EXPERIMENTATION AND ECONOMIC THEORY

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

by

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SUMMARY

The main aim of this thesis has been to examine the relationship of experimental method to economic theory and the potential of experimentation for theoretical development. In the process four experimental studies were developed and examined. The major results from these studies were:-

Experiment 1 (Chapter 5)

Time pressures on decision making lead to market inefficiencies which are related to the institutional environment in which trading takes place. The information-rich double-auction market is not necessarily superior in terms of efficient price adjustment to the information-poor private negotiation market when decision times are short.

Experiment 2 (Chapter 6)

At a progressive auction for multiple units of a homogeneous commodity the number of traders taking part determines the nature of the price adjustment process. Specifically, with aggregate demand constant the greater the number of buyers the lower the average price during the adjustment period because of the adoption of information-seeking delaying strategies. This reversal of the normally accepted relationship between market size and price is the outcome of examining disequilibrium rather than equilibrium dynamics.

Experiment 3 (Chapter 7)

Under certain, common, institutional arrangements quantity and quality may be of equal or greater importance to traders than price. A misplaced emphasis on price in modelling progressive auctions such as the Australian wool market is shown to lead to model mis-specification.

Experiment 4 (Chapter 8)

Buyers at progressive auctions,who tend not to self-discriminate when faced with homogeneous commodities, do so when faced with a commodity in which there are quality differences

and

Selling commodities in which there are quality differences simultaneously by progressive oral auction leads to greater benefits for both buyers and sellers than selling them sequentially but the difference is greatest when there is a wide variation in buyer estimates of the commodity values.

All of these studies testify to the importance of the institutional framework when examining the process of market price adjustment. This is not the view that has been traditionally adopted. In fact institutional economics has generally had a very low status ranking with economic theorists, being regarded as more descriptive than analytic. Chapter 2 considers why this has been true in the past and outlines the path that economic theory has taken so far. It emphasizes the difficulty of obtaining reliable and relevant data and the consequent construction of mathematical models that avoid, as far as possible, any recourse to empirical or institutional data whatsoever. Chapter 10 uses the experimental framework developed in Chapter 3 and the results of the experimental studies conducted to show why this situtation has now changed and why micro economic price theory cannot be developed fully in its present institutional vacuum. Furthermore, it shows, following on from the detailed study of methodology in Chapter 9, how the techniques of experimentation can lead to developments in economic theory by posing new questions and opening up new lines of enquiry and how it is uniquely able to explore some of the problems of disequilibrium dynamics. Finally it considers where experimentation now stands and where it may go in the future.

28th February 1983.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person except where due reference is made in the text.

Signed:

Jill Penelope Ann Burns

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EXPERIMENTATION AND ECONOMIC THEORY

Penny Burns

CHAPTER 1

INTRODUCTION

1.1 A Word of Explanation

Had I been aware, when I first developed an interest in the use of experimental games as a research technique, of the work of Vernon Smith, Charles Plott and others in the U.S.A., this work would probably have taken a different direction from the one that it has. As it was, it was not until over a year into my research that I came across Vernon Smith's 1962 paper and subsequently discovered the few other published experimental studies that existed in 1978. This discovery brought with it both disappointment and reassurance. Disappointment that I was not to be the pioneer that I had, until then, thought myself to be and reassurance that I was, anyway, on the right track.

Shortly after this, in October 1979, I was fortunate enough to be invited to the Second Conference of Experimental Economics in Tucson, Arizona, organized by Vernon Smith and attended by some thirty researchers either actively experimenting or interested in using experimental results in their theoretical work. They fell roughly into two camps. On the one hand there were the researchers into individual behaviour theory using animals as subjects and on the other, there were those who were more interested in group behaviour and were using human subjects to investigate areas of complex subject interaction such as market theory or voting procedures.

The great diversity of topics and procedures adopted in the papers presented at that meeting confirmed my belief in the enormous potential of experimental economics as a research technique. But it did not answer the questions I had originally set myself: how experimentation fitted into the existing framework of theory and analysis in economics; what advantages, if any, it had over existing analytical techniques and what the problems or limitations were to its application.

This is a very wide field of enquiry. In order to confine it somewhat the emphasis here has been placed on the first of these questions: the relationship of the experimental method to economic theory, although it will be necessary, in order to answer this question, to look at the other questions also.

1.2 The Plan of This Thesis

The thesis is divided into three parts. Part one presents an overview of the problem, Part Two the experimental core, the analysis of which allows us to develop the main theme in Part Three, the relationship of experimental method to economic theory.

The main theme is first introduced in Chapter 2. It answers the basic question, why experiment?, and it does this by detailing the difficulties experienced with economic data and the way that economic theory has developed as a consequence. Experimentation is seen as a way of obtaining relevant and statistically testable data for examining economic hypotheses and also as a method of developing new hypotheses. Chapter 3 then looks at the *how* of experimentation and develops a theoretical framework in which experimental markets can be related to empirical market studies and in which the analysis of experimental markets can be related to existing forms of market analysis and to microeconomic theory. Chapter 4 concludes this overview with a brief survey of what has so far been accomplished in the experimental literature.

Over the past four years I have conducted over 200 markets which have examined a variety of questions concerned with economic analysis and experimental methodology. The four studies in Part Two (representing about forty of these market experiments) have been chosen for their value in illustrating different experimental approaches and techniques. They consist of a series of double auction markets, single object progressive auction markets and multiple object progressive auction markets. A large series of double auction markets and sealed bid tenders that I have conducted, and a smaller series using excess demand schedules, where traders adopt a buying or a selling stance depending on the relationship of the market price to their scheduled values, have been omitted to give preference to a series of experiments that have a natural progression in terms of the methods used, but also a sense of continuity, in that the same or similar themes are addressed. To avoid possible bias no experiment conducted for the purpose of answering the questions addressed in these four studies has been omitted; they are complete studies. The other, omitted studies, have inevitably influenced my overall approach and occasional reference will be made to them in footnotes throughout the current work.

Each of the studies in Part Two has been designed primarily to examine problems in the design and use of experimental economic markets and only secondarily for their application to economic problems. Nevertheless, in presenting the analysis it is useful to reverse this ordering and to deal first with each study as a study in economic analysis in its own right, since this is the ultimate purpose of experimentation, and then, on the basis of what the analysis is attempting, to examine the methodological problems involved in doing so. Thus in each of the four chapters of Part Two the economic analysis will be followed by a methodological critique.

Each study in this section is related to the others in a special way. It begins with a study of decision time and buyer behaviour in two widely different forms of market organization - a centralized double auction and a decentralized private-treaty market. This is primarily an exploratory model involving many factors and using a fractional factorial statistical design. In the following study of buyer behaviour in a multi-object auction, just one of the factors considered in the first study is taken and analyzed in depth. This factor is the strategic implications of the number of buyers in an auction market, for examination of which an appropriate market structure is the progressive auction. Because the results that are obtained from this analysis are, in some respects, counter-intuitive Chapter 7 addresses the question of how the results obtained from the experimental models are related to the design of these models and, in particular, to the choice of subjects for these models. Taking a progressive auction model similar to that of Chapter 6 this chapter examines the effect of using experienced wool buyers as subjects instead of university students. The many ideas that this gives rise to are tackled in the fourth of these studies on a simultaneous progressive auction with heterogeneous commodities, where experimental markets are used in conjunction with Monte Carlo computerized simulations.

Chapter 9, in Part Three, first summarizes, then expands upon the methodological critiques contained in the previous section. Armed with the knowledge gained from the experimental studies of Part Two it is possible to return to the major theme in Chapter 10 and deal in more detail with the relationship of experimental method to economic theory. This chapter concludes the thesis with an assessment of the current state of the art and possible future directions.

CHAPTER 2

WHY EXPERIMENT? - DATA, THEORY TESTING AND EXPERIMENTATION IN ECONOMICS

CHAPTER 2

WHY EXPERIMENT? - DATA, THEORY TESTING AND EXPERIMENTATION IN ECONOMICS

Experimental market analysis is a method for testing and developing microeconomic theory. In brief, the method involves generating market data by conducting experiments under controlled market conditions appropriate to the theory being tested. These data may then be used in a statistical analysis of the hypotheses under examination. The generality of the data may be tested by replication of the experiments.

In the past, data limitations have made it almost impossible to definitively refute any economic theory. This is because any theory which is well constructed, that is, without logical defects must be "true", that is, internally consistent, by definition. What is important is how *relevant* it is. The problem is that the relevance of a theory is determined by its assumptions but *may only be tested* by its predictions. Now for a theory to be refuted, i.e. falsified, it must first be subject to falsification and for this the economic theorist must '... specify in advance potential empirical falsifiers, not just for the parameters of his theory but for his fundamental assumptions; but neo-classical economists were unable and unwilling [to do this]'. (Latsis, 1976, p. 10). This point has created considerable heat in the methodology literature (see, for example, Machlup, 1956, 1967; Friedman, 1953). It is not important for present purposes that either methodological position be adopted, we merely acknowledge the nature of the debate.

It is with respect to this two-sided aspect of economic theory that experimental market analysis has a decided advantage, for besides generating data specific enough to test the predictions, information on the process by which the data are arrived at can be used to analyze the assumptions.

The nature of data limitations in economics and the way in which limitations have affected the development of economic theory are discussed in Sections 2.1 and 2.2 respectively. This discussion provides the rationale for the experimental approach which is outlined in Section 2.3. A look at some problem areas where experimental market analysis could usefully be applied then follows in Section 2.4 with Section 2.5 containing the conclusions to be drawn from this analysis.

2.1 Data Limitations in Economics

In order to appreciate the value of data which is experimentally generated it is necessary to consider the limitations of currently available empirical data.

2.1.1 Theory Based

The first point to notice is that all data are theory-based. This is necessarily so since, of the infinite number of possible "facts", those which we choose to record and analyze are determined by our view of what is important; in other words by our theory of the world, or at least that particular part of it which is of current interest.

This Popperian approach finds expression in the following passage from "What is History?" by E.H. Carr.

> "The only reason why we are interested to know that the battle was fought at Hastings in 1066 is that historians regard it as a major historical event. It is the historian who has decided for his own reasons that Caesar's crossing of that petty stream, the Rubicon, is a fact of history, whereas the crossing of the Rubicon by millions of other people before or since interests nobody at all".
>
> (Carr, 1964, p. 11)

Now, as a result of this theoretical orientation, data which have been collected according to one theory may be quite unsuitable for testing another. For example, accounting theories based on the concept of the flow of funds are ill-served by simply taking, as an estimate of the flow, the difference between the static end-year account figures available under the older accounting system. By this process too much of what is *now* of interest has already been netted out. As another example, and one that is closer to the theme to be pursued in later chapters of this thesis, theories of market price adjustment cannot be satisfactorily developed while analysts are forced to accept average market price data as an estimate of the long term equilibrium values.[1] This problem, common to historical and natural sciences as well as social science, is, in economics, seriously aggravated by two particular features of economic data - lack of precision and time dependency.

2.1.2 Lack of Precision

Data lack precision, or contain much extraneous variation, because the cause and effect structure of the world itself is vastly more complex than the theories which we are able to develop and wish to test. Moreover, many of the causes are temporary influences only and are not common to the entire data set. The explanatory power of our

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1 A procedure that is only correct if the economy has reached a stationary state.

theories is not improved by building in these particular short-run random events. Rather we would prefer data with these transient effects removed; "clean" data, as it were. Much of the considerable effort and progress that has been made in the field of statistics over the past 50 years, for example in the development of multiple regression techniques and the use of spectral analysis, has been directed to isolating the factors of interest in basically "unclean" data.

In general, the unreliability of data has meant that very few economic theories are ever effectively refuted. For as Machlup (1952, p. 73) writes, 'When there is an apparent conflict between observations and the theory they are supposed to test, the observations can usually be disqualified as of uncertain reliability; and where this will not do the conflict can usually be reconciled by means of auxiliary hypotheses'. But these auxiliary hypotheses tend to restrict rather than expand the area of application.

While this problem may differ from that faced by, say, natural scientists, in extent only, the difference is nevertheless crucial. As a general rule we may say that water boils at 100 degrees centigrade. We may wish to be more specific and state the conditions of water purity and of altitude and that the vessel be an open one, but all the conditions can be listed in science, and furthermore, by seeking situations in which the list is incomplete or the general rule does not apply the scientist is led to develop new conjectures and eventually more complete theories which expand rather than contract the generality of the rule. Without an experimental framework, economics does not have this option. Economists are dealing with the behaviour of extremely complex systems with an enormous amount of interaction between the component parts and it is rarely possible *even to list* all the many *ceteris paribus* assumptions which lie behind each theory.

These differences between the scientist and the economist are expressed in the following passage by Leonard Silk:-

> 'Even if he [the economist] gets numbers that look clean, he knows that they are only shadows of a world that is anything but neat, precise, orderly, systematic. He knows that he must try to impose order on a disorderly mass of information as his normal job. Other scientists may have to do this in the beginning of their sciences or may have to do it at crucial turning points in its development, but thereafter they are filling in parts of an empirically solid structure ... [the economist] must apprehend reality freshly each time he confronts it'. (Silk, 1964, p. 3)

2.1.3 Time and Culture Dependence

In science the relationships between the heavenly bodies, or space, time and mass, are the same whether we are talking about the middle ages or today. The same could not be said of anything but the most general of economic relationships, for, unlike atoms or molecules, individuals can and do change their behavioural responses. These changes are made according to the individual's awareness of the incentives and opportunities that present themselves, always of course within the limits of the institutional framework in which they have to operate. However, since the human minds which understand the system, or think they do, are themselves part of the system, they can use their knowledge to alter it. Thus even institutions can change and may change relatively rapidly compared to the duration of human life, and we have to cope with interactions of a higher logical order.

The implication of the above for economics is that the "truth" or relevance of economic data is, like the economic relationships they represent, dependent on the time in which they occur. For the same reasons they may also differ between regional areas at the same point of time. The stereotype of the hard-working, loyal Japanese, the competitive American, the happy-go-lucky Australian, may not be entirely correct but there are definitely cultural differences that appear to prohibit the successful translation of one country's economic policies to another.[2]

'Economics', says Simon, '... is history-bound and culture-bound'. The reason for this is that

> 'Economics is one of the sciences of the artificial. It is a description and explanation of human institutions, whose theory is no more likely to remain invariant over time than the theory of bridge design. Decision processes, like all other aspects of economic institutions, exist inside human heads. They are subject to change with every change in what human beings know, and with every change in their means of calculation. For this reason the attempt to predict and prescribe human economic behaviour by deductive inference from a small set of unchallengeable premises must fail and has failed'. (Simon, 1976, p. 146).

2.2 Rational Economic Man, the Neoclassical Model of the Firm and Behavioural Theory

The economist, then, in trying to construct a workable network of economic rules and relationships cannot rely on that 'solid empirical structure' Silk refers to. This lack of readily available data to refute or confirm economic theories has led to the development of

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2 These differences are denied by Becker (1976) who assumes preferences 'not to change substantially over time, nor to be very different between wealthy and poor persons, or even between persons in different societies and cultures', p. 8. Admittedly such preferences 'have to be defined over fundamental aspects of life, such as health, prestige, sensual pleasure, benevolence, envy, that do not always bear a stable relation to market goods and services', p. 5. But even in this general form it is hard to imagine preferences divorced from cultural history.

particular economic models that place minimal reliance on such data.

2.2.1 Neoclassical Theory

Consider the neoclassical theory of the firm. The use of 'rational economic man' in the role of the entrepreneur is particularly appealing because it is a primarily deductive approach 'that requires almost no contact with data once its assumptions are accepted' (Simon, 1959, p. 254).

The actions of the profit maximizing entrepreneur, as with the utility maximizing consumer, are completely predictable given perfect information. Recent modifications of the neoclassical theory of decision making have, however, taken account of less than perfect information. Risk and uncertainty[3] have been introduced by assuming that variables are random but with a known distribution. Techniques of sampling theory then allow the optimum decision to be made. Incomplete knowledge of future states of the world are assumed to be caused by incomplete information about available alternatives, the consequences of any alternative usually being considered perfectly forecastable. Stigler (1961) has developed an information search procedure, involving the application of marginal analysis, which gives the method for determining the choice to be made. Other modifications to the neoclassical theory can and have been made through changing the conditions and constraints as well as the goals. The results have been primarily to make the theoretical predictions probabilistic rather than

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3 But not uncertainty in the Knight/Keynesian sense of unique events for which probability, is inappropriate. This is more properly dealt with by hueristics rooted in the properties of human information processing, for example, Simon's concept of procedural rationality. See Section 3.

purely deterministic. The entire analysis can still be done mathematically with little or no need for data.

This reliance on logical, mathematical models has been the main strength of economic research techniques and hypothesis building and has led to an impressive collection of interrelated rules and relationships in economics which has become the envy of other behavioural sciences. So much so that the basic concepts of rational economic man and the maximization of some well defined goal have been extended to many problems normally thought to be outside the scope of the economist (Tullock, 1972; Becker, 1976).

