, Plott and Sunder note that diverse information is aggregated in such a manner that enables traders to "identify that state with certainty."(ibid., p. 1085) They argue that aggregation of information improved over time and that the actual price was close to rational expectation predictions, evidence that aggregation occurred. Plott and Sunder conclude that markets can both aggregate diverse information efficiently and disseminate information efficiently. They also suggest from their findings that strong form market efficiency can be expected in the case of a single security market where the "traders have similar preferences,"(ibid., p. 1117). In other words, where there are common valuations, achievement of RE may be contingent upon traders' knowledge of such preferences.

I have based this thesis upon the above papers' arguments and findings, however, none explicitly compare number of insiders[1] or continuous vs. discrete parameterization schedules. The scope of this study is to examine these two unanswered questions. From the literature presented above ther exists strong rationale for using RE as a bench mark by which to test various market environments against each other. In testing environments against each other a complete study might enlist a variety of price prediction models. Due limited time and Research Assistant funding this study is restricted to using RE as a benchmark for comparing environments.

3. Market Design

The nine markets in this paper are based upon the same computerized Double Auction structure used by Friedman and Copeland (1987). The markets reported here consist of a number of trading periods that vary from 24 to 41. Each trading period is 2 to 3 minutes in duration.

A typical experiment goes as follows. Eight traders, from a pool of about 45 U.C.S.C. undergraduates, meet at a prearranged time and place with the principal investigator to participate in an experiment that lasts about 2 hours. All subjects are trained in using the market program and have had substantial practice. Each trader takes her/his place at one of several terminals with the experimenter making sure that

[1] von Borries deals with this in a secondary, non-statistical manner.

traders can not see each others' screens. The nature of the experiment varies from session to session. Information on the nature of the experiment is given to the traders before the session begins. An experiment is either a continuous version or a discrete version. In a discrete version the traders (outsiders) are informed that an asset is worth x amount or y amount with a fifty-fifty probability of each. In a continuous version the traders are informed that the asset value is drawn from a uniform distribution with known end-points.

Figure one (following the text), shows a typical trader screen. This trader's assets are worth $1.90 per share, with a 50 percent chance, and $.30 per share, with a 50 percent chance. In the upper right corner of the screen there is a ticker that tells the trader that there are 65 seconds left in this trading period. A ticker tape tells the trader that four transactions have occured at $1.76, $1.35, etc. during this trading period. Currently, the best (highest) bid is $1.00 and the best (lowest) ask is $1.60. The spread of this market is currently $.60. Our trader currently is offering to sell at $1.80 and buy at $1.00. The asterisk next to her/his one dollar bid signifies that she/he holds the best market bid. A continually updated holdings section at the middle bottom alerts our trader to changes in her/his cash and assets. Key representations at the bottom of the screen remind the trader which keys do what, i.e. cancel bid, ask etc..

Traders practice for two rounds in order to refamiliarize themselves with the market program. For approximately half of the experiments, all traders share the same value for the asset. The terminology for this is 'common valuation', which means that all traders share the same preferences. At other times, the value of the asset differs from trader to trader. This information is presented to the traders at the beginning of each session. Here the defining term is 'private valuation', which means that there are two groups with preferences constant within group, but different across groups.[2] Traders are told that there will only be one sub-period per trading period, during which insiders receive information on the asset. Traders do not know how many periods there will be in a session, in order to maintain consistent economic behavior. Otherwise a trader may act eratically if she/he believes that a session is coming to a close. Traders receive an endowment at the start of each trading day of $50.00 and 4 shares for series A, B, and C. For series D only 3 shares are received as part of the initial endowment along with the standard $50.00. The endowment is not

[2] Some critics might argue that this is a semi-common valuation, since not all traders have different preferences.

carried over to the next day. Over the course of a trading day, traders enter, at their discretion, bids (offers to buy) and asks (offers to sell), and may accept the best bid (highest) and best ask (lowest). Bids and asks may be canceled at any time during the trading day. A trader can not cross bids and asks, i.e., enter a bid that is higher than her/his own ask. Short sales, that is negative share balances, are not permited. A negative cash balance is virtually impossible since each trader has an initial endowment of cash that allows her/him to buy all shares in the market. At the conclusion of each trading day, there is a twenty second interm screen that informs the trader of her/his final realized value. The interm provides information on the transactions made during the day, the profit and loss on each transaction, and the total trading profit for the day. Also, the trader receives a running total of her/his trading profits for the entire experiment. Trading profits are consumer surplus for buys and producer surplus for sales. Traders are paid a fraction of this in private valuation experiments, while in common valuation experiments they are paid a fixed amount (usually $15) plus or minus a fraction of trading profits. In both cases a minimum payment of $5 is guaranteed.

In the common valuation treatment, all eight traders share the same payout schedule. Everyone's final asset valuation is either good or bad. In private valuation markets, where different traders have different payouts, eight traders are divided into two groups of four. Traders within the same group share the same payout schedule. All experiments reported here are of the homogeneous news variety. If one group receives a high or low payout, the other group will receive the same type of news (high or low), albeit a different value. In a continuous parameterization schedule this amounts to sharing the same random number between 0 and 1. This random number is then multiplied by the range for a group and then added to the lower endpoint. The same random number is used for both groups to find the asset worth for a given day.

The nine markets reported here were designed with the intent to facilitate two studies, one by myself and the other by Rod Merys. His study is also a comparison of market environments, however, he looks at common vs. private valuation and fixed vs. random informational environments. The nine experiments used in this study are divided into four series, labeled A, B, C, and D. Series A consists of markets 1 and 2; series B, 3 and 4; series C, 5 and 6; and series D, 7 through 9 (tables 1a through 1d at the end of the text).

Series A is defined by its common valuation and continuous payout schedule. Experiment one consisted of mostly one informational insider periods with a so called 'random' informational structure being used. In this type of structure the identities of the informational insiders are varied from period to period. This is in direct contrast to experiment two where the first twenty or so days are of the 'fixed' variety. In a noiseless informational structure the identities of the insiders are held constant for four periods in a row so they may become accommodated to the environment and better exploit their privilege. The last twenty days of market two return to a random informational environment. Both experiments in this series consists of 40 trading days, which are each 100 seconds in duration.

Series B shares the common valuation with series A, but has a discrete payout schedule. Market three contains many trading days with no insiders in a random informational environment. This was due to a software malfunction, but actually proves useful as a conformation of no-information market behavior. The first part of market four is a fixed informational environment with one, two, and three insider cases present. A random informational structure characterizes the second part of market four with mostly two and three insider trading periods. As in series A, both experiments have 40 trading periods of 100 seconds each.

Series C combines a private valuation with a continuous payout schedule. The first twenty four periods of market five consist of information monopolist cases in a fixed information environment. Later periods in this experiment are mostly two and three insider cases in a random informational environment. Market six for the first twenty periods is a fixed informational environment with one, two, and three insider cases represented. A random informational environment with mostly two and three insider cases makes up the second half of this experiment. Trading days are of 100 seconds in duration. Market five consists of 41 trading days while market six consists of 40 trading days.

Series D is the same private valuation as in Series C, but a discrete payout schedule is used instead of a continuous payout schedule. While Series A, B, and C each have two experiments, Series D has three experiments. The first of these, market seven, has twenty-eight trading periods with all but the last four having one insider. This market as well as market nine are of the fixed informational environment. Market eight has twenty-four trading periods with one and zero insider cases being represented. The last market in this series, market nine, is made up of mostly one and two insider cases. Like market seven this experiment has twenty-eight trading periods. All markets in this series had trading periods of three minutes.

4. Variables: Treatment, Performance, and Statistical

The following section explains the variables encountered in this paper. There are three types of variables of importance: treatment variables, performance variables, and statistical variables. The treatment variables in this paper are first, the number of insiders in a given trading period and second, the functional form of the payout schedule, be it continuous or discrete. These treatment variables characterize different market environments. This paper compares performance, in terms of efficiency, of markets that are characterized by different environments with the aid of statistical variables.

The number of insiders in a given trading period varies from zero to four, over the course of the nine markets reported. At the start of the period there may be a 100 percent chance of the asset being worth a \$1.50 for an insider. Whereas for outsiders, there may be a 50 percent chance of the asset being worth \$1.50 and a 50 percent chance of the asset being worth \$2.00. This informational news is constant for the duration of the trading period. In a continuous parameterization[3] schedule the insider might know an asset is worth \$1.67, while the outsiders would only know the endpoints of a uniform distribution, \$1.50 and \$2.00. All levels of number of insiders are used in conjunction with both types of parameterization in order to understand how these market environment variables interact.

Four different performance variables are looked at in comparing different market environments. Using RE price predictions and the actual price at which assets changed hands we can calculate two different price error values. The first of these *RMSE* is defined as follows:

$$RMSE = \sqrt{\frac{1}{ntrans} \sum_{i=1}^{i=ntrans} \left[x_i - p\right]^2}$$

ntrans is the number of transactions in a trading period and x is the transaction price. Since it involves squared deviations it is particularily sensitive to distant outliers. All performance variables reported here are sensitive to distant outliers. Therefore bids, asks, and transactions that were so far out of the experi-

[3] Technically the so called continuous parameterization schedules reported here are actually discrete. The uniform probability distribution refered to above is actually discontinuous and only defined at the whole numbers in pennies between the two endpoints. However, there does not appear to be any reason to believe that a closer apporximation to a continuous payout schedule would create different results.

ment bounds as to be considered errors were changed to, still out of bounds, yet less distant values.[4]

A time weighted version of this variable is also included. It is called *TWRMSE* and is defined as follows:

$$TWRMSE = \sqrt{\frac{1}{T}\sum_{i=1}^{i=ntrvls}\left[\frac{t_i}{2}\left(a_i+b_i-2p\right)\right]^2}$$

where p is the predicted price of the model. t is the length of the time interval and T is the duration of all time intervals. *ntrvls* is the number of intervals where existing market prices were constant. a and b are the best bid and ask at those times. This statistic is very much like *RMSE* except that it gives greater weights to transactions near the end of the trading period. Thus it is a better measure of what the transaction price actually converges to rather than what the average transaction price is. Strong form efficient markets will have very small values for *RMSE* and *TWRMSE*, while less efficient markets will have larger values for the price error variables.

The third and forth performance variables are both measures of spread, one time weighted and one not. The spread of a market is the difference between the best (highest) bid and the best (lowest) ask. Efficient markets would be expected to have small values for spread, while inefficient markets would be expected to have larger values for spread. The first of these measures of spread is *SPRD* and is defined as follows:

$$SPRD = a_{close} - b_{close}$$

It is the difference between the best ask and the best bid at the close of the trading period. *SPRD* is then a good measure of what the spread of a market converges to when the trading day comes to a close.

TWSPRD, on the other hand, takes into acount the value of the market spread over the entire couse of the trading period. It is defined as follows:

$$TWSPRD = \frac{1}{T}\sum_{i=1}^{i=ntrvls}\left[t_i\left(a_i-b_i\right)\right]$$

The notation in this equation is identical to that used in the earlier equations. From this formula it can be

[4] In order to remove distant outliers that have no economical relationship to the parameters at hand --- bids, asks, and transactions more than $.25 outside most extreme payoffs for a given market were changed to $.25 outside most extreme payoffs in order to calculate performance statistics.

seen that *TWSPRD* is just the average (area/length) distance between the ask and bid curves. If only one or neither of these curves is defined then this portion of the area is not included in the *TWSPRD* statistic. *TWSPRD* then gives equal weight to the the whole trading period, at least to those parts of the trading period where both bid and ask lines are defined. All four of the performance statistics share the characteristic that small values indicate efficiency while larger values indicate inefficiency.

Before getting into detail regarding the subtleties of the different statistical comparison variables it is necessary to discuss the nature of the statistical comparisons used below. Let us say that we are testing the difference between 0 and 1 informational insiders in terms of *RMSE*. We first take all trading periods that have 0 insiders and put them in an imaginary urn refered to a urn X. The same is done for all trading periods having 1 insider with the urn being refered to as urn Y. Our statistical tests then test the null hypothesis that the values in urn X and urn Y come from the same big urn. In other words, *RMSE* is no different between 0 and 1 insider cases. The farther the test statistic is from zero the stronger is the rejection of the null hypothesis that RMSE is no different between the two environments being tested. Positive test values favor urn Y over urn X because *RMSE* values are higher for urn X cases then for urn Y cases.

