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ALLOCATIVE EFFICIENCY OF EXPERIMENTAL MARKETS UNDER CONDITIONS OF SUPPLY AND DEMAND UNCERTAINTY

The Ohio State University

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Allocative Efficiency Of Experimental Markets
Under Conditions Of Supply And Demand Uncertainty

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
W. Timothy Rhodus, B.A., M.S.

* * * * *

The Ohio State University
1985

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Finally, I wish to express my gratitude to the other members of my committee: Dr. Francis E. Walker, Dr. David H. Boyne, and Dr. Lynn Forster. Their comments and suggestions on earlier drafts provided valuable assistance in the preparation of this final document.
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Chapter I

INTRODUCTION

A basic problem facing all economic systems is the allocation of scarce resources among competitive uses. Under pure competition, resources are allocated up to the point where the value of marginal product is equal for all alternative uses. This leads to an allocation that maximizes allocative efficiency and is termed Pareto optimal.

Traditional economic theory states that possession of complete information is one of a set of sufficient conditions for a Pareto optimum allocation of resources. However, possession of complete information is a theoretical concept and real world market participants either lack complete information or possess different amounts of information among them.

One reason for the disparities in information possession is the fact that participants do not necessarily have equal access to identical pieces of information. This creates a situation where buyers and sellers may not possess equal amounts or equal kinds of information. Thus, relative
bargaining positions are affected and a misallocation of resources may occur.

As a means to overcome the problem of information disparities between agricultural buyers and sellers, public price reporting (PPR) was initiated in the early 1900's. At that time, communication systems were fairly limited and many rural farmers were isolated from obtaining up-to-date market information, relative to the more centrally located packing houses. But as time passed, this was no longer the case. This led to a redefinition of the objective of PPR - improving arbitrage by providing information to help traders determine at which markets supplies were least plentiful (Armbruster, et. al. 1983).

By 1980, the structure of agriculture was very different from that of the 1920's. Increased concentration among producers and buyers in numerous commodities created an environment in which the need for public price reports came under attack. This led to the argument that price reports (market information) satisfy the requirements of a "public good" and therefore deserve public support. These requirements being indivisibility, uncertainty, and nonappropriability (Riemenschneider, 1980).

However, the issue of improved allocative efficiency is still the basic test of the value of public price reporting. On the one hand, if public price reports
increase the welfare of imperfectly informed sellers, at the expense of more informed buyers, then PPR becomes another means of redistributing income between two groups within society. On the other hand, if public price reports increase the overall welfare of both buyers and sellers (society), then PPR becomes a vehicle for improving overall resource allocation.

Allocative efficiency may also be affected by the price establishment process which exists in the market. Received economic theory identifies decreases in allocative efficiency as markets become less competitive in structure but does not identify the impact on allocative efficiency as pricing mechanisms change, holding structure constant. Evidence on the relative efficiency of various pricing mechanisms has been provided by researchers in the area of experimental economics. Research in this area over the past 20 years has established that allocative efficiency is greater with a double auction pricing system than with a posted pricing system.¹ A possible explanation for this behavior is that the double auction process provides greater feedback to preliminary bids or offers in the form of counter offers and counter bids, with which market participants can generate additional information about supply and demand conditions within the market. Given this

¹ See Smith (1982) for a review of previous research in experimental economics.
added information, market equilibrium more nearly approximates the competitive equilibrium and allocative efficiency is greater.

An example of posted pricing is the posted bid price for hogs to farmers at the packing plant. This price is set by the packer in response to local supply and demand conditions within the market (Rhodus, et. al., 1985). Farmers then decide what quantity of hogs to sell at the posted price. Obviously, their decision is greatly influenced by the availability of relevant information concerning market trends, weather conditions, and alternative bids. Given incomplete information, farmers are likely to be making decisions under uncertainty and allocative inefficiencies may result.

However, this does not necessarily imply that the direct market for hogs is "technically" inefficient, where technical efficiency refers to the degree to which marketing costs are minimized. It may well be that direct markets provide benefits to buyers and sellers which result in lower marketing costs than public auction markets. These benefits include improved producer-packer coordination, a more orderly flow of product from seller to buyer, reduced handling costs, and lower overhead expenses involved with collecting and holding hogs prior to and

---

2 This type of market has been characterized as a direct market which employs posted bid pricing.
immediately following sales. Furthermore, when public auction markets pass on their higher operating expenses through service charges, hog producers find additional incentive to deal directly with the packer.

By being "technically" efficient, direct markets improve society's welfare by minimizing the marketing costs associated with buying and selling slaughter hogs. By being "allocatively" efficient, public auction markets improve society's welfare by better equating supply and demand conditions within the market. So, which alternative should society prefer?

One possibility is to try and improve the technical efficiency of the public auction markets. This may be accomplished by the increased use of electronic marketing, whereby remotely located market participants buy and sell products by description via an electronic communication system. Pricing is done on an auction basis and product is delivered directly from seller to buyer. ³

Another possibility is to try and improve the allocative efficiency of the direct markets. This may be accomplished by providing market participants with additional market information through public price reporting or by employing a more efficient pricing mechanism - auction pricing.

³ See Rhodus, et. al., 1985 for a description of the H.A.M.S. experiment in the electronic marketing of slaughter hogs.
instead of posted bid pricing. This would seem to indicate that some sort of tradeoff exists between providing market information and choice of pricing mechanism when attempting to improve the allocative efficiency of a direct market.

In order to better understand these possible tradeoffs, this study will: (1) examine the allocative inefficiencies that result from incomplete information and different pricing mechanisms, and (2) experimentally determine the possible tradeoffs between the amount of market information and the type of pricing system used in the market in order to achieve a given level of allocative efficiency.

**SEARCHING FOR INFORMATION**

A sufficient condition for the efficient allocation of resources within an economy is that buyers and sellers possess complete information with respect to the quality and nature of the product and the prevailing price. However, in reality buyers and sellers do not possess complete information. This creates an element of uncertainty about where the product can be bought at the lowest price or where it can be sold for the highest price. In order to reduce their level of uncertainty, buyers will engage in searching out the lowest offer (holding quality and other facets of the product constant) from the distribution of offers while sellers engage in searching out the highest bid from the distribution of bids.
The result of this search activity by buyers and sellers is information, where information can now be referred to as a change in the searcher's knowledge of the amount of price dispersion present in the market (Miller, 1978). But how much information is necessary? Assume that searching requires resources and time. The rational individual will continue to search for a lower offer or a higher bid up to the point where the expected return from one more unit of search will not cover the cost of that activity. However, search costs are not constant across all individuals. This will enable some to continue beyond where others have stopped. As a result, price dispersion and thus uncertainty will continue to exist since not all buyers are able to search out the lowest offer and not all sellers are able to search out the highest bid.4

The returns to search are affected not only by the actual cost but by other factors. As the importance of the object in the budget increases, returns to additional search will also increase because any reduction in uncertainty will be translated into greater savings (profits). As the durability of the information gained increases, returns to additional search will also increase

4 Search activities may also be aimed at developing a proxy for the desired price. Such cases may arise due to the unavailability of prices from private transactions or unreliability associated with prices obtained through normal channels.
since it will pay to invest in additional search if the additional information can be used for an extended period of time (Hirshleifer, 1973). Finally, returns to search are affected by the extent of the individual's prior information as to the distribution or dispersion of prices.

In the case of complete ignorance about the underlying distribution, there is a two-stage procedure such that in the first stage the searcher gathers information by drawing a few prices merely to learn something about the distribution and postpones a decision while in the second stage he searches with the intention of buying (or selling) (Telser, 1973).

The seller's search efforts are related to his anticipation of buyer search behavior, his standing in the price distribution (assuming he knows it), and the search efforts of competitors (Hirshleifer, 1973). Additionally, the distinctiveness of the commodity and the rarity of buyers will affect the optimal amount of search.

In this context, the search behavior of buyers and sellers would appear to result in a narrowing of the distribution of prices since high-priced sellers will lose customers over time and low-priced sellers will become swamped, leading to corrective movement of price offers in both cases. As these corrections occur, the gains from search decline. However, in a market where the exogenous
conditions which determine supply and demand are everchanging, additional price dispersion/uncertainty will be created, thereby justifying the continuance of further search (Hirshleifer 1973). As a result, this type of market (basically a real world market) continually reinforces the need for additional market information by both buyers and sellers.

**EFFECT OF SUPPLY AND DEMAND UNCERTAINTY ON EFFICIENCY**

Within a competitive market, equilibrium occurs at the point where market supply equals market demand. These supply and demand functions are generated by the summation of the individual supply and demand functions of the participants in the market. Under conditions of complete information, sellers (buyers) are certain as to what quantity of the product they will offer (demand) at any given price level. The summation of these individual supply and demand functions yields market supply and market demand functions, whose intersection determines a unique competitive equilibrium outcome.

In the case where market participants lack complete information, sellers (buyers) are no longer certain as to what quantity of the product they will offer (demand) at any given price level. This uncertainty over quantity is due to the fact that participants do not have perfect
information on the underlying distribution of prices. As such, they are uncertain about offering (demanding) \( Q \) units or \( Q+1 \) units at price \( P \) or \( Q \) units at price \( P \) or \( P+1 \). The summation of these uncertain supply and demand functions produces market supply and market demand functions which no longer identify unique price-quantity relationships but rather a range of quantities for any given price.\(^5\) Figure 1.

**Figure 1: Market Supply and Demand Under Uncertainty**

With perfect information, market supply equals \( SC \) and market demand equals \( DC \). Their intersection leads to a unique market equilibrium at price \( P1 \) and quantity \( Q1 \), point \( E \).\(^6\) Under incomplete information, market supply is

\(^5\) Alternatively, the market supply and demand functions identify a range of prices for any given quantity.

\(^6\) This assumes that buyers and sellers are risk neutral. If traders are risk averse, then market equilibrium would be at point \( A \).
the region between SU and SU* and market demand is the region between DU and DU*. In this case, market equilibrium is not a unique point but rather an area. Equilibrium prices may range from P2 to P3 while equilibrium quantity may range from Q2 to Q3. The precise outcome is no longer obvious. Recognizing that point E is the most efficient outcome attainable, incomplete information in the market may lead to outcomes which deviate from E and are less efficient than E. As the degree of uncertainty increases i.e., the spread between SU and SU* or DU and DU* increases, the area ABCD increases and it becomes less likely that market equilibrium will occur at E. Conversely, as the spread between SU and SU* or DU and DU* decreases, the probability of market equilibrium occurring at E increases.

ROLE OF THE PRICE ESTABLISHMENT PROCESS

A basic function of any price establishment system within a market economy is to facilitate the movement of resources into those areas where they yield the highest rate of return. This is accomplished by having prices provide signals to participants as to the relative scarcity of all resources. By incorporating all the relevant information present in the market, these signals will lead to an allocation of resources which is Pareto optimal,
assuming a competitive market structure. Therefore, in order to insure allocative efficiency, prices should be established in an environment of total market information.

However, information never exists in concentrated form within a single individual, but rather as dispersed bits of incomplete and frequently contradictory knowledge among all individuals (Hayek, 1945). As a result, allocative efficiency is dependent upon the utilization of knowledge not given to anyone in its totality. Hayek goes on to state that the economic problem of society (allocative efficiency) can be achieved with a price establishment system under which,

The whole acts as one market, not because any of its members survey the whole field, but because their limited individual fields of vision sufficiently overlap so that through many intermediaries the relevant information is communicated to all (Hayek, p.526).

However, merely communicating the information is not a sufficient condition for achieving allocative efficiency. Participants must also be able to act on that information. Such actions might take the form of rejecting a bid/offer, proposing a counter offer/bid, etc. By facilitating such actions better, the auction market may create gains in allocative efficiency that are not possible with posted bid pricing, even with the same level of market information.
ALLOCATIVE EFFICIENCY AND THE PRICING SYSTEM

A common form of price establishment is the auction mechanism. Auctions can be organized as one-sided or two-sided (double). In the one-sided case, buyers (sellers) make repeated price bids (offers) until no higher (lower) bids (offers) are forthcoming. The contract is completed at that price. In the two-sided case, price bids are announced by buyers and price offers are announced by sellers. Once a bid or offer has been made it can only be replaced by a higher bid or lower offer. A binding contract occurs when any buyer (seller) accepts the offer (bid) of another seller (buyer) (Schrader and Henderson, 1980).