2.2.2 The Rationality Assumption

Within economics however, strong differences have developed over this use of rational economic man. Many 'claim that households and firms do not maximize, at least not consistently, that preferences are not well ordered, and that the theory is not useful in explaining economic behavior' (Becker, 1962, p. 1). The standard answer is that while some individuals may behave irrationally, markets themselves behave 'as if' the individuals were rational. Becker (1962) has shown why this is so with respect to downward sloping demand curves and the magnitudes of elasticity measures, pointing to the controlling influence of the opportunity set which can over-ride such irrational behaviour as impulsive or inert responses.

Now it may be that, for the issues in which economists are interested, the outcomes may be explained entirely in terms of real world parameters such as prices and income, with behavioural responses being so heavily constrained that they have negligible influence. But this should not be merely assumed, it should be tested. In Chapter 3 we set up a possible framework within which the interrelatedness of real world opportunities, incentives and individual behaviour may be examined using experimental methods. For the moment however we wish to note that the *as if* rational market behaviour that Becker reports, strictly requires large numbers of market participants - the typical "perfectly competitive" market situation.[4] It is, however, apparent that many, if not most, of our market institutions fail to satisfy the requirements of the perfectly competitive model. Oligopoly is ubiquitous and there are many cases worth examining with small numbers.

2.2.3 Small Number Markets and the Game Theoretic Approach

Game theory has furthered the development of economic theory by providing a vehicle for exploring rational behaviour in situations with small numbers of participants such as duopoly and oligopoly, involving crossed conjectures, coalitions and bargaining. Its expositors have sought 'to establish satisfactorily ... that the typical problems of economic behavior become strictly identical with the mathematical notions of suitable games of strategy' (Von Neumann and Morgenstern, 1944, p. 2).

Game theory has provided a definition of rational behaviour under these circumstances in the concept of "minimaxing". And this too has found many applications ouside the sphere of economics, particularly in defence and military strategy.

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4 Although it is worth noting that Baumol (1982) has shown that many of the perfectly competitive results may be obtained with quite small numbers of participants if there is free exit and entry for all, a condition which characterizes what he calls a perfectly contestable market.

Both game theory and neoclassical economic theory yield 'optimal' solutions. However, the optimal solutions may not be unique and some may be unobtainable in practice. For example, the prescription that enterpreneurs may maximize their profits by equating marginal cost and marginal revenue takes no account of the fact that in practice it may be impossible to estimate accurately either marginal cost or marginal revenue.[5]

2.2.4 Similarity of the 'Satisficing' and 'Second-Best' Approaches

In some quarters there has been dissatisfaction with optimal criteria that yield no practical solution. In certain cases policies implemented to improve conditions, that is to move them closer to the prescribed optima, can actually lead to overall lower levels of utility. An example would be policies designed to create conditions for perfect competition in publicly owned industries while privately owned industries remained imperfect.

Such dissatisfaction resulted in the 'Theory of the Second Best'. Lipsey and Lancaster (1956) were able to show, by using mathematical analysis, that when an economy was in a situation where some industries were operating competitively and some were not, it would not necessarily improve the system, as a whole, to move some parts of it closer to the theoretical competitive optimum. The logical argument that the economy should seek 'satisfactory' rather than 'optimal' goals, was arrived at mathematically but its subsequent development has been slow; for while the optimizing approach is amenable to mathematical analysis the "satisficing" (to use Simon's word) or "second-best" approach is not.

5 They are testable, but only in part, by comparative statics.

Simon's work (1959) has many similarities with that of Lipsey and Lancaster in that the emphasis is on sensible solution procedures and "good" but not necessarily "optimal" goals.

2.2.5 Simon's Behavioural Approach

From his work in the field of decision-making Simon has produced a concept of rational behaviour, "procedural rationality", which he contrasts with the standard concept of economic rationality referred to as "substantive rationality".

'Behaviour is substantively rational when it is appropriate to the achievement of given goals within the limits imposed by given conditions and constraints. Notice', he says, 'that, by this definition the rationality of behaviour depends upon the actor in only a single respect - his goals' (Simon, 1976, pp. 131-2). Given well defined goals and the condition of substantive rationality there is a single correct "optimal" solution.

Procedural rationality, on the other hand, is 'the outcome of appropriate deliberation'. By this definition behaviour is only irrational when it is the result of inadequate or inappropriate thought or reasoning, e.g., impulsive or inert behavioural responses. Procedural rationality requires more of the actor than a knowledge of his goals. It is concerned with the information that he gathers and the way he processes it. It follows that there may be many solutions that are procedurally rational.

Economic research on such decision-making has thus to be concerned with such typical topics from psychology as learning, problem solving and concept attainment. By adopting the viewpoint of procedural rather than substantive rationality the attention is shifted from the sole importance of the final decision to the processes by which the decisions are made.

Clearly in deciding to make the switch there are two important questions to be asked. One, can a viable analytical technique be devised that can utilize this new concept of rationality to generate explanations and predictions similar to, or greater in scope than, those achieved using the concept of substantive rationality? And, two, would the adoption of this concept substantially or significantly change the understanding that economists have of behavioural relationships in economics and thus the explanations and predictions they would wish to make?

Given the wide scope of applicability of existing economic tools in other behavioural sciences these questions are of importance not only to economists.

2.3 The Rationale for Experimental Market Analysis

In the preceding two sections we have shown that data limitations have prevented the testing of economic theory and that as a result theory has tended to develop along lines that require minimal recourse to data once its assumptions are accepted. These assumptions have been questioned many times in the past but no unified theoretical concept has been proposed to take their place until the work of Herbert A. Simon. With experimental techniques the essentially psychological orientation of Simon's concept of procedural rationality can be incorporated into economic analysis for the first time.

It is no coincidence that the first experimental studies[6] in economics were the joint work of an economist (Fouraker) and a psychologist (Siegel) nor that their initial study of bilateral monopoly behaviour (Siegel and Fouraker, 1960) took the extreme case in economics where the importance of the individual in market behaviour is at its most pronounced.

A subsequent study of duopoly behaviour (Fouraker and Siegel, 1963) was specifically addressed to the question of the appropriate behavioural assumptions. This was a question on which quite respectable economic opinion was divided. Pareto had argued that sellers would jointly charge the monopoly price and share the profits. Bertrand, on the other hand, attacking Cournot, argued that in the absence of overt collusion, sellers would tend to undercut each other until they reached the point of zero profits for each. This was clearly a case of whether co-operative or competitive behaviour could be assumed. Fouraker and Siegel set up an experiment in which they were able to specify which outcomes would refute or support one theory and which the other.

Since then, many other experiments have been conducted extending the results that Fouraker and Siegel uncovered, generating new hypotheses and potentially developing a more wide ranging theory of duopoly behavour. (See, for example, Murphy, 1966; Cohen and Johnson, 1967; Stech and McClintock, 1971).

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6 Chamberlin (1948) is the first economist known to have conducted experimental economic studies but his work was directed towards teaching and demonstration rather than being research oriented.

2.3.1 Comparison of Laboratory and Field Experimentation

Recently governments have conducted a number of large scale social experiments, for example, the income maintenance experiments in New Jersey and other studies of supported work programs, health insurance, electricity rates and housing. These are reviewed, along with the problems and prospects of social experimentation, in a survey article by Ferber and Hirsch (1978). In it they make the following comments:

> 'The promise of social experiments has been so great that in the past ten years hundreds of millions of dollars have been spent on them ... still ... a great deal of work could be done using other techniques given the costs being expended on social experiments'. (p. 1380)

and

> 'Some economists have used laboratory approaches to testing some of the basic precepts of economic theory, often in a quite ingenious manner and in a way that also provides information for policy purposes'. (pp. 1388-9)

Laboratory experiments, while not inexpensive, are much less costly than these large scale investigations. They also have two other advantages. The first is that they can be replicated. Not only the cost involved but also the administrative difficulty in finding comparable population samples means that social experiments must inevitably be unique. Secondly, subjects in a social experiment are aware that eventually the experiment will end. Their behaviour will be influenced by this fact. Actions and financial inducements intended to replicate long term policy may thus be seen only as short term and reacted to accordingly. Unless the experiment is to run for a considerably long period of time this is unavoidable. Within the laboratory experimental situation the end of the experiment does not mean reversion to some pre-existing condition, the experiment just ceases, the experimental world comes to an end, as it were. There are no incentives for maximizing returns based on conditions applying after the experiment finishes. 'End period' effects, that is the effect of behaviour in last period differing from those preceding it because it is known to be the last period, can largely be avoided by experimental design, with features like making the end of the experiment unknown to subjects.

It may be that experimental behaviour is systematically different in all periods from that which would result from the interaction of real traders in a real market situation. If this is the case the model has failed to select the appropriate set of incentives, opportunities and knowledge conditions to correctly reflect the situation being simulated. This problem is common to all model and theory building. But if the experiment being conducted is for the purpose of testing an existing theory the complexity of the experimental market should match that of the theory being tested and it is no criticism of the experiment itself that the conditions are not more complex or should be different in detail.

The major disadvantage of experimental market analysis at this stage of its development is that the effects of condensing of time are so far unknown.

2.3.2 Laboratory Experimentation Rationale

Laboratory controls enable the experimenter to set up a working model of the theory under examination which is just as detailed, or just as simplified, as the theory itself. The data thus generated is theory-specific and, of course, time and culture relevant. Replication increases the precision of the results and the confidence with which they are regarded. Both Smith (1976) and Wilde (1980) have provided methodological justifications for experimental procedures but the ultimate justification will be the use that is made of them. Three rationales are suggested here.

2.3.2.1 Testing Predictions

The use of experimental markets means that the economist can now specify empirical falsifiers for his predictions.

Being able to refute hypotheses puts the economist in the same position as the natural scientist who can use the knowledge of conditions in which the theory does not apply to develop new hypotheses leading to new and improved theories with wider scope. This may be compared with the present situation where the discovery of conditions under which hypotheses do not apply only leads to more and more qualifiers being adopted so that the theory has progressively smaller and smaller fields of application to any problem of real world interest.

In economics, however, the relevance of the new, expanded theory or hypothesis must always be seen as subject to further revision not only in the light of more knowledge, which is the case also in the natural sciences, but also in the event of *changing behavioural responses*. It is for this reason that a *method* for generating new theory-specific data and thus establishing the falsehood or (probable) truth of a new hypothesis may be more useful than an existing body of facts relating to an established, but possibly outdated, old truth.

2.3.2.2 Analyzing Assumptions

Empirical falsifiers may also be established for assumptions through the use of *crucial* experiments, that is experiments in which conditions are chosen such that different assumptions lead to significantly different predicted results. An example of this is the Siegel and Fouraker duopoly behaviour study already cited.

Experimental market analysis can be used to examine assumptions precisely *because* they utilize the concept of procedural rationality. That is, intelligent, reasoning, subjects are chosen and allowed to respond as they see fit to the opportunities and incentives that the simulated market environment provides. This may be compared with a computerized market simulation where equations formalizing subject behaviour must be chosen in advance and the resulting data simply produce the natural consequences of these *a priori* assumptions.

Comparison may also be made with the game theory approach, for both are concerned with analysis of economic behaviour and decision making strategies. The difference between them is that while game theory takes a mathematical approach requiring perfect information and substantive rationality and yields optimal solutions, experimental market analysis - often called 'gaming' - uses the selective information processing of procedural rationality and aims at discovering the actual solutions that players adopt when faced with given conditions. Moreover the optimal solutions of game theory frequently take the form of a solution set rather than a unique point and to learn where in the set people land, according to Von Neumann and Morgenstern, institutional information is required. Experimental economics can examine this sort of a question.[7]

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7 I am indebted to Roger Sherman for this observation.

In game theory as stated, perfect knowledge is assumed, in fact, the minimaxing concept is only substantively rational given perfect knowledge. In experimental markets the degree of knowledge is a game parameter. Knowledge is provided in two ways. It may be presented at the beginning of the experiment as part of the given data or it may be generated during the operation of the market itself. Both types of information may be known to all players or known only to one or a few. Control over the supply of knowledge parameter is especially useful for experimental markets engaged in analyzing problems of search behaviour (e.g., Schotter and Braunstein, 1981) which are inevitably based on the assumption of imperfect knowledge.

2.3.2.3 A Comparison of Procedural and Substantive Rationality

Finally, experimental markets can be used to check the actual results of markets in which players adopt procedural rationality against the predicted results of theory using substantive rationality. So far, experimental markets, replicated many times with different subject pools and different experimenters, have established the predictive power of the theoretical equilibrium price under certain conditions. These are that the market be organized as a double auction (that is both buyers and sellers are able to make and accept bids and offers), and that market conditions be kept constant for a number of periods (see, e.g. Smith, 1979). Under these conditions the actual market price will usually tend to the equilibrium price within three to five periods. Convergence is quicker if experienced players are used. This is consistent with the tendency to a long run equilibrium price under stable conditions that Marshall predicted. The efficiency of these markets, in the sense of Pareto optimal distributions, is close to 100 per cent.

Having established this result it can now be used as a reference point against which to judge the efficiency and convergence properties of other trading rules and market conditions. Much of the literature in experimental market analysis has been concerned with such comparisons.

Experimental Market Analysis is particularly useful in developing hypotheses in disequilibrium economics because the path of adjustment to the theoretical equilibrium price is clearly evident in the data generated.

In summary, then, Experimental Market Analysis may be used to generate data specific enough to test the predictions of traditional economic theory; to analyze and examine its assumptions; and to develop the concept of procedural rationality to see whether this leads to results that are substantially and significantly different from those of existing models of economic behaviour using substantive rationality.

Not all economic questions can be answered using experimental techniques. In particular it is unsuitable for generating real world parameters, for example the proportion of the new car market that will prefer 4 to 6 cylinder motor cars. However it can be useful in studying the behavioural aspects behind this question, the reactions of individual decision makers to the opportunities and incentives offerred in the car market, and thus suggest ways in which the appropriate real world data may be collected. Similarly if we have a theory that states that the degree of innovativeness on the part of farmers is related to the amount of debt that they have incurred and their current borrowing possibilities, experiments can be run that will test the basic dependence relationship and thus determine whether the collection of real world data on the amount of debt and borrowing possibilities is worth the expense.

2.4 Potential Areas of Application

Experimentation can be used for any problem which can be specified precisely enough to permit the concepts involved to be made operational and where sufficient controls can be applied. It is particularly useful in the analysis of complex market interactions, where theoretical work has been hampered by the necessity to assume complete information on the part of market participants and where, once even modest assumptions are made concerning traders' subjective beliefs, the analysis rapidly becomes intractable (Barr and Schaftel, 1976). Some examples of possible applications are given below. They are concerned with areas in which there is insufficient appropriate empirical data to test predictions or incomplete knowledge of behavioural responses.

2.4.1 Areas of Insufficient or Inappropriate Data

In the study of duopoly or oligopoly both of these problems (insufficient data, unknown behavioural responses) apply. Data, where obtained, is frequently restricted, since the publication of aggregate data could permit firms to gain information on their competitors' costs and profits. And small numbers markets, as Shubik points out, are not so amenable to aggregate analysis. 'In contrast with the many person market, duopolistic behaviour, bilateral monopoly, bargaining and oligopolistic behaviour in general appears to depend upon detailed information. The other individuals in the market cannot be safely regarded as part of an anonymous aggregate' (Shubik, 1973, p.736). For these reasons imperfect competition is a natural field for behavioural and therefore experimental enquiry. (See Siegel and Fouraker, 1960; Fouraker and Siegel, 1963; Hoggatt, 1959; Hoggatt, Friedman and Gill, 1976; Riley, 1979; Friedman, 1979; and Friedman and Hoggatt, 1979).

Where new theories are being developed the data required may be inconsistent with data previously collected. To force the theory to adopt to the existing data bank could be to distort the results and reduce or obscure the value of the theory itself. This problem can be seen to be particularly acute when the theory in question involves not merely variations on existing themes but a radically different approach. A good example of this is the experimental study of Benbasat and Dexter (1979) of the role of accounting in the presentation of information to decision-makers.

Data may not exist at all when the institutions or trading rules hypothesized in the theory do not yet exist. Yet we need a method by which to compare the planned or hypothetical institution with existing ones. The study of simultaneous progressive auctions in Chapter Eight is such an application of the experimental method which allows the level and dispersion of auction prices to be compared under different institutional arrangements.