Two different statistical comparison variables are used on the four different performance variables to test for differences across environments. The first of these is the parametric pooled t statistic which has the following formula:

$$t = \frac{(\bar{X}-\bar{Y})\sqrt{\frac{(n_X n_Y)}{(n_X+n_Y)}}}{\sqrt{\frac{S_X{}^2 n_X + S_Y{}^2 n_Y}{n_X+n_Y-2}}}$$

where S_X and S_Y are the standard deviations. n_X and n_Y are the number of observations for each sample. $\bar{X}$ and $\bar{Y}$ are means of respective urns. This t statistic assumes that the underlying error terms are normally distributed. By taking account of the distances between different values of the same variable it is sensitive to large outliers.

The Wilcoxon rank sum test, on the other hand, is not sensitive to the distances between different values of the same variable. Because it does not make any distributional assumptions about the underlying error term, the above test is nonparametric in nature. It is refered to as the Z value and is defined as follows:

$$Z = \frac{SR_1 - \mu_{SR\,1}}{\sigma_{SR\,1}}$$

$\mu_{SR\,1}$ represents the mean of the ranked sum and $\sigma_{SR\,1}{}^2$ the variance of SR_1 under H_o.[5] These figures are calculated using the following formulas. $\mu_{SR\,1} = \frac{n_1(n_1+n_2+1)}{2}$ and $\sigma_{SR\,1}{}^2 = \frac{n_1 n_2(n_1+n_2+1)}{n-1}$. This test simply ranks the values from lowest to highest and assigns each value a number; 1 for the lowest, 2 for the second lowest, etc. up to n for the highest value. By keeping track of which values come from which urn (urn X for the 1st environment and urn Y for the 2nd environment) the computer program (SAS) that calculates this test statistic tests the null hypothesis that the values in both urns come from the same uderlying population distribution. Of course, both the above statistical tests assume independent observations, however, this is surely not the case and all we can satisfy ourselves with is that these tests are used in the same manner throughout the experimental literature. For both the pooled t and the Wilcoxon statistics described above test values of greater than 1, 2, and 3 roughly corespond to weak, moderate, and strong levels of significance.

5. Theory

In this section, I first discuss the RE equilibrium model, and some examples of its usage. Second, I present relevant efficiency predictions of the environmental comparisons which are the focus of this study.

5.1. Rational Expectations equilibrium

The central hypothesis of RE is that all private information is revealed to traders through market signals. Reasonable economic actors consider all available information in formulating market strategies, rather than just their own private information. From this hypothesis, predictions can be made about economic activity. In direct contrast to the RE model is the private information (PI) equilibrium model which supposes that traders only use their own private information in determining the value of an asset. Insiders can profitably exploit their information in the PI model and not in RE. PI is then less than strong form efficient. However, the PI and RE models predict similar activity when all traders receive the same

[5] The null hypothesis in this case is that all observations come from the same underlying distribution.

information.

Although traders are expected to act with an abundance of uncertainty, this study is based upon the assumption that traders are risk neutral. We assume this to be the case because the simplicity of the models and the incentives are such that traders are not inspired to be risk averse. Critics would argue that there is a diminishing marginal utility of money which would make risk neutrality a bad assumption. However, repetitive small stakes should alleviate any risk averse behavior. This is particularly the case in common valuation markets where traders are paid a fixed amount, plus or minus a fraction of trading profits.

In order to more formally discuss the RE equilibrium model it is necessary to define the concept of a reservation price. It is the price at which a trader values an asset. The trader will sell an asset above this price and buy an asset below this price. As from above we assume risk neutrality. In the context of uncertainty this means that if a trader is privately informed that the probability of two asset values is 1/2 each then she/he will have a reservation price midway between these two values. For the PI model, traders use all of their private information to determine their reservation price. In the RE model, uninformed traders determine reservation prices through market signals. So the nature of reservation prices in RE is the same as PI, however, in RE there is more information for every trader to use in order to formulate a reservation price. Due to a fixed supply of assets in this market and an infinitely elastic demand for the assets, we would expect to find the market clearing at the demand price. The RE price prediction is the highest of the individual reservation prices.

Some examples will illustrate the RE equilibrium model and how the resultant price predictions work. The first example is of the common valuation type, series A and B in this study. In market one[6], day 1, trader zero[7] has full information while traders 1 through 7 only know the endpoints of a uniform distribution $.40 and $2.00 respectively. Trader 0 has a reservation price of $.70, the worth of the assets. Traders 1 through 7 also have a reservation price of $.70, in the case of RE, since they can read market signals and interpret the asset value. Everyone shares a reservation price midway between $.40 and $2.00 if there are no informed traders present. Common valuation markets share the characteristic that all traders

[6] Market design is presented on tables 1 through 4.
[7] Traders are numbered 0 through 7 in all markets.

have the same RE reservation price. With this being the case there is no incentive for trade.

In private valuation markets, series C and D of this study, different groups of traders[8] have different asset values. For example, on day 1 of market 6, traders 0 and 4 have insider information of asset worth. However, since they belong to different groups, their respective insider information differs. Trader 0 knows her/his final asset value of $.77, while trader 4 knows her/his final asset value of $.98. Traders 1 through 3 are given endpoints of a uniform distribution from $.60 to $2.00, while traders 5 through 7 are given endpoints of a uniform distribution from $.90 to $1.60. Traders 0 and 4 determine reservation prices based upon their asset value. In the model, market signals in this RE model reveal the final asset worth to participants 1 through 3 to be $.77 and participants 5 through 7 to be $.98. In reality, disclosure of private information may occur when the insider attempts to exploit the knowledge of asset worth for her/his own profit.

5.2. Environmental Comparison predictions

The above RE model provides us with price predictions with which we can construct price errors for each trading period. Unlike price errors, spread -- another measure of market efficiency, does not rely on any equilibrium price theory. Economic theory will allow us to predict outcomes of environmental comparisons. Number of informational insiders and types of parameterization schedules are the treatment variables to be examined in this study.

In markets with 0 informational insiders present the market is expected to be less than weak form efficient. In this case, market participation can best be described as gambling. There are no asset valuation revealing market signals because there are no insiders to provide these signals. Given RE reservation prices, we assume that there would be no incentive for trade in common valuation markets since everyone shares the same reservation price. Furthermore, there is even more disincentive to trade since traders do not know if there are informational insiders present. Trading with the insider is thought to always be a losing proposition to the outsider. Outsiders are expected to be cautious. Private valuation markets would share the same less than weak form efficiency with 0 insiders. Differences in the midpoints of endpoints

[8] All private valuation markets in this study have two groups.

are small between trader groups and would therefore, not provide enough incentive to overcome general caution. If traders differ in home-grown risk aversion then there might be an incentive for trade.

In the case of one information insider, we predict that the market will be weak or semi-strong form efficient (PI). Traders use market signals to make decisions, yet those signals are not fully revealing and the insider is still able to achieve a greater profit than the uninformed traders. The skill of the insider in exploiting her/his information without revealing asset valuation plays a large part in determining the efficiency of one insider markets.

With two insiders present, we would expect to find markets becoming strong form efficient. Homogeneous news, which is used in all private valuation markets,[9] expedites this drive to efficiency. Both insiders, even though they are from different groups, will generally be either buyers or sellers in which case they will compete directly against each other. As buyers,[10] both insiders act on similar knowledge of asset values and continuously outbid each other. As a result the market moves towards strong form efficiency. Three and four insiders would only increase the competiveness of this process, making the markets strong form efficient.

Actual comparisons between these market environments may lead to statistically discernable differences between 0 and 1, 1 and 2, but not 2 and 3, or 3 and 4 insiders. Unfortunately there are only 6 observations of 4 insiders, which is not enough to do statistical comparisons. Zero insider markets are presumed to be less efficient than 1 insider markets, i.e. higher price errors and market spread than markets with insiders present. As the number of insiders increases from 1 to 2 and on to 3 and 4 more efficient markets are predicted with differences moving towards zero as the number of insiders increase. Due to differences in trader ability, it is possible that statistically discernable differences occur between 2 and 3 insider markets. However, it is difficult to predict statistically discernible results between 3 and 4 insider markets because of the larger amount of competition. Of course, traditional theories would predict inefficiency gradually approaching zero as the number of insiders becomes infinite.

[9] Common valuation markets are by their very nature homogeneous.

[10] Insiders with knowledge of asset prices above respective group midpoints will be buyers, whereas, insiders with knowledge of asset prices below respective group midpoints will be sellers. Von Borries, in 1988, notes that such competition is weaker for informed sellers.

Markets defined by discrete parameterization schedules are expected to disseminate insider information to a larger degree than continuous parameterization schedules. There are only a small handful of possible asset valuations in discrete schedules, compared to approximately 120 in continuous schedules.[11] On one hand, the few possible outcomes make discrete markets more efficient than continuous markets. On the other hand, continuous markets appear to be, in some cases, more efficient than discrete markets. The way these markets were designed resulted in this inherent problem. The distance between the endpoints of the continuous asset value distribution is the same as that of the high and low payouts for discrete markets. For prices that are chosen randomly, discrete environments are expected to have higher price errors resulting from reservation prices that are at the extremes of the relevant range. This is in contrast to continuous markets that can have asset valuations that fall between the two endpoints, which results in lower price errors, on average. Therefore, in a comparison of continuous and discrete there are offsetting conditions that affect market efficiency. It is thus impossible to predict which schedule, discrete or continuous parameterization, is most efficient using *RMSE* and *TWRMSE* performance variables.[12] However, for *SPRD* and *TWSPRD*, it is predicted that discrete markets will be more efficient.

6. Results

The results section is organized into six subsections. First, an overview of a few of the graphs is presented in order to help the reader better understand the workings of these experimental markets. This is followed by a discussion of some trading strategies. Then four subsections, each one devoted to an environmental comparison, analyze the results of the experiments.

6.1. Graphs: an Interpretation

Since there are 321 total trading periods it would make little sense to present them all. Therefore only a few examples are presented here. Two examples are presented of zero, one, and two insider markets. One example each of three, four, continuous, and discrete markets are then discussed.

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[11] The continuous markets in this study use uniform distributions of asset values for a given market that have a domain which includes about 120 possible values.

[12] These effects could be seperated by looking at percentage root mean squared error.

Figure 2a shows two examples of zero insider markets. The top part of this figure is trading period 35 from market 3, while the bottom part is trading period 10 from the same experiment. Market 3 is a common value discrete market with two possible outcomes. Period 10 is a good example of the market behaving how it would be expected to behave. Bids and asks are fairly weak throughout the period with transactions scattered around the midpoint. Period 35 is a good example of a bubble. This is when a slight movement in one direction can cause traders to incorrectly believe that market signals are revealing asset value. By the 80 second mark all evidence indicates that the asset is going to be worth \$0.30. All concerned were probably quite surprised when the asset value was revealed on the interm screem to be \$1.90.

Figure 2b presents two examples of one insider markets. The top part of this figure is trading period 2 from market 3 and the bottom part of is trading period 13 from market 2. Both markets are in some way inefficient which is characteristic of one insider markets. Period 2 of market 3 is inefficient in both price error and market spread. The insider here makes very profitable use of her/his information. In the case of period 13 for market 2 the insider does not make profitable use of her/his information. Since *RMSE* is very low this market would be considered efficient in terms of price error. However, the spread is fairly wide and in this regard the market would be considered inefficient.

Figure 2c shows two examples of two insider markets. Trading period 34 of market 3 is presented in the top portion, while trading period 12 of market 9 is presented in the bottom portion. By inspection both markets are more efficeint than the the one insider markets on the previous figure, which is very much in line with the results of this study. The top graph is an example of full dissemination of information with marginal trading profits for insiders. The bottom graph is an example of not so full dissemination of information with some profits for insiders. Since this second market has private values this is as expected.

Figure 2d presents an example of a three insider market along with an example of a four insider market. The top graph is of period 17 in market 2, which is of the common value continuous variety. The bottom graph is period 21 of the same market. Both markets are highly efficient with small price error and market spread. It can be seem, however, that the four insider market is slightly more efficient especially with regard to spread. This is very much in line with the prediction that additional insiders improve efficiency.