A more common form of price establishment is the posted offer market. This system is represented by normal retailing practices whereby sellers announce a price that they are willing to accept for their product and maintain the offer for a period of time before revising the offer. A similar arrangement is followed with the posted bid market. In this case, buyers announce a price for which they are willing to buy a certain product and maintain the bid for a period of time before revision. Examples include posted bids for corn and soybeans at elevators and for livestock at packing plants.
Unlike an auction process, the participants in a posted offer (bid) system do not compete directly with other posters over every transaction. Those posting the offer (bid) set the price at a level which will maximize the anticipated profits resulting from the successful completion of future contracts with other buyers (sellers) in the market. As these profits materialize or fail to materialize, this provides additional information which the poster may use to make revisions in the posted price. Thus, there is a time delay between initial offers (bids) and revised offers (bids) as information is collected.

The length of this delay is directly related to the time it takes to collect a "critical mass" of information. This includes information about their own realized profits and market share as well as their competitor's prices, market share, and perhaps profits. Once this information is collected, the poster can decide whether or not to revise the offer (bid). Because of this time delay in acquiring relevant information, it is reasonable to assume that allocative inefficiencies will occur under the posted price mechanism and these inefficiencies will be greater as the difficulty in obtaining information increases or as the period between price revisions increases. 7

7 In some situations, this time period may be specified in writing e.g., wages offered to union workers are not revised until their contract expires.
As information becomes increasingly difficult to obtain, it would appear that public price reporting offers a solution to the problem. By facilitating easier and quicker access to relevant market information, revised offers (bids) may be made quicker and this should lead to an improvement in the allocative efficiency of the posted offer (bid) market. This would seem to indicate that there is a possible hierarchy in terms of allocative efficiency among different pricing mechanisms. Given that the double auction enables traders to obtain information on what their competitors and the market is doing and then act on that information, this form of pricing should exhibit a higher degree of allocative efficiency than posted pricing. Because of the lengthy time delay associated with collecting information in a posted pricing system, the market with public price reporting should exhibit greater allocative efficiency than one without price reporting.

EFFECT OF VARIOUS PRICING SYSTEMS ON EFFICIENCY

Evidence on the relative efficiencies of auction and posted price markets has been provided by Charles Plott and Vernon Smith through their use of controlled pricing experiments. In these experiments, efficiency was consistent with the concept of maximizing the sum of consumers' plus producers' surplus. The system attains an
efficient (Pareto optimal) allocation if and only if the subjects as a group maximize the total monetary payments from the experimenter (Plott, 1982). This implies that the additional cost of one more unit produced would exceed the benefit gained from one more unit consumed. Thus, no one can be made better off without someone else being made worse off. This is the Pareto optimal allocation.

Numerous experiments involving the use of a double auction and generally eight agents (four buyers and four sellers) have demonstrated that allocations and prices converge to levels near the competitive equilibrium within three to four trading periods (Issac and Plott, 1981; Smith, 1962, 1964, 1965, 1976). In those experiments involving a one-sided auction, the efficiency of the market approached 100 percent (Smith, 1964; Plott and Smith, 1978). However, the approach to equilibrium was from above (below) for those auctions that were one-sided bid (offer). This behavior led to a redistribution of income away from the side that actively bid (offered).

Results of the posted price experiments seem to indicate that posted offer (bid) markets tend to have higher (lower) prices than do oral double auction markets and that the adjustment to equilibrium tends to be from above (below) and either converges to equilibrium more slowly or does not converge at all. These results were first observed by Fred
Williams (1973) and later by Plott and Smith (1978). Efficiency of the posted bid markets in Plott and Smith averaged 95 percent of theoretical maximum. Although this seems fairly efficient, their oral bid auction markets consistently exhibited an efficiency rate of 99 and 100 percent.

One possible explanation for the deviation in prices between the auction and the posted price markets in the experiments may be that "counter-speculation", or "failure to deal" by the non-posting side did not lead to higher (lower) bids (offers) in the posted price market because once the price is posted it could not be changed until after the period was over (Plott, 1982). Alternatively, because both oral and posted bids/offers are initially made with some uncertainty, the imposed time delay between collecting additional information (reducing uncertainty), revising bids/offers, and receiving feedback (further reduction of uncertainty) associated with the posted price mechanism suppresses the markets ability to adjust prices as rapidly as in the auction.

The comparative efficiency of the auction market versus the posted price market was also examined in Rhodus, et al. (1985). Efficiency measures were compared between an experimental electronic slaughter hog auction market in Ohio, where buyers bid competitively via computer terminals
and a posted bid market in Indiana. They concluded that the pricing behavior of the electronic market was generally more efficient than the other market based upon the theoretically developed measures of frequency and average amount of price change and the impact of previous price on current price. But it was not determined to what extent these efficiency gains were due to the electronic market or to differences between auctions and posted price markets.

The difference in allocative efficiency under oral auctions, as opposed to posted prices where there are several sellers, led to further experiments with five buyers and only one seller—a monopoly market. These experiments showed that with posted offer pricing, prices and quantities converge to the monopoly outcome, while with double auction pricing prices tend to converge to the competitive equilibrium price but with volume and efficiency somewhat below the competitive equilibrium levels (Smith, 1981).

These results seem to indicate that the market outcome under a given structure can be manipulated by the choice of the price establishment process. It is especially interesting to find near-competitive outcomes within a monopoly market. One possible explanation for this behavior is that additional information is generated by the double auction mechanism, relative to the posted offer
mechanism. This additional information is generated by the fact that the time required for feedback to initial bids/offers is decreased. By possessing this additional information, buyers are able to overcome the informational barriers imposed by posted offer pricing and this leads to an improved outcome, where improvement is measured by greater allocative efficiency.

**POTENTIAL TRADEOFFS BETWEEN PRICING SYSTEMS AND UNCERTAINTY**

The hypothesized relationship between allocative efficiency and uncertainty under various pricing systems is presented in Figure 2.

![Figure 2: Expected Tradeoff Between Information and Pricing System](image)

In this case, double auction pricing exhibits greater allocative efficiency than posted pricing at all levels of
uncertainty. If the market is currently at a level of uncertainty equal to 0.3, employs posted pricing without PPR, and the goal is to improve allocative efficiency; then there are three courses of action: (1) expect individuals to collect additional information so as to reduce their uncertainty about market supply and demand, (2) institute public price reporting, or (3) switch over to auction pricing.

Reliance on the first alternative will perpetuate the information disparities among market participants. Reliance on the second alternative has been the traditional response to the desire for improved allocative efficiency. Reliance on the third alternative may be a possible way for the government to withdraw from its role as a market reporter and leave the market operate on its own.

PROPOSED STUDY

As previously indicated, a possible explanation for the high degree of allocative efficiency associated with auction pricing may be that participants are able to acquire information from the market that is not available under alternative pricing mechanisms. If this is the case and if the market is characterized by supply and demand uncertainty, then there may be possible tradeoffs between the need to collect/provide additional information and the
choice of an alternative pricing mechanism when trying to improve allocative efficiency. However, what are the costs to society of these two alternatives? Currently, there are many individuals involved in collecting, digesting, and disseminating information to market participants through federal and state market news services. In order to improve upon current levels of allocative efficiency, additional resources would have to be spent. Alternatively, it may be more cost effective to institute auction pricing practices where posted pricing currently exists. This provides the motivation for this research.

OBJECTIVES

The main objectives of this study are:

1. Experimentally determine the level of allocative efficiency associated with an oral double auction market, a posted bid market with price reports, and a posted bid market without price reports at various levels of supply and demand uncertainty.

2. Examine those factors within the experimental markets that explain changes in the level of allocative efficiency.

3. Quantify the incremental amount of price uncertainty that may substitute for a more efficient pricing mechanism, holding allocative efficiency constant.
In order to examine the first objective, a series of controlled pricing experiments will be conducted. Changes in the level of allocative efficiency under various levels of supply and demand uncertainty will be measured.

The second objective will develop a multiple regression model. This model will be used to explain changes in the level of allocative efficiency of various experimental markets.

The third objective will utilize the information developed from the first two objectives. Changes in allocative efficiency due to pricing mechanisms or price uncertainty will be compared in order to arrive at an estimate of the possible tradeoffs between information and pricing systems.

RESEARCH HYPOTHESES

The following research hypotheses will be investigated in order to address the main objectives of this study.

1. The allocative efficiency of a market declines as the amount of price uncertainty associated with supply and demand increases.

2. The allocative efficiency of an oral double auction market is greater than that of a posted bid market at similar levels of supply and demand uncertainty.
In order to clarify the organization of this study, the following topics will be included: Chapter Two - a discussion of the methodologies relating to each research hypothesis of the study and specific hypotheses to be tested, Chapter Three - a presentation of the results obtained, after analyzing each statistical hypothesis, and Chapter Four - a discussion of the conclusions drawn from analyzing the data pertaining to each hypothesis and the implications arising from these conclusions.
Chapter II
METHODOLOGY

The main objective of this study is to examine the allocative efficiency of auction markets and posted bid markets under conditions of supply and demand uncertainty. While this issue is very important to economists, real world markets do not provide the information necessary to make such comparisons. This occurs because no one is able to quantify what the "true" equilibrium should be for any given market at any given time. Without knowing where a market "should be", it is impossible to determine how efficient that same market really is. Also, since the real world does not reproduce identical supply and demand conditions from day to day, it is impossible to test for changes in relative efficiency of different pricing mechanisms under identical conditions. As a result, economists have turned to the laboratory as a source of information on the relative efficiency of different types of markets. Therefore, this study will conduct a series of controlled pricing experiments in order to examine the main research hypotheses.
Researchers within various social science fields have made use of the controlled experiment as a strategy for:
(1) theory rejection- does the theory accurately predict the observed outcomes, (2) theory competition- which theory among many best predicts the observed outcomes, (3) model robustness- what parameter limitations does the theory depend upon, (4) measurement- gaining numerical values to hypothesized relationships while controlling for extraneous influences, and (5) simulation- how might a given situation evolve over time (Plott, 1982).

This type of research has not been used as extensively in economics for several reasons. Critics of experimental research claim that "real" businessmen do not behave as do the subjects in the experiments. However, given that subjects pursue real profits within the context of real rules it seems reasonable to assume that the same principles of economics are in effect and that the choice of subjects is not critical (Plott, 1982). Critics also claim that naturally occurring phenomena are more complex than simpler laboratory designs. While this argument is not exclusive to economics, it does form the basic motivation behind all experimental research. By investigating a complex phenomena a little bit at a time, information is accumulated. This information can then be used to form new theories and reject old ones. As time
goes on, this process enables us to better understand the phenomena under question. Also, as the nature of the economic questions preclude direct manipulation of the environment because manipulation is either impossible or impractical, the use of experimental results becomes even more imperative.

LABORATORY PROCEDURES

Experience with experimental economics over the past 20 years by Plott, Smith, and others has led to a fairly standard set of procedures that one can use as a guide for further work in this area. The procedures described below are consistent with these standards.

This study involved the use of three different series of pricing experiments, one for each type of price establishment process of interest (double auction, posted bid with price reporting, and posted bid without price reporting). As a control for any selection-treatment interaction, one replication of each experiment was performed with different subjects. This resulted in a total of six different experimental groups being needed.8 Within each group, six subjects were designated as

8 While it could be argued that one replication is not enough, it is certainly reasonable to conclude that no replications are too few. Therefore, this study used one replication and will rely on future researchers to provide information as to the possible interaction effects of other populations.
"sellers" and six as "buyers". Thus, 72 subjects were required.

Subjects were recruited from a number of undergraduate classes in the Department of Agricultural Economics. Each subject was randomly assigned to one of the six experimental groups (schedules permitting) and randomly assigned to one of the experimental roles (buyer or seller). Each group met for one hour a week over the course of nine weeks, same time each week. The first session was used as an introductory session. All subjects were given a set of general instructions, which outlined the nature and the procedures of the experiment and specific instructions, which contained instructions on how subjects were to behave in their assigned roles. Following this, the experimenter read a set of instructions which outlined the price establishment procedures to be used for each experimental group. The first session also contained two practice rounds of trading, so as to familiarize subjects with the process of making bids, offers, and completing contracts. Individual and group performance during the practice rounds was not included in the final

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9 A maximum of five buyers and five sellers were actually used in any given trading session. Two extra subjects were recruited and given the same training so as to fill in for a missing trader.