Where institutions are actually in existence and empirical data has been generated the data may nevertheless be insufficient or misleading. This is most likely to be the case where the market institution being analyzed is new or in a transitional stage. Apart from the fact that market data may be 'thin' the data itself is affected by the fact that the behavioural responses of market traders are undergoing a transition. It takes time for market traders to change from procedures that they have previously discovered to be optimal under old trading rules to those that *will* be optimal under the new rules. If both the old institution and the new one co-exist data may be further confused by a biased sample of traders. The type of trader that tends to be the first into a new trading scheme need not, and generally will not, be typical of the general trader population and the population that can be expected eventually to utilize the new system. An experimental examination of this problem with respect to a shift in the U.S. treasury's method of auctioning treasury bills was undertaken by Smith (1967). The development of a system of computerized wool selling in Australia was analyzed statistically at an early stage by Metcalfe (1975) in which all the problems with empirical data listed above occur. The results of this study showed that the computerized wool selling system yielded lower prices to sellers than the traditional progressive auction. Experimental studies (unpublished) have thrown doubt on these results which seem to have been at least partially responsible for the very slow development of the system since its inception.[8]

2.4.2 Theory Reduction

The central theme of the earlier part of this paper has been that potentially contradictory theories in economics co-exist for many years because their predictions over the range of market conditions normally available for testing are too similar to enable distinctions to be made between them. The great advantage of experimental markets is that they can be used to create conditions which, though perhaps rare in practice, generate predictions which could allow the theories to be distinguished and thus tested against actual game results. These are called 'crucial' experiments for they enable the crux of the difference between the two theories to be examined. Examples would be the earlier Siegel and

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8 An experimental study using sealed bid tenders with and without discretionary options was designed to simulate the Australian computerized system. It is not included in the studies in Part Two.

Fouraker (1960) already mentioned and a study of price adjustment by Smith (1965) in which he compared the Walrasian and Excess Rent Hypotheses.

Somewhat similar are "weeding out" experiments. They are designed to test an hypothesis, not against an opposing hypothesis as above, but against specific data and a model situation as restricted as that specified in the hypothesis, to test its internal validity. Any hypothesis not being supported under such conditions, constructed so as to give the theory its "best chance" must be considered to be an unlikely contender for explanation in the real world. Experimental markets, though simple, are "real" markets. They reproduce the incentive, opportunity and information structures of the real world - but in simplified form. Most experimental studies are of this type. For example; Smith (1962, 1964); Miller, Plott and Smith (1977).

2.4.3 Experience Gaining

Whilst most experimental studies have a strong theoretical base it is possible to use experiments for "experience gaining" in areas where there has not so far been very much theoretical or empirical work. Here the experiments are of a "probing" or "exploratory" nature. It is hoped that by analyzing ("eyeballing") the experimental data certain patterns or regularities will occur that will suggest relationships between the variables and thus lead to the development of testable theories. The space probes and recent manned rocket flights to Venus may be considered scientific examples of this "experience gaining" type of experiment. In economics examples may be taken from the studies by Frahm and Schrader (1970) on bidding procedures and Carlson (1967) on lag cycles. The study of decision time in Chapter Five as well as the previously cited

Chapter Eight simultaneous auction study are experience gaining experiments.

Theory development may be considered an extension of the "experience gaining" experiment. This is the situation which occurs when experiments, designed either as tests of established theory or as probing experiments, throw up unexpected but consistent results suggesting new areas of investigation which then lead to changes in the experimental model and more tests. New elements can be incorporated in the theory without destroying its validity or making it tautological since the new theory can then be tested on new data. If a theory were to be adjusted simply to adapt to empirical data for which no replication was possible it would no longer be a valid explanation. This pattern of test, idea and re-test is clearly evident in the sequence of papers by Smith (1962, 1964, 1965) and a later interchange involving Williams, Plott and Smith (Smith, 1964; Williams, 1973; Plott and Smith, 1978).

The use of computers has increased the scope for experimental study from the computerized auctions of Smith and colleagues (Williams, 1978; Smith and Williams, 1979; Smith, Williams, Bratton and Vannoni, 1981) to the use of programmed robot players which increase the control over player interaction in duopoly studies (Hoggatt, 1959; Wolf and Shubik, 1975).

2.5 Summary

This chapter looked at the nature of data limitations as they apply to economic analysis, to wit: the collection of data on the basis of one theory which may render it inappropriate as a test of another; the lack of precision in economic data which results from the complexity of the real world and the relative simplicity of economic hypotheses; and the time and cultural limits to the relevance of economic data which are continually changing. The consequent development of economic theory based on logical extensions of untestable premises was then considered. While this procedure has led to an impressive body of interrelated rules and relationships in economics which has become the envy of other behavioural sciences, it is not without its problems. It has led to the development of optimum rather than actual solutions. In some cases, the 'optimum' is not attainable while in others it may not be what is needed. Lancaster and Lipsey's theory of the Second-Best or Simon's satisficing approach, while perhaps of more potential relevance, have failed to be developed to the same extent as the optimizing models because they have not been so amenable to mathematical manipulation. In fact, there has not been a satisfactory analytical technique to deal with them. Here it is suggested that the experimental approach is such a technique and one moreover that is capable of testing not only the predictions but also the assumptions of standard microeconomic theory.

CHAPTER 3

A FRAMEWORK FOR MARKET ANALYSIS - OPPORTUNITIES, INCENTIVES AND INFORMATION

CHAPTER 3

A FRAMEWORK FOR MARKET ANALYSIS - OPPORTUNITY, INCENTIVES AND INFORMATION

While, in principle, there is no reason why economic experimentation should not be applied to any area of economic analysis where the problem can be clearly and precisely specified, it has tended to be applied principally to price discovery and the associated problems of efficient market behaviour. This is, however, a particularly fruitful area of research, for many non-market problems may also benefit from a non-cooperative decision making approach which utilizes information feedback, such as these market studies involve. Such an approach has already been successfully applied to problems of collective public choice (Smith, 1979b) and to some aspects of political economy (Plott, 1979). Because of its potentially wide application, and to maximize the use of insights gained from existing studies, this market price and efficiency orientation is pursued in the four experimental studies analyzed in this paper.

3.1 Price Discovery and Price Determination

Price discovery should be distinguished from price determination *per se*. Considering the market as the entire area (by which we understand time as well as geographical and commodity space) within which supply and demand operate, we can determine the theoretical equilibrium or "market-clearing" price as the intersection of the appropriate demand and supply schedules. Whether the market "place" - be it a centralized auction or a decentralized collection of individual negotiators - generates or "discovers" this equilibrium price is the question at issue. It will be argued that this will depend, in part, upon the skills of the market operators in correctly assessing price making forces and, in part, on the institutional framework which provides the opportunities, incentives and the informational structure within which market operators - "traders" - make their decisions. It is the process of price discovery rather than price determination which is analyzed in experimental markets.

3.2 Competitive Exchange Markets

The focus of this study is the competitive exchange market, where "competitive" is used in the sense of non-cooperative decision making; it does not imply large numbers, perfect knowledge, perfect foresight or price-taking behaviour. It will be shown, in Chapter 10, that these assumptions are both unnecessary and insufficient for the purpose for which they are normally introduced, that is, the generation of equilibrium market prices.

This is true in theoretical as well as experimental market analysis. For example it has been known for some time that experimental markets with as few as four buyers and four sellers can generate equilibrium exchange prices in a short time if the market is constituted as a double auction and is stationary (Smith, 1976b). Recently Baumol (1982) has shown that the benefits associated with perfect competition can be achieved with very small numbers of producers provided that there is freedom of entry and exist in the sense that new entrants are under no cost disadvantage *vis a vis* established producers and that producers can leave the industry costlessly. This theory has been subject to an experimental treatment by Coursey, Isaac and Smith (1981). These producers, "waiting in the wings", act as a control on the behaviour of established producers. In the exchange markets studied here production is not included but the extra-marginal buyers and sellers play a rather similar role enabling competitive market results with relatively small numbers of traders, depending on the type of market and the trading rules.

3.3 The Market Place

For the purpose of relating the structure of real market places and their experimental counterparts it is useful to consider the market place in terms of the characteristics of its institutional framework.

There are several ways in which this can be done. Sosnick (1961), in a paper which predates current interest in experimental markets, develops what he calls a 'theoretical scaffolding for the analysis of market structures' in which he outlines market characteristics in a way which is most amenable to experimental modelling. Market outcomes are defined as all the contracts that occur and their associated facts, such as what each buyer buys from each seller, the prices paid, and the costs, profits and quantities. Market performance 'consists of "interesting" attributes of the outcomes' (Sosnick, 1961, p. 1346). Sosnick distinguishes between the performance of a single market session which corresponds to Marshall's market day, and 'is an interval of time during which a given demand and supply interact to produce a set of contracts' (ibid, p. 1347) and multisession performance which relate to the characteristics of a group of market sessions taken as a whole.

This analysis of price, profit and quantity outcomes from single and multiple market sessions has been adopted in all the experimental literature where, in addition, experimenter knowledge of the demand and supply schedules, buyer and seller surpluses and their distribution, and the theoretical equilibrium or market-clearing price, has enabled far more precise analysis of outcomes than related empirical studies.

3.4 Opportunities, Incentives and Information

This procedure has also been adopted in the experimental studies which follow. However, here the emphasis has been placed on behavioural analysis of market performance, that is, we are interested in examining the reactions of individuals and groups that compose the market on the assumption that if we know *how* and *why* traders react as they do we will be in a better position to design more effective resource mechanisms. A further assumption, and one that will be tested, is that the reactions of traders to their surroundings are predominantly a feature of those surroundings rather than individual makeup. (One exception to this rule is the broad classification of individuals into groups who are risk averse, risk neutral or risk preferring). For this purpose it seems more fruitful to look at the characteristics of the institutional framework in terms of the *opportunities* that present themselves and the *incentives* that exist for market traders to take advantage of these opportunities. And since it is the perception of these opportunities and incentives by traders that is crucial, rather than their absolute existence, the *information* structure of the market place is an equally important element.

3.4.1 Opportunities

By *opportunities* we mean the options that the trading rules make available, such as who is able to make the bids and/or offers, whether these are to be made sequentially or simultaneously, whether they can be revised during the course of the trading session, whether there are time constraints - and if so the nature of such constraints - and whether recontracting is permitted.

Institutional factors affecting opportunities would be the frequency of market exchanges and whether there was a choice of market places (for example, whether a cattle owner could sell his cattle by private treaty negotiation as well as by auction). Other factors include the time lag between deciding to bring commodities to market and the actual market exchange as well as the ease with which such decisions could be reversed if necessary. Existing financial arrangements would also pose limits to traders' opportunities.

3.4.2 Incentives

The basic *incentive* or motivation for any trade is profit. This will often mean the incentive to acquire a unit at the lowest price or to sell at the highest price. However the actual working out of this profit motive in a market may take different forms. For example, in the study using experienced wool buyers which is reported in Chapter 7 it is made clear that buyers facing both price *and* quantity limits have, because of the structure of the market, a much stronger incentive to meet their quantity rather than their price limits and would indeed stand ready to "shave" their prices, i.e., raise their upper price limits, and to average their prices over successive units, rather than fail to meet a quota. Furthermore they would deliberately engage in a policy to push up prices to their competitors once they had secured their quotas, even if, as a result they occasionally have to buy an unwanted unit. This conduct can be seen as entirely reasonable when it is realized that these agents will be competing again in a resale market; they thus have an incentive to ensure that no competitor secures a unit at a price less than the price they have just paid.

Both the level and the structure of rewards affect incentives. Where buyers are agents buying on commission the incentive for them is to acquire their quotas; where they are speculative buyers buying on their own account the incentive is to secure at the lowest price. In both cases the positive incentive effect of expected gain needs to be set against the negative effect of the risks associated with it to establish the net incentive.

3.4.3 Information

Information has a complex effect on market behaviour. On the one hand it is the mechanism by which traders become aware of the opportunities and incentives that are open to them. This is the communication aspect of information. The theory of communications, although implicit in economic theory, does not play an explicit role. Actually the transmission of information is both time consuming and subject to equivocation. There are costs of both time and effort in acquiring information before a market exchange. There may also be costs incurred in obtaining the information generated during the market exchange. The nature and amount of such costs will depend on the type of market and the trading rules. Some information, such as the highest and lowest accepted bid at a sealed bid tender, though less revealing of general market preferences than a progressive auction, may nevertheless serve to focus attention on the cutoff position which is the critical value. Schelling developed several experiments in which he showed that competitive agreement was more likely if the information provided was focussed on one aspect rather than if it was diffuse (Schelling, 1960, Chapter 3). More information rather than less may thus be counterproductive in this sense as well as involving higher processing costs and perhaps, therefore, selective processing (Simon, 1959).

On the other hand, information *changes* the nature of the opportunities and incentives themselves. In a state of uninformed disequilibrium many gains (and losses) can be made by trading at non-equilibrium prices. But the position changes as decision makers increase their knowledge by the cumulative experience of "doing while learning". As market traders become more informed there are fewer opportunities to gain from disequilibrium trades - and correspondingly less incentive to seek them out. When all are fully informed there is no opportunity - nor the incentive to seek - for any trade that will return an economic surplus greater than the difference between the trader's subjective valuation of the commodity - his utility - and the equilibrium price. This is then an equilibrium situation. It need not necessarily be achieved but note that traders need have knowledge only of the equilibrium price, there is no need for them to know the aggregate supply and demand schedules that generate this price.

In the studies that follow, the interest lies in examining the adaptive processes of markets that are out of equilibrium, it is thus a study of disequilibrium dynamics. This area has not yet been well developed in the theoretical literature and what follows will be, of necessity, descriptive and suggestive. Chapter 10 discusses how the theoretical aspects may be further developed.

3.5 Market Types

Of the great variety of markets which could be examined we select just three for experimental analysis. In Chapter 5 we compare a centralized double auction, in which both buyers and sellers can make and accept bids and offers, with a decentralized bargaining model where buyers and sellers make exchange deals on a one-to-one basis, a system that Cassady (1967) refers to as private treaty negotiation. Chapters 6 to 8 take as their model the most popular of agricultural commodity auction markets - the progressive or English auction. The detailed characteristics of these markets vary from place to place but basically they are as follows.

3.5.1. Double Auction Market

The double auction is also referred to as a 'stock exchange' model since this method of trading has been adopted by most of the country's stock exchanges. Under this trading system both buyers and sellers, working through brokers as their agents, call out their buying bids and their selling offers. The highest buying bid and the lowest selling offer are recorded and are subject to constant revision as buyers and sellers re-adjust their bids and offers, subject always to the requirement to reduce the spread between the existing buying and selling prices. When a bid or an offer is accepted a contract is arranged between the traders concerned. Neither buyer nor seller knows the supply or demand volume before the start of the auction and indeed, the quantity exchanged is determined, along with the price, by the actions of the traders on the day, unlike the progessive auction where the supply is more or less fixed.

3.5.2 Progressive Auction Market

The Progressive or English auction is the most common auction model for agricultural commodities. In this auction the sellers are essentially passive, delegating their authority to the auctioneer either with or without a reserve price limit which has the effect of withdrawing the unit from sale if the bidding does not reach the reserve level. Items or 'lots' are sold sequentially with buyers calling out their offers to the auctioneer. Each offer must exceed the preceding one and there is usually a minimum acceptable increment which varies from auction to auction. When no buyer is prepared to increase the existing bid the item is declared sold to the highest outstanding bidder at his bid price (or, in some circumstances such as the South Australian cattle markets, at one increment below the bid price).

Through inspection, or by reference to the auctioneer's catalogue, buyers are aware of the total volume on offer at the beginning of the auction, within the margins of uncertainty created by the unknown reservation prices. Their estimates of the demand schedule will generally be far less certain. Where markets are composed of a reasonably regular set of buyers who are well known to each other and their needs are fairly constant, each buyer's estimate of the aggregate demand schedule may be reasonably accurate. But this estimate will be less accurate where there is a fluctuating demand, especially if it is associated with the irregular participation of buyers or where individual requirements and price limits are difficult to estimate, for example, where there is much speculative buying. At progressive auctions it is usually the case that supply is known with far more certainty than demand, an asymmetry that is not characteristic of the double auction described above.

3.5.3 Private Treaty Negotiation

This market is also characterized by asymmetry. Typically buyers travel from farm to farm and make individual arrangements for the disposal of farm commodities. Sellers typically have little knowledge of current demand conditions and only a rough estimate of the supply (in aggregate) of their competitors. Buyers, being generally less numerous, may be better informed about the general demand conditions, and because they are more mobile they also have more information concerning aggregate supply. Nevertheless, the total amount of supply is not known with as much certainty as at a progressive auction. In general neither side is well informed, but buyers have more information than sellers.

Auctions have been used at least since Roman times and many variations have developed but the three market types selected above cover an interesting range of contrasts. The double auction is a centralized market in which buyers and sellers are equally informed and are of equal strength in bargaining. The progressive auction is also a centralized auction but is asymmetrical in both information and bargaining strength. Private treaty negotiation is the least informed of the three models, it is decentralized and buyers have more bargaining strength than sellers.

3.6 Modelling Auction Markets

In order to see how these real markets are represented in experimental models a typical experimental progressive auction market is described here with sample schedules, tables and diagrams.

3.6.1 Description of a Progressive Auction Experiment

In this auction there are twelve buyers and each wishes to obtain one unit of a hypothetical and unspecified exchange commodity. Their incentive for doing so is to be able to resell the unit which they acquire to the experimenter for some predetermined value. The difference between this value and their costs of acquisition becomes their profits which are paid to them, in cash, at the end of the session.

The resale values, determined by the experimenter (see Table 1 below) represent the buyer's subjective upper limit price or "reservation" price, the value beyond which it does not pay him to bid. Aggregation of these limit prices gives the market demand schedule (Figure 1). The supply schedule in this instance is vertical at eight units, the "fixed" supply. There are no seller reserve prices. All buyers are aware of the supply limits before the bidding starts but do not know, of course, their competitors' limit prices and thus do not know the demand schedule.