Figure 2e contrasts a continuous market with a 'matched' discrete market. The continuous graph is from period 8 of market 5, while the 'matched' discrete market is the same period from market 7. The word 'matched' here means that state, number of insiders, and valuation type are held constant. Valuation type for both of these trading periods is private. As is consistent with the statistical comparisons the continuous market is much more efficient than the discrete market. Section 6.6 discusses why this might be the case. This brief overview of the graphs should give the reader a better understanding of the trading stategies used in these markets.

6.2. Trader Strategies

This section outlines various theoretical trading stategies that may be used by traders in the double auction experiments in this study. Different strategies are employed by insiders and outsiders. Insider trading strategies are based on perfect information, while outsider trading strategies rely on market signals revealed by insiders. Included, is a discussion of the actual strategies that were used by individual traders, as observed during the market period.

Copeland and Friedman, in 1988 (p. 8), present possible stategies for insiders and outsiders in the types of markets reported here. There are three stategies for informational insiders. First, insiders may follow a risk-neutral trading strategy which would entail accepting (refusing) offers to sell at prices above(below) that insiders reservation price and refusing(accepting) similar offers to buy shares. This strategy does not reveal insider information. Second, insiders may follow an aggressive strategy that entails raising(undercutting) the existing best bid(ask) if held by someone else as long as it is below(above) that insider's reservation price. If there exist two insiders with the same reservation price, both pursuing an aggressive trading strategy, insider information will be disseminated very quickly. If traders embody both of the above characteristics, they are said to be pursuing an aggressive risk-neutral trading strategy. This strategy maximizes a trader's expectation of her/his final wealth as long as the following two conditions are met: 1) she/he believes no other trader has superior information and 2) the trader believes that she/he can not systematically affect future terms of trade by current actions. An insider might not believe that her/his actions affect future terms of trade. Specifically, a trader might initiate a couple of transactions at a loss in an attempt to reveal false information. This is considered a Nathan Rothschild ploy. If outsiders are susceptible to the dissemination of false information, an insider can earn large trading profits by taking advantage of traders with misleading reservation prices.

Outsiders can pursue either of two trading stategies. First, they can withdraw from the market by only buying below their lowest possible payout and selling only above their highest possible payout. In common valuation markets where the outsiders know there are insiders present this strategy would seem to make the most sense. If all outsiders pursue this stategy insiders will be forced to reveal their information in order to transact. Second, outsiders can employ one of the insider strategies, after inferring asset valuation from market signals. In this case, the outsider must correctly be able to read market signals. The uncertainty present when trying to read market signals, in order to infer asset value, increases the risk.

In this study some of the above strategies were observed. Market 1, the first common valuation market, produced some confusing results. Traders were told that everyone would share the same payout and that zero or more insiders would have perfect information. Logic should lead outsiders to conclude that they can only lose by transacting with the insiders, given this zero-sum game. However, fairly large numbers of transactions were observed. The reason for this became apparent during the last common valuation experiment, market 4, where many of the traders were the same ones that participated in other common valuation markets. In the first few experiments, outsiders had been exploited by the insiders. Yet, by the last experiment they had moved towards a withdrawal strategy given poor results with other strategies. Informational monopolists seemed to be able to successfully use a risk-neutral trading strategy to exploit their perfect information. This was less so in common valuation markets where information was more completely disseminated. As the number of insiders increased, aggressive behavior eroded insider profits, while insiders competed against each other for scarcer and scarcer profits.

6.3. 0 vs. 1 informational insiders

This section statistically compares the two market environments: 0 insiders and 1 insider. Table 2 presents these results. *RMSE* and *TWSPRD* are the only performance variables where 0 insiders had statistically more inefficient values than 1 insider for both the Wilcoxon and the pooled t tests. On one hand, *SPRD* favors 1 insider over 0 insiders for both statistical tests, but is only significantly discernible in the Wilcoxon test. *TWRMSE*, on the other hand, favors 0 insiders over 1 insider, but not at any acceptable level of significance.

The different price error measures, unexpectedly result in different signs. It is believed that traders take time to familiarize themselves to the market and its complexities. Confusion in early reps can influence overall results. Looking at late reps (reps later than 10) we see that the numbers are very similar to the overall numbers. Therefore, the overall results are not necessarily influenced by the early round results. The negative and positive signs resulting from the different comparisons are certainly worthy of future investigation. Also worthy of future investigation is the 51.7 cent price error associated with 0 insiders. In discrete environments, the above is possible. However, in the case of continuous environments, such occurrence seems implausible, since the range of possibilities is barely more than twice this value. In private valuation trading periods price error keeps its sign, but loses its significance. While the time weighted version stays insignificant, but switches signs. The common valuation trading periods and the random information trading periods give almost the exact same results as the overall comparisons, with *TWRMSE* becoming more significant. In fixed infomation periods price errors kept their sign, but became very insignificant, while the time weighted version became statistically significant with the same sign. This is expected as outsiders improve their ability to discern market signals in fixed informational environments, thus making 1 insider cases more efficient. In conclusion, price errors are statistically larger in zero insider environments than in one insider environments. The time weighted comparisons are interesting, but only point towards future examination.

SPRD and *TWSPRD* both favor 1 insider over 0 insiders. The magnitude is much greater for the time weighted version with most comparisons highly significant, while *SPRD* comparisons border on significance with one exception. That one exception is the fixed information structure where *SPRD* is highly significant: 3.45 for the Wilcoxon and 3.46 for the pooled t. This is to be expected. In 0 insider cases with fixed information, traders would be expected to lose interest which would tend to increase *SPRD*. The same is true for the highly significant values for the *TWSPRD* comparisons. In fact this comparison understates the actual difference. *TWSPRD* is the area between the ask curve and the bid curve. It is only defined when bids and asks are present. This measure of inefficiency is then biased downwards if both curves are occassionally defined together.

Overall, it appears that 1 insider markets are more efficient than 0 insider markets with the exception of fixed information cases using the preformance variable *TWRMSE*.

6.4. 1 vs. 2 informational insiders

This section statistically compares the two market environments: 1 insider and 2 insiders. Table 3 presents these results. *RMSE* and *TWSPRD* are the only performance variables where comparisons give significant results. Interestingly enough, these results are of differing signs. *RMSE* comparisons favor 2 insiders over 1 insider, whereas, *TWSPRD* comparisons favor 1 insider over 2 insiders. *TWRMSE* and *SPRD* produce significant results for both tests in only one of eighteen comparisons.

Price error comparisons with, few statistically insignificant exceptions, all have positive signs indicating that 2 insider markets are more efficient than 1 insider markets. *RMSE* is generally significant throughout all nine comparisons with one notable exception. Fixed information market environments show almost no difference between 1 and 2 insider cases. In fact the pooled t test has a value of zero and the Wilcoxon has a value of .04. Possibly in fixed information markets insiders are able to collude causing the addition of more insiders to not have a significant effect on efficiency. Contrastingly, *TWRMSE* is mostly insignificant with the notable exception of random information cases. In this case the Wilcoxon and pooled t values are 2.67 and 2.73 respectively. It is possible that in the case of random information environments both insiders tend to pursue aggressive strategies which will cause markets to be strong form efficient.

Different measures of market spread conflict since *SPRD* and *TWSPRD* have different results. Five out of nine Wilcoxon tests on *SPRD* are significant, favoring 2 insiders over 1 insider, while none of the pooled t tests are significant with no concensus on sign. What these comparisons seem to suggest is that the difference between best ask and best bid at the end of trading periods is fairly similar for 1 and 2 insider cases. Yet, *TWSPRD* is significant and consistent in sign for all nine comparisons using both the Wilcoxon and pooled t tests. What is interesting is that 1 insider cases have lower values than two insider cases (meaning that adding another insider lowers efficiency). A plausible explanation is that an underlying confounding factor causes 2 insider cases to be less efficient. It is also possible that when *TWSPRD* is only defined when bids and asks are both present, 1 insider cases appear to be more efficient than they really are.

Assuming that the confounding factor is that both bids and asks are not defined in 1 insider markets, we conclude that 2 insider markets are more efficient than 1 insider markets.

6.5. 2 vs. 3 informational insiders

This section statistically compares the two market environments: 2 insiders and 3 insiders. The results are presented in Table 4. The sign convention is such that positive numbers favor 3 insiders over 2 insiders. Comparisons of all four performance variables across environments produced significant results for at least one of two types of comparisons. Unlike the above two environmental comparisons where differing performance variables had different signs, here all four performance variable comparisons had the same sign.

Price error comparisons were significant in the positive direction with most Wilcoxon and pooled t values greater than 1.5. One of the most interesting results of this study is the degree of significance between 2 and 3 insiders. Before conducting the experiments it was assumed that 3 insider markets would be more efficient than 2 insider markets, the magnitude of this difference being marginal at best. In fact, the average price error, *RMSE*, drops from 26.8 cents in the case of two insiders to 17.0 cents in the case of three insiders. This indicates that the addition of another insider increases competition between insiders enough to increase the dissemination of asset valuation informaition. The Wilcoxon and pooled t statistic values are 3.29 and 2.51. Unlike the results from the 1 vs 2 insider comparison, the results are robust to a time weighting. All of the subcomparisons of 2 vs 3 insiders for *RMSE* and *TWRMSE* were positive and distributed evenly around the value of 2.0 with the exception of fixed information cases. For this case, using the *RMSE* performance statistic, the Wilcoxon gives a value of 1.27 and the pooled t gives only a value of 0.39. Time weighted versions of the above comparison give similarly insignificant Wilcoxon and pooled t values. This is balanced out by random information cases which had values greater than 2.0 for both performance statistics. It is surmised that if market insiders are in collusion, increasing their numbers does not affect efficiency.

Market spread performance variables, *SPRD* and *TWSPRD*, have significant Wilcoxon values, and almost significant pooled t values. *SPRD* comparison values are evenly distributed around 2.0 for the seven sub-comparisons with the notable exception of fixed information markets. Like the two other performance variables above, *SPRD*, loses significance for both the Wilcoxon test, and the pooled t test, 0.61 and 0.53, respectively. As with the case of price error variables, in fixed information markets, it appears that insider collusion diminishes the effect of more insiders on market spread. *TWSPRD* comparison values are very similar to the above non weighted version of this performance statistic. Again fixed information markets are the exception. For *TWSPRD* the Wilcoxon statistic is slightly negative, -0.36, and the pooled t statistic is almost significantly negative, -1.87. The small number of observations with 3 insiders in fixed information markets hinders the significance of these numbers. The figures suggest that the addition of one more insider decreases market efficiency. This seems contrary to economic theory. Therefore, no conclusions will be drawn at this time.

Overall, 3 insider markets seem to be more efficient than 2 insider markets. Does the addition of a fourth insider in these 8 trader experimental double auction markets have a significantly positive effect on efficiency? It was assumed that the difference between 2 and 3 insiders would be insignificant. Therefore, the experiments were not designed to test 3 versus 4 insiders.

6.6. Continuous vs. Discrete Parameterization

While the primary focus of this paper is the comparison of number of insiders, it also, on a secondary note, compares types of market parameterization. For this comparison the same four performance variables used above are used here. Wilcoxon and pooled t tests are applied to each variable. The sign convention is such that positive numbers favor discrete over continuous parameterization. Overall, comparisons of the four performance variables indicate that continuous markets are more efficient than discrete markets.

Price error comparisons are in almost all cases highly significant for both the Wilcoxon and the pooled t tests. In fact, many values are below -5.0. Section 5.2 above outlines the two effects resulting from the experimental design. The most plausible explanation for the large negative values is that the discrete environments are more efficient than the continuous environments. However, the effect of larger expected values of *RMSE* for discrete environments seems to overide the first effect, producing large negative values. *RMSE* comparisons values are all less than -1.0 with the notable exception of the Wilcoxon test for 3 insider markets. Relative to other market environments 3 insider markets, with a Wilcoxon value of 0.24, are very efficiency. The statistical insignificance of the value of 0.24 indicates that the type of parameterization has little effect on efficiency in 3 insider markets. *TWRMSE* comparison values are all less than -3.0 with no exceptions. As with the non time weighted performance statistic, the larger expected value of price error effect appears to dominate the effect of greater discrete market efficiency.