10 See Appendices A-F for a complete description of all instructions.
An important aspect of all markets is the value individuals place on the object being traded. In the experiments, individuals traded units of a fictitious commodity called "amazin grain" and are assumed to be indifferent about this item. Their preferences are induced by an application of derived demand theory (Smith, 1976). As such, the commodity is given value by the experimenter. Buyers make money by buying from sellers and reselling to the experimenter according to a given redemption schedule. The difference between the negotiated price and the guaranteed resale price is their profit. Sellers earn a profit by purchasing units from the experimenter according to a given cost schedule and reselling the units to buyers. The difference is their profit.

Most of the research in this area has utilized a cost schedule and resale schedule which identified a specific cost (value) for each unit sold (purchased) in the market. As a point of departure from this earlier work, this study incorporated the aspect of supply and demand uncertainty. This was accomplished by presenting sellers (buyers) with a cost (redemption) schedule which identifies a range of costs (values) for each unit sold (purchased) in the market. Traders did not know the final cost (value) of any unit traded until all trading had been completed within a
trading session. Therefore, trading is conducted within an environment of price uncertainty. By increasing the range of costs (resale values) associated with a given unit, the level of price uncertainty within the market was also increased. The level of price uncertainty was constant for all subjects within a trading session but was varied from one session to the next. Subjects were not told that the range of values was normally distributed around an expected value that corresponded to the "certain" value. Information of this sort would enable participants to trade off of the expected value and ignore the other values in the range.

After trading had been completed, each of the ten participants drew a chip from a cup containing ten chips. Each chip had a number on it. The number drawn becomes the settlement value for all units traded by that subject. Calculation of the seller's (buyer's) gross profits is determined by the difference between the

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11 The range of possible values actually corresponds to twice a random percentage (0 to 50 percent) of the value of equilibrium price for that trading period.

12 The ten numbers on the chips were randomly generated from a normal distribution having a range of possible values equal to the range of values presented on the cost and redemption schedules.

13 For example, if seller one's expected cost for one unit is given to be 0-9, 4-13 for the second unit, etc. and the settlement value is 2; then the actual cost of the first unit is 2 and the second unit is 6.
negotiated price and the actual cost (resale) schedule for each unit traded. A seller's (buyer's) net profits per period are the difference between gross profits and a constant fixed cost. This fixed cost is equal to $1.96 for each seller per trading session and $3.69 for each buyer per trading session. The fixed cost is used for three purposes: (1) it provides an incentive for subjects to participate in the market, (2) it leads to an equalization in the expected profits between buyers and sellers at the rate of approximately $3.50 per hour, and (3) it is a realistic counterpart to the average level of fixed costs that a real world seller or buyer has to overcome in order to earn a profit.

Experiments were conducted over a series of trading periods with each period lasting 15 minutes. A total of 24 trading periods were used for each experimental group. Each period is considered to be independent with its own demand and supply conditions. Changes in supply and demand between days are done by the experimenter so as to replicate changing conditions in the real world. Since there is no carryover of inventory between periods, each period can be viewed as a single marketing year with sellers deciding how much to produce and buyers deciding

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**Equilibrium price for each period was randomly selected from values between $.50 and $1.00. Equilibrium quantity for each period was randomly selected from the following values: 25, 30, 35, 40, 45, 50, 55, and 60.**
how much to consume.

Subjects were paid their net earnings after the completion of all experimental sessions. Any buyer or seller who attended a session but was not used as an active trader received the average net earnings of the buyers or sellers who participated in that trading session.

The elasticity of supply was constant for all trading sessions and equalled 0.35 at the margin. The elasticity of demand was also constant for all trading sessions and equalled -0.5 at the margin. These schedules were deliberately designed to be relatively inelastic so as to replicate the conditions under which many agricultural products are traded in real world markets.

In order to better understand the trading schedules, see Appendix G for a sample cost schedule. As a seller, the cost of production for the first unit sold in the market was between 0 and $.14, column 2. The actual cost was not known until all trading had been completed but it would not be less than 0 nor greater than $.14. If a buyer agreed to pay an amount greater than $.14, then this seller would have covered their production costs for the first unit. In order to sell a second unit, the production cost was between $.01 and $.15, between $.03 and $.17 for the third unit, etc.
Each time a unit was sold, the seller recorded the selling price in column 5 of the "Seller's Profit Calculator". When trading had been completed, the seller drew a chip with a number on it. In this case, the possible settlement values were normally distributed between zero and 14, with a mean of seven. Once the settlement value was chosen, it was recorded in column 3. The actual cost for each unit sold, column 4, equals the settlement plus the minimum value associated with each unit sold in column 2. Gross profit per unit, column 7, is the difference between selling price and actual cost of production. The difference between the fixed cost and the sum of gross profits is the seller's net profits. If net profits were negative at the end of a trading day (each day was made up of three trading sessions), the balance in their account was not reduced.

A sample resale schedule is presented in Appendix H. As a buyer, the resale value for the first unit purchased in the market was between $1.64 and $1.78, column 2. The actual resale value was not known until all trading had been completed. If a buyer purchased the first unit for an amount less than $1.64, than that buyer would achieve a positive gross profit for the first unit. The resale value for the second unit would be between $1.63 and $1.77, the resale value for the third unit would be between $1.61 and $1.75, etc.
Each time a unit was purchased, the buyer recorded the purchase price in column 5 of the "Buyer's Profit Calculator". After trading, a settlement value was drawn and the actual resale value for each unit purchased was determined, column 4. Gross profit per unit, column 7, is the difference between actual resale value and purchase price. The difference between the fixed cost and the sum of gross profits is the buyer's net profits. If net profits were negative at the end of a trading day, the balance in their account was not reduced.

The determination of the equilibrium price and quantity can be done by examining Appendix G and Appendix H together, see Figure 3.

At the twelfth unit, buyers should be willing to pay between $.87 and $1.01. At the twelfth unit, sellers should be willing to sell at $.85 to $.99. The expected value for the actual cost of production of the twelfth unit is $.92 and the expected value for the actual resale value is $.94. This allows a one cent expected profit for both buyers and sellers who trade at a price of $.93. Therefore, equilibrium price would be $.93. Equilibrium quantity is determined to be twelve units per trader since there are no longer any gains to be made by trading past the twelfth unit. At unit 13, sellers would not be expected to trade below a value of $1.05 and buyers would
Figure 3: Determination of Equilibrium Within Experimental Markets
not be expected to trade above a value of $1.80. Therefore, no trades would be forthcoming.

In terms of the specific experiments, the following procedures were followed:

**Experiment One - Double Auction**

The first five buyers and sellers to the laboratory were the active participants. The sixth buyer and sixth seller were dismissed for that trading day. Buyers and sellers were then given cost and redemption schedules for the three trading sessions to be conducted that day. Sellers begin by announcing opening offers and buyers begin by announcing opening bids. Subsequent offers (bids) must be lower (higher) than the most recent offer (bid). A contract for a unit is completed when one buyer and one seller come to an agreement over price. Sellers recorded the transaction price and the transaction number as a sale was completed. Buyers also recorded the transaction price and the number of the seller. Trading halts at the end of 15 minutes or when no further trades are forthcoming. Settlement values were then determined and individual profits or losses were calculated.\(^{16}\)

\(^{15}\) Transaction number refers to the sequencing of transactions throughout a trading period. The experimenter keeps track of the sequence number.

\(^{16}\) In some trading periods, expected gross profits did not exceed the level of fixed costs.
Experiment Two - Posted Bid With Price Reporting

The first five buyers and sellers to the laboratory were the active participants. The sixth buyer and sixth seller were dismissed for that trading day. Buyers and sellers were then given cost and redemption schedules for the three trading sessions to be conducted that day. Buyers begin by recording opening bids on a display card with no knowledge of other buyers' bids. (The card is visible only to the sellers.) Each buyer has the option to limit the number of units purchased from any single seller at the posted price. Sellers respond to opening bids by indicating their identification number and the number of units to sell on separate slips of paper (chits) for each buyer. Buyers receive their chits and separately record the number of units purchased at the opening bid. All chits are then handed to the experimenter who computes an average price for all completed transactions and announces it to the market. If no purchases were made at the initial bids, experimenter announces, "too little trading activity to determine a price". Buyers then have an opportunity to revise their posts and their limits on purchases. Trading continues for 15 minutes or until no further transactions are forthcoming. Settlement values were then determined and individual profits and losses were calculated.

17 Initially, the amount purchased may be zero units.
Experiment Three - Posted Bid Without Price Reporting

Organization is identical to Experiment Two. However, after chits are passed from buyers to experimenter, there is no price announcement. Buyers make posting revisions only on the basis of the number of units purchased at the previous bid. Trading lasts for 15 minutes. Settlement values are determined at the end of trading and profits or losses are calculated.

MEASURING ALLOCATIVE EFFICIENCY

The generally received approach to quantifying the results from experimental markets has been to develop the following measures: (1) price ratio, (2) quantity ratio, (3) consumers' surplus ratio, and (4) producers' surplus ratio. The price ratio equals the average price during a trading session divided by the competitive equilibrium price. The quantity ratio equals the number of units traded during a trading session divided by the competitive equilibrium quantity. The consumers' surplus ratio and the producers' surplus ratio equal observed surplus (profits) divided by the theoretical maximum.¹⁶

In order to quantify the allocative inefficiencies resulting from market structure, pricing mechanisms, or informational disparities, researchers have generally

¹⁶ These four ratios will be multiplied by 100 so as to express the result as a percentage.
compared the outcomes from experimental markets to a theoretically optimal. The theoretical reference point has traditionally been the competitive equilibrium outcome. Allocative efficiency has typically been quantified as the ratio of observed producers' plus consumers' surplus to the theoretical maximum. For an example of how this measure is constructed see Table 1.

**TABLE 1**
Computation of PCS Ratio

<table>
<thead>
<tr>
<th>Trans-</th>
<th>Actual</th>
<th>Max.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>action</td>
<td>Resale</td>
<td>Seller</td>
<td>Buyer</td>
</tr>
<tr>
<td>Unit</td>
<td>Price</td>
<td>Cost</td>
<td>Value</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>1</td>
<td>$.50</td>
<td>$0</td>
<td>$.90</td>
</tr>
<tr>
<td>2</td>
<td>.45</td>
<td>.05</td>
<td>.80</td>
</tr>
<tr>
<td>3</td>
<td>.40</td>
<td>.10</td>
<td>.70</td>
</tr>
<tr>
<td>4</td>
<td>.35</td>
<td>.15</td>
<td>.60</td>
</tr>
<tr>
<td>5</td>
<td>.30</td>
<td>.20</td>
<td>.50</td>
</tr>
<tr>
<td>6</td>
<td>.25</td>
<td>.27</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$1.50</td>
<td>$1.50</td>
<td>$81</td>
</tr>
</tbody>
</table>

Sum of seller and buyer profits = $3.00
Sum of maximum seller and buyer surplus = 3.02
Producer Plus Consumer Surplus Ratio = 99.3

In this case, there is one buyer and one seller in the market and they trade five units among themselves. The
negotiated prices are listed in column 1. The actual cost of production and actual resale values are listed in columns 2 and 3, respectively. The seller's profit, column 4, is the difference between columns 1 and 2. The buyer's profit, column 5, is the difference between columns 3 and 1. Given that the theoretical equilibrium price, column 6, is constant for all units, the theoretical maximum producer surplus, column 7, and the theoretical maximum consumer surplus, column 8, can be calculated by taking the difference between columns 6 and 2 and the difference between columns 3 and 6, respectively. The producer plus consumer surplus (PCS) ratio is the ratio of the sum of seller and buyer profits to the sum of the theoretical maximum surpluses.\(^{19}\) In this case the market exhibited a PCS ratio of 99.3, which is very near optimal.

However, did this market indeed perform optimally? There were no transactions at the equilibrium price, sellers earned 185 percent of their theoretical surplus while buyers earned only 68 percent of their theoretical surplus, and the market stopped trading short of the equilibrium quantity. This would seem to indicate some serious problems with using the PCS ratio as a measure of allocative efficiency. Some of these problems include: (1) it is not sensitive to income redistributions between

\(^{19}\) This ratio is multiplied by 100 to express the result as a percentage.
buyers and sellers, (2) it is not sensitive to the speed with which a market approaches equilibrium, and (3) it is not sensitive to the number of units traded.

The first problem becomes apparent when we observe that trading at prices different from equilibrium still result in a very high PCS ratio. In the example, producers earned considerable rent at the expense of the buyers but the measure did not reflect any deviations away from optimal allocation of income between the two groups. The second problem is related to the first. If the PCS ratio is not sensitive to transaction prices occurring at values away from equilibrium, then it can't be sensitive to the speed with which a market approaches equilibrium. Thus, markets which never traded at the equilibrium price would be judged just as efficient as markets which traded all units at the equilibrium price. Finally, the PCS ratio does not consider the number of units traded in the market. In the example, traders could have traded one more unit among themselves and still be as well off (assuming a zero cost of trading units). However, the PCS ratio did not reflect any trading inefficiencies in the market.