Players are instructed in the bidding procedure of this auction. All bids must be in multiples of five cents with a minimum increment of five cents, and each bid must exceed the previous bid. When no bid has been received for a period of seven seconds the unit is declared sold to the highest bidder. That bidder then withdraws from the market, having obtained his sole required unit and another unit is put up for auction. The continues until all eight units have been sold.

All buyers are required to identify themselves before calling their bid. They do this by means of a player number which is assigned to them at the beginning of the auction. This enables the experimenter to keep a chronological record of bids made.

Figure 1

Basic Demand Schedule

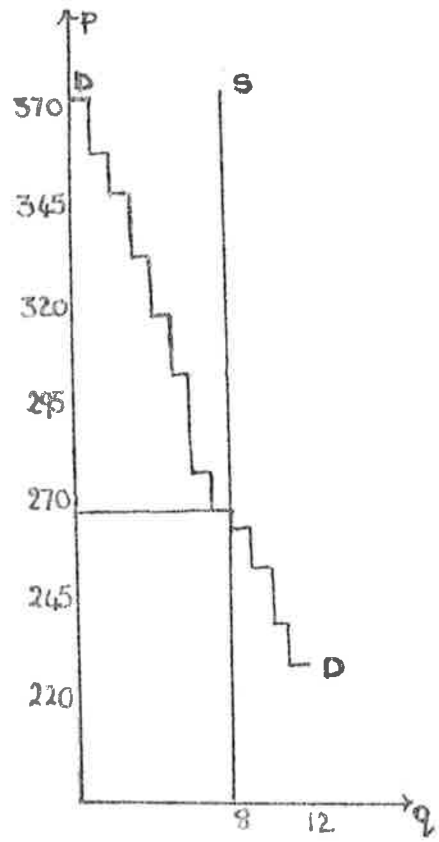

Table 1 - Resale Values

Player	1	2	3	4	5	6	7	8	9	10	11	12
Resale Value	265	320	335	375	350	255	360	240	270	230	305	280

As one auction "day" is completed, i.e., the eight units are sold, another commences. The same demand and supply schedules remain in force for five successive days. This allows the buyers to learn about market conditions and information is acquired by "doing while learning". Market learning is a key feature in all experimental models.

In Figure 2 the effects of market learning can clearly be seen in the "flattening out" of the contract price curve around the theoretical equilibrium or market-clearing price as the days proceed. Buyers who bought at a high price early in the market only to see subsequent units sell for lower prices - units are homogeneous - learn not to be so "eager" whilst others also learn who, observing the fall of prices throughout the auction day, decide to hold off in their bidding but in fact hold off too long so that they eventually miss out. In this way market "imperfections", that is prices and trades other than equilibrium ones, are the signals by which market adjustments are made. And it is through traders trying to take advantage of them, in other words trying to make disequilibrium contracts, that the market moves towards equilibrium.

3.6.2 General Discussion of Market Modelling

All the parameters of the model: the number of traders, the quantities to be exchanged, the costs and values, are determined by the experimenter and can be changed to suit the purpose of the enquiry. an examination of the effect of the number of market traders on buyer behaviour, abstracting from changes in the actual volume of trading to be conducted would be almost impossible to undertake empirically, but by appropriate changes the above progressive auction model can be adapted to this task as we show in the study reported in Chapter 6.

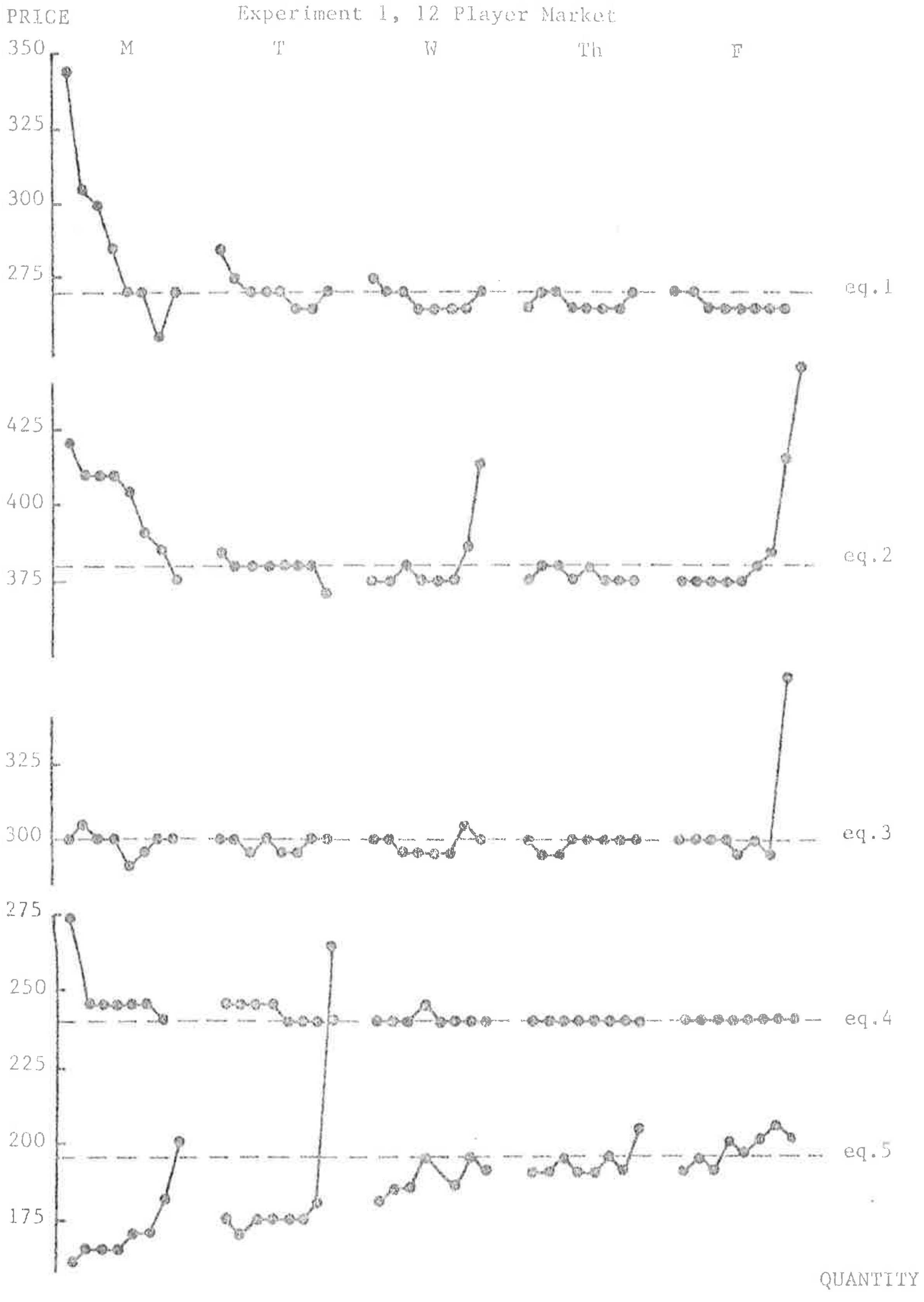
PRICE
Experiment 1, 12 Player Market
350
M
T
W
Th
F
325
300
275
eq.1
425
400
375
eq.2
325
300
eq.3
275
250
eq.4
225
200
eq.5
175
QUANTITY

figure 2

The trading rules adopted are similarly subject to the experimenter's control and he can choose the degree of simplicity or complexity that is desired. In any modelling task the aim is to retain the essential and to remove the incidental. To this end the "chivvying" role of the auctioneer in progressive auctions is suppressed and his place taken by the experimenter who functions merely as a receiving agent for buyer bids and follows a pre-determined rule for announcing the winning bid. In the double auction model the experimenter's role is basically the same, one of organizing and controlling the flow of information.

The type of auction and the choices, or opportunities, facing the experimental subjects are defined and described in the operating rules. In the progressive auction described above, subjects have a relatively limited set of choices. They can choose whether to purchase a unit at all, in the light of the going prices, and if so, when to buy and what price to pay. While markets are in a disequilibrium state the problem of when to purchase and at what price are interlinked.

The incentives for subjects in this model are provided by the cash reward stucture which encourages but does not necessitate a profit maximizing approach. Such a strategy would require the subject to estimate the lowest price at which he could acquire his one unit. Even if he correctly estimates this as the theoretical equilibrium price he may still prefer to pay more if he is risk averse. (Price trends associated with risk aversion have been documented for empirical auction studies by Buccola, 1982).

For the first trade no buyer has any information concerning the position of the equilibrium price and the only limit on actual contract prices is the highest valuation of the buyer subjects. As contracts take place traders learn about their environment. While the market is in disequilibrium it does not necessarily pay any subject to adopt an equilibrium strategy. However, the opportunities for gains over and above consumer surplus in this model (and buyer and/or seller surplus in a double auction model) will decline as more information becomes available and ultimately only equilibrium strategies will be optimal.

3.7 Time

This last result is largely a function of the way that time is used in these models. Price adjustments are sequential rather than simultaneous as they are in most theoretical models; however, the irreversability of such decisions strictly only applies during any one auction session. At the beginning of each new auction day traders are returned to their starting position, only rather wiser, and their purchase or their failure to purchase on previous day(s) has no effect on their ability to trade on the current day. This permits an analysis of the learning potential of the market trading rules. The limitations of this approach will be further discussed in Chapter 10 after the presentation of the experimental studies of Chapters 5 to 8.

3.8 Market Price Analysis - A Comparison

The importance of time for learning, changed behaviour patterns and information feedback is not generally considered in existing methods of market analysis. Sosnick (1961) details three procedures which are available to economists for the analysis of individual market performance. These are price analysis, probability modelling and performance correlation. It is instructive to compare these forms of analysis with that available with experimental markets.

3.8.1 Price Analysis

Price analysis is the obtaining of demand and supply functions by analysis of time series. The benefit of this method is that it yields specific predictions of quantity and average price. However its disadvantages are many, not the least of which is the disentangling of shifts in the two functions, the statistical "identification problem", and the necessity to take average price as an estimate of the equilibrium price or theoretical demand-supply intersection. (This will be shown in Chapter 6 to be, in fact, a biased estimate when the market is organized as a progressive auction). With experimental market analysis problems of identification do not arise. The schedules and their interaction point are known with certainty. The problem is not one of estimating the equilibrium position but of finding whether, and if so, how, the market arrives at this position.

3.8.2 Probability Modelling

Probability modelling requires estimating the subjective values of the market traders and making assumptions about their market conduct, that is 'their collusion, communication strategies, and pricing formulas' (Sosnick, 1961, p. 1350). This is the basis of computerized market simulations. The problem here is in ascertaining the needed data for subjective values and market conduct. Rudd (1961) in commenting on Sosnick's paper doubts that the data are available for probability modelling - 'and it follows that without the ability to obtain such data much of the proposed model becomes academic'. This comment is now twenty years old but estimates of market conduct are still mostly guesses with little empirical data to back them up. The output generated by computer simulations and probability modelling tells us the probability of certain outcomes *given* the assumed values for the inputs. How *likely* the assumed input values are still need to be determined outside the model, generally by empirical or field analysis.

Experimental market analysis prescribes the subject trader values and so knows these with certainty. It finesses the conduct estimates by allowing market subjects the right to choose their own conduct and behaviour consistent with the institutional framework and given trading rules.[1] In this way experimental markets are empirical markets (although necessarily, and desirably, less complex than most real world markets).

Market conduct which is consistently repeated under replications of these markets with different subject groups would seem therefore to be a function of the institutions and rules under which the market is organized rather than behavioural idiosyncracies of the individual subject groups and thus becomes a valuable addition to our knowledge of market behaviour.

3.8.3 Performance Correlation

Performance correlation is the attempt to find market attributes that match those of the probability models.

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1 In many experimental markets these rules prohibit communication between traders so that explicit collusion is not possible. thus simplifying the analysis. However, this rule is not mandatory, Isaac and Plott (1981) have investigated experimentally the possibility of collusion under a regime of limited communication between traders.

> 'Quite exact predictions apparently can be made for a market with these four attributes: (1) no collusive communication; (2) a homogeneous commodity; (3) negligible interest of any participant in a second unit; and (4) rules of trading that prescribe sale of all units simultaneously either by ordinary auction or by bilateral sealed bids with all prices to equal to highest rejected bid. In these circumstances offer segments are predetermined and a uniquely optimal pricing formula containing no reference to others' actions should be obvious to all participants. A perfectly competitive outcome results.' Sosnick (1961), p. 1,351. (numbers added)

However, the problems of most practical interest to market economists are ones in which hardly any of these four attributes ever apply. Progress in examining relevant market problems by experimental analysis has been made by gradually relaxing these rather restrictive assumptions on market attributes. Isaac and Plott (1981) have examined the case of collusion and restraint of trade, whilst Dolbear *et al.*, (1968) have analyzed experimentally the case of market price signalling in oligopolies. Multiple unit buying and selling requirements have been examined in many contexts and the effect of different trading rules on market conduct and performance has been the main occupation of the authors whose work is briefly summarized in Chapter 4. To date little experimental work has been done using heterogeneous products which is the subject of the study in Chapter 8.

3.9 Summary

Experimental market analysis is a combined theoretical-empirical approach to market behaviour or conduct. As with other empirical studies we can observe structure and performance but have to infer behaviour or conduct. This paper is confined to a study of price discovery in competitive exchange markets. Taking a limited number of market types, the studies that follow examine individual and group behaviour in the light of the opportunities, incentive and information structure of the market. Time is recognized as an important element in this behaviour.

Output data are considerably more detailed than normal market observations would permit. For example, not only do we have price, quantity and profit data but we are able to tell who bid what, when and in relation to what valuations. We know what bids/offers were rejected or accepted and by whom. And, most especially, all of the above can be related to known supply and demand schedules and known equilibria. This makes it possible to tackle many questions that have previously been inaccessible.

CHAPTER 4

EXPERIMENTS IN COMPETITIVE PRICE DISCOVERY - A BRIEF REVIEW OF THE LITERATURE

CHAPTER 4

EXPERIMENTS IN COMPETITIVE PRICE DISCOVERY - A BRIEF REVIEW OF THE LITERATURE

The earliest study of experimental markets, Chamberlin's, was published in 1948 and it was not for some time after this that other work began to appear:- Siegel and Fouraker's prize winning study of bilateral monopoly in 1960 (the forerunner of many imperfect market studies) and Vernon L. Smith's work on the experimental analysis of perfect markets in 1962. Interest in experimental economic research accelerated in the 19670s and there are now over a hundred experimental studies recorded, not necessarily in journal form, but circulating as private research papers. To attempt to cover the whole field in a few pages would be fruitless. Instead this chapter will concentrate on some of the earlier papers in the perfect market framework and show how the topics considered and the methods developed in those papers acted as a springboard for many of the later studies.

4.1 Private Treaty Markets

Chamberlin's pioneering study consisted of 46 experimental markets, organized as private treaty markets, each running for one period only. Subjects numbers varied but were approximately 40 per market, 20 buyers and 20 sellers. The supply and demand schedules used were straight line curves represented by a limit price card for each even numbered price between \$18 and \$104. Chamberlin's method was to shuffle each set of cards prior to the beginning of the market and issue them from the top. This ensured a random draw from a given and known distribution.

Buyers and sellers then moved around the room making contact with each other and bargaining individually. Whenever a contract was made the two traders dropped out of the market. Only a few of the results of these experiments were presented. Chamberlin's main conclusions were that (1) the pattern of contract prices varied widely over the trading period but showed no tendency to converge to the theoretical equilibrium price and (2) that the volume of sales was higher than the equilibrium level in 42 out of 46 markets and never lower and the average price was higher than the equilibrium price in 7 markets and lower in 39 markets. He suggests that only a bias on the part of seller subjects could account for the lower price, a point which is supported by Berczi (1979) in a later computerized 're-visitation' of the Chamberlin model. This is discussed further in Section 9.

4.2 Double Auction Markets

The private treaty market has some limitations for recording the pattern of market transactions and the single period market operation did not lend itself to market learning. So Smith, who was one of the students who took part in the earlier Chamberlin markets, developed the 'repetitively constant double auction' framework which has become the basic experimental design for most of the 1960's and 1970's. In his first study Smith (1962) used the student class format adopted by Chamberlin, with each subject having one unit to trade but, instead of circulating and negotiating privately subjects called out their bids and offers to an 'auctioneer' who wrote them on the board. A contract was formed whenever a buyer accepted a selling offer or a seller accepted a buyer's bid. The trading sessions lasted some 5-10 minutes each.

The level of market information in the double auction market was considerably increased above that in the private negotiation markets since *all* buyers and sellers were privy to all bids and offers. This increase in information however did not generate equilibrium prices *in the first session*. Indeed the results of the double auction markets supported Chamberlin's contention that there was, in this first period, no tendency for prices to converge to the equilibrium level. However if demand and supply conditions remained constant for several periods the average price in each successive period approached the equilibrium level more closely. This result has since been substantiated by many replications by other experimenters using different subject pools and is one of the better established experimental results.