Market spread comparisons do not suffer from the same design flaw as the price error comparisons. *SPRD* comparisons are generally negative, but most values are insignificant. Therefore, continuous markets are slightly more efficient than discrete markets in regard to market spread at the end of the trading period. The one exception is the 0 insider market comparisons. Both the Wilcoxon and the pooled t tests producė significant negative values for 0 insider markets. Such results are explained in that the variance for continuous markets is much smaller than with discrete markets. *TWSPRD* comparisons are all negative with most values highly significant. In discrete markets, as with *SPRD*, it is very risky to have bids and asks near the midpoint, especially early in trading periods. Since *TWSPRD* gives equal weight to all times during the trading period, large early spreads may cause the condition of larger *TWSPRD* values for discrete markets. be responsible for discrete markets having larger *TWSPRD* values.

Because the two effects occur simultaneously, it is difficult to evaluate the underlying economic processes in relation to price error. If the larger expected price error in discrete markets could be eliminated, while still yielding similar results, this would challenge the prediction that discrete markets are more efficient. The market spread comparison results seem just as expected.

7. Conclusion

In the evaluation of economic behavior in nine computerized, Double Auction asset markets, several conclusions can be made regarding the influence of differing numbers of informational insiders on market efficiency. Experimental markets are believed to yield insight to the nature of real world markets. In this study, comparisons were made of the numbers of informational insiders and predictions were made of how many insiders are needed to make the market strong form efficient. The types of comparisons examined were price error and market spread. Of secondary interest was the comparison of continuous and discrete parameterization schedules.

Results from the study showed that one insider markets are more efficient than zero insider markets with the exception of fixed information cases using the preformance variable *TWRMSE*. For cases in which the confounding factor both bids and asks are not defined in 1 insider markets, we conclude that 2 insider markets are more efficient than 1 insider markets. Overall, 3 insider markets are more efficient than 2 insider markets. It is concluded that with increasing numbers of insiders, there is greater competition and increased dissemination of asset valuation. Market signals are more easily discerned by non-informed traders, leading to strong form market efficiency.

In regards to the comparison of continuous and discrete parameterization schedules, the study results suggest that continuous markets may be more efficient than discrete markets. Continuous markets have greater possible asset valuations and discrete markets have a higher expected price error. Because these conditions occur simultaneously, it is difficult to evaluate the underlying economic processes in relation to price error. It was predicted that discrete markets are more efficient. Yet, this proved to be contrary to the results. The prediction was possibly unrealized because of the larger expected price error in discrete markets. If this effect can be eliminated, while still yielding similar results, then the prediction would be challenged.

As this paper is not the final outcome of this study there are many shortcomings in the above analysis that will be addressed in subsequent papers. Since the comparison of 2 vs. 3 informational insiders yielded significant results, the comparison of 3 vs. 4 insiders would further illuminate economic behavior in experimental markets. Two later experiments were conducted in order to provide data for the above comparison. Also, two more performance variables, insider excess profit and volume, will be included in an updated version of this study to give the above comparisons a more complete test.