As a means of overcoming the deficiencies associated with the PCS ratio, the following market performance measures were developed to also compare the trading behavior of the six experimental groups: (1) weighted price
deviation ratio, (2) quantity deviation ratio, and (3) market efficiency deviation index. The first two measures were developed so as to compare the observed price and quantity behavior of an experimental market to that of the theoretically efficient market, under identical supply and demand conditions. The third measure is simply the product of the first two. It was developed so as to better understand the overall performance of a market, in terms of allocative (combined price and quantity) efficiency.

In this context, a market is price efficient if all units are priced at the equilibrium price and it is quantity efficient if the equilibrium number of units is traded. Maximum allocative (market) efficiency is achieved when a market is both price and quantity efficient.

The weighted price deviation (WPD) ratio is an average that is computed for each trading session, Figure 4.

```
Equilibrium Price

<table>
<thead>
<tr>
<th>0</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
```

Figure 4: Theoretical Pricing Behavior of Efficient Markets
The efficient market would trade all units at the equilibrium price (indicated by *'s) while an inefficient market would trade some or all units at prices different from equilibrium (indicated by 0's). If the market is accumulating information as trading proceeds throughout the session, then prices should be approaching equilibrium as trading progresses. Therefore, the occurrence of negotiated prices above or below equilibrium on early trades should be less indicative of an inefficient market than when price deviations from equilibrium occur toward the end of a trading session. By applying an increasing weighting system to the series of price differences (actual transaction price minus equilibrium price), a measure is developed which is sensitive to the timing of specific transactions and can be used to compare the relative pricing efficiencies of various markets.

However, since equal deviations above and below the equilibrium price would tend to cancel each other, the absolute value of each price deviation was used. If a transaction price occurred at the equilibrium price, that trade was assigned a value of 100. Trades with a price at plus or minus 10 percent of equilibrium were assigned a value of 90, and so on. These values were then multiplied by the sequence number of each specific trade, i.e., 1 for the first trade, 2 for the second, etc. The mean of this
weighted series was compared to the mean of a weighted series consisting of the same number of trades, all occurring at the equilibrium price. The resulting ratio was then multiplied by 100. This yielded a measure ranging from 0 to 100, with 100 indicating a price efficient market.

The quantity deviation (QD) ratio is computed in a similar fashion, except there is only one observation, the total number of units traded. The number of units traded is expressed as a ratio of the equilibrium quantity. Markets which traded the equilibrium quantity were assigned a value of 100. Markets which traded plus or minus 10 percent of equilibrium were assigned a value of 90, and so on.20

The product of the weighted price deviation ratio and the quantity deviation ratio was divided by 100 and termed the market efficiency deviation (MED) index. This index ranges from 0 to 100, with 100 representing the theoretically efficient market. The three performance measures were then averaged over the 24 trading sessions of each group.

20 In the course of 144 experimental sessions, the actual number of trades exceeded the equilibrium amount in only one instance.
IMPACT ON MARKET PERFORMANCE

In order to identify the effects of pricing mechanisms and uncertainty on market performance, multiple regression analysis will be used. The following model will be estimated using ordinary least squares:

\[ Y = A + B_1 GR_1 + B_2 GR_3 + B_3 GR_4 + B_4 GR_5 + B_5 GR_6 
+ B_6 UNGR_1 + B_7 UNGR_2 + B_8 UNGR_3 + B_9 UNGR_4 
+ B_{10} UNGR_5 + B_{11} UNGR_6 + B_{12} T_1 + B_{13} T_1 SQ 
+ B_{14} T_2 + B_{15} T_2 SQ + B_{16} T_3 + B_{17} T_3 SQ + B_{18} T_4 SQ 
+ B_{19} T_4 SQ + B_{20} T_5 + B_{21} T_5 SQ + B_{22} T_6 + B_{23} T_6 SQ + e \]

where \( Y \) = market performance measure, \( A \) = the intercept, \( GR_1 \) = a dummy variable for group 1 (double auction, replication 1), \( GR_3 \) = a dummy variable for group 3 (posted bid without price reporting, replication 1), \( GR_4 \) = a dummy variable for group 4 (posted bid without price reporting, replication 2), \( GR_5 \) = a dummy variable for group 5 (posted bid with price reporting, replication 1), \( GR_6 \) = a dummy variable for group 6 (posted bid with price reporting, replication 2), \( UNGR_1 \) = the level of price uncertainty times

\[ 21 \text{ Market performance is measured by: (1) the PCS ratio, (2) the WPD ratio, (3) the QD ratio, and (4) the MED index.} \]

\[ 22 \text{ The intercept accounts for the effect of group 2 (double auction, replication 2) on market performance. This group was used as the reference group because the stated hypotheses argue that market performance of the double auction is superior to that of the other pricing mechanisms. Therefore, it seems reasonable to compare the performance of the other groups to that of a double auction group.} \]
GR1, GR2, GR3, GR4, GR5, GR6 = the level of price uncertainty times GR1, GR2, GR3, GR4, GR5, GR6, UNGR1 = the level of price uncertainty times GR1, UNGR2 = the level of price uncertainty times GR2, UNGR3 = the level of price uncertainty times GR3, UNGR4 = the level of price uncertainty times GR4, UNGR5 = the level of price uncertainty times GR5, UNGR6 = the level of price uncertainty times GR6. T1 = the sequence number of trading session for group 1, T1^2 = T1 squared, T2 = the sequence number of trading session for group 2, T2^2 = T2 squared, T3 = the sequence number of trading session for group 3, T3^2 = T3 squared, T4 = the sequence number of trading session for group 4, T4^2 = T4 squared, T5 = the sequence number of trading session for group 5, T5^2 = T5 squared, T6 = the sequence number of trading session for group 6, T6^2 = T6 squared. T1 through T6^2 are included in the model as a statistical control for the possible effects of time/learning on the market performance of each of the six groups.

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23 The level of price uncertainty is expressed as a percentage of the equilibrium price. By multiplying the level of price uncertainty times GR1, UNGR1 will contain nonzero values for the 24 observations corresponding to those of group 1 and zero otherwise.

24 T1 will contain nonzero values for the 24 observations corresponding to those of group 1 and zero otherwise.

25 Smith (1982) has propositioned that convergence to equilibrium under double auction pricing occurs quicker as the trading experience of the subjects increases. However, he fails to comment as to the functional form of this learning curve. As a result, both a nominal and a quadratic term were included in the analysis so as to detect any possible non-linear relationships between learning and market performance.
In this model, $B1$-$B5$ will indicate the difference in market performance between groups 1, 3, 4, 5, and 6 relative to group 2. $B6$-$B11$ will indicate the relative impact of price uncertainty on market performance for each of the six groups. $B12$-$B23$ will indicate the possible change in market performance by each of the six groups over the course of 24 trading sessions. In other words, $B12$-$B23$ will be a proxy for any learning effects on market performance that the groups exhibit as they become more familiar with their roles as buyers and sellers. While these variables were included in the estimated model, their purpose was more for statistical control than for hypothesis testing.

A one-tail t-test will be applied to test the following hypotheses:

1. $H_0: B1 = 0$ versus $H_a: B1 \neq 0$
2. $H_0: B2 = 0$ versus $H_a: B2 < 0$
3. $H_0: B3 = 0$ versus $H_a: B3 < 0$
4. $H_0: B4 = 0$ versus $H_a: B4 < 0$
5. $H_0: B5 = 0$ versus $H_a: B5 < 0$
6. $H_0: B6 = 0$ versus $H_a: B6 < 0$
7. $H_0: B7 = 0$ versus $H_a: B7 < 0$
8. $H_0: B8 = 0$ versus $H_a: B8 < 0$
9. $H_0: B9 = 0$ versus $H_a: B9 < 0$
10. $H_0: B10 = 0$ versus $H_a: B10 < 0$
11. $H_0: B11 = 0$ versus $H_a: B11 < 0$
Rejection of any of the null hypotheses will indicate a statistically significant impact on the level of allocative efficiency from the associated independent variable. In this case, it is expected that group 1 and group 2 will not be significantly different from each other on any of the market performance measures. As a result, B1 is not expected to be significantly different from zero. It is hypothesized that the double auction is superior to the other pricing mechanisms in market performance. As a result, B2 through B5 are expected to be negative in sign. It is also hypothesized that increasing the level of price uncertainty in the market decreases allocative efficiency. Therefore, B6 through B11 are also expected to be negative in sign.
Chapter III

ANALYTIC RESULTS

This chapter reports the results obtained as they relate to each of the research hypotheses. Acceptance or rejection of the specifically tested hypotheses will shed light on the impact of alternative pricing mechanisms and price uncertainty on allocative efficiency.

IMPACT ON MARKET PERFORMANCE

This section is broken down into two subsections. The first deals with the relative effects of pricing mechanisms, price uncertainty, and time on the generally received measure of allocative efficiency, the sum of producers' plus consumers' surplus (PCS) ratio. The second subsection deals with the relative effects of pricing mechanisms, price uncertainty, and time on the new measures of market performance, the weighted price deviation (WPD) ratio, the quantity deviation (QD) ratio, and the market efficiency deviation (MED) index.
**Impact on Generally Received Measures**

The average performance of each of the six groups in terms of the typically used performance measures is presented in Table 2.

**TABLE 2**

Mean of Generally Received Performance Measures

<table>
<thead>
<tr>
<th>Group</th>
<th>Price Ratio</th>
<th>Quantity Ratio</th>
<th>Consumers' Surplus Ratio</th>
<th>Producers' Surplus Ratio</th>
<th>PCS Ratio$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>113.34</td>
<td>84.34</td>
<td>83.37</td>
<td>117.12</td>
<td>94.28</td>
</tr>
<tr>
<td></td>
<td>(27.15)$^b$</td>
<td>(11.46)</td>
<td>(28.70)</td>
<td>(41.93)</td>
<td>(8.62)</td>
</tr>
<tr>
<td>Group 2</td>
<td>101.55</td>
<td>86.99</td>
<td>97.00</td>
<td>98.85</td>
<td>95.12</td>
</tr>
<tr>
<td></td>
<td>(17.64)</td>
<td>(7.46)</td>
<td>(22.94)</td>
<td>(28.32)</td>
<td>(6.30)</td>
</tr>
<tr>
<td>Group 3</td>
<td>91.99</td>
<td>91.86</td>
<td>101.87</td>
<td>78.14</td>
<td>93.91</td>
</tr>
<tr>
<td></td>
<td>(17.40)</td>
<td>(4.43)</td>
<td>(23.14)</td>
<td>(37.50)</td>
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</tr>
<tr>
<td>Group 4</td>
<td>98.74</td>
<td>87.05</td>
<td>97.62</td>
<td>96.18</td>
<td>95.04</td>
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<tr>
<td></td>
<td>(18.47)</td>
<td>(5.90)</td>
<td>(19.52)</td>
<td>(34.83)</td>
<td>(5.53)</td>
</tr>
<tr>
<td>Group 5</td>
<td>106.23</td>
<td>88.31</td>
<td>89.48</td>
<td>108.70</td>
<td>96.47</td>
</tr>
<tr>
<td></td>
<td>(17.52)</td>
<td>(5.86)</td>
<td>(23.22)</td>
<td>(31.33)</td>
<td>(5.69)</td>
</tr>
<tr>
<td>Group 6</td>
<td>93.93</td>
<td>86.86</td>
<td>101.76</td>
<td>82.74</td>
<td>93.82</td>
</tr>
<tr>
<td></td>
<td>(19.91)</td>
<td>(8.07)</td>
<td>(24.38)</td>
<td>(37.22)</td>
<td>(5.41)</td>
</tr>
</tbody>
</table>

$^a$ Sum of producers' surplus plus consumers' surplus divided by theoretical maximum.

$^b$ Standard deviation
These results indicate that the six groups differed quite a bit in terms of the price ratio (113.34 for group 1 to 91.99 for group 3), the consumers' surplus ratio (83.37 for group 1 to 101.87 for group 3), and the producers' surplus ratio (117.12 for group 1 to 78.14 for group 3), but weren't too different for the quantity ratio (84.34 for group 1 to 91.86 for group 3) or the PCS ratio (96.47 for group 5 to 93.82 for group 6). The relative performance of each group in terms of their price ratio and quantity ratio is presented in Figure 5.