4.3 Symmetry and Asymmetry in Schedules

Of the ten market experiments reported in the 1962 Smith paper nine were constituted as double auctions. The demand and supply schedules for these were arranged so that buyers' rent exceeded sellers' rent in two markets, was less than sellers' rent in four markets and equal in the remaining three. Where asymmetry in the schedules gave rise to unequal rents average market prices approached equilibrium from the side of the greater rent. Thus if buyers' rent exceeded sellers' rent prices tended to approach equilibrium from above, and vice versa. Where the rents were equal the average prices were close to the equilibrium by the third trading period. A model set up to test the effect of the excess buyer-seller rent component failed to indicate any statistical significance, but these results generated interest in the *direction of price adjustment* that led to further experiments in asymmetrical markets in Smith (1965) and later to studies on price controls which affect the market asymmetrically (Isaac and Plott, 1981 and Smith and Williams, 1981).

4.4 One-Sided Markets

The remaining market in this early paper was designed so that only buyers could bid and sellers were obliged merely to accept or reject the bids made. With this bidding arrangement average prices stabilized at a level significantly above the equilibrium level. Smith conjectured that this arose because giving sellers more information concerning aggregate demand than buyers were receiving about aggregate supply placed the buyers at a disadvantage. This was subsequently put to the test in a later experiment (Smith, 1964). Thus the initial experiment designed to test the proposition that markets, constituted as double auctions in which supply and demand are held constant, will approach the theoretical equilibrium level, not only supported that proposition but gave rise to two other enquiries.

In his 1964 study, designed to answer the questions posed by the one-sided market result, Smith set up six markets under 3 market conditions: (1) buyer only bids, (2) seller only bids and (3) both can bid. The results supported the hypothesis that average prices would be highest in the buyer only case and lowest in the seller only case.

In this study Smith also makes a methodological improvement. Whilst still using 'captive' class subjects these subjects are now motivated to maximize their profits by cash payments related to their game profits and they are paid out at the end of the session. Cash payments have remained the rule in all of Smith's experiments since, although other experimenters have used a variety of motivational methods and some have not adopted any method at all.

4.5 Posted Price Institutions

In direct line of enquiry from the 1964 Smith study is the study by Fred Williams (1973) using buyer only and seller only markets but with a posted price institution rather than a double auction and extending the number of units that each trader could trade from one to between 8 and 10. With the posted price system each buyer (seller) determines the price at which he is prepared to exchange at least one unit and this price then remains unchanged for the entire auction period. The sellers (buyers) then 'shop' with the traders offering the most favourable prices until the quantities of one or other are exhausted. The Williams results are the reverse of the pattern that Smith observed, average prices are *higher* under the seller only condition and *lower* under the buyer only condition thus favouring, rather than favouring the side that gives the greater information. Is this reversal the result of a move from single to multiple unit trading or a result of the market institution used and if so, why?

It is not unusual for an experimental study to generate more questions than it answers. The fact that they so often do leads to further developments, both in the method and in the theory that the method is designed to examine. In this case Plott and Smith (1977) took-up the challenge and used the results of an experiment designed for quite different purposes to throw light on the issues involved. They methodically removed any doubt that the extension of single unit to multi-unit bidding was the cause of the ordering reversal by replicating Williams' posted bid 'buyer only' experiment with their subject pool and comparing the results with an oral bid multi-unit 'buyer only' experiment. This established that the earlier Smith results with single unit bidding could be generalized to the multi-unit case and showed that the price reversal must be attributable to the posted bid system.

Under the posted bid system bids are gathered up, written on the board and remain in force for the rest of the trading period. Thus there is no opportunity for buyers to try to outbid each other *during the auction period*. This would have had the effect of keeping prices lower than under Smith's continuous revision case. Moreover since each buyer could make only one price offer per period this would seriously restrict the amount of market information generated during the trading sessions - and thus retard the attainment of equilibrium. (This is supported by the fact that even after 7-10 sessions Williams' markets appear not to have stabilized whilst by period 5 or 6 all of Smith's had). However perhaps the most significant aspect of the changed system is the opportunity for seller discrimination. With all buyer bids written up sellers could choose the highest to sell to first, they would only move to lower bidding buyers when they could sell no more to the highest. It is this aspect which relates the posted bid system to Smith's studies in sealed bid discriminatory pricing markets (1967). Under discriminatory pricing it was shown, in that study, that buyers would offer lower price bids than under competitive conditions. The essence of discriminatory pricing was that buyers had to pay their bid price whilst under competitive conditions they paid the market clearing price. It is true that in the sealed bid auctions subjects knew only the highest and lowest accepted bid price whilst in the posted bid system all prices were known. Nevertheless, if this informational difference was minor, one would expect price bids in oral auctions to dominate those in posted bid auctions just as price bids in competitive sealed bid auctions dominated those in discriminative sealed bid auctions. And this turned out to be the case in the further replications reported.

This series of experiments (from Smith, 1962, to Plott and Smith, 1977) show several interesting patterns. On the one hand, there is the progressive nature of the experiments, as unexplained oddities or conjectures that arise in the course of one set of experiments give rise to other experiments, and on the other hand, the interweaving of results from one set of studies to explain problems arising in another, such as the use of Smith's discriminatory pricing studies to explain Williams' results. There is also an interesting isomorphic relationship between the discriminative and competitive sealed bid studies and ascending and descending auctions analysed by Frahm and Schrader (1970).

4.6 Dutch and English Auctions

Taking their basic hypotheses from an earlier game theory approach by Vickrey (1961), Frahm and Schrader look at the English or ascending auction, where bidders direct progressive offers seriatim at the auctioneer, and where the final bid (among rational bidders) would normally be the second highest value among the bidders, and compare this with the Dutch or descending auction. Here the auctioneer calls out prices in descending order until a buyer accepts. Clearly if a buyer buys as soon as the price comes down to his full value then he will maximize his chance of obtaining the item, but equally clearly he will make no gain by so doing. As the announced price falls lower and lower his potential gain increases but his chance of being the successful bidder decreases. In this case bidding becomes a 'game' in the technical sense of an interactive strategy. Each player's best bid depends on his expectations of the bids of others. This is not true for the English auction. Here bidders do not have to out-guess each other since they have the opportunity to place their bid after another has spoken - and this is true for all bidders.

Consider the structural similarity between the Dutch or descending auction and the discriminative pricing, sealed-bid, auction study of Smith. Smith's problem concerned the simultaneous auction of many units but once we allow for this the case of the descending price auction is essentially the same. The optimal bid is just slightly above the market clearing price (in this one unit case it will be the bid of the next highest bidder). In most cases it will not pay a buyer to bid his full subjective valuation. With the English or progressive auction the optimal bid does not have to be decided in advance. It will pay the bidder to continue to raise his price until it covers his subjective valuation, thus the progressive auction encourages bidders to reveal their true demand whereas the regressive auction does not.

In the many unit case examined by Smith it was suggested - and supported by the experiments conducted - that sellers' revenue would be higher under competitive than under discriminative pricing. This suggests that English auction prices should exceed those in a Dutch auction. Frahm and Schrader however proposed contrary hypotheses, probably unaware of the structural relationships or the model they were working with, and their statistical analysis was inconclusive. The authors also commented that all buyers tended towards self-discrimination, that is bidding their full reservation prices, and that this practice appeared to outweigh any restraining effect of uncertainty concerning the number of items to be sold and competitor behaviour (p. 533). They thus fail to see that it is the uncertainty itself that leads to self-discriminatory behaviour. This point is discussed more fully in Chapters 6, 7 and 8 of this thesis. Self-discriminatory practice resulting from risk aversion has recently been studied experimentally by Buccola (1982).

The relationship between English, Dutch and Sealed Bid auctions has been further examined by Coppinger, Smith and Titus (1981), who find that while English and Second Price auctions appear to be isomorphic, Dutch and First Price auctions are not. An interesting result from this study that will probably lead to further work is that the results of the comparisons are dependent on the method for determining buyer valuations. Sealed bid auctions have also been studied by Belovicz (1979), and by Miller and Plott (1980) who look at the revenue generating properties of one price and discriminative sealed bid auctions when the demand is "steep" or "flat". Smith, Williams, Bratton and Vannoni (1982) have compared the sealed bid and double auction institutions.

4.7 Intertemporal Markets

Using the basic double-auction model adapted to a two period stock/flow market model, Miller, Plott and Smith (1977) were able to examine experimentally the effect of carryover decisions on the equilibrium intertemporal price. This was then extended by Plott and Uhl (1980) who considered the effect of middlemen on the attainment of the competitive equilibrium, and by Hoffman and Plott (1980) who considered the intertemporal problem in the light of the seller posted offer auction, thus extending the theory to a different market institution and method of experimental examination.

4.8 Asset Markets

The two period intertemporal equilibrium model was then adapted by Forsythe, Palfrey and Plott (1981) into an asset price model which formed the starting point for the study of asset markets by Friedman, Harrison and Salmon (1982) and also their study of futures markets (1982). (Plott and Sunder, 1981, look at an asset price model in a one period asset market where no carryover is allowed between periods and consider the effect of 'insider information').

The double auction methodology can be traced through the early papers on the tendency of markets to converge to the theoretical equilibrium, to the one-sided market studies, the examination of price controls and the intertemporal equilibrium and asset market studies. It has been an enormously successful method for the examination of many aspects of market behaviour. The posted price institution studies have been relatively less developed but have yielded valuable insights into the behaviour of retail markets whilst sealed bid auction studies have had direct relevance to changes in pricing behaviour of the U.S. treasury in the selling of its treasury bills. The work on Dutch and English auctions has largely been confined to single unit auctions and the studies in Part Two of this thesis are largely designed to extend the work on multiple unit English auctions with quantity limitations.

Not all of the experimental economic studies, however, fit into a neat progression in terms of the model used or the topic addressed. Some break-away studies include Carlson's (1967) attempt to experimentally establish a cobweb cycle or supply-response lag. This was not successful and gave rise instead to a study of response times. Recently Schotter and Braunstein (1981) have used experimental methodology to examine some hypotheses in the theoretical literature on "optimal" economic search. Out of the competitive framework but related to it are the studies of monopoly by Smith (1980) and the examination of nautral monopoly in relation to the contestable markets hypothesis by Coursey, Isaac and Smith (1981). And, related to their work on price controls, Isaac and Plott (1981) develped an interesting examination of the opportunity for conspiracy in the restraint of trade.

Surprisingly little work has been undertaken so far on what would appear to be an economic phenomena worthy of examination - and that is the speed of market adjustment to changing prices. Hess (1972) initiated this line of enquiry with interesting results which showed that as prices changed in successive market periods the gap between the average market price and the equilibrium price widened. Smith (1977) designed an experiment in which prices increased after a period of stability and remained at the new level for several periods before changing again. This market design led to greater market learning by participants and faster convergence but it is a moot point which design is more relevant to the facts of world price changes.

Certain methodological features, such as repetitive constancy, multiple unit trading but only one unit at a time, and a motivational structure designed to reward profit maximization strategies are now standard practice. The use of 'robots' or computerized players which has great potential for added control in experimental work has, for some reason, not found favour. Williams (1973) used it in his posted price study mentioned earlier and Hoggatt (1959) made very effective use of it in some duopoly studies but it has not been adopted in the competitive market framework. Nevertheless, the use of computerized auctions in which all players are human but the computer administers the market have had, perhaps the fastest growth of all, since the pioneering work of Williams (1978).

This brief survey of the questions that have been addressed by experimentalists, and the methods used, has not attempted to be exhaustive. Good summaries of the literature can be found in Smith (1977, 1979 and 1980) and, for related politico-economic studies, in Plott (1979 and 1981).

CHAPTER 5

DECISION TIME, INFORMATION AND MARKET BEHAVIOUR

CHAPTER 5

DECISION TIME, INFORMATION AND MARKET BEHAVIOUR

Summary:

One of the many purposes for which experimental markets may be designed is the exploratory study of an area not well charted in the theoretical literature. This is the rationale for the current study of the effects of time pressure on information processing, decision making and market efficiency. Two market structures, which differ greatly in the amount of information generated during the trading period, are compared under the same conditions of time pressure. They are the double auction and the private treaty markets. Under severe time pressures the information-poor, private treaty markets are shown to be relatively more efficient than the information-rich, double auctions and under medium pressure they are at least as efficient. This experiment, completed in 1979*, represents the first known use of a fractional factorial design in experimental economics.

5.1 Introduction and Objectives

In Chapter 5 we consider the proposition, forcefully argued by Henry Simon (1959), that available market information frequently exceeds the processing capacity of decision makers who then have to choose which information to gather and process, a condition now popularly known as information overload. By varying the time available to absorb and

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* An earlier version was presented at the Second Conference of Experimental Economics at Tucson, Arizona in October, 1979.

process information we can increase or decrease the extent of the overload and observe the resultant market decisions. Such variations in time pressure occur spontaneously in the real world, for example trading on the major financial stock markets may change considerably when there is a major change in government policy or some foreign economic collapse. It is interesting to ask what effect such pressures have on the efficiency of markets constituted in different ways. In the present study we compare an 'information-rich' double auction market with an 'information-poor' private treaty market. By allowing subjects to respond to the incentives and opportunities provided by the given market situation, experimental market analysis implicitly adopts a procedural rationality approach, necessary for such an examination of market response to time pressure.

5.2 Background

The experiment reported in this chapter originated with the comparison of two studies of quantity-variation duopoly (Murphy, 1966, and Stech and McClintock, 1971). Both studies started from the same point, an earlier study by Fouraker and Siegel (1963) in which experimental tests were used to decide whether the duopolists would jointly charge the monopoly price and share the profits or whether they would undercut each other until arriving at the point of zero profits for each. The Fouraker and Siegel results showed that the duopolists overwhelmingly chose to undercut, thus taking a competitive rather than a co-operative stance. However, the original study did not include price choices at which it was possible to make a loss. Arguing that such loss prices would encourage more co-operation between duopolists Murphy, and Stech and McClintock separately set about extending the original design to incorporate loss prices. However, despite the close similarity in design and intent they arrived at opposite conclusions.

Reasons for their lack of agreement were sought in the experimental design used in each study. This revealed that one of the studies provided relatively little time in which to make each decision, about one eighth of that provided by the other[1] and, at the same time, paid smaller rewards for successful decisions,[2] suggesting that lower financial *incentives*[3] combined with a much shorter decision period - and thus lack of *opportunity* to plan ahead - caused subjects in that study to emphasize short-run as compared to long-run considerations.

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1 The Stech and McClintock study stated that 'half an hour was sufficient for some 40 to 60 decisions'. Murphy's subjects were allowed some three hours to make 26 decisions. Allowing half an hour for introductory messages this still leaves about 6 minutes per decision for the Murphy experiment as against 45 seconds or even 30 seconds at the upper limit for the Stech and McClintock study. With such a short time to make decisions in this study subjects would scarcely have been able to take stock of the situation, analyze the information they were receiving by way of their opponent's price bids, and formulate a plan for co-operation. It was not surprising therefore that a simple pattern of 'reduce bid if previous bid was the higher of the two' was the one most generally adopted, regardless of the consequences.

2 The financial inducements in the Murphy experiments, after allowing for price changes between the two time periods considered, was approximately twice that of the Stech and McClintock study. Moreover the Murphy experiment chose profit figures that provided higher returns to the self-maximization position (106 cents) than to the joint profit level (68 cents) whereas the Stech and McClintock study provided 50 cents at both. The Murphy study thus adopted a financial incentive structure calculated to encourage competition, his co-operative results are therefore all the stronger.

3 This suggested a study of the effect of different levels of monetary motivation on the efficiency and learning behaviour of market traders. Such a study was carried out in March 1979 but the results, at least with inexperienced subjects, did not seem strong enough to account for the difference found in the two duopoly studies. (See Appendix 2 for a discussion and the results of this experiment).

These results led to questioning the effects of decision time on information, opportunity and incentives for participants in competitive exchange markets, for it seemed reasonable to assume that if changing the decision time period led to changed behavioural responses in duopoly situations it would also do so in others. The conjecture that the nature of the response changes would be determined by the characteristics of the market, seemed to be worth exploring.

Experimental studies (Smith, 1962, 1964 and 1965) had shown that markets organized as double auctions would, if conditions remained constant for several successive periods, generate average prices that converged to the theoretical equilibrium or market-clearing level. It had also been shown that such double auction markets were more efficient in reaching this equilibrium than one sided auctions (Smith, 1964) or exchange markets characterized by posted prices (that is, where price quotations could not be altered during the exchange period) (Williams, 1973; Plott and Smith, 1978). These experimental results supported the commonly held view that the financial stock exchange market which the double-auction model represented, albeit without repetitive constancy, best approaches the limit of a perfectly efficient exchange market.

This assessment of market efficiency is consistent with the high *level of information* generated during a centralized double auction in such markets. All buyers and sellers are made aware, not only of the price at which actual contracts are made, but also of all the unsuccessful bids and offers that lead up to these contracts. In simulated double auction markets bidding is sequential so that bids may be made in the light of information gained from bidding on previous contracts.