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Figure 1

```
Double Auction Market 2.0              Trader Name                          Time left:  1:05
Experiment test:  Day #1               (Trader #0)


  Prob.  Worth
  .50    $1.90
  .50    $0.30



      Your  Mkt
      Price Price
Asks: 1.80  1.60
Bids:*1.00  1.00

Ticker Tape:  1.76  1.35  .98  1.22

==>
+------+ +------+ +------+ Holdings:                          +------+ +------+ +------+
|  Q   | |  E   | |  R   |                                    |  U   | |  I   | |  P   |
|      | |Accept| |      | Start:   25.00    0.00             |      | |Accept| |      |
| Ask  | | Best | |Cancel| Change:   0.00    0.00             |Cancel| | Best | | Bid  |
|      | | Bid  | | Ask  | Now:     25.00    0.00             | Bid  | | Ask  | |      |
+------+ +------+ +------+                                    +------+ +------+ +------+
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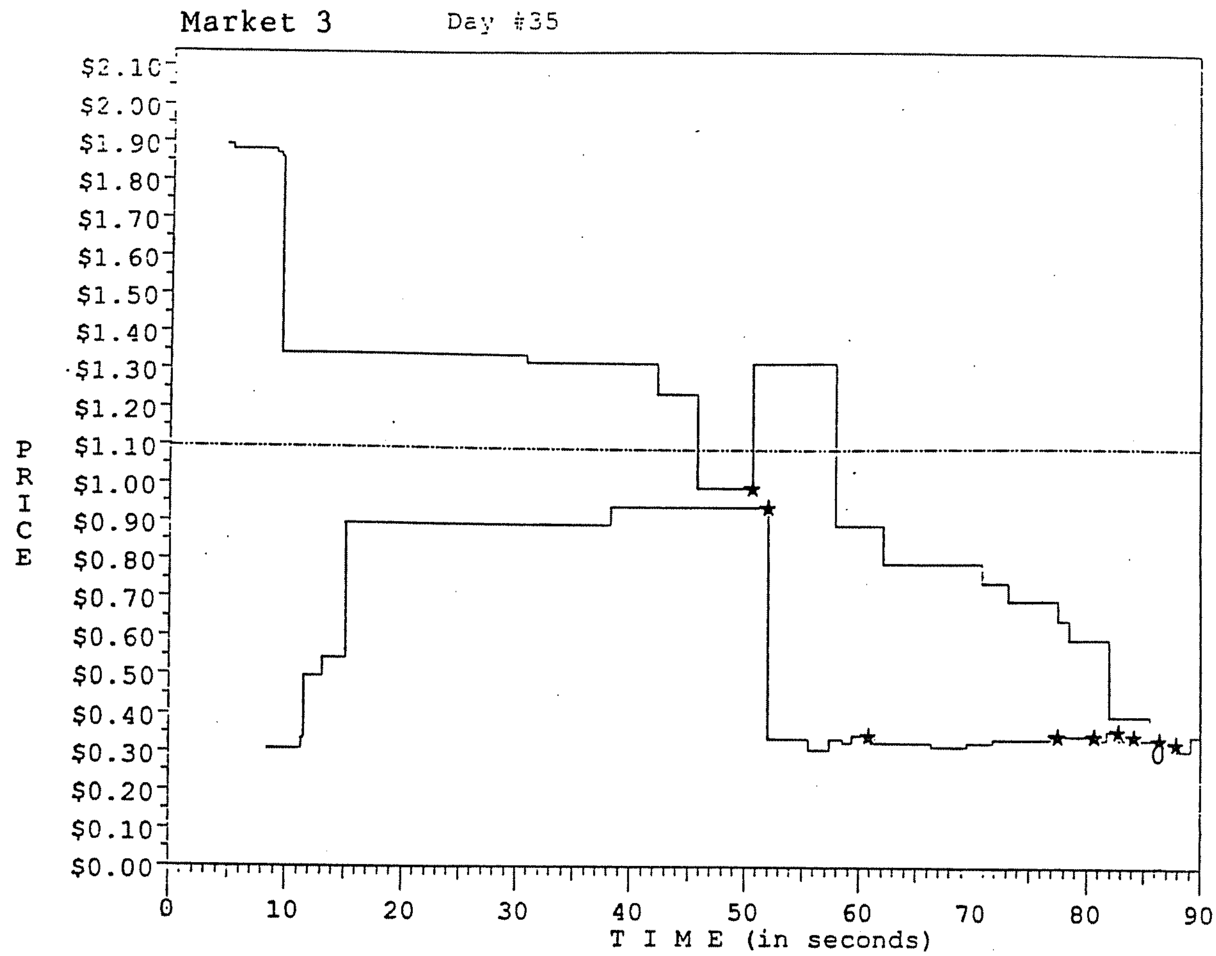
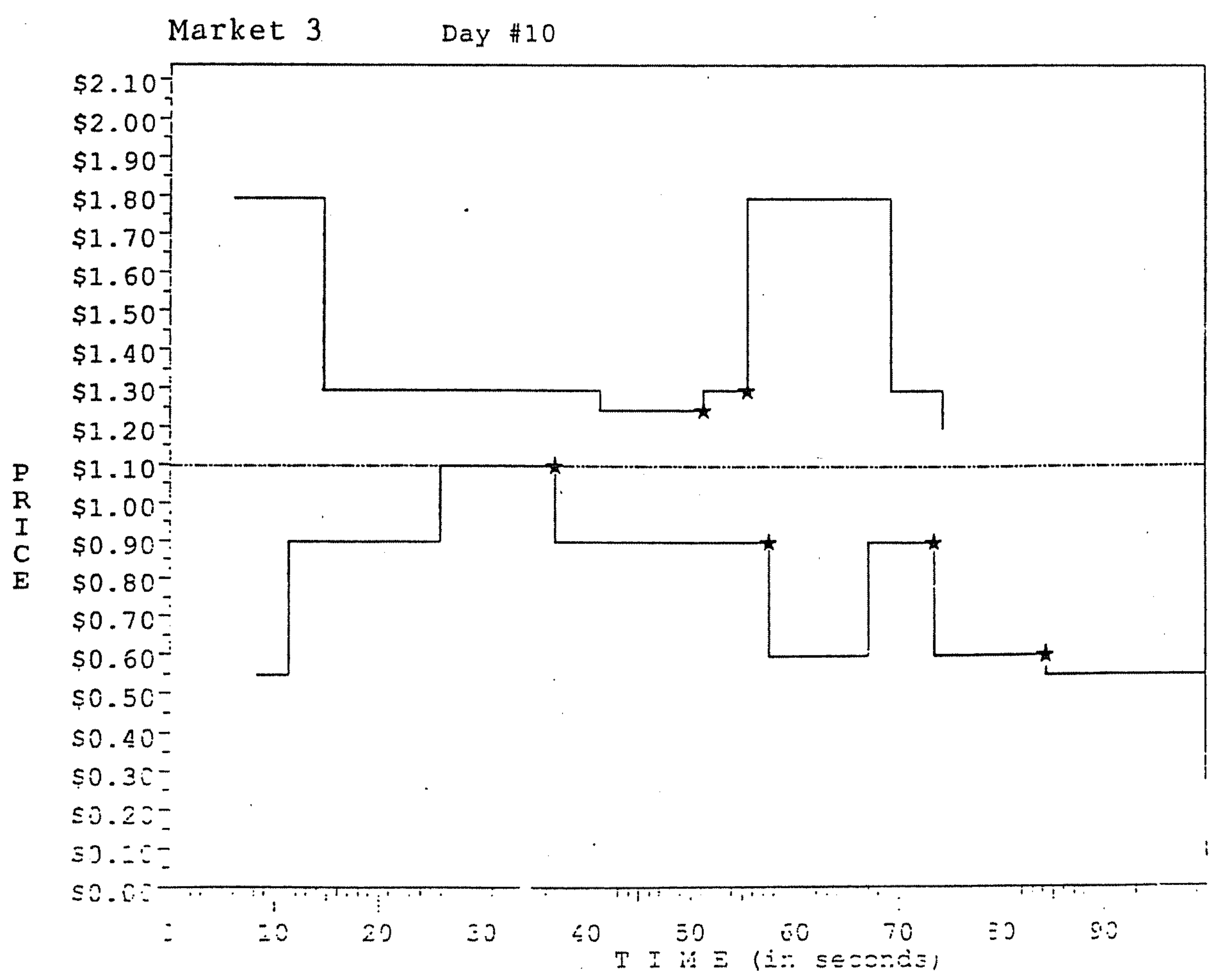

Market 3
Day #35
$2.10
$2.00
$1.90
$1.80
$1.70
$1.60
$1.50
$1.40
$1.30
$1.20
$1.10
$1.00
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
PRICE
0
10
20
30
40
50
60
70
80
90
T I M E (in seconds)

Figure 2a


Market 3
Day #10
$2.10
$2.00
$1.90
$1.80
$1.70
$1.60
$1.50
$1.40
$1.30
$1.20
$1.10
$1.00
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
PRICE
10
20
30
40
50
60
70
90
T I M E (in seconds)

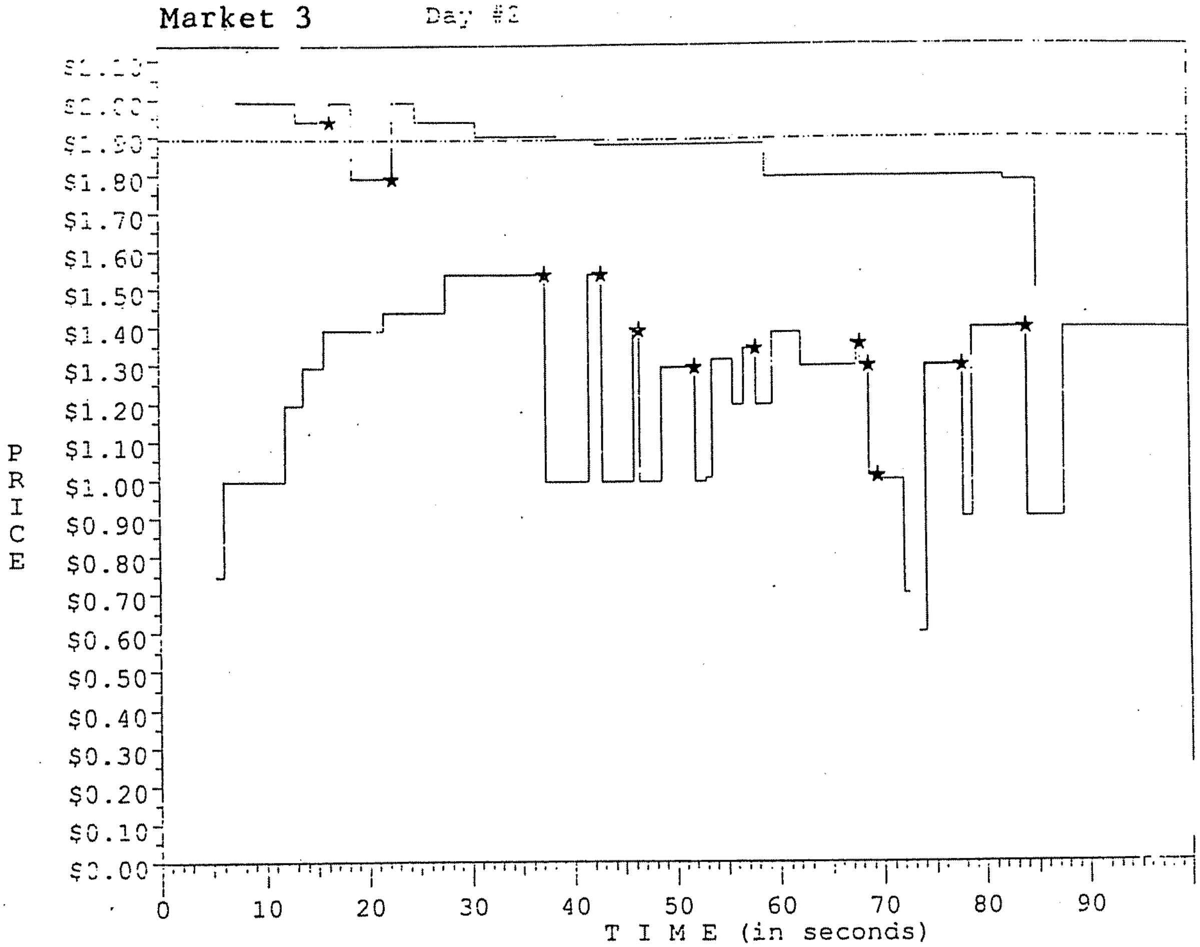
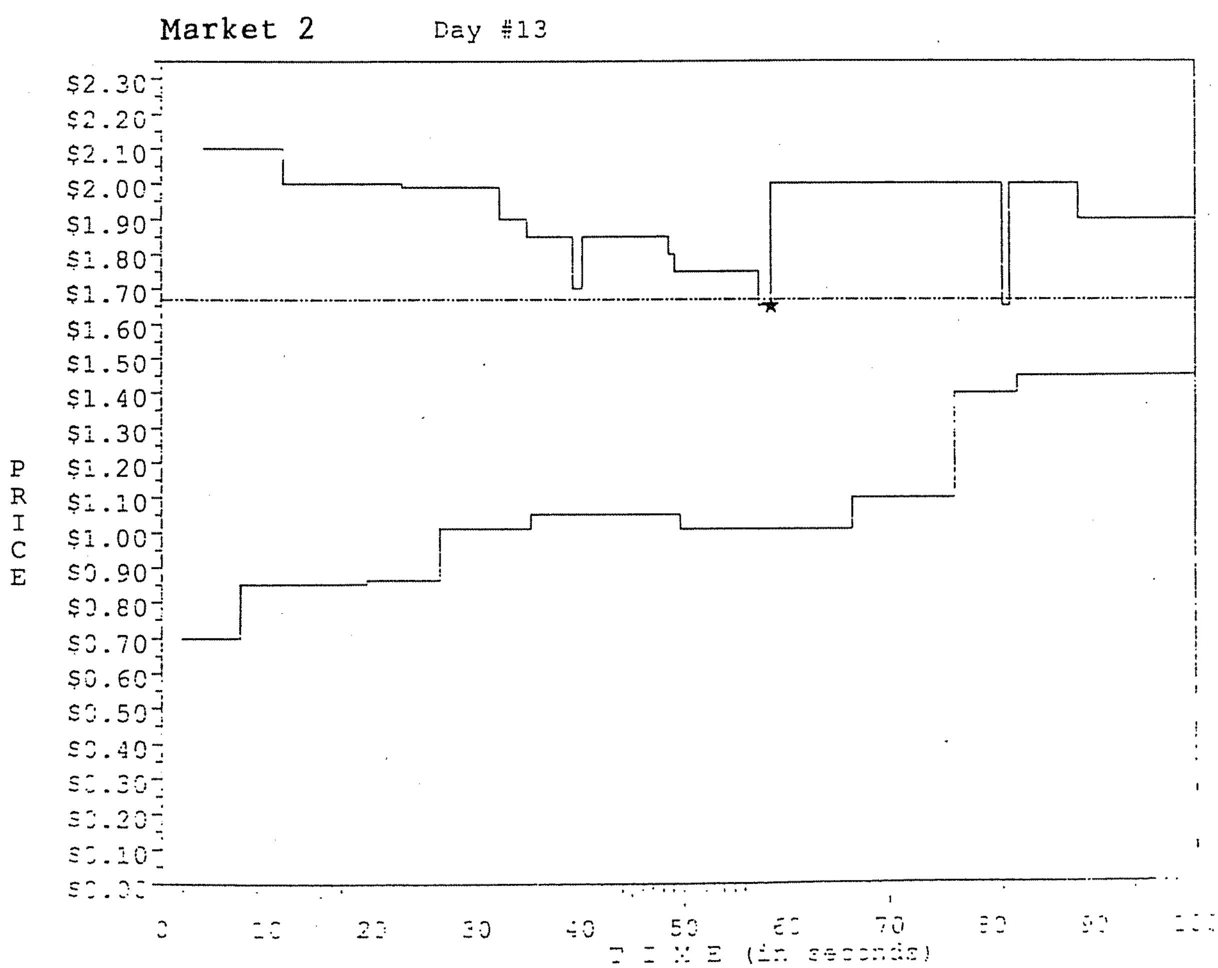
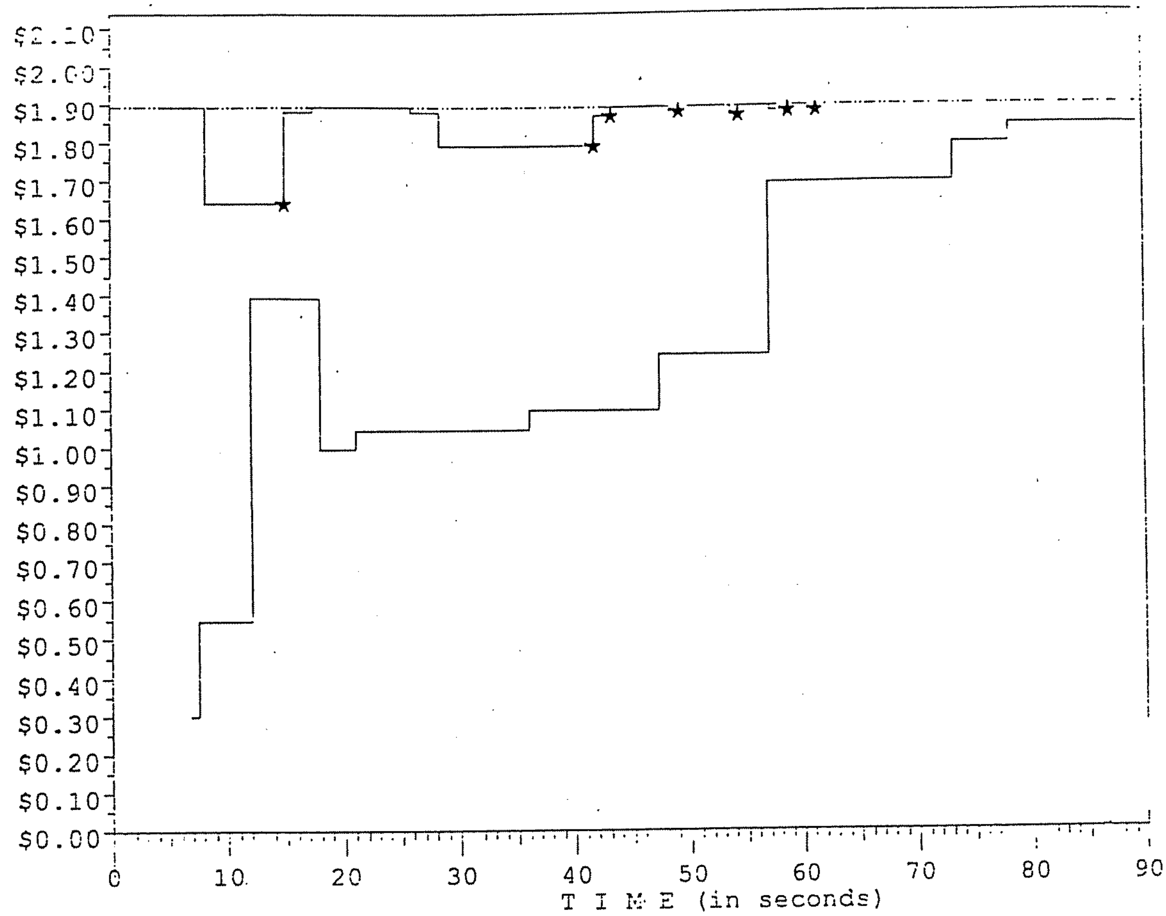

Market 3
Day #2
PRICE
$1.80
$1.70
$1.60
$1.50
$1.40
$1.30
$1.20
$1.10
$1.00
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
0
10
20
30
40
50
60
70
80
90
T I M E (in seconds)

Figure 2b


Market 2
Day #13
PRICE
$2.30
$2.20
$2.10
$2.00
$1.90
$1.80
$1.70
$1.60
$1.50
$1.40
$1.30
$1.20
$1.10
$1.00
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00

Market 3 Day #34



Market 9 Day #12

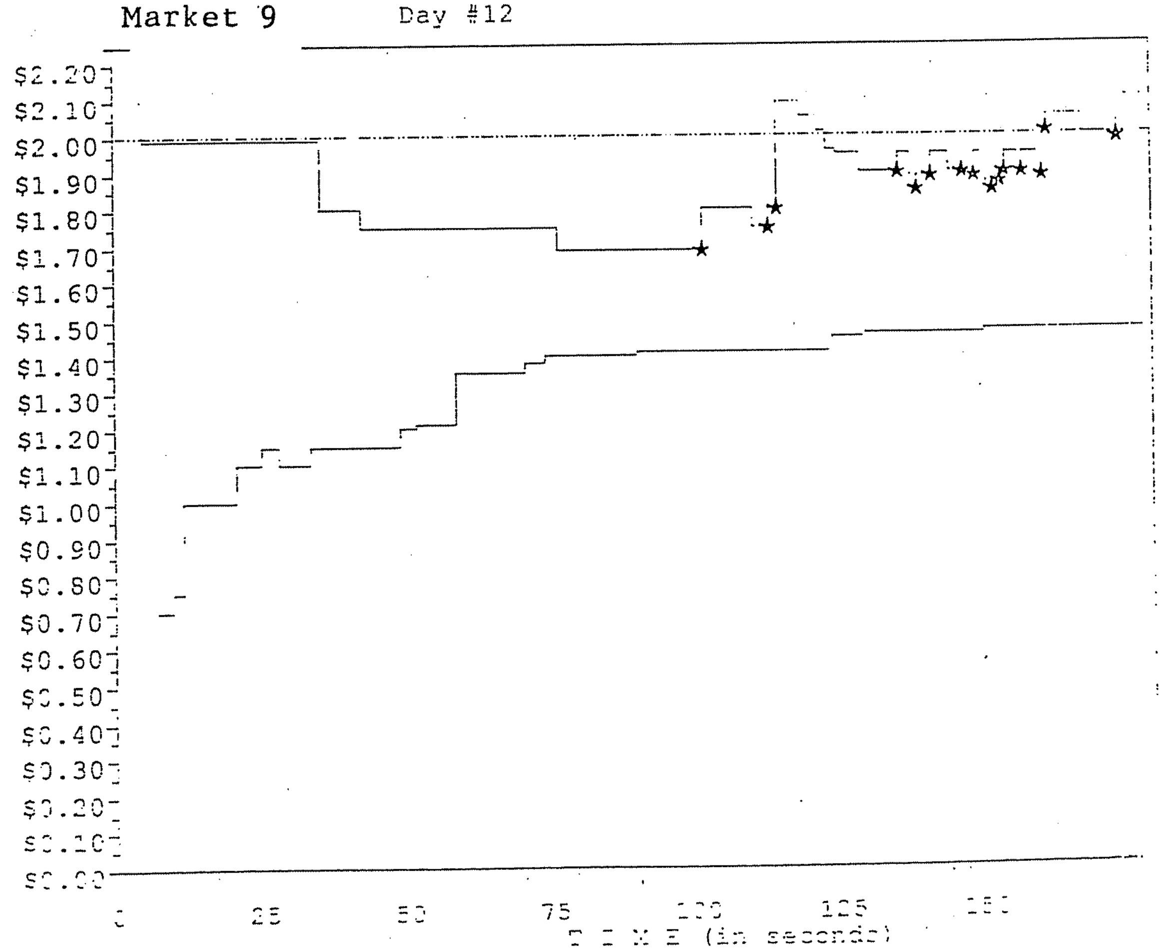


Figure 2c

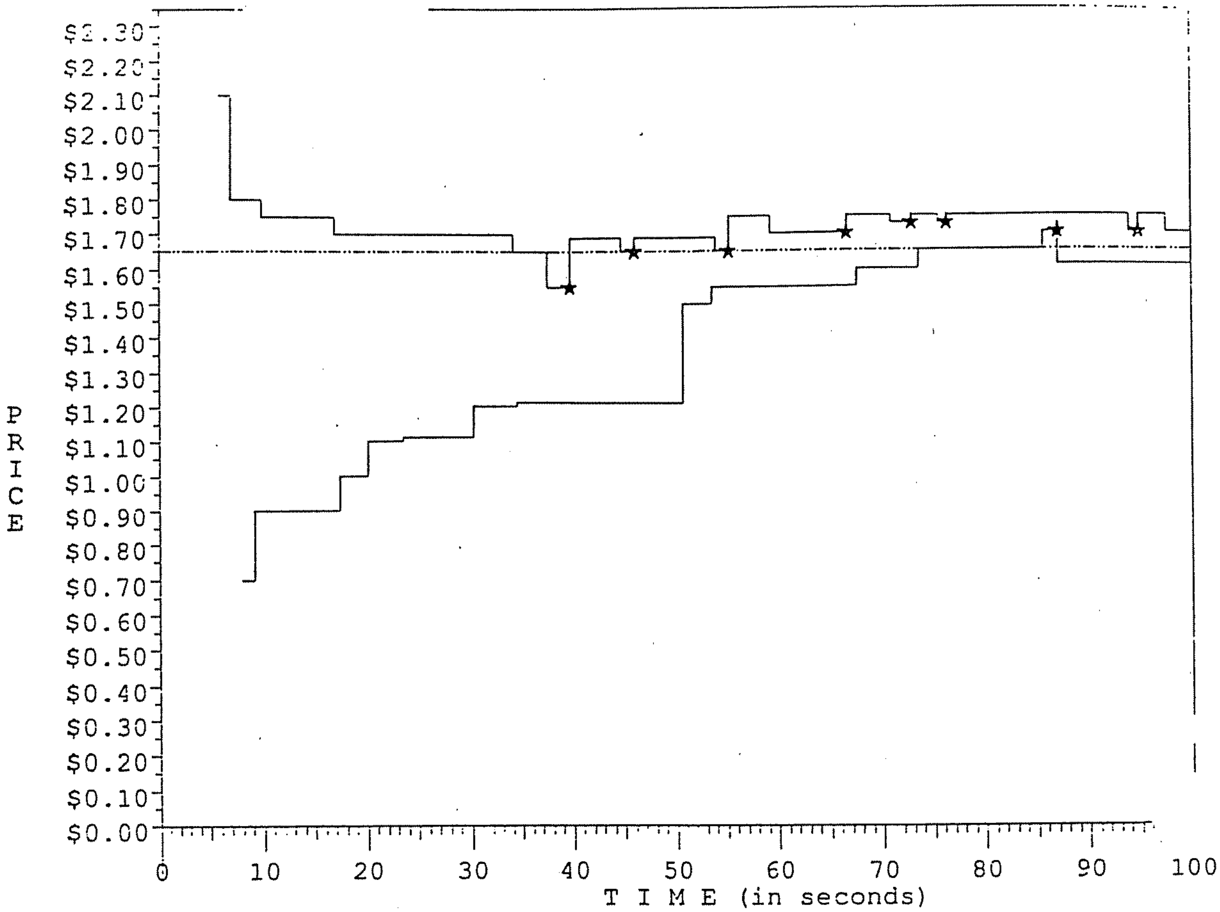
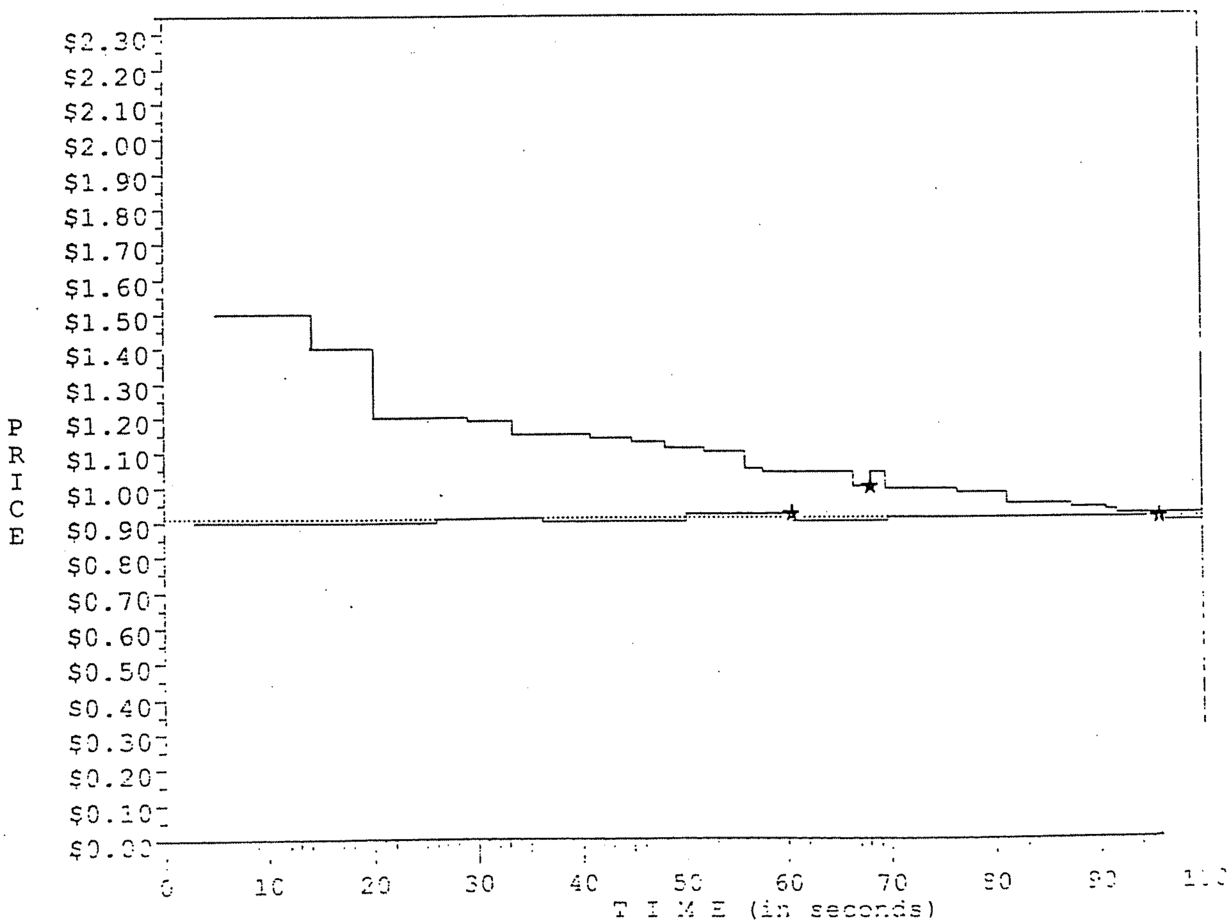
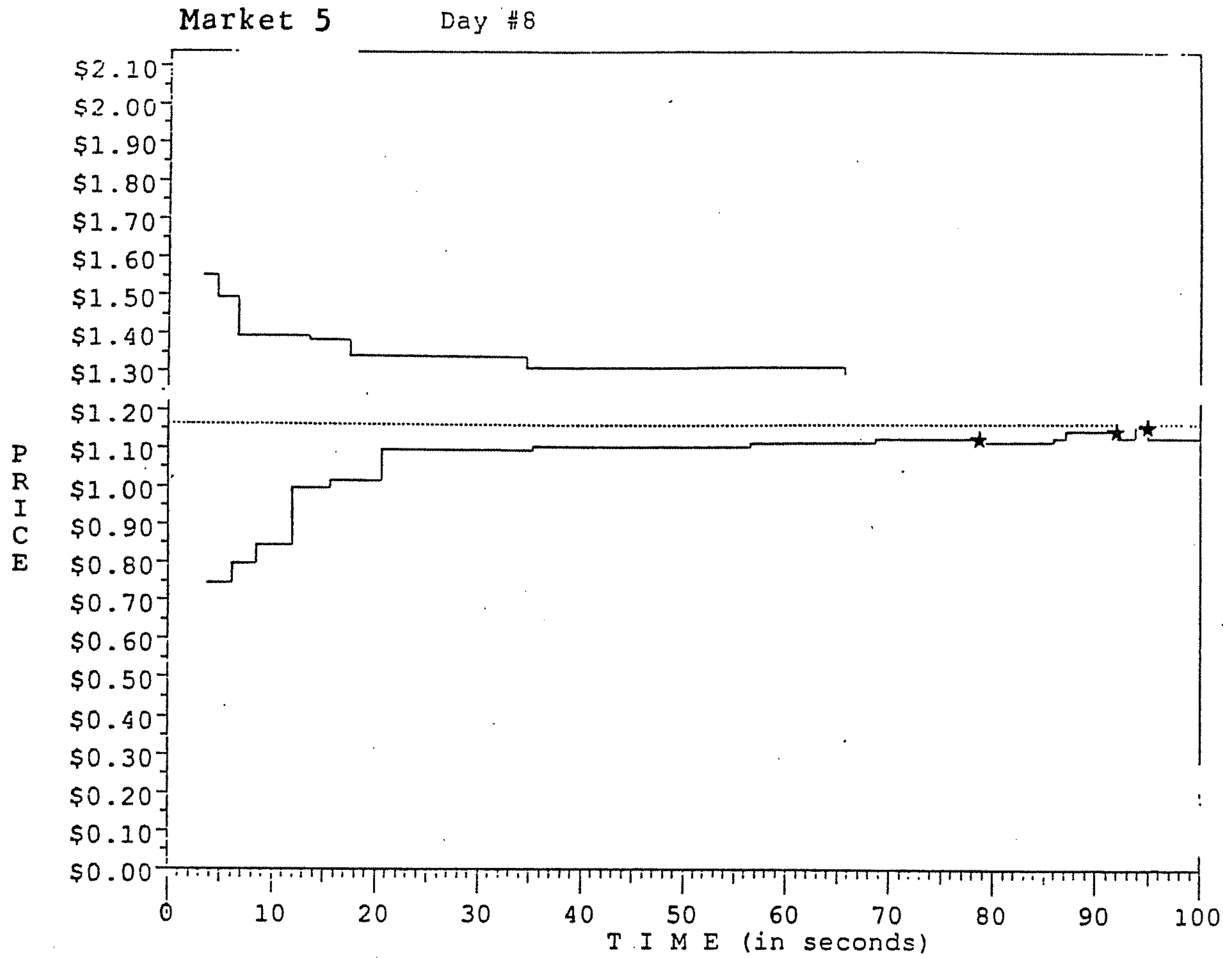


Figure 2d

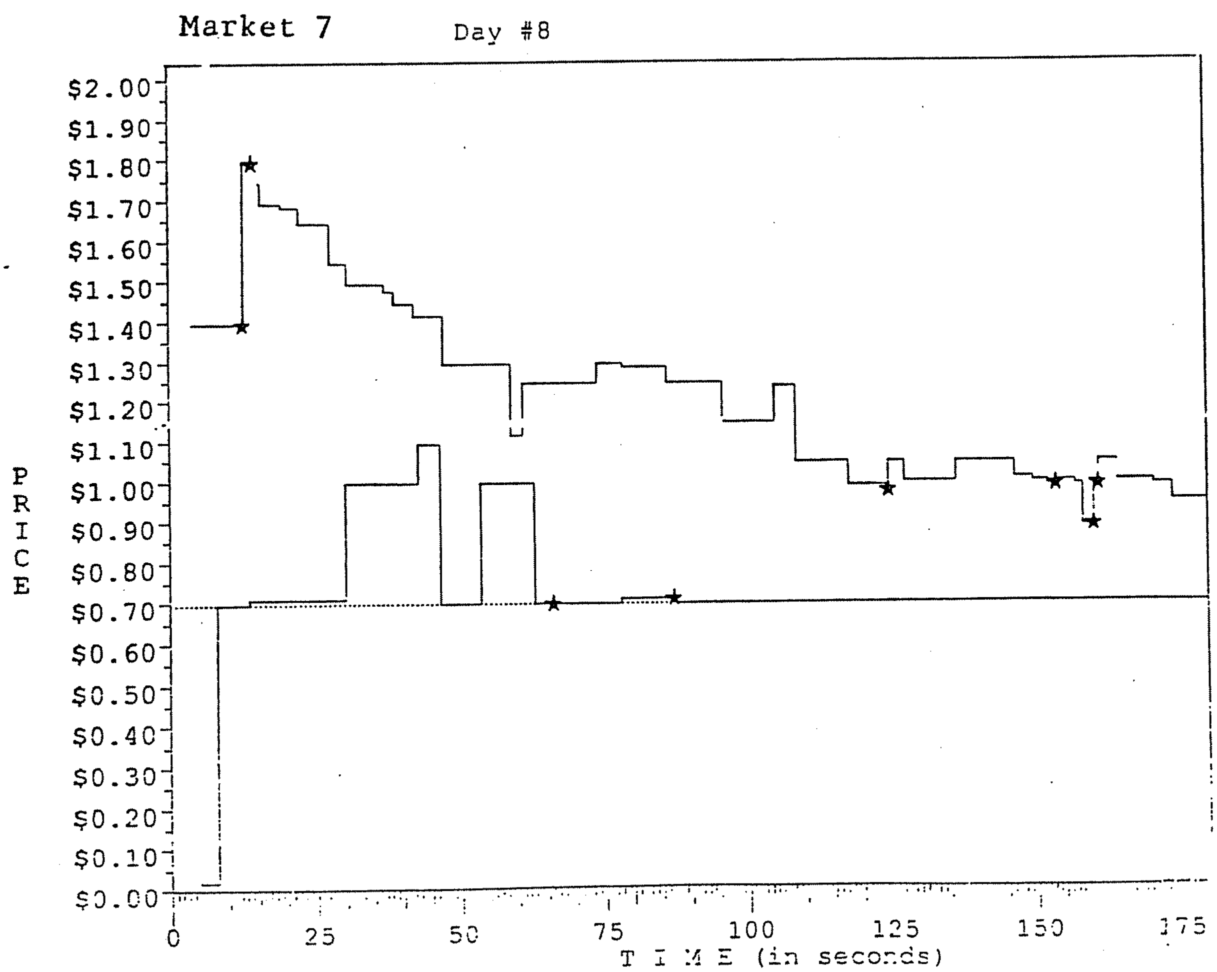
Market 2 Day #21





Market 5
Day #8
$2.10
$2.00
$1.90
$1.80
$1.70
$1.60
$1.50
$1.40
$1.30
$1.20
$1.10
$1.00
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
PRICE
0
10
20
30
40
50
60
70
80
90
100
TIME (in seconds)

Figure 2e



Market 7
Day #8
$2.00
$1.90
$1.80
$1.70
$1.60
$1.50
$1.40
$1.30
$1.20
$1.10
$1.00
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
PRICE
0
25
50
75
100
125
150
175
TIME (in seconds)

Table 1a
Series A
COMMON VALUE CONTINUOUS PAYOUT SCHEDULE

	Market1 Range $.40 - $2.00		Market2 Range $.70 - $2.10	
Day	Informed Traders (ID#)	State	Informed Traders (ID#)	State
1	0	.70	0,4	.87
2	1	1.62	0,4	.77
3	2	.54	0,4	1.68
4	none	.94	0,4	1.96
5	2	1.42	1	1.16
6	0	1.12	1	1.64
7	0	1.68	1	.90
8	3	.43	1	.94
9	0	1.78	2	1.90
10	4	.48	2	1.37
11	5	1.80	2	2.04
12	5	1.63	2	.84
13	0	.45	5	1.67
14	3	.62	5	1.01
15	6	1.46	5	1.51
16	5	1.02	5	1.78
17	0	1.50	3,5,6	1.65
18	1	1.03	3,5,6	1.02
19	7	.67	3,5,6	.78
20	4	.67	3,5,6	2.09