Figure 5: Market Performance, Average Prices and Quantities Traded
These results indicate that on average group 1 traded the fewest number of units per session at the highest average price, while group 3 traded the most units per session at the lowest average price. Groups 2, 4, 5, and 6 traded on average approximately the same number of units. Groups 2 and 4 traded closest to the competitive price.

The relative performance of each group in terms of the PCS ratio is presented in Figure 6.

![Percentage Of Maximum](chart)

Figure 6: Market Performance, PCS Ratio

Overall, there appears to be little difference in average performance as measured by the PCS ratio among the six groups. This would appear to be in conflict with the
outcomes presented in Figure 4, which suggests a wider disparity in actual performance. This also appears to be inconsistent with previous studies that have found the double auction mechanism to exhibit greater levels of efficiency than posted bid markets.

In order to determine the level of allocative efficiency associated with the three pricing mechanisms, holding the level of price uncertainty and time constant, multiple regression analysis was used. Since dummy variables were used to identify the six different experimental groups, one of them needs to be dropped in order to avoid singularity. The effect of this is that the intercept term reflects the level of allocative efficiency associated with group 2. The estimated model is presented in Table 3.26

Because of the non-significant F ratio, the results imply that the linear combination of independent variables does not explain any of the variability in the PCS ratio about its mean. This suggests that the PCS ratio is not sensitive to disturbances that would be expected to affect allocative efficiency such as: (1) changing price mechanism, (2) varying levels of price uncertainty, or (3) learning by market participants. Combining this apparent lack of sensitivity with the previously discussed deficiencies, it is apparent that the PCS ratio is

26 Supporting material is presented in Appendix I.
TABLE 3

Estimated Model - PCS Ratio

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>PARAMETER ESTIMATE</th>
<th>T RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>95.9336**</td>
<td>20.358</td>
</tr>
<tr>
<td>GR1</td>
<td>-15.74666*</td>
<td>-2.322</td>
</tr>
<tr>
<td>GR3</td>
<td>0.30987</td>
<td>0.048</td>
</tr>
<tr>
<td>GR4</td>
<td>0.05565</td>
<td>0.009</td>
</tr>
<tr>
<td>GR5</td>
<td>-1.86795</td>
<td>-0.268</td>
</tr>
<tr>
<td>GR6</td>
<td>-5.78232</td>
<td>-0.828</td>
</tr>
<tr>
<td>UNGR1</td>
<td>-0.03427</td>
<td>-0.773</td>
</tr>
<tr>
<td>UNGR2</td>
<td>-0.10055*</td>
<td>-2.226</td>
</tr>
<tr>
<td>UNGR3</td>
<td>-0.08792*</td>
<td>-1.734</td>
</tr>
<tr>
<td>UNGR4</td>
<td>0.12549</td>
<td>0.456</td>
</tr>
<tr>
<td>UNGR5</td>
<td>-0.01764</td>
<td>-0.395</td>
</tr>
<tr>
<td>UNGR6</td>
<td>-0.06171</td>
<td>-1.383</td>
</tr>
<tr>
<td>T1</td>
<td>2.94430**</td>
<td>3.624</td>
</tr>
<tr>
<td>T1SQ</td>
<td>-0.10216**</td>
<td>-3.228</td>
</tr>
<tr>
<td>T2</td>
<td>0.69307</td>
<td>0.853</td>
</tr>
<tr>
<td>T2SQ</td>
<td>-0.02149</td>
<td>-0.682</td>
</tr>
<tr>
<td>T3</td>
<td>0.46807</td>
<td>0.498</td>
</tr>
<tr>
<td>T3SQ</td>
<td>-0.01748</td>
<td>-0.490</td>
</tr>
<tr>
<td>T4</td>
<td>-0.55354</td>
<td>-0.531</td>
</tr>
<tr>
<td>T4SQ</td>
<td>0.02269</td>
<td>0.563</td>
</tr>
<tr>
<td>T5</td>
<td>0.15779</td>
<td>0.192</td>
</tr>
<tr>
<td>T5SQ</td>
<td>0.00663</td>
<td>0.207</td>
</tr>
<tr>
<td>T6</td>
<td>0.99627</td>
<td>1.213</td>
</tr>
<tr>
<td>T6SQ</td>
<td>-0.02717</td>
<td>-0.847</td>
</tr>
</tbody>
</table>

F RATIO = 1.512
R SQUAR Ex = 0.076
Number of Observations = 144

* Significant at 95 percent confidence level
** Significant at 99 percent confidence level
inappropriate for testing the research hypotheses. As a result, the theoretically superior measures of weighted price deviation ratio, quantity deviation ratio, and market efficiency deviation index will be used to test the hypothesized relationships between market performance and pricing mechanism/price uncertainty.

**Impact on New Performance Measures**

The average performance of each of the six groups in terms of the new performance measures is presented in Table 4.

These results indicate that group 1 averaged 76.02 on the WPD ratio while group 2 averaged 87.94, group 1 averaged 83.78 on the QD ratio while group 3 averaged 91.86, and group 1 averaged 64.12 on the MED index while group 2 averaged 76.79. Once again, group 1's performance is inconsistent with prior expectations. One possible explanation for these results is that this group represents an "outlier" type of group. As such, their performance is not to be considered typical of future groups, given the same circumstances. Another possibility is that individual trading strategies within group 1 were such that the sellers dominated the buyers throughout most of the trading sessions. While personal differences in terms of age, background, and prior exposure to auction markets may be a
### TABLE 4
Mean of New Market Performance Measures

<table>
<thead>
<tr>
<th>Group</th>
<th>Weighted Price Deviation Ratio</th>
<th>Quantity Deviation Ratio</th>
<th>Market Efficiency Deviation Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>76.02 (16.18) a</td>
<td>83.78 (10.61)</td>
<td>64.12 (17.45)</td>
</tr>
<tr>
<td>Group 2</td>
<td>87.94 (11.04)</td>
<td>86.99 (7.45)</td>
<td>76.79 (13.00)</td>
</tr>
<tr>
<td>Group 3</td>
<td>83.48 (10.53)</td>
<td>91.86 (4.43)</td>
<td>76.67 (10.15)</td>
</tr>
<tr>
<td>Group 4</td>
<td>85.09 (10.33)</td>
<td>87.05 (5.90)</td>
<td>74.15 (10.86)</td>
</tr>
<tr>
<td>Group 5</td>
<td>83.69 (9.81)</td>
<td>88.31 (5.86)</td>
<td>73.88 (9.72)</td>
</tr>
<tr>
<td>Group 6</td>
<td>77.69 (12.24)</td>
<td>85.86 (8.07)</td>
<td>67.41 (12.04)</td>
</tr>
</tbody>
</table>

*a Standard deviation

A possible explanation for a trader's marketing strategy; there may be other unknown factors which identify "successful" traders from "unsuccessful" traders. Unfortunately, data describing a trader's marketing strategy throughout the experiments are unavailable for analysis. Therefore, the market performance of group 2 will be used as a reference point when comparing the
performance of the posted bid pricing groups to that of an auction group. Group 2's performance is also much more consistent with results from previous studies.

The relative performance of each group in terms of the MED index is presented in Figure 7.

Overall, there appears to be greater difference in average performance among the six groups than was indicated in Figure 5. There also appears to be a decline in market efficiency when comparing the results of groups 3 through 6...
to group 2. Group 1 would appear to be an outlier and this is consistent with the findings in Figure 4.

In order to determine the level of allocative efficiency associated with the three pricing mechanisms, holding the level of price uncertainty and time constant, multiple regression analysis was used. Recognizing that the quantitative measure of allocative efficiency being used, the MED index, is composed of two subparts, one part capturing a market's pricing efficiency and the other part capturing a market's trading efficiency; the proposed model was estimated three times, once with the WPD ratio as the dependent variable, once with the QD ratio as the dependent variable, and finally with the MED index as the dependent variable. Dummy variables were used to identify the six different groups. As a result, one of these needs to be dropped in order to avoid singularity. The result of this is that the intercept term reflects the level of market performance associated with group 2. The estimated models are presented in Table 5.27

These results indicate that each of the estimated models had a statistically significant F ratio and individual R square's ranging from 0.3698 for the WPD ratio model, 0.2776 for the QD ratio model, and 0.4343 for the MED index model. This would seem to indicate that these three

27 Supporting material is presented in Appendices J-L.
**TABLE 5**

Estimated Models - WPD Ratio, QD Ratio, MED Index

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>WPD RATIO</th>
<th>QD RATIO</th>
<th>MED INDEX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COEFF. a T RATIO</td>
<td>COEFF. a T RATIO</td>
<td>COEFF. a T RATIO</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>84.73**</td>
<td>12.064</td>
<td>87.19**</td>
</tr>
<tr>
<td>GR1</td>
<td>-36.93**</td>
<td>-3.655</td>
<td>-10.87</td>
</tr>
<tr>
<td>GR3</td>
<td>-16.71*</td>
<td>-1.738</td>
<td>1.79</td>
</tr>
<tr>
<td>GR4</td>
<td>-2.46</td>
<td>-0.256</td>
<td>0.86</td>
</tr>
<tr>
<td>GR5</td>
<td>-20.37*</td>
<td>-1.958</td>
<td>5.89</td>
</tr>
<tr>
<td>GR6</td>
<td>-21.15*</td>
<td>-2.033</td>
<td>2.91</td>
</tr>
<tr>
<td>UNGR1</td>
<td>0.02</td>
<td>-0.227</td>
<td>-0.16**</td>
</tr>
<tr>
<td>UNGR2</td>
<td>0.10</td>
<td>1.503</td>
<td>-0.10*</td>
</tr>
<tr>
<td>UNGR3</td>
<td>-0.14*</td>
<td>-1.847</td>
<td>-0.02</td>
</tr>
<tr>
<td>UNGR4</td>
<td>-0.06</td>
<td>-0.696</td>
<td>-0.08</td>
</tr>
<tr>
<td>UNGR5</td>
<td>0.02</td>
<td>0.291</td>
<td>-0.09*</td>
</tr>
<tr>
<td>UNGR6</td>
<td>0.02</td>
<td>0.234</td>
<td>-0.13**</td>
</tr>
<tr>
<td>T1</td>
<td>6.67**</td>
<td>5.507</td>
<td>2.39**</td>
</tr>
<tr>
<td>T1SQ</td>
<td>-0.27**</td>
<td>-5.643</td>
<td>-0.07*</td>
</tr>
<tr>
<td>T2</td>
<td>-0.31</td>
<td>-0.256</td>
<td>0.75</td>
</tr>
<tr>
<td>T2SQ</td>
<td>0.01</td>
<td>0.206</td>
<td>-0.02</td>
</tr>
<tr>
<td>T3</td>
<td>3.21*</td>
<td>2.294</td>
<td>0.84</td>
</tr>
<tr>
<td>T3SQ</td>
<td>-0.08</td>
<td>-1.596</td>
<td>-0.03</td>
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<td>T4</td>
<td>0.13</td>
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<td>0.05</td>
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<td>T4SQ</td>
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<td>0.348</td>
<td>0.01</td>
</tr>
<tr>
<td>T5</td>
<td>2.49*</td>
<td>2.033</td>
<td>-0.22</td>
</tr>
<tr>
<td>T5SQ</td>
<td>-0.06</td>
<td>-1.310</td>
<td>0.01</td>
</tr>
<tr>
<td>T6</td>
<td>1.06</td>
<td>0.867</td>
<td>0.001</td>
</tr>
<tr>
<td>T6SQ</td>
<td>0.002</td>
<td>0.004</td>
<td>0.02</td>
</tr>
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</table>

F RATIO  4.648  3.389  5.773
R SQUARE 0.3698 0.2776 0.4343
Number of Observations = 144

* Estimated partial correlation coefficient

** Significant at 95 percent confidence level

* Significant at 99 percent confidence level
efficiency measures are indeed sensitive to market disturbances that theoretically affect market performance and should be considered appropriate for testing the research hypotheses. While future researchers may develop alternative performance measures which are more sensitive to the type of pricing mechanism and level of price uncertainty, this study will utilize the WPD ratio, QD ratio, and the MED index as indicators of allocative efficiency.