At the other end of the scale, as far as information-generation is concerned, is the private treaty bargaining arrangement common in agricultural commodity marketing, involving face to face negotiations between buyers and sellers on a one-to-one basis. Neither buyer nor seller has any knowledge of the details of contracts contracted between other buyers and sellers, some of which may have occurred prior to the current bargaining and some which may be occurring simultaneously.

An experimental study of a decentralized private treaty market by Chamberlin (1948) had found no tendency for prices to converge and average prices tended to be below the equilibrium level whilst quantity levels tended to be above. Chamberlin however, had run his experiments for one period only and similar examination of the first session of the various stock exchange experiments also shows little convergence tendency, with average prices that are sometimes above and sometimes below the equilibrium level. At the time of conducting this study no experiments had been conducted with decentralized private treaty markets incorporating repetitive stationarity, which seems to have been first adopted by Siegel and Fouraker (1960) in their monopoly and duopoly studies and introduced into competitive exchange markets by Smith (1962).

A comparison of the two market forms, with stationarity, examining the effects of changes in decision time seemed to be intrinsically interesting, for while the double auction model generates a great deal of information the necessity to convey (and absorb and process) such information, as well as the need to form contracts sequentially rather than simultaneously, is extremely time consuming. When the level of trading per period (in terms of both number of traders and units to be traded) is high, the information processing ability of individual traders may become strained resulting in 'rule of thumb' information selection devices and less than efficient trading. If this be the case some form of decentralization which permits traders to assess a limited amount of information more carefully, with trades taking place simultaneously, need not necessarily be inferior to a centralized system where more information is available but there is insufficient time for processing.

5.3 Statistical Design - A Fractional Factorial Analysis

There are many aspects of decision-making which may be relevant to the classification of any time period as "short" or "long", and little theoretical basis for judging *a priori* which should or should not be included. This study is essentially an exploratory one, the aim is to discover regularities that may be later subjected to more rigorous analysis and test.

In the natural sciences and engineering, when many factors need to be examined at a relatively superficial level rather than a few factors in depth, the statistical design chosen is frequently a fractional factorial. The use of a fractional factorial design allows certain economies to be made while permitting an analysis of factor interaction. A full analysis of six treatments in a 2^6 factorial design would require 64 experimental games. But by careful balancing of treatments, it is possible to conduct a quarter replicate and, with only 16 games, to obtain data on all variables and low level interactions with the accuracy of an eight-fold replication. What is lost is the higher-order interactions, but four-way interactions and above are exceedingly difficult to interpret and in any case are seldom significant.

The increased efficiency of the fractional replicate is however not obtained without cost. And this cost is the confounding of different effects. Thus in the current design the fifth variable is confounded with a four-way interaction term involving the other main variables. In fact, every observation is capable of four different interpretations. However, by selecting confounds which team low level interactions with higher order interactions that are frequently of little significance problems of interpretation may be minimized. If these higher order interactions are considered relevant the fractional economy cannot be employed. Also it is sometimes inevitable that two or more low level interactions are teamed together. Various techniques have been devised for analyzing such situations but sometimes the only solution is to run more experiments. In this case the experiments already conducted can be used as part of the expanded design. However other economies can be reaped if one of the selected variables should prove to be insignificant when the results are analyzed, for it can be then dropped from the model, raising the design to the status of a half replicate, with only two contending interpretations for each measurement. Removal of two such variables reduces the design to a full factorial with no confounding and two possibly relevant variables have been rejected at no cost. Fractional factorial designs are frequently used for exploratory studies in the natural sciences.[4]

The six treatments considered in this 2^{6-2} factorial analysis are listed in Table 1. Decision Time, as the key variable, is considered at four possible levels, represented in the design by two columns, Time 1

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4 See Box, Hunter and Hunter (1978), John and Quenouille (1977) and Bliss (1970).

TABLE 1

Experimental Design

Experiment (a)	Decision Time (b) in minutes (m)	(Private Treaty, PT, or Double Auction, DA)	Market Size (Number of Traders)	Information Certainty	Decision Task Complexity
1	3m	PT	10	High	Low
2	3m	PT	20	High	High
3	3m	DA	10	Low	High
4	3m	DA	20	Low	Low
5	6m	PT	10	Low	High
6	6m	PT	20	Low	Low
7	6m	DA	10	High	Low
8	6m	DA	20	High	High
9	9m	PT	10	Low	High
10	9m	PT	20	Low	Low
11	9m	DA	10	High	Low
12	9m	DA	20	High	High
13	12m	PT	10	High	Low
14	12m	PT	20	High	High
15	12m	DA	10	Low	High
16	12m	DA	20	Low	Low

(a) Order of performing experiments was randomized.

(b) Decision time is a combination of two time treatments, Time 1 which distinguishes between short (3 and 6 minute) and long (9 and 12 minute) decision times and Time 2 (3 and nine minute) and (6 and 12 minute).

TABLE 2

Individual Supply & Demand Schedules

Sellers' Schedules

	1st unit	2nd unit	3rd unit	4th unit	5th unit
Schedule 1	17	20	23	(26)	(29)
2	16	20	<u>24</u>	(28)	(32)
3	15	18	21	<u>24</u>	X
4	18	22	(26)	(30)	X
5	15	20	(25)	X	X

Buyers' Schedules

	1st unit	2nd unit	3rd unit	4th unit	5th unit
Schedule 1	27	24	21	(18)	(15)
2	28	24	<u>20</u>	(16)	(12)
3	29	26	23	<u>20</u>	X
4	26	22	(18)	(14)	X
5	29	24	(19)	X	X

Notes:

(1) Figures underlined are marginal valuations and those in brackets are extramarginal valuations, see discussion p. 13, Chapter 5.

(2) In the larger markets with twenty traders, two of each set of schedules were used.

and Time 2. The other variables are each considered at two levels.[5] These are the type of market - double auction or private treaty - and three variables considered to affect time pressure on decision making; (a) the quantity of information to be dealt with, represented by the size of the market; (b) the level of certainty with which information is held; and (c) the complexity of the decision-making process itself. The way in which each of these concepts has been operationalized is discussed in the following section.

5.4 The Experimental Market

The aggregate supply and demand schedules for the experimental markets used in this study are given in Figure 1. Ten subjects took part in each of the smaller markets and twenty in the larger markets. Multiple object trading was permitted and each buyer (seller) had an individual demand (supply) schedule representing a demand for (supply of) three to five units. The individual buyer and seller schedules are given in Table 2. Aggregating these gives the aggregate supply and demand schedules shown in Figure 1. Extramarginal units, that is values which occur to the right of the demand-supply intersection, and the trading of which would result in market inefficiency, are represented in Table 2 by brackets. Those underlined are marginal values. It is perhaps worth pointing out that these are marginal and extramarginal from the market's viewpoint, relative to the equilibrium values. Trading such an extramarginal value may not be inefficient from the

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5 This could have been designed as a 4×2^4 model but the simpler modelling requirements of a 2^6 design have been utilized here by using two factors, in combination, to represent time. This also has the advantage that the model can then detect a non-linear time curve, for this, refer to the next section on hypothesis development.

individual's viewpoint, if the price he receives for it is in excess of its cost to him (or less than the resale value in the case of a buyer). Only if the trade of a unit, any unit, intra- or extra-marginal, reduces the overall trader surplus is the trade inefficient from the viewpoint of the individual.

The supply and demand schedules are symmetrical to avoid possible bias.[6] Penalties are imposed for non-purchase. When the object being exchanged has no intrinsic value it is difficult to motivate trades exactly at the margin, for there is no purpose to an exchange that leaves the trader as well off as he was before. However, unless experimental traders do exchange at the margin, it is not possible to designate an equilibrium value. A rational method of overcoming this resistance is to pay traders a commission representing their subjective trading costs (Smith, 1962). This may be likened to the carrot. An alternative method is the stick. Penalties can be imposed on untraded items. These two methods, although they may be rationalized differently, are symmetrical in their effects. A commission of five cents encourages the trader to trade at the margin because, although he obtains no trading surplus, his overall returns are greater by five cents. A penalty of five cents also encourages trading at the margin, since by doing so the trader avoids the five cent penalty and his overall returns are greater by five cents. In practice, it has been found that penalties are psychologically more compelling than commissions, an important factor where all profits are "imagined" rather than real.

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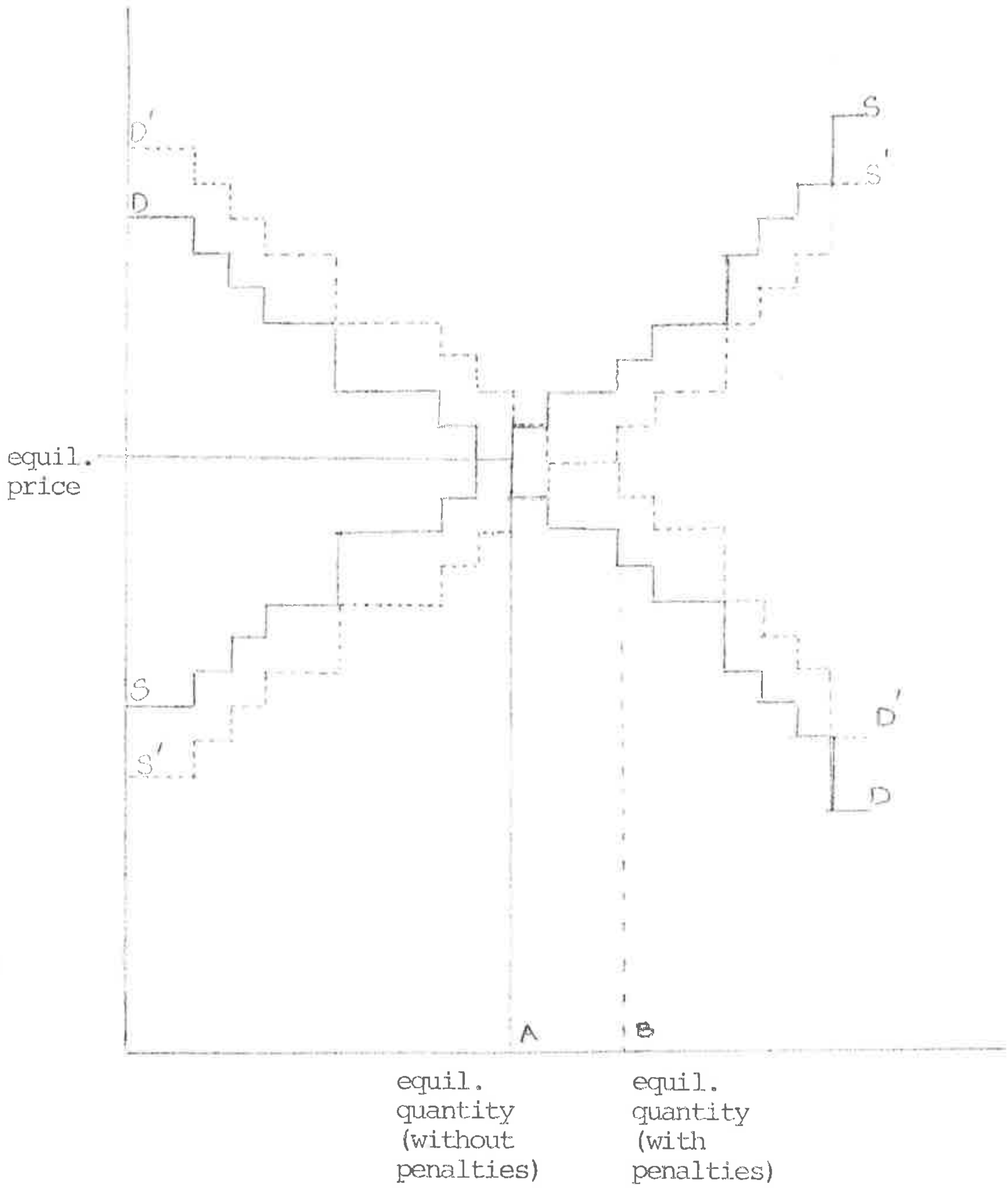
6 Chamberlin (1948) suggested that bias could result from asymmetrical schedules and this has been supported by several experimental studies (see Smith, 1968, Smith, Williams, Bratton and Vannoni, 1979).

FIGURE 1

SUPPLY AND DEMAND SCHEDULES
(WITH (DOTTED) AND WITHOUT PENALTIES)



In the current study subjects are not paid their game profits. This does not mean that subjects are unmotivated but it has been suggested by Plott[7] and by Smith (1962) that the results could be more variable than situations in which subjects are financially motivated.[8] To a large extent, this possible extra variability is compensated for in the current study by the very large number of subjects participating in the experiment, 240 in all. Also, as the object of an exploratory study is merely to determine broad trends which could merit further study, the degree of motivation of the subject pool in this case may be considered satisfactory.[9]

Subjects were instructed to attempt to maximize profits in a similar fashion to the thought exercises originally carried out by Smith (1962).[10] They were informed that the values on their schedules represented their costs (sellers) or resale values (buyers). However, no explicit instructions were given forbidding them to exceed these values. Thus, with a 2 unit penalty, sellers with a cost value of 24 were prepared to sell at 22 whilst buyers with a resale value of 20 were prepared to buy at 22. This has the effect of maintaining the equilibrium price at its pre-penalty level but increasing the equilibrium quantity, the schedule represented by the dotted line in

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7 In correspondence with the author, dated 27th December, 1979.

8 The evidence for this proposition is not well documented. This problem is considered in further sections.

9 A more important objection may be the use of untrained subjects. Several studies have reported considerable differences between naive and experienced subjects, see for example, Smith and Williams (1979). An example of this is given in the methodological issues section of the next chapter.

10 Instructions and Sample Schedules are given in Appendix 1 to this chapter.

Figure 1. If marginal trading were to be provoked instead by commissions, but no explicit instruction given forbidding traders to exceed their schedule values, the same schedule adjustment would result. In fact even where explicit instructions are given to the contrary, subjects may still exceed their valuations if their subjective transaction costs are less than the commission provided. The design in this study merely formalizes this position.

The size of the market, both in terms of number of traders and volume of trading, was taken as a proxy for the level of information processing required. Complexity of the decision making process was represented by two different ways of presenting cost information. For the high complexity games players were provided with cost data in the form of total costs and they had to calculate marginal values for themselves. In the low complexity games players were given, in addition, the marginal cost valuations (marginal resale valuation for buyers).

The certainty with which information was held was varied by the use of schedule rotation. In each market there were five different schedules for buyers and a symmetrical set of five different schedules for sellers. The experiments were run for five consecutive market sessions. Throughout these five sessions aggregate demand and supply was constant. In the high certainty mode players retained the same schedules throughout the five sessions, thus the constancy of their own schedules gave them added certainty about the constancy of the overall schedules and greater certainty that information so far discovered was valid for all of the five sessions. In the low certainty mode the schedules were systematically rotated so that each player got a new schedule each session. This reduced his certainty that overall conditions were constant.

5.5 Hypotheses

Although this is an exploratory study, certain hypotheses seem to have *a priori* reasonableness. Thus if time is too short to allow traders to make sensible, reasoned decisions, this might be expected to reveal itself in large price variances and a large number of intra-marginal trades left unmade. It is just as plausible that traders without sufficient time to consider the consequences of their actions could be panicked into making unwise extra-marginal sales. Both of these in turn would be reflected in lower trader profits. Thus it is hypothesized that inefficiencies, measured in terms of intra- and extra-marginal trades made, will decrease as the time available for decision making increases.

What constitutes a "short" time limit may vary according to the level of information to be processed in the time, the certainty with which that information is held and the complexity of the processing task. These factors may have a direct effect on efficiency or they may act indirectly by interacting with the time component. If the effect is direct, higher information processing requirements might be expected to lead to lower efficiency levels for any given time limit, as would higher levels of complexity of the decision-making task whilst greater certainty of information might be expected to result in higher efficiency levels.

Significant interaction terms would be expected for time and type of market for whilst the stock exchange, double auction, model must be presumed (on the basis of existing studies) to be the most efficient overall, its relative efficiency might be reduced in favour of a decentralized model when decision time is short.

5.6 The Experiments

Eight experiments were run as double auctions. In these markets buyers and sellers made oral bids comprising both quantity and price and these were written on the board and could either be accepted or countered with another bid or offer. All bids and offers, with identifying subject numbers, were left on the board throughout the entire market session. A one-minute warning was given before the end of each session. At the close of each session, schedules were collected and new ones distributed. For the high certainty mode the new schedules issued would be the same as the old ones; for the low certainty mode they would be different, although aggregate supply and demand remained constant throughout as explained in Section 5.4.

Eight experiments were run as private treaty markets. Here buyers and sellers were gathered together in a large room. Buyers were distinguished from sellers by the colour of the schedules they carried and by the identifying subject numbers on their label badges.[11] For each market session each trader would need to seek out an opposition member and engage in negotiations. If these failed to produce a trade or if not all of the demand or supply could be catered for, the trader would need to move off and find another opposition trader and recommence negotiations. Traders were allowed to convey their costs or resale values to the other traders, and in doing so they could (and probably would be expected to) lie. They were not permitted to show their schedules, even in defence of their arguments. This was policed by superviser surveillance. A one minute warning was given in these markets also.