21	0,2	.62	2,3,4,5	.91
22	2,6	.62	0,4	2.03
23	4	1.92	1,4	1.93
24	4	.82	1,5,7	.74
25	1	.58	1,4,5	1.86
26	7	1.47	none	.77
27	3	1.95	0,3,5,6	1.04
28	5	.66	2,4	1.57
29	0	1.57	1,4,6	.71
30	2,3	1.60	1,7	1.85
31	4	.82	0,4	.97
32	5,7	1.42	2,6,7	1.76
33	3,6	.82	0,2,7	1.14
34	1,4	1.79	3,5	.84
35	7	1.94	1,2,6	2.06
36	0,5	1.54	none	1.40
37	6,7	1.12	0,3,7	1.93
38	6	1.68	2,6	1.96
39	0,2	.42	0,3,6	.97
40	1,3	1.79	3,7	1.82

Table 1b
Series B
COMMON VALUE DISCRETE PAYOUT SCHEDULE

	Market3 X = \$1.90, Y = \$.30		Market4 X = \$1.90, Y = \$.50	
Day	Informed Traders (ID#)	State	Informed Traders (ID#)	State
1	0	Y	0,4	Y
2	1	X	0,4	Y
3	2	Y	0,4	X
4	none	Y	0,4	X
5	2	X	1	Y
6	none	Y	1	X
7	none	X	1	Y
8	3	Y	1	X
9	none	X	2	X
10	none	Y	2	Y
11	none	X	2	X
12	none	X	2	Y
13	none	Y	5	X
14	3	Y	5	Y
15	none	X	5	X
16	none	Y	5	X
17	0	X	3,6,7	X
18	1	Y	3,6,7	Y
19	none	Y	3,6,7	Y
20	3	Y	3,6,7	X
21	0,2	X	2,3,4,5	Y
22	2	Y	0,4	X
23	none	X	1,4	X
24	none	Y	1,5,7	Y
25	none	Y	1,4,5	X
26	none	X	none	Y
27	0	X	0,3,5,6	Y
28	none	Y	2,4	X
29	0	X	1,4,6	Y
30	2,3	X	1,7	X
31	5,6	Y	0,7	Y
32	5,7	X	2,6,7	X
33	3,6	Y	0,2,7	Y
34	1,4	X	3,5	Y
35	none	X	1,2,6	X
36	0,5	X	none	Y
37	6,7	Y	0,3,7	X
38	none	X	2,6	Y
39	0,2	Y	0,3,6	X
40	1,2	X	3,7	X

Table 1c
Series C
PRIVATE VALUE CONTINUOUS PAYOUT SCHEDULE

	Market5 Range I $.60 - $1.90 Range II $.80 - $1.40		Market6 Range I $.60 - $2.00 Range II $.90 - $1.60	
Day	Informed Traders (ID#)	State	Informed Traders (ID#)	State
1	7	1.88, 1.39	0,4	.77, .98
2	7	.73, .86	0,4	.67, .94
3	7	1.08, 1.02	0,4	1.58, 1.39
4	7	.70, .85	0,4	1.86, 1.53
5	3	1.55, 1.24	1	1.06, 1.13
6	3	1.70, 1.31	1	1.54, 1.37
7	3	.74, .87	1	.80, 1.00
8	3	1.17, 1.06	1	.84, 1.02
9	0	.65, .83	2	1.80, 1.50
10	0	1.74, 1.33	2	1.27, 1.24
11	0	1.45, 1.19	2	1.94, 1.57
12	0	.90, .94	2	.74, .97
13	5	.60, .80	5	1.57, 1.38
14	5	1.82, 1.36	5	.91, 1.06
15	5	1.60, 1.26	5	1.41, 1.30
16	5	1.01, .99	5	1.68, 1.44
17	2	.81, .90	4,6,7	1.55, 1.38
18	2	.79, .89	4,6,7	.92, 1.06
19	2	1.65, 1.29	4,6,7	.68, .94
20	2	1.87, 1.39	4,6,7	1.99, 1.58
21	6	1.59, 1.26	2,3,4,5	1.00, 1.11
22	6	.91, .94	0,4	1.56, 1.93
23	6	1.82, 1.36	1,4	1.52, 1.83
24	6	1.71, 1.31	1,5,7	.92, .64
25	1	1.38, 1.16	1,4,5	1.48, 1.76
26	3,7	1.67, 1.09	none	.94, .67
27	0,5	1.78, 1.35	0,3,5,6	1.07, .94
28	4	.63, .81	2,4	1.34, 1.47
29	1,2,6	1.39, 1.17	1,4,6	.91, .61
30	3,4	1.30, 1.12	1,7	1.48, 1.75
31	0,7	1.60, 1.26	0,4	1.04, .87
32	2,4,5	.77, .88	2,6,7	1.43, 1.66
33	1	1.81, 1.36	0,2,7	1.12, 1.03
34	2,6	1.72, 1.32	3,5	.97, .74
35	5,7	.83, .71	1,2,6	1.58, 1.96
36	1,3,4	1.46, 1.19	none	1.25, 1.30
37	2,7	1.37, 1.15	0,3,7	1.52, 1.86
38	0,5,6	.61, .81	2,6	1.53, 1.86
39	4	.78, .89	0,3,6	1.04, .87
40	1,7	1.74, 1.32	3,7	1.46, 1.72
41	4	1.89, 1.39		

Table 1d
Series D
PRIVATE VALUE DISCRETE PAYOUT SCHEDULE

	Market7 Type I X=$1.80,Y=$.50 Type II X=$1.30,Y=$.70		Market8 Type I X=$1.80,Y=$.40 Type II X=$1.20,Y=$.70		Market9 Type I X=$2.00,Y=$.50 Type II X=$1.40, Y=$.80	
Day	Insiders (ID#)	State	Insiders (ID#)	State	Insiders	State
1	7	X	7	X	0,1	X
2	7	Y	1	Y	0,1	X
3	7	Y	6	X	0,1	Y
4	7	Y	4	Y	0,1	Y
5	3	X	none	X	4	X
6	3	X	none	Y	4	X
7	3	Y	4	X	4	X
8	3	Y	3	X	4	Y
9	1	Y	none	Y	6,7	X
10	1	X	7	Y	6,7	Y
11	1	X	3	X	6,7	Y
12	1	Y	none	X	6,7	X