Impact on Weighted Price Deviation Ratio

The results of the estimated model are presented in columns 1 and 2, Table 5. In regard to the WPD ratio, groups 1, 3, 5, and 6 were significantly lower than group 2. Group 4 was lower than group 2 but not statistically lower at the 95 percent confidence level. Groups 5 and 6 averaged four points lower than group 3 on the mean level of pricing efficiency, holding all else constant. These findings offer confirmation for previous findings that reported greater pricing efficiency with double auctions. However, the performance of group 1 appears inconsistent both with previously reported research results and with a priori expectations.
The unexpected behavior of group 1 was evidenced with prices that averaged 113 percent of equilibrium. Table 2. This was the greatest deviation from equilibrium price for any group and consequently resulted in group 1 exhibiting the lowest level of pricing efficiency.

The amount of price uncertainty associated with supply and demand did not have a statistically significant impact on the relative pricing efficiency of five of the six groups. Group 3 was the exception. In that group, increasing price uncertainty by plus and minus five percent would lower pricing efficiency by 1.4 points. This suggests that the ability to price products at the equilibrium value is more a function of pricing mechanism than conditions of uncertainty within the market.

The effect of time/learning was significantly different from zero for groups 1, 3, and 5. Groups 3 and 5 increased their relative pricing efficiency by 3.2 and 2.5 points, respectively on each new trading session. Groups 2, 4, and 6 did not exhibit any significant change over the course of the experiments. Group 1 maximized pricing efficiency by the 13th session and deteriorated thereafter. This is evidenced by the fact that during weeks one through three, prices for group 1 averaged 126 percent of equilibrium value, during weeks four and five (which ended with session 13), prices averaged 89 percent of equilibrium, and during
the last four weeks, prices averaged 118 percent of equilibrium. Recognizing that pricing efficiency increases as the absolute difference between transaction prices and equilibrium price decreases, then the observed pricing behavior of group 1 would result in pricing efficiency starting out low, improving, and then dropping off.

However, what factors led to a lowering of prices during weeks four and five? A possible explanation may be that a "slow learner" phenomena existed. This hypothesis would argue that buyers in group 1 were "slow" in recognizing a trading strategy that would counter the quicker learning sellers, evidence the high prices during the first three weeks. By week four, buyers were developing more successful trading strategies, evidence the lowering of prices. But starting with week six, the sellers reasserted themselves as the dominant traders and held that position until the end of the experiments. This would seem to indicate that the buyers failed to learn a second "counter" strategy. Failure to assess any deliberate change in a trader's strategy precludes the testing of this slow learner concept, but future efforts should be alert to its possibility.
Impact on Quantity Deviation Ratio

The results of the estimated model are presented in columns 3 and 4, Table 5. The estimated model indicates that the six groups were not significantly different (at the 95 percent confidence level) in trading efficiency as measured by the QD ratio. These results were not consistent with a priori expectations. Previous studies have reported that quantities traded are affected by the type of pricing mechanism (Forster and Henderson, 1984), but have failed to report an analysis of variance which would indicate whether observed differences were significantly different from zero.

The level of price uncertainty associated with supply and demand conditions did significantly reduce trading efficiency for groups 1, 2, 5, and 6. Groups 3 and 4 also exhibited a negative response to uncertainty but statistically it was not different from zero. These findings appear to indicate that the amount of response is influenced by the amount of market information available to traders. By reducing price uncertainty by plus and minus five percent, trading efficiency would increase by an average of 1.29 points under a double auction or 1.1 points under posted prices and market news. The two groups which traded in the absence of public information, groups 3 and 4, failed to exhibit any consistent change in the number of units traded as price uncertainty was varied.
Group 1 was the only group to exhibit any learning effects on trading efficiency. This group maximized their trading efficiency, holding all else constant, by the 18th session. After that, trading efficiency declined. Once again, the "slow learner" hypothesis may be a possible explanation.

Impact on Market Efficiency Deviation Index

The results of the estimated model are presented in columns 5 and 6, Table 5. The estimated model indicates that group 1 was significantly lower than group 2 (at the 95 percent confidence level) in terms of the MED index. While this finding was not consistent with a priori expectations, it is consistent with the previous results concerning group 1's level of pricing and trading efficiency. It comes as no surprise that the group with the lowest level of pricing and trading efficiency would also exhibit the lowest level of allocative efficiency.

There was also some evidence that groups 3, 5, and 6 exhibited lower market efficiency than group 2, but the difference was not statistically significant at the 95 percent confidence level. However, groups 3 and 6 were significantly lower at the 90 percent confidence level and group 5 was significantly lower at the 89 percent confidence level. Accepting these confidence levels as
satisfactory, group 3 averaged 13.72 points lower than group 2 in market efficiency, while groups 5 and 6 averaged 13.39 and 16.69 points lower than group 2, holding all else constant.

While these findings do not prove that double auction markets are more efficient than posted bid markets, they are consistent with previous research. Perhaps, these findings would be very much in line with the results of other studies if an analysis of variance had been performed.

The level of price uncertainty significantly affected market efficiency for groups 1 and 3. It was negative. As a result, if price uncertainty decreased by plus and minus five percent, then market efficiency would increase by 1.4 points and 1.5 points, respectively.

Group 3 exhibited a steady increase in market efficiency throughout the experiments of 3.6 points per session. Group 1 maximized their market efficiency by the 14th session and declined thereafter. This behavior is probably due to their similar behavior on the WPD ratio and the QD ratio.

In summary, it appears that the type of pricing mechanism has a greater effect on the pricing efficiency of a market than the quantity efficiency. On the other hand, changing the level of price uncertainty appears to result
in a greater quantity response than a pricing response. This would seem to indicate that inefficiencies in the marketplace resulting from pricing inaccuracies are due to the pricing mechanism while inefficiencies resulting from a lack of trading activity are due to uncertainties over prices.

**IMPACT OF PRICE REPORTING**

The effect of market information on allocative efficiency, within a posted bid market, appears to be inconsistent with a priori expectations. Results from this research, Table 4, indicate that the posted bid market with no feedback (groups 3 and 4) averaged 3.6 points higher than the posted bid market with price feedback (groups 5 and 6) on the WPD ratio, 1.9 points higher on the QD ratio, and 4.8 points higher on the MED index. Although these differences are not statistically significant, it is curious to learn that the additional market information provided by the experimenter did not achieve the desired results, improvement in allocative efficiency.  

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28 See Appendices M-0 for results of three regression models where the intercept term represented the effect on market performance of the posted bid market with no market news (PNN). In these models, the following variables were used: DA is a dummy variable for the two groups using a double auction, PWN is a dummy variable for the two groups using posted bids with market news, UNDA is the level of price uncertainty times DA, UNPNN is the level of price uncertainty times PNN, UNPWN is
A possible explanation for these findings may be that merely reporting the average price of completed contracts is insufficient information to aid the market in discovering equilibrium. Alternatively, this bit of information may allow buyers to get a better understanding of what the competition is bidding and then bid at about the same level, thus, minimizing competitive pressures that would move the market to equilibrium, rather than increasing such pressures. Similar results were reported by Smith (1976) in which he found that subjects possessing complete information on each other's payoff contingencies competed less intensively and were less likely to arrive at equilibrium, even under a double auction pricing system.

TRADEOFFS BETWEEN INFORMATION AND PRICING MECHANISM

It is not possible to give a true estimate of the amount of information that may substitute for an alternative pricing mechanism, given the lack of generally accepted statistical difference between each of the group's performances. However, if one were to use the information previously presented, then groups 5 and 6 averaged 15.04

the level of price uncertainty times PWN, TDA is the sequence of trading sessions for double auction groups, TDASQ is TDA squared, TPNN is the sequence of trading sessions for the posted bid - no news groups, TPNNSQ is TPNN squared, TPWN is the sequence of trading sessions for the posted bid - with news groups, TPWNSQ is TPWN squared.
points lower than group 2 in market efficiency. Assume, for example, that an increase in price uncertainty of plus and minus five percent would lower market efficiency 1.4 points for a double auction market (group 2's performance). Then, if the market for a commodity was presently trading under posted bid pricing with public price reporting and zero price uncertainty, switching over to double auction pricing would increase allocative efficiency 15.04 points. Increasing price uncertainty under the double auction to plus and minus 53.7 percent would reduce allocative efficiency to approximately the same level as before. If the cost of instituting a double auction was less than the resources freed up from information dissemination activities, society would be better off. However, these tradeoffs have not been firmly established by this study.
Chapter IV

CONCLUSIONS

This chapter contains a brief summary of the major findings of this study, conclusions and implications resulting from the information gained, perceived limitations arising within this study, and possibilities for further related research.

SUMMARY

This research project has examined the impact on allocative efficiency within an experimental market as a result of varying: (1) the pricing mechanism, (2) the level of price uncertainty about supply and demand conditions, and (3) the amount of public information available to market participants. Possible tradeoffs between the type of pricing mechanism and the level of price uncertainty needed to maintain a constant degree of allocative efficiency were discussed but could not be tested.

In order to quantify allocative efficiency, researchers within the field of experimental economics have typically compared the sum of consumers' surplus (buyer profits) plus
producers' surplus (seller profits) to the theoretical maximum. This measure, the sum of producers' plus consumers' surplus (PCS) ratio has been the generally received measure of allocative efficiency. However, results indicated that the PCS ratio was not sensitive to market disturbances that theoretically affect allocative efficiency. This led to the development of new market performance measures: (1) the weighted price deviation (WPD) ratio, (2) the quantity deviation (QD) ratio, and (3) the market efficiency deviation (MED) index.

Results indicate that the relative pricing efficiency of an experimental market, as measured by the WPD ratio, is affected more by the pricing mechanism than the amount of price uncertainty in the market. Results also indicate that the relative quantity efficiency of an experimental market, as measured by the QD ratio, is affected more by the amount of price uncertainty than the type of pricing mechanism.

The effects of providing public price reporting to a market that is characterized as a posted bid market are not conclusive. However, there is evidence that public price reporting provides buyers with information on what their competitors are bidding and leads to less competition, rather than more. As a result, movement toward equilibrium or an increase in allocative efficiency was not forthcoming.
Potential tradeoffs between the amount of price uncertainty in the market and the type of pricing mechanism, holding allocative efficiency constant, can only be approximated by this study.

CONCLUSIONS AND IMPLICATIONS

This series of pricing experiments has demonstrated that the impact of a structural change (change in pricing mechanism) or an environmental change (varying the level of price uncertainty) in an experimental market may result in either a change in the relative pricing efficiency of a market or a change in the relative quantity efficiency of a market. Unless both possibilities are accounted for, researchers may be unaware of the true implications of their findings when extrapolating from experimental results to real world cases. The apparent lack of movement toward equilibrium, after providing a market with additional information, has not been established but the evidence is consistent with previous studies. The possibility for tradeoffs between the pricing mechanism and the level of price uncertainty, holding allocative efficiency constant, has been examined but could not be tested by this study.

This study has also demonstrated the need for researchers to be aware of inherent deficiencies in their choice of market performance measures. Even though the
rationale behind using the sum of producers' plus consumers' surplus ratio is consistent with an economically efficient market, this measure yields identical results for a wide variety of possible outcomes. By developing the new measures of market performance, weighted price deviation ratio, quantity deviation ratio, and market efficiency deviation index, this study has provided measures which are both consistent with an economically efficient market and are sensitive to market disturbances that theoretically affect allocative efficiency.

The conclusions on the allocative efficiency of various pricing mechanisms under conditions of supply and demand uncertainty have implications to various groups of individuals on the future of market organization.

**Market Participants**

Successful traders have innate characteristics that are not predetermined by the structural conditions of the market. Buyers and sellers within groups 2 and 4 shared market power pretty evenly. In groups 3 and 6, the buyers dominated the sellers, while just the opposite occurred in groups 1 and 5. This would seem to indicate that market participants who perceive themselves in a disadvantaged bargaining position, under an existing pricing system, may well continue in that position even after a change in the
pricing structure of the market. If traders are to be successful in the market, then they need to identify those traders who are successful and "go in with them" or purchase their expertise. Unfortunately, it is very unlikely that any single trader will always be number one, so deciding who is successful in the short run may not be the same as deciding who is successful in the long run.

**Public Policy Makers**

Public policy makers who are involved with overseeing the activities of the reporting of market news may be able to cut back on their efforts in light of the evidence presented here. On the one hand, it appears that present levels of allocative efficiency may be preserved by switching to double auction pricing, for those commodities presently being priced under posted bid pricing, and freeing resources that are currently used to reduce price uncertainty about supply and demand. If the benefits of freed-up resources exceed the cost of instituting double auction pricing, then policy makers may have a new legislative alternative. This alternative may also be appealing in light of the administration's campaign to have commodity prices more "market determined". On the other hand, policy makers may desire to discontinue public price reporting based on the partial evidence which indicates
that allocative efficiency decreases as buyers become more aware of what the competition is doing.