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11 Buyers had even numbers, sellers, odd.

5.7 The Subjects

The subjects were 240 students at the University of Adelaide[12] in the first and second year microeconomics courses. They participated as part of a course exercise. None of the subjects had any previous experimental experience. They were not paid but were asked to commit themselves to a thought experiment in which the aim was to maximize their paper profits. In all of these respects the conditions are the same as those employed by Smith (1962).

5.8 The Results

5.8.1 Market Efficiency

In this section only short-run, static efficiency will be considered, that is, the efficient distribution of a given and fixed quantity, or Pareto efficiency. The current experiments have not been designed to consider a longer run type of analysis such as the effect of market prices on the short run supply or demand schedules and the analysis considers only exchange markets.

Pareto efficiency is achieved when all tradeable units are distributed to the traders who value them the most, that is, have the highest valuations. Inefficiency in this sense may be measured in experimental markets by the profits actually earned expressed as a percentage of profits that could potentially have been earned,[13] which

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12 The subjects in one market misunderstood the instructions resulting in some unusual bidding practices in the first two sessions. This was cleared up in the third round but the market was subsequently re-run. A comparable subject pool was chosen from the third year economic stream at the Adelaide College of Advanced Education.

13 Plott and Smith (1978).

is represented as the area between the demand and supply schedules to the left of the intersection point (see Figure 1).

5.8.2 Efficiency in Previous Experiment Results

In experiments that have been previously reported the efficiency rating for double auctions is usually quite high, from about 95 to 100 per cent. Similar experiments involving other market institutions usually return somewhat lower figures, about 75 to 85 per cent. The average profit efficiency for the current series of eight double auction and eight private treaty experiments is, by these standards, very low at 48 per cent, but this figure is directly the result of the treatments examined. Decision time limits that bite show that they bite precisely in creating inefficiencies.

Previous experimental designs have not imposed binding time limits; the decision time period has either been flexible or else long enough not to affect traders' actions. In addition the markets have been relatively simple, many requiring only one unit to be traded per trader per session, or where multiple units are to be traded, traders have been required to trade them one at a time. In this set of experiments traders were assigned the more complex task of trading multiple units in multiple unit deals. Finally, most of the reported experimental designs in which the market is repetitively stationary, adopt, for administrative simplicity, the practice of issuing all the schedules for the succession of stationary time periods at the beginning of the experimental session. Traders are therefore aware that at least *their* schedules will not vary over the coming market periods. This practice was deliberately not adopted. The treatment variables in the current study account for the differences in efficiency ratings between the current experiments and those reported in previous experimental results as will be explained more fully below.

5.8.3 Current Experimental Results

In order to examine the effects of time pressures, complexity of decision-making and certainty, as well as size and type of market institution, on the level of efficiency in experimental markets, it is necessary to work with measures somewhat more disaggregated than the global profit measure described above in Section 5.8.1. Consider the nature of inefficiency. It may be divided into two categories: (1) intramarginal units which fail to be traded and (2) extramarginal units which nevertheless are traded. In both cases the opportunity to retrade would result in a higher level of profits for traders and greater efficiency.

Table 3 below reports the results of an analysis of variance performed on the figures for extramarginal trades and intramarginal trades (both expressed as percentages of the total number of such trades that were possible) and the actual level of profits as a percentage of potential profits.

5.8.3.1 Unmade Intramarginal Trades

It can be seen from Table 3 that not all treatment variables are significant for all measures. Whereas all key variables (with the exception of Time 1) are significant in the global profit measure, it is found, when examining the component parts of inefficiency which together generate the profit results, that the significant effects are different.

It is to be expected, and was in general found, that the proportion of intramarginal (IM) units left untraded would be directly related to the pressure of time limits on trading. Thus the proportion of unmade IM trades diminished as the decision or trading time increased. A comparison of all the markets with shorter time periods, that is 3 and 6 minutes, against the longer time period markets, 9 and 12 minutes (the Time 1 variable), supports this proposition - (see Table 4); the shorter time periods resulted in 9.0 per cent of unmade IM trades, whilst the longer time periods resulted in 4.8 per cent, a difference which is significant at the 1 per cent level.

Time pressures would be expected to be greater on the sequential decision-making processes of the double auction than on the simultaneous trading of the private treaty markets and this difference, 9.5 per cent of unmade intramarginal trades for the double auction and 4.3 per cent for the private treaty is also significant at the 1 per cent level. Size is not a significant variable overall when considering IM trades but the interaction between type and size is, as is the interaction between Time 1, type and size. Table 4 above shows the pattern of IM trades, made by time, type and size.

Whereas in the double auction markets, doubling the number of traders and the volume to be traded within a given time period had the anticipated effect of increasing pressure and thus the number of unmade IM trades, this was not the case for the private treaty markets. With the exception of the 9 minute markets the proportion of unmade IM trades was uniformly lower in the larger private treaty markets than in the smaller. The explanation of this may be that a larger number of potential trading partners affects the trading strategies employed. In the private treaty markets there is always an implicit strategy trade-off between pursuing negotiations with the current trader in the hope of

TABLE 3

Market Efficiency - Analysis of Variance

Main Factors and 2-way Interactions(a)	D.F.	Unmade Intramarginal Trades S	Extramarginal Trades SS	Profit Percentage SS
Time 1	1	651**	360**	0
Time 2	1	1,295**	14	8,385***
Type	1	226	527***	2,667*
Size	1	801*	95	2,505*
Complexity	1	1,196**	9	2,195*
Certainty	1	247	29	2,096*
Period	4	4,208**	198	16,473**
Time 1 x Time 2	1	1,102**	43	1
Time 1 x Type	1	1	43	125
Time 1 x Size	1	293	74	125
Time 2 x Type	1	44	12	2,778*
Time 2 x Size	1	65	38	2,948*
Type x Size	1	44	201**	1,429
Period x Time 1	4	1,412	137	1,389
Period x Time 2	4	2,362*	315	349
Period x Type	4	328	26	942
Period x Size	4	1,503	32	2,508
	32	15,778	2,153	46,915
3-way Interactions(a)				
Time 1 x Time 2 x Size	1	762*	(b)	2,504*
Time 1 x Type x Size	1	882*	112*	(a)
Time 2 x Type x Size	1	(b)	(b)	2,347*
Explained		17,422	2,265	51,766
Residual		6,425	1,145	21,852
Total		23,847	3,410	73,618

* significant at 10 per cent level
** significant at 05 per cent level
*** significant at 01 per cent level.

(a) Insignificant, included in error term.

(b) Most 3-way interactions and 2-way interactions involving complexity and and certainty are insignificant and included in error term.

TABLE 4

Unmade Intramarginal Trades[a] x Time x Type x Size

Market Type and Size	Decision Time				
	3 min %	6 min %	9 min %	12 min %	Total %
PRIVATE TREATY					
- Small	6.4	6.4	2.1	4.3	4.8
- Large	5.3	4.6	3.6	1.8	3.8
DOUBLE AUCTION					
- Small	8.6	6.4	5.0	7.1	6.8
- Large	20.4	14.0	7.1	7.1	12.1
BOTH MARKET TYPES					
- Small	7.5	6.4	3.6	5.7	5.8
- Large	12.9	9.3	5.4	4.5	8.0

(a) As a percentage of the total possible.

a better deal, or breaking off relationships with the current trader and seeking another. It is possible that the prospects of finding another trader who is both willing and (by virtue of not having already traded with someone else) able to provide a better deal, are not regarded as highly when there are only five buyers and five sellers as when they are ten buyers and ten sellers. There may, therefore, be a greater commitment to the current negotiations in the smaller markets and less trader mobility, resulting in less fruitful contracts. Since each trader had a variable number of units to sell, some three, some four and some five, the possibilities for mis-matching were increased where there was reduced mobility of traders.

In both private treaty and double auction markets the small scale markets experienced an increase in the proportion of unmade IM trades when the decision time rose to 12 minutes. This is in contrast with the larger scale games which either followed the declining time trend (large private treaty market) or stabilized (large double auctions market). A possible explanation is that given the long decision time relative to their needs, traders adopted different, more time-consuming strategies - particularly by delaying bidding.

5.8.3.2 Extramarginal Trades

The number of extramarginal (XM) trades actually contracted is subject to a more complex analysis than IM trades. For while time pressures will prevent XM trades just as they prevent IM trades, relaxation of these time pressures may be expected to have two, contrary, effects. On the one hand reducing time pressures will permit traders to make more XM trades but it will also give them more time to consider the desirability of so doing. So while XM trades are greater in the longer time period markets, forty per cent for the 9 and 12 minute markets as against thirty five per cent for the 3 and 6 minute markets (difference significant at 1 per cent level) there is not a monotonic increase as time limits increase.

Table 5 shows the pattern of XM trades by time, type and size. The large and the small private treaty markets and the large double auction follow a similar pattern in that the effect of increasing the time period leads to more XM trades until the 12 minute time period when XM trades fall. This suggests that the lower XM trades in the shorter time periods are not a result of greater collective wisdom on the part of the market but that desires to overtrade are frustrated. That is, the greater efficiency of these markets with respect to XM trades conceals greater underlying inefficiency in trading behaviour. This is also suggested by Table 6 where the pattern of XM trades is shown by time and auction period. In the 3 minute markets there is no trend in XM trades over the five auction sessions suggesting that no learning is taking place which, given the time limits, is not surprising. The 6 and 9 minute markets show some learning trend but not strong and rather variable. The 12 minute markets however show strong learning effects by the fourth and fifth auction period.

The proportion of XM trades, as was the case also for IM trades, seems to be unaffected by the certainty variable but whereas complexity of decision-making had no effect on IM trades it is strongly significant in its effect on XM trades. Unlike most experimental studies which provide only marginal data the basic design for these experiments involved presenting each trader with cumulative data from which, in the high complexity treatment, they would need to calculate their own marginal valuations - having first realized the desirability of doing

TABLE 5

Extramarginal Trades[a] x Time x Type x Size

Market Type and Size	Decision Time				
	3 min %	6 min %	9 min %	12 min %	Total %
PRIVATE TREATY					
- Small	28.8	33.8	50.0	30.0	35.6
- Large	40.0	43.8	52.5	37.5	43.5
DOUBLE AUCTION					
- Small	43.8	28.8	28.8	33.8	33.8
- Large	28.8	32.5	32.5	30.6	31.1
BOTH MARKET TYPES	35.3	34.6	48.4	33.0	37.8
- Small	36.3	31.2	39.4	31.9	34.7
- Large	34.4	38.1	57.5	34.1	41.0

(a) Extramarginal trades actually transacted as a percentage of those possible.

TABLE 6

Extramarginal Trades[a] x Decision Time x Auction Period

Auction Period	Decision Time 3 min %	 6 min %	 9 min %	 12 min %
1	35.2	38.3	74.2	39.8
2	33.6	53.1	44.5	45.3
3	32.8	35.9	46.9	41.4
4	38.3	21.1	37.5	19.5
5	36.7	25.0	34.0	18.8

(a) As a percentage of those possible.

so. They were not compelled to calculate and use marginal data and most calculated average valuations instead. An increasing proportion calculated marginal data as the experiment progressed but of these some still used average valuations in their decision-making. The use of average valuations would lead to more XM trades being recorded (see Figure 2 and associated discussion in Section 5.9.4). In the low complexity mode the marginal data were provided in addition to the cumulative data, however many traders still calculated and used average valuations. With hindsight this method of presentation probably led to a higher degree of overall complexity than was intended (see discussion in Section 5.9.2) and the combination of the two data sets may have proved more confusing than helpful. This is suggested by the fact that the proportion of unmade IM trades is higher (7.23 per cent) in the "low" complexity mode than in the "high" complexity mode (6.56 per cent), a difference which is significant at the 5 per cent significance level.

5.8.3.3 Profits

If Extramarginal Trades were complicated to analyze this is even more so for profit patterns which encompass the profits (or rather losses) from unmade IM trades as well as XM trades. Although profits are usually higher in the 12 minute markets than in the 9 minute markets (see Table 7), overall, the 6 minute markets have, marginally, the highest profits, and the pattern is a see-sawing one. This represents a complex of underlying constraints and learning patterns, as has been shown in the previous discussion. The dip in profit positions in the 9 minute markets, which is consistent over both market types and no matter whether large or small, is almost certainly the effect of reduced

TABLE 7

Profits[a] x Time x Type x Size

Market Type and Size	Decision Time				
	3 min %	6 min %	9 min %	12 min %	Average %
PRIVATE TREATY	56.19	54.88	43.57	62.26	54.23
- Small	57.62	55.71	46.19	62.85	55.59
- Large	54.76	54.48	40.95	61.67	52.97
DOUBLE AUCTION	20.12	62.85	32.98	54.76	42.68
- Small	33.33	74.76	62.38	39.52	52.50
- Large	6.90	50.95	3.57	70.00	32.86
BOTH MARKET TYPES	38.15	58.87	38.27	58.51	48.85
- Small	45.48	62.24	54.29	51.19	54.05
- Large	30.83	52.50	22.26	65.83	42.85

(a) Actual profits as a percentage of potential.

constraints on extramarginal trading whereas the subsequent rise in the 12 minute markets, which is almost as consistent, in all likelihood, represents greater learning potential. Neither of these is likely to be the only explanation however, as the previous discussion shows.

The experiments have demonstrated that there is no simple linear relationship between market efficiency and decision time. In the very short time period (3 minutes) the private treaty markets are clearly more efficient than the double auction markets which is to be expected, but they are also more efficient in the 9 and 12 minute markets which was not expected. The amount of variation in the data however suggests that these results be held in reserve until further testing can be done. But the traditional argument that double auctions are the most efficient market form does not emerge from these experiments in which multiple unit trading and average pricing is permitted. Time pressure is a feature common to almost all real world markets and the exploratory analysis above suggests that it is worthy of further consideration.

5.8.4 Summary of Experimental Results

Under very severe time pressures, the information-poor, private treaty markets, with simultaneous trading, are shown to be considerably more efficient than the information-rich, sequential trading, double auctions. In all time periods with the exception of the largest, the small double auction markets clearly out-perform the larger double auctions. For the private treaty markets the smaller size has only a slight edge over the efficiency of the larger size market. These results are consistent with the conjecture that greater time pressure on decision-making, particularly where much information needs to be processed in a sequential fashion, leads to increased inefficiencies and lower ratios of actual to potential profits. The breakdown of inefficiency into untraded intramarginal units and traded extramarginal units yields added information on the effects of time pressures in the different markets.

5.9 Methodological Critique

5.9.1 Purpose

Each experimental study should have a clearly defined purpose. This purpose will determine the type of statistical design to be used, the choice of subjects and the nature of the experimental market itself. In Chapter 5 the exploratory nature of the proposed study suggested the fractional factorial approach. When there is little theory to act as a guide to selecting appropriate variables or to suggest definite hypotheses for testing, an exploratory approach may be called for as an initial step. From this it may later be possible to focus more sharply on one or two variables of interest or the results may suggest hypotheses which may be incorporated in a new experimental model designed specifically for testing purposes. A fractional factorial is an economical way of rejecting possibly insignificant variables in a scientific rather than in an ad-hoc manner.

A factorial design, though not necessarily a fractional one, is also necessary where interaction between the variables is seen to be a potentially important element of the study. An anonymous referee, commenting on an earlier version of this work, remarked that the study would have been improved by dealing with the treatment variables one at a time. Where variable interaction is likely to be significant, however, as in the present study, such a one-variable-at-a-time design would constitute gross model mis-specification.

5.9.2 Validity

'How valid are these laboratory experiments?' When this question is asked people are generally concerned with two problems, namely the internal *consistency* of the experiment, or how sure we are that the observations result from the treatment variable, and the *representativeness* of the experiment, or how far the results may be generalized to contexts wider than the experimental laboratory. As Campbell (1957) indicates, the desire for internal consistency and representativeness need not always be compatible, and if one has to be sacrificed to the other, 'Internal validity is the prior and indispensable consideration' (p. 310). Thus we turn first to internal validity.

How sure can we be of the main result of this study which is that the decentralized experimental markets are more efficient when there is severe time pressures on decision-making and about as efficient as the double action, centralized market when time pressures are moderate? Could this result, in other words, have occurred by chance or by some unintended design factor or artefact? Experimentalists can never be one hundred per cent sure that there is no design artefact left undetected but the possibility of chance occurrences can largely be eliminated by appropriate statistical testing.

In the current study the number of statistically significant differences between the two market types as time pressures are changed, suggested that the results obtained are not chance occurrences. The statistical design used is a particularly strong one, allowing as it does for the equivalent of an eight-fold replication of each treatment variable. However there is always the possibility of wrong interpretation in fractional factorial designs no matter how the fractions are designed. An exploratory study such as this is not intended to provide a definitive test of hypotheses but rather to suggest possibilities. Further testing will be necessary once the hypotheses have been decided and for this purpose a different experimental design is required, one which does not leave open the possibility of other interpretations.