13	6	Y	1	Y	0,3	Y
14	6	X	2	X	0,3	X
15	6	X	none	Y	0,3	Y
16	6	Y	none	Y	0,3	X
17	3	Y	5	X	2	X
18	3	Y	none	Y	2	Y
19	3	X	5	X	2	Y
20	3	X	1	X	2	X
21	6	X	0	X	4,5	Y
22	6	Y	2	Y	4,5	X
23	6	X	none	X	4,5	X
24	6	X	6	X	4,5	Y
25	1,4	X			1,2,6	X
26	1,4	Y			1,2,6	Y
27	1,4	Y			3,5,7	Y
28	1,4	X			3,5,7	X

Table 2
0 vs. 1 INSIDERS*

SAMPLES X vs. Y	STATISTIC	PERFORMANCE MEASURES RMSE	TWRMSE	SPREAD	TWSPREAD
1. All	Wilcoxon	2.6	-1.36	2.25	4.72
	t	3.02	-.99	.88	6.11
	Means	51.7,36.1	36.5,40.6	39.2,29.6	58.2,37.1
	Nob's	31,152	33,154	32,144	33,154
2. Private Value	Wilcoxon	.98	.90	1.15	.95
	t	1.15	.97	.88	.62
	Means	47.0,37.4	47.7,40.9	31.7,25.0	37.9,35.2
	Nob's	10,88	10,89	9,82	10,89
3. Common Value	Wilcoxon	2.51	-1.89	1.84	4.42
	t	2.77	-1.58	.34	5.45
	Means	54.0,34.3	31.6,40.2	42.1,35.7	67.1,39.8
	Nob's	21,64	23,65	23,62	23,65
4. Continuous	Wilcoxon	-.33	-2.49	-1.88	2.54
	t	-.42	-2.24	-.53	3.82
	Means	25.4,31.0	13.6,34.2	8.8,29.9	56.0,30.0
	Nob's	3,80	5,82	4,75	5,82
5. Discrete	Wilcoxon	1.83	-1.79	2.24	2.42
	t	2.06	-1.56	2.20	3.26
	Means	54.5,41.7	40.6,47.9	43.5,29.2	58.6,45.2
	Nob's	28,72	28,72	28,69	28,72
6. Early	Wilcoxon	.87	-.73	1.67	1.43
	t	.81	-.90	1.68	2.44
	Means	44.3,37.1	33.9,41.4	38.0,24.7	52.5,36.9
	Nob's	9,63	9,63	9,58	9,63
7. Late	Wilcoxon	2.52	-1.21	1.63	4.57
	t	2.99	-.54	.42	5.50
	Means	54.8,35.4	37.4,40.0	39.7,32.9	60.4,37.2
	Nob's	22,89	24,91	23,86	24,91
8. Fixed info.	Wilcoxon	.72	-2.41	3.45	3.13
	t	.46	-2.25	3.46	3.59
	Means	36.3,32.4	22.9,37.2	56.4,24.7	61.5,40.8
	Nob's	9,90	9,92	9,86	9,92
9. Random info.	Wilcoxon	2.10	-.94	.17	4.28
	t	2.43	-.55	-.23	5.54
	Means	58.0,41.5	41.6,44.8	32.4,36.8	57.0,31.7
	Nob's	22,62	24,62	23,58	24,62

* Positive numbers favor 1 insider over 0 insiders.

Table 3
1 vs. 2 INSIDERS*

SAMPLES X vs. Y	STATISTIC	PERFORMANCE MEASURES RMSE	TWRMSE	SPREAD	TWSPREAD
1. All	Wilcoxon	3.05	.92	2.15	-3.87
	t	2.90	.88	.58	-3.79
	Means	36.1,26.8	40.6,38.2	29.6,25.1	37.1,45.6
	Nob's	152,84	154,84	144,77	154,84
2. Private Value	Wilcoxon	1.76	-.17	-.41	-3.21
	t	1.29	-.34	-1.17	-2.98
	Means	37.4,31.5	40.9,42.2	25.0,33.6	35.2,42.6
	Nob's	88,40	89,40	82,36	89,40
3. Common Value	Wilcoxon	2.53	1.24	3.14	-1.85
	t	2.61	1.47	1.27	-2.20
	Means	34.3,22.5	40.2,34.5	35.7,17.7	39.8,48.3
	Nob's	64,44	65,44	62,41	65,44
4. Continuous	Wilcoxon	2.14	1.28	-.23	-3.90
	t	2.64	1.69	.53	-3.06
	Means	31.0,20.9	34.2,28.5	29.9,22.2	30.0,37.2
	Nob's	80,42	82,42	75,36	82,42
5. Discrete	Wilcoxon	2.24	-.12	2.78	-2.35
	t	1.80	0	.25	-2.72
	Means	41.7,32.6	47.9,47.9	29.2,27.1	45.2,54.0
	Nob's	72,42	72,42	69,41	72,42
6. Early	Wilcoxon	1.26	.14	.14	-2.49
	t	1.14	.02	-1.39	-2.20
	Means	37.1,29.3	41.4,41.3	24.7,40.9	36.9,45.2
	Nob's	63,18	63,18	58,18	63,18
7. Late	Wilcoxon	2.63	1.02	2.28	-3.01
	t	2.51	.92	1.23	-2.96
	Means	35.4,26.1	40.0,37.3	32.9,20.3	37.2,45.7
	Nob's	89,66	91,66	86,59	91,66
8. Fixed info.	Wilcoxon	.04	-1.52	.68	-2.34
	t	0	-1.58	-.77	-1.72
	Means	32.4,32.4	37.7,44.1	24.7,31.0	40.8,46.2
	Nob's	90,32	92,32	86,31	92,32
9. Random info.	Wilcoxon	4.24	2.67	2.46	-3.97
	t	4.52	2.73	1.15	-4.16
	Means	41.5,23.3	44.8,34.6	36.8,21.1	31.7,45.2
	Nob's	62,52	62,52	58,46	62,52