Society as a Whole

An apparent benefit to society of double auction pricing is increased allocative efficiency. Overall, society is better off with any increase in allocative efficiency, but it is hard to actually identify how individual members of society are better off. If too many resources were being allocated to a specific sector, then an increased efficiency of prices would allocate these resources elsewhere. As a result, should a specific sector be expected to bear the burden for the rest of society? Policy makers will be forced to decide if it is in society's best interests to improve allocative efficiency and if so, how will different sectors of society be compensated.

LIMITATIONS OF THE STUDY

A major limitation of this study in experimental economics is the problem of selection bias. While this is a threat to the external validity of many studies, it points to the need for replications with subjects from various populations. The usefulness of college students has been mainly in their availability. It is not
unreasonable to conclude that students are motivated by the same factors as real world participants, but their risks are considerably less. Failure to earn a profit or avoid a loss at the end of a trading session may have very different consequences for the producer or processor, relative to the student.

An additional limitation of this study is the fact that the replication of identical experiments did not yield uniform results, particularly in regard to groups 1 and 2. Even though these two groups traded from identical schedules and met on the same day of the week, their group behavior was very different. Obviously, personal differences between the two groups need to be examined in order to better understand these unexpected differences. Also, information concerning a subject's trading strategy and their preferences for risk would be very helpful when trying to compare the market performance of the different experimental groups.

An additional limitation of this study is the lack of information concerning the exact trading circumstances in each experimental session. Information of this type would include bids and offers made but not accepted, at what time in the session were transactions completed, and possible influences from dominant personalities (either buyer or seller).
As previously mentioned, the conclusions regarding the possible tradeoffs between pricing mechanism and price uncertainty and the impact of public price reporting on a posted bid market were not conclusive. This is due to the lack of generally accepted statistically significant results. With these limitations in mind, every effort has been made to arrive at conclusions which are consistent with the data.

**POSSIBILITIES FOR FURTHER RESEARCH**

As researchers in experimental economics attempt to quantify changes in allocative efficiency, it is imperative that the measures being used are indeed sensitive to market disturbances that theoretically affect allocative efficiency. While this study has developed some new measures, future studies will need to assess whether these measures are the most appropriate or need further refining.

Additional research should be aimed at identifying what distinguishes a successful trader from an unsuccessful one. Social psychologists have already been working in this area but these efforts need to account for differences in market organization, time allowed for a decision to be made, and long term versus short term trading strategies.

Relative performance of various markets may be affected by the degree of risk averseness of the individual traders.
If the market is composed of mainly risk averse traders, then market equilibrium is more likely to approach point A, Figure 1, than point E. By examining a market's performance, relative to the risk averse outcome, it may be possible to incorporate this additional information when comparing market performance across several groups or across various pricing mechanisms.

The relationship between pricing efficiency or quantity efficiency and price uncertainty was tested under conditions of relatively inelastic supply and demand schedules. As a result, the market equilibrium area ABCD, Figure 1, extended over a relatively small range of quantity values but over a relatively large range of price values. This may explain why changes in pricing efficiency were not explained by changes in uncertainty. Therefore, in order to completely test the relationships between pricing or quantity efficiency and uncertainty, an alternative set of experiments should be conducted which utilize relatively elastic supply and demand schedules. This would create a market equilibrium area that extends over a relatively large range of quantity values but over a relatively small range of price values. By varying the level of uncertainty, researchers may find that pricing efficiency is affected but not trading efficiency.
Finally, additional research should be aimed at refining the experimental market experience into a teaching tool for both students and real world market participants. It appears to this researcher that if a producer or processor can simulate five to ten years of basic production and marketing decisions within a one hour session, then they will certainly gain some valuable information that the real world only offers through a costly trial and error process.
REFERENCES


- 78 -


Appendix A

GENERAL INSTRUCTIONS

This is an experiment in market decision making. In the experiment, you will be simulating a market. Some of you will be buyers and some sellers. If you make good decisions, you might earn considerable money which will be paid to you in cash.

The market will be organized in a series of trading periods. Each trading period will last 15 minutes. After a break to check transactions, a new 15 minute trading period will begin. There will be two practice trading periods today.

Buyers and sellers will be trading "amazin grain". Sellers are producers. They sell to buyers for a negotiated price. Sellers have a cost of production. They will have this cost of production deducted to determine their profits. Buyers are consumers of "amazin grain". They buy from sellers at a negotiated price. Buyers redeem this grain for a predetermined price at the end of each trading period.
Appendix B

SPECIFIC INSTRUCTIONS TO SELLERS

During each trading period, you are free to sell as many units as you want. The expected cost of each unit is listed in column (2) of your SELLER'S PROFIT CALCULATOR. The actual cost will not lie outside this range but you will not know the actual cost until all trading has been completed. At that time, you will draw a random number that will determine what the actual cost was for each unit sold. The difference between the selling price and the actual cost is your gross profit. There is a fixed cost of $1.96 per period. The difference between your gross profits and fixed cost is yours to keep. Good Luck.
Appendix C

SPECIFIC INSTRUCTIONS TO BUYERS

During each trading period, you are free to purchase as many units as you want. After trading has been completed, you will resell your purchases to the experimenter according to the expected values listed in column (2) of your BUYER'S PROFIT CALCULATOR. The actual redemption value will not lie outside this range but you will not know the actual redemption value until all trading has been completed. At that time, you will draw a random number that will determine what the actual redemption value is for each unit purchased. The difference between the purchase price and the actual redemption value is your gross profit. There is a fixed cost of $3.69 per period. The difference between your gross profits and fixed cost is yours to keep. Good Luck.
Appendix D

DOUBLE AUCTION - MARKET INSTRUCTIONS

This market will be organized as a double auction market. Trading will last for 15 minutes. Any buyer is free to announce an opening bid and any seller is free to announce an opening offer for one unit of the commodity we call "amazin grain". Subsequent bids must be higher than the opening bid and subsequent offers must be lower than the opening offer. A contract for one unit is completed when a buyer accepts an offer from a seller or when a seller accepts a bid from a buyer. At that time, the buyer will record the purchase price in column (5) of their PROFIT CALCULATOR and the transaction number in column (6), while the seller records the sale price in column (5) of their PROFIT CALCULATOR and the buyer's number in column (6). Trading will continue until no more trades are forthcoming or the time runs out. After trading has completed, each buyer and seller will draw a number from a cup containing 10 random numbers. The number chosen becomes the settlement value for each participant and is recorded in column (3). Sellers add the settlement value.
to the minimum expected cost for each unit sold. Buyers add the settlement value to the minimum expected resale value to arrive at their actual resale value for each unit purchased. Are there any questions?
Appendix E

POSTED BID WITH PRICE REPORTING - MARKET INSTRUCTIONS

This market will be organized as a posted bid market. Buyers begin by recording opening bids on a card with no knowledge of other buyers' bids. Each buyer has the option to limit the number of units purchased from any single seller at the posted price. Sellers respond to opening bids by indicating their identification number and the number of units to sell on separate slips of paper (chits) for each buyer. They also record the sale price in column (3) of their PROFIT CALCULATOR for all units sold. Buyers receive their chits and separately record the number of units purchased at the opening bid. They also record the purchase price in column (3) of their PROFIT CALCULATOR for all units purchased. All chits are then handed to the experimenter who computes an average price for all completed transactions and announces it to the market. If no purchases were made at the initial bids, experimenter announces, "too little trading activity to determine a price". Buyers then have an opportunity to revise their
posts and their limits on purchases. After trading has completed, each buyer and seller will draw a number from a cup containing 10 random numbers. The number chosen becomes the settlement value for each participant and is recorded in column (3). Sellers add the settlement value to the minimum expected cost for each unit sold. Buyers add the settlement value to the minimum expected resale value to arrive as their actual resale value for each unit purchased. Are there any questions?
Appendix F

POSTED BID WITHOUT PRICE REPORTING - MARKET INSTRUCTIONS

This market will be organized as a posted bid market. Buyers begin by recording opening bids on a card with no knowledge of other buyers' bids. Each buyer has the option to limit the number of units purchased from any single seller at the posted price. Sellers respond to opening bids by indicating their identification number and the number of units to sell on separate slips of paper (chits) for each buyer. They also record the sale price in column (3) of their PROFIT CALCULATOP for all units sold. Buyers receive their chits and separately record the number of units purchased at the opening bid. They also record the purchase price in column (3) of their PROFIT CALCULATOP for all units purchased. All chits are then handed to the experimenter. Buyers then have an opportunity to revise their posts and their limits on purchases. After trading has completed, each buyer and seller will draw a number from a cup containing 10 random numbers. The number chosen becomes the settlement value for each participant and is
recorded in column (3). Sellers add the settlement value to the minimum expected cost for each unit sold. Buyers add the settlement value to the minimum expected resale value to arrive as their actual resale value for each unit purchased. Are there any questions?
<table>
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<tr>
<th>Units sold during trading period</th>
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<th>Settlement value for all units</th>
<th>Actual cost of this one unit</th>
<th>Selling price of this one unit</th>
<th>Buyer Number</th>
<th>Profit on this unit Col.(5) - Col.(4)</th>
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Total Gross Profits

Fixed Cost

Net Profits
### Sample Resale Schedule

**BOYER'S PROFIT CALCULATOR**

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<th>Units present during trading period</th>
<th>Expected resale value of this one unit</th>
<th>Settlement value for all units (2)</th>
<th>Actual resale value of this one unit (3)</th>
<th>Purchase price of this one unit (4)</th>
<th>Transaction number (6)</th>
<th>Profit on this unit (7) = (4) - (5)</th>
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<td>0.00-0.14</td>
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<td></td>
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</table>

**Total Profits**

**Fixed Costs**

**Net Profits**

---

*Note: The table provides a sample calculation of resale profits for various units, with columns for expected resale value, actual resale value, purchase price, and profit calculation.*
Appendix I

REGRESSION MODEL FOR PCS RATIO

| VARIABLE  | DF | PARAMETER ESTIMATE | STANDARD ERROR | T RATIO | PROB>|T| |
|-----------|----|--------------------|----------------|---------|-------|
| INTERCEPT | 1  | 95.93336           | 4.712387       | 20.358  | 0.0001|
| GR1       | 1  | -15.74666          | 6.780316       | -2.322  | 0.0219|
| GR3       | 1  | 0.30987            | 6.453278       | 0.048   | 0.9618|
| GR4       | 1  | 0.055505           | 6.451759       | 0.009   | 0.9931|
| GR5       | 1  | -1.86795           | 6.979857       | -0.268  | 0.7895|
| GR6       | 1  | -5.78232           | 6.979857       | -0.828  | 0.4091|
| UNGR1     | 1  | -0.03427           | 0.044328       | -0.773  | 0.4410|
| UNGR2     | 1  | -0.10055           | 0.045176       | -2.226  | 0.0279|
| UNGR3     | 1  | -0.08792           | 0.050698       | -1.734  | 0.0855|
| UNGR4     | 1  | 0.02549            | 0.055916       | 0.456   | 0.6493|
| UNGR5     | 1  | -0.01764           | 0.044615       | -0.395  | 0.6932|
| UNGR6     | 1  | -0.06171           | 0.044615       | -1.383  | 0.1692|
| T1        | 1  | 2.94430            | 0.812369       | 3.624   | 0.0004|
| T1SQ      | 1  | -0.10216           | 0.031643       | -3.223  | 0.0016|
| T2        | 1  | 0.69307            | 0.812873       | 0.853   | 0.3956|
| T2SQ      | 1  | -0.02149           | 0.031536       | -0.682  | 0.4968|
| T3        | 1  | 0.46807            | 0.939250       | 0.498   | 0.6192|
| T3SQ      | 1  | -0.01748           | 0.035696       | -0.490  | 0.6252|
| T4        | 1  | -0.55354           | 1.042330       | -0.531  | 0.5964|
| T4SQ      | 1  | 0.02269            | 0.040309       | 0.563   | 0.5745|
| T5        | 1  | 0.15779            | 0.821066       | 0.192   | 0.8479|
| T5SQ      | 1  | 0.00663            | 0.032076       | 0.207   | 0.8366|
| T6        | 1  | 0.99627            | 0.821066       | 1.213   | 0.2274|
| T6SQ      | 1  | -0.02717           | 0.032076       | -0.847  | 0.3987|
## Appendix J

**REGRESSION MODEL FOR WPD RATIO**

**DEP VAR: WPD RATIO**

| Variable | DF | PARAMETER ESTIMATE | STANDARD ERROR | T RATIO | PROB>|T| |
|----------|----|--------------------|----------------|---------|-----------------|
| INTERCEPT | 1  | 84.72503           | 7.022895       | 12.064  | 0.0001         |
| GR1      | 1  | -36.93216          | 10.104740      | -3.655  | 0.0004         |
| GR3      | 1  | -16.71492          | 9.617353       | -1.738  | 0.0848         |
| GR4      | 1  | -2.45829           | 9.615089       | -0.256  | 0.7946         |
| GR5      | 1  | -20.36716          | 10.402116      | -1.958  | 0.0526         |
| GR6      | 1  | -21.15116          | 10.402116      | -2.033  | 0.0442         |
| UNGR1    | 1  | -0.01501           | 0.066062       | -0.227  | 0.8207         |
| UNGR2    | 1  | 0.10122            | 0.067326       | 1.503   | 0.1353         |
| UNGR3    | 1  | -0.13958           | 0.075556       | -1.847  | 0.0672         |
| UNGR4    | 1  | -0.05798           | 0.083332       | -0.696  | 0.4879         |
| UNGR5    | 1  | 0.01937            | 0.066491       | 0.291   | 0.7714         |
| UNGR6    | 1  | 0.01554            | 0.066491       | 0.234   | 0.8156         |
| T1       | 1  | 6.66705            | 1.210678       | 5.507   | 0.0001         |
| T1SQ     | 1  | -0.26611           | 0.047157       | -5.643  | 0.0001         |
| T2       | 1  | -0.31070           | 1.200428       | -0.256  | 0.7980         |
| T2SQ     | 1  | 0.00967            | 0.046998       | 0.206   | 0.8373         |
| T3       | 1  | 3.21081            | 1.399769       | 2.294   | 0.0235         |
| T3SQ     | 1  | -0.08491           | 0.053198       | -1.596  | 0.1131         |
| T4       | 1  | 0.12819            | 1.553390       | 0.083   | 0.9344         |
| T4SQ     | 1  | 0.02090            | 0.060073       | 0.348   | 0.7285         |
| T5       | 1  | 2.48809            | 1.223640       | 2.033   | 0.0442         |
| T5SQ     | 1  | -0.06263           | 0.047803       | -1.310  | 0.1927         |
| T6       | 1  | 1.06098            | 1.223640       | 0.867   | 0.3876         |
| T6SQ     | 1  | 0.00021            | 0.047803       | 0.004   | 0.9966         |

**SSE 11619.253**

**F RATIO 4.6480**

**DFE 120**

**PROB>|F| 0.0001**

**MSE 96.82711**

**R-SQUARE 0.3698**
### Appendix K

**REGRESSION MODEL FOR QD RATIO**

| VARIABLE   | DF | PARAMETER ESTIMATE | STANDARD ERROR | T RATIO | PROB>|T| |
|------------|----|--------------------|----------------|---------|-------|
| INTERCEPT  | 1  | 87.18975           | 4.601751       | 18.947  | 0.0001|
| GR1        | 1  | -10.87243          | 6.621131       | -1.642  | 0.1032|
| GR3        | 1  | 1.78975            | 6.301770       | 0.284   | 0.7769|
| GR4        | 1  | 0.88018            | 6.300287       | 0.137   | 0.8916|
| GR5        | 1  | 5.38751            | 6.815986       | 0.864   | 0.3894|
| GR6        | 1  | 2.91316            | 6.815986       | 0.427   | 0.6629|
| UNGR1      | 1  | -0.16027           | 0.043287       | -3.702  | 0.0003|
| UNGR2      | 1  | -0.09773           | 0.044115       | -2.215  | 0.0286|
| UNGR3      | 1  | -0.02361           | 0.049508       | -0.477  | 0.6343|
| UNGR4      | 1  | -0.07869           | 0.054603       | -1.451  | 0.1521|
| UNGR5      | 1  | -0.09384           | 0.043568       | -2.154  | 0.0333|
| UNGR6      | 1  | -0.12647           | 0.043568       | -2.903  | 0.0044|
| T1         | 1  | 2.38915            | 0.793297       | 3.012   | 0.0032|
| T1SQ       | 1  | -0.06899           | 0.030900       | -2.233  | 0.0274|
| T2         | 1  | 0.74555            | 0.793788       | 0.939   | 0.3495|
| T2SQ       | 1  | -0.02239           | 0.030795       | -0.727  | 0.4686|
| T3         | 1  | 0.84159            | 0.917198       | 0.918   | 0.3607|
| T3SQ       | 1  | -0.03134           | 0.034858       | -0.899  | 0.3705|
| T4         | 1  | 0.04559            | 1.017859       | 0.045   | 0.9644|
| T4SQ       | 1  | 0.01256            | 0.039363       | 0.319   | 0.7502|
| T5         | 1  | -0.22317           | 0.801790       | -0.278  | 0.7812|
| T5SQ       | 1  | 0.01446            | 0.031323       | 0.462   | 0.6452|
| T6         | 1  | 0.00146            | 0.801790       | 0.002   | 0.9985|
| T6SQ       | 1  | 0.01653            | 0.031323       | 0.528   | 0.5986|

**DEP VAR: QD RATIO**

- SSE: 4988.755
- F RATIO: 3.3890
- DF: 120
- PROB>|F|: 0.0001
- MSE: 41.57296
- R-SQUARE: 0.2776
### Appendix L

**Regression Model for Med Index**

**Dep Var: Med Index**

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<tbody>
<tr>
<td>MSE</td>
<td>97.92230</td>
</tr>
<tr>
<td>R-Square</td>
<td>0.4343</td>
</tr>
</tbody>
</table>

| Parameter Estimate | Standard Error | T Ratio | Prob>|T| |
|--------------------|----------------|---------|-------|
| **Intercept** | 74.16362 | 7.062500 | 10.501 | 0.0001 |
| GR1 | -37.73724 | 10.161726 | -3.714 | 0.0003 |
| GR3 | -13.72464 | 9.671590 | -1.419 | 0.1585 |
| GR4 | -1.05585 | 9.669313 | -0.109 | 0.9132 |
| GR5 | -13.394781 | 10.460779 | -1.280 | 0.2028 |
| GR6 | -16.69279 | 10.460779 | -1.596 | 0.1132 |
| UNGR1 | -0.13947 | 0.066434 | -2.099 | 0.0379 |
| UNGR2 | -0.00318 | 0.067706 | -0.047 | 0.9626 |
| UNGR3 | -0.14806 | 0.075982 | -1.949 | 0.0527 |
| UNGR4 | -0.11641 | 0.083802 | -1.389 | 0.1674 |
| UNGR5 | -0.06545 | 0.066866 | -0.979 | 0.3296 |
| UNGR6 | -0.09027 | 0.066866 | -1.350 | 0.1795 |
| T1 | 7.18183 | 1.217506 | 5.899 | 0.0001 |
| T1 SQ | -0.26859 | 0.047423 | -5.664 | 0.0001 |
| T2 | 0.38621 | 1.218260 | 0.317 | 0.7518 |
| T2 SQ | -0.01001 | 0.047263 | -0.212 | 0.8327 |
| T3 | 3.56749 | 1.407663 | 2.549 | 0.0121 |
| T3 SQ | -0.10206 | 0.053498 | -1.908 | 0.0588 |
| T4 | -0.00714 | 1.562150 | -0.005 | 0.9964 |
| T4 SQ | 0.03548 | 0.060412 | 0.587 | 0.5581 |
| T5 | 2.04218 | 1.230540 | 1.660 | 0.0996 |
| T5 SQ | -0.04398 | 0.048072 | -0.915 | 0.3621 |
| T6 | 0.96379 | 1.230540 | 0.783 | 0.4350 |
| T6 SQ | 0.01288 | 0.048072 | 0.268 | 0.7893 |
Appendix M

REGRESSION MODEL FOR WPD RATIO - COMBINED GROUPS

**DEPENDENT VARIABLE:** WPD RATIO

| Variable | DF | Estimate  | Standard Error | T Ratio | Prob>|T| |
|----------|----|-----------|----------------|---------|--------|
| Intercept| 1  | 75.033015 | 5.196309       | 14.440  | 0.0001 |
| DA       | 1  | -8.56601  | 7.675741       | -1.116  | 0.2665 |
| P4N      | 1  | -11.06715 | 7.992810       | -1.385  | 0.1685 |
| UNDA     | 1  | 0.03121   | 0.052706       | 0.592   | 0.5547 |
| UNPNN    | 1  | -0.104724 | 0.062132       | -1.686  | 0.0943 |
| UNPWN    | 1  | 0.01745   | 0.052624       | 0.332   | 0.7407 |
| TDA      | 1  | 3.22220   | 0.957700       | 3.365   | 0.0010 |
| TDAQ     | 1  | -0.12914  | 0.037240       | -3.468  | 0.0007 |
| TPNN     | 1  | 1.78039   | 1.158814       | 1.536   | 0.1268 |
| TPNSQ    | 1  | -0.03675  | 0.044374       | -0.828  | 0.4091 |
| TPWNN    | 1  | 1.77453   | 0.968443       | 1.832   | 0.0692 |
| TPWNSQ   | 1  | -0.03121  | 0.037833       | -0.825  | 0.4109 |

**SUMMARY STATISTICS:**

- **SSE:** 16011.861
- **DFE:** 132
- **MSE:** 121.30200
- **R-SQUARE:** 0.2105
- **F RATIO:** 4.4650
- **PROB>F:** 0.0001
### Regression Model for QD Ratio - Combined Groups

**Appendix N**

**Dep Var:** QD Ratio  
**SSE:** 5800.028  
**DFE:** 132  
**MSE:** 43.93960  
**F Ratio:** 5.0260  
**Prob > F:** 0.0001  
**R-Square:** 0.2365

| Variable | DF | Parameter Estimate | Standard Error | T Ratio | Prob>|T| |
|----------|----|--------------------|----------------|--------|------|
| Intercept| 1  | 88.593406          | 3.127441       | 28.328 | 0.0001|
| DA       | 1  | -6.80997           | 4.619707       | -1.474 | 0.1428|
| PWN      | 1  | 2.99667            | 4.810537       | 0.623  | 0.5344|
| UNDA     | 1  | -0.13345           | 0.031721       | -4.207 | 0.0001|
| UNPWN    | 1  | -0.05679           | 0.037395       | -1.519 | 0.1313|
| UNPWN1   | 1  | -0.11015           | 0.031572       | -3.478 | 0.0007|
| TDA      | 1  | 1.59077            | 0.576400       | 2.760  | 0.0066|
| TDA SQ   | 1  | -0.04626           | 0.022413       | -2.064 | 0.0410|
| TPNW     | 1  | 0.47004            | 0.697442       | 0.674  | 0.5015|
| TPNW SQ  | 1  | -0.00994           | 0.026707       | -0.372 | 0.7103|
| TPWN     | 1  | -0.11085           | 0.582865       | -0.190 | 0.8495|
| TPWNSQ   | 1  | 0.01549            | 0.022770       | 0.680  | 0.4974|

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### Appendix 0

**REGRESSION MODEL FOR MED INDEX - COMBINED GROUPS**

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T RATIO | PROB>|T| |
|---|---|---|---|---|---|
| INTERCEPT | 1 | 66.73883 | 5.267841 | 12.669 | 0.0001 |
| DA | 1 | -11.24835 | 7.781405 | -1.446 | 0.1507 |
| PWN | 1 | -7.61900 | 8.102838 | -0.940 | 0.3488 |
| UNDA | 1 | -0.08412 | 0.053431 | -1.574 | 0.1178 |
| UNPNN | 1 | -0.14271 | 0.062987 | -2.266 | 0.0251 |
| UNPWN | 1 | -0.07786 | 0.053348 | -1.460 | 0.1468 |
| TDA | 1 | 3.83544 | 0.970884 | 3.950 | 0.0001 |
| TDA SQ | 1 | -0.14042 | 0.033753 | -3.719 | 0.0003 |
| TPNN | 1 | 1.91891 | 1.174766 | 1.633 | 0.1048 |
| TPNN SQ | 1 | -0.03831 | 0.044985 | -0.852 | 0.3959 |
| TPW | 1 | 1.50298 | 0.981774 | 1.531 | 0.1282 |
| TPW SQ | 1 | -0.01555 | 0.038354 | -0.405 | 0.6858 |