* Positive numbers favor 2 insiders over 1 insider.

Table 4 2 vs. 3 INSIDERS*					
SAMPLES		PERFORMANCE MEASURES			
X vs. Y	STATISTIC	RMSE	TWRMSE	SPREAD	TWSPREAD
1. All	Wilcoxon	3.29	2.81	3.02	2.97
	t	2.51	2.57	1.89	1.72
	Means	26.8,17.0	38.2,30.0	25.1,11.5	45.6,39.3
	Nob's	84,43	84,44	77,41	84,44
2. Private Value	Wilcoxon	2.06	3.05	2.03	3.00
	t	1.92	2.93	1.36	3.26
	Means	31.5,20.5	42.2,27.8	33.6,14.6	42.6,32.0
	Nob's	40,20	40,20	36,18	40,20
3. Common Value	Wilcoxon	2.65	1.07	2.37	1.29
	t	1.61	.68	1.37	.47
	Means	22.5,14.0	34.5,31.7	17.7,9.1	48.3,45.4
	Nob's	44,23	44,24	41,23	44,24
4. Continuous	Wilcoxon	2.26	1.78	2.84	2.02
	t	2.40	1.76	2.68	2.05
	Means	20.9,13.6	28.5,23.7	22.8,11.6	37.2,32.0
	Nob's	42,28	42,28	36,25	42,28
5. Discrete	Wilcoxon	1.76	1.02	2.18	.98
	t	1.13	1.34	1.03	.27
	Means	32.6,23.3	47.9,40.9	27.1,11.4	54.0,52.1
	Nob's	42,15	42,16	41,16	42,16
6. Late	Wilcoxon	2.82	2.44	2.53	2.62
	t	2.30	2.29	2.01	1.58
	Means	26.1,17.0	37.3,30.0	20.3,11.5	45.7,39.3
	Nob's	66,43	66,44	59,41	66,44
7. Fixed info.	Wilcoxon	1.27	.54	.61	-.36
	t	.39	.72	.53	-1.87
	Means	32.4,28.7	44.1,39.0	31.0,20.8	46.2,57.6
	Nob's	32,11	32,12	31,12	32,12
8. Random info.	Wilcoxon	2.70	2.43	2.98	3.36
	t	2.83	2.54	2.72	2.97
	Means	23.3,13.0	34.6,26.6	21.1,7.7	45.2,32.4
	Nob's	52,32	52,32	46,29	52,32

* Positive numbers favor 3 insiders over 2 insiders.

Table 5
CONTINUOUS VS. DISCRETE*

SAMPLES X vs. Y	STATISTIC	PERFORMANCE MEASURES RMSE	TWRMSE	SPREAD	TWSPREAD
1. all	Wilcoxon	-4.93	-7.44	-.91	-8.55
	t	-5.34	-7.82	-.91	-8.92
	Means	24.6,39.4	29.7,45.8	23.9,29.1	33.1,50.6
	NOB's	157,159	161,160	143,156	161,160
2. Private Value	Wilcoxon	-5.22	-5.76	-1.17	-4.85
	t	-5.48	-6.25	-1.79	-5.49
	Means	24.5,43.6	30.8,48.7	20.9,30.9	31.7,42.1
	NOB's	80,80	81,80	69,77	81,80
3. Common Value	Wilcoxon	-2.04	-4.92	-.13	-7.14
	t	-2.46	-4.84	-.06	-7.79
	Means	24.6,35.2	28.6,42.9	26.7,27.3	34.5,59.2
	NOB's	77,79	80,80	74,79	80,80
4. Early	Wilcoxon	-4.10	-4.28	-1.88	-4.04
	t	-3.91	-4.09	-1.96	-4.34
	Means	25.5,44.8	30.5,48.7	19.6,37.2	32.2,46.5
	NOB's	40,50	40,50	37,48	40,50
5. Late	Wilcoxon	-2.94	-5.94	.18	-7.59
	t	-3.80	-6.49	-.01	-7.97
	Means	24.2,36.9	29.5,44.5	25.4,25.5	33.4,52.5
	NOB's	117,109	121,110	106,108	121,110
6. Fixed info.	Wilcoxon	-3.38	-4.06	-1.68	-5.70
	t	-3.45	-4.17	-2.54	-5.99
	Means	24.5,38.5	31.0,44.0	18.5,34.8	35.7,51.7
	NOB's	62,80	64,81	59,79	64,81
7. Random info.		Wilcoxon	-3.43	-6.24	.53
	t	-4.10	-6.70	.49	-6.44
	Means	24.6,40.4	28.9,47.6	27.7,23.2	31.3,49.6
	NOB's	95,79	97,79	84,77	97,79
8. 0 Insiders	Wilcoxon	-1.70	-2.64	-2.39	-.48
	t	-1.47	-2.43	-2.05	-.21
	Means	25.4,54.5	13.6,40.6	8.8,43.5	56.0,58.6
	NOB's	3,28	5,28	4,28	5,28
9. 1 Insider	Wilcoxon	-2.60	-3.95	-1.26	-6.32
	t	-2.72	-4.23	.07	-6.62
	Means	31.0,41.7	34.2,47.9	29.9,29.2	30.0,45.2
	NOB's	80,72	82,72	75,69	82,72
10. 2 Insiders	Wilcoxon	-2.12	-5.56	1.89	-4.63
	t	-2.54	-5.89	-.42	-5.02
	Means	20.9,32.6	28.5,47.9	22.8,27.1	37.2,54.0
	NOB's	42,42	42,42	36,41	42,42
11. 3 Insiders	Wilcoxon	.24	-3.23	2.01	-1.57
	t	-1.58	-4.09	.04	-2.92
	Means	13.6,23.3	23.7,40.9	11.6,11.4	32.0,52.1
	NOB's	28,15	28,16	25,16	28,16

* Positive numbers favor discrete over continuous.