Statistical design aside one might, nevertheless, query the relevance of the experimental market design to the wider context of real markets. This is the question of representativeness, involving the relative "simplicity" or "complexity" of the market structure.

It could be argued, for example, that the market structure used in the current study is too complex, not so much in the number of treatments considered, which the statistical design is quite well equipped to handle, but in the basic format of multi-unit trading with associated cumulative costs and resale values. However, a simpler structure involving one unit trading with data presented in the form of marginal costs or resale values, as was the common design up to the time the experiment was conducted, would have presented fewer strategical problems to be solved. Not only would this have meant setting shorter real time limits to simulate the same degree of time pressure on decision-making but such pressure would then tend to occur at the purely mechanical level of making and recording bids rather than in absorbing and processing information. The relative complexity of the current model is not designed to replicate the complexity of the real world but to abstract those elements of it which relate to strategical decision-making. Such a design choice is thus necessary to order to operationalize the concept of time pressure. (Some other aspects of operationalizing theoretical concepts are discussed in the next section).

Complexity, especially if it relates to the decision task, presents a problem in the choice of subjects to be used. Ideally experienced subjects should be used for all experimental testing but this is not always possible. In the present case an alternative would have been to incorporate more 'on-the-job-learning' by extending the number of auction sessions beyond five, say to ten or even fifteen or more. There is increasing evidence to suggest that experienced subjects will react in a systematically different fashion to inexperienced subjects, and evidence of this with respect to the next study is presented in Chapter 6. But even groups of inexperienced subjects may react differently if their prior experience in related areas differs. This effect of prior experience with real auction buyers is examined in Chapter 7.

The complexity of the market, in terms of the difficulty of the decisions that the subjects are required to make, may impact on the choice of subject pool in another way, in that the simpler the market the more easily bored with it experienced players may become. For example, even though all the players were inexperienced in the current study there is the possibility that the relative ease of managing the decision requirements in the 12 minute time period might have made that period too long for players to maintain concentration, especially when, as in the small size markets, eleven units was the optimum number of units that needed to be exchanged between the players, which, with multi unit trading could mean as few as four or five contracts. Subtle changes in strategy were noted at this upper end of the range. The tendency to make more contracts, with fewer units per contract, as the time for making such contracts increased was suddenly reversed at this upper level in both the centralized and decentralized models. Instead, more time was spent either preparing for, or negotiating, a *larger* multiple unit contract. And "holding off" strategies were noticeable in the double auctions where both buyers and sellers would wait for the other side to make concessions; some minutes often elapsing without a bid being made on either side. Further work is necessary before anything definite can be said about the adoption of trading strategies but the experimental framework is obviously well suited to this type of enquiry which could explain or elucidate what many observers see to be 'perverse' reactions in the real market place.

5.9.3 Operationalizing Concepts

Experimental modelling involves taking a theoretical concept and giving it practical substance. In marketing practice this is called "operationalizing" concepts and there may be several different ways to operationalize any particular concept, possibly with different experimental results.

With respect to the study in Chapter 5 the concepts "certainty" and "complexity" are worth discussion. High certainty was achieved by keeping each individual trader's schedule constant so that he gradually became aware of market constancy, as a trader might in a real market. An additional feature would have been to announce from the beginning that all periods were to remain constant. The low certainty mode would retain the rotated schedules and there would be no announcement. This method would increase the difference in certainty levels between the two situations.

Complexity is an example of an operationalization that failed to work. Reasoning from the standpoint of an economic theoretician, it seemed clear that, since equating marginal cost and marginal revenue would maximize profits, calculations of marginal values would be necessary for optimal decision-making in the market. Thus the traders furnished with the marginal values already calculated, additional to the cumulative total values, would have an information processing advantage over those traders who were provided with total values only and their task would be less complex. However the subjects did not see the problem in the same light. Most of them calculated average values, even when marginal values were given, possibly led to do so by the instructions to record the average price of their multi-unit sales, but also by the general feeling among many that the average values were somehow more relevant anyway. For these subjects the provision of two sets of data, when neither was what they really wanted, only added to rather than reduced the level of information complexity. This may be responsible for the fact that efficiency levels were actually higher in the so-called high complexity mode. In general, complexity as a variable was seldom significant and this mis-specification may have been the cause.

An operationalizing problem which faces all experimentalists is the correct representation of time. Time is collapsed in experimental markets. The real time that elapses between decisions, even between successive markets, is a matter of minutes only rather than hours or days or perhaps weeks. Although some large scale business management games have been run in real time, lasting maybe six or twelve months, there has been no systematic study of the effect that real time reduction has on learning and strategical behaviour in experimental gaming.

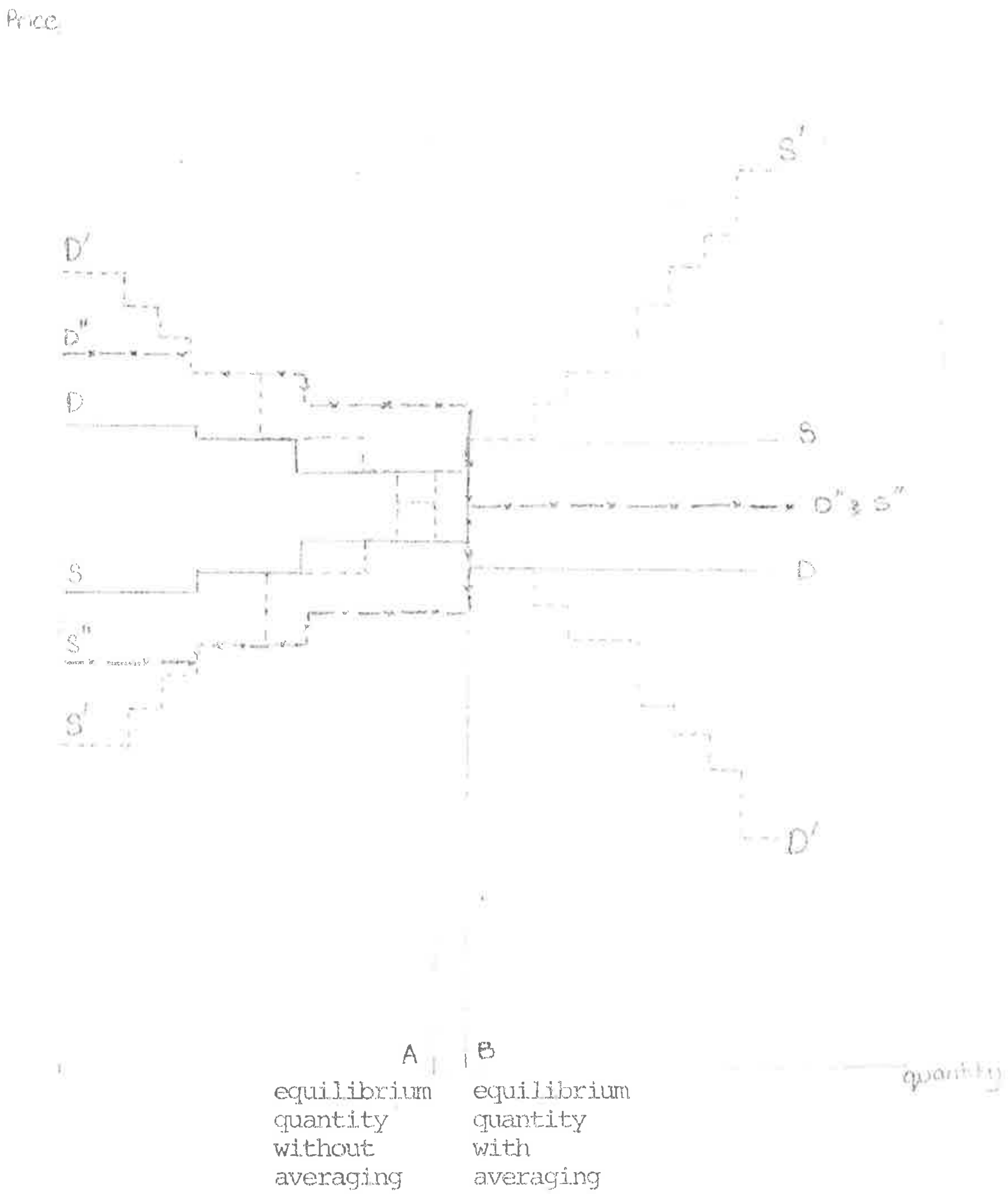
5.9.4 Measurement

The sensitivity of the test instrument is important in the choice of measurements. A range of values is needed to pick out the influence of different variables. If all measures cluster around the one point the measurements are of little use. In the current study, however, it is possible that the range of values was in fact too narrow, in that even the largest time limit failed to achieve high profit efficiency ratings. This could indicate that the 3, 6, 9 and 12 minute time periods did not exhaust the range of values from extreme to no time pressure, as was intended.

In most experimental markets players are not permitted to sell at less than the marginal cost nor to buy at greater than their marginal resale value. The present design, however, with multi-unit trading, left open the possibility that traders could "average price". If all traders had calculated the average price at which they could trade all their units and based their bidding on this average price, the relevant demand and supply curves would be DD and SS as shown in Figure 2 where the dotted lines D'D' and S'S' show the original demand and supply curves. The schedules are still symmetrical but the intersection price is now a range (21-23) and the quantity is increased (from 11 to 12) which is consistent with the overtrading in this market experiment, but the effect is not large enough to fully account for the experimental results. However, if the averaging effect is taken together with the penalty effect the two schedules S''S'' and D''D'' come together making possible the complete exchange of all units. Such an average price strategy however does not maximise profits and with market learning subjects moved away from average strategies.

FIGURE 2

EFFECT ON EQUILIBRIUM PRICES AND QUANTITIES
OF A TOTAL AVERAGING STRATEGY WITH AND WITHOUT PENALTIES



5.9.5 Controls

There has been general agreement amongst experimental economists that there is likely to be considerably more variance in experimental results where subjects are not monetarily motivated. This seems to have developed from observations on the high variance of committee decisions (Fiorina and Plott, 1978) and a failure to trade marginal units without commission (Plott and Smith, 1978) as well as a failure to trade period in "for fun" auction markets (unpublished work of Plott and Smith which agrees with early work done by the present author). However, apart from one short reference in a footnote to Smith's 1962 study and two pilot experiments with partial payments (Smith, 1965) which had ambivalent results, there seems to have been no systematic work to determine whether it is motivation per se which is necessary or monetary motivation itself. In his work on induced valuations, Smith (1976) was careful not to suggest that a monetary form of motivation was necessary.

More recently Kormendi and Plott (1980) have produced an experimental study in which subjects, university students, are motivated by linking their grade point to their game outcomes. Non-monetary forms of motivation have considerable advantage over money in that larger reward levels may be used than would be possible with money payments, and losses can be built into the design more easily.

The level of the reward is itself a critical feature of monetary motivation which does not seem to have been subjected to analysis. Do higher reward levels encourage more efficient, that is, profit-maximizing behaviour on the part of subjects, as suggested by Smith (1976)? Might not the higher reward levels result instead in less profit-maximizing and more profit-satisficing? Either result is intuitively plausible.

This question is also directly relevant to the comparison of the two duopoly studies which largely initiated the present study since higher reward levels were adopted in the Murphy study than in that by Stech and McClintoch. In order to determine whether this financial incentive difference could be considered to be the crucial factor a preliminary study was developed in which the same basic double-auction, multi-unit, market as used in the current study was conducted with three groups of student subjects under different payment systems. In one experiment, payments were set equal to the university casual labour hourly rate, in another they were set at half this level. In both of these experiments subject payments were related to the profits earned by subjects. In the third experiment the payment was again set at half the casual rate but this time it was made by way of a lump-sum payment unconnected with market profits. Thus in this case the payment could not be said to have any incentive effect. (The subjects had already volunteered to take part before the payment scheme was announced.) The results of these experiments are given in Appendix 2. They are summarised below.

Financial Motivation Experiment, March 1979,
Trader Profits as a Percentage of Total Possible

	Profit %			
	Period 1	Period 2	Period 3	Period 4
Experiment 1 (lump sum payment half casual hourly rate)	76	66	90	77
Experiment 2 (profit related payment half casual hourly rate)	85	88	67	80
Experiment 3 (profit related payment casual hourly rate	76	94	85	85

Although the overall average profitability increases as the incentive level rises the variability is such that these results are not statistically significantly different.

At the time this experiment was conducted there had been no previous economic experiments conducted in the Adelaide University and the subjects were therefore all inexperienced. So, too, were the controllers running the experiments. Unlike computerized experiments, manually run experiments have to contend with human influence. It is a moot point how much of the variance in experimental results replicated in different establishments is due to the different subject pool and how much to different controllers. In any case the results of the financial motivation experiment with inexperienced traders did not suggest a large efficiency difference for different payment levels. This is not surprising. In order to be able to take advantage of the incentives offered, subjects have to be in good control of their situation, that is, know how to operate in these experimental markets. Replication of this study with experienced subjects would therefore be a useful exercise.[14]

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14 Unfortunately, funds have never been available to undertake it.

APPENDIX 1 TO CHAPTER 5

UNIVERSITY OF ADELAIDE

J.P.A. Burns
August 1979

EXPERIMENT IN MARKET ANALYSIS

Instructions

1. In the experiment you will be a buyer or a seller.

2. The controller will hand out your buying or selling instructions. (Demonstration sheets with hypothetical values are attached. Note that the values to be used during the experiment will be different from those attached and different buyers and sellers will have different values.)

3. Some time will be allotted for you to become familiar with your particular values. DO NOT show them to anyone or comment on what they contain. They are for your information only.

4. The controller will then allow trading to take place. One minute before the end of the session he will warn traders that time is almost up. Details of individual trades must be recorded as they are made.

5. At the end of the session, sheets are to be returned to the controller who will then issue new ones.

6. There will be five trading sessions in all.

PB:KC

NIVERSITY OF ADELAIDE

.P.A. Burns.

CODE NO. I

Market Experiment - Selling Agent

You have been commissioned to sell up to 4 units of a homogeneous good on behalf of your clients. Subject only to the constraint that you may not sell more units than the number for which you hold commissions, you are free to make as many separate trades as you want and to sell as many or as few units as you wish. There will, however, be a *penalty of* 2 on any unsold unit. You have complete freedom to negotiate for the best possible price and your profit on each unit is the selling price less its marginal cost, as given below. You should attempt to maximize your own profits.

Whenever you agree to make a trade with a buying agent, BOTH partners to the trade should record the code number of the other person, the number of units traded and the *average price per unit traded* in the space provided below. At the end of the trading period, this sheet must be handed back to the controller.

Your selling costs, expressed in cumulative number of units and cumulative cost is:

Cumulative No. Units.	1	2	3	4	5	6
Cumulative (Total) Cost	18	40	66	96	X	X

The same schedule expressed in terms of marginal cost, is:-

	1st Unit	2nd Unit	3rd Unit	4th Unit	5th Unit	6th Unit
Marginal Cost	18	22	26	30	X	X

N.B. This section was omitted in the high complexity mode.

ord of Trades:	Buyer's Code No.	No. Units Traded	Av. Price Per Unit

UNIVERSITY OF ADELAIDE CODE NO. P

J.P.A. Burns.

Market Experiment - Buying Agent

You have been commissioned to buy up to 5 units of a homogeneous good on behalf of your clients. Subject only to the constraint that you may not buy more units than the number for which you hold commissions, you are free to make as many separate trades as you want and to buy as many or as few units as you wish. There will however be a *penalty of* 2 on each unit not bought. You have complete freedom to negotiate for the best possible price and your profit on each unit is its marginal resale value minus the buying price, as given below. You should attempt to maximize your profit.

Whenever you agree to make a trade with a selling agent, BOTH partners to the trade should record the code number of the other person, the number of units traded, and the *average price per unit traded* in the space provided below. At the end of the trading period, this sheet must be handed back to the controller.

Your resale values, expressed in cumulative number of units and cumulative value is:

Cumulative No. Units	1	2	3	4	5	6
Cumulative (Total) Value	27	51	72	90	105	X

The same schedule, expressed in marginal resale values, is:

	1st Unit	2nd Unit	3rd Unit	4th Unit	5th Unit	6th Unit
Marginal Resale Value	27	24	21	18	15	X

N.B. This section was omitted in the high complexity mode.

Record of Trades:	Buyer's Code No.	No. Units Traded	Av. Price Per Unit

APPENDIX 2

The following set of three double oral auction experiments (experiments 1, 2 and 3) was designed to test the proposition that increasing the level of financial motivation would increase the level of performance, measured by the percentage of profits earned related to the theoretically available total consumer and producer surplus.

Experiment 79-1 set the return as a lump sum rate of $1.25 for the half hour of the experiment, thus the return to earned profits was zero.

Experiment 79-2 set the return to earned profits to average $1.25 per head.

Experiment 79-3 set the return to earned profits to average $2.50 per head.

Conclusion in brief: with inexperienced players, varying the level of financial renumeration appears to have no decided effect on performance.

Further discussion of these experiments will be found in Section 5.9.5.

INSTRUCTIONS TO PARTICIPANTS

This is an experiment in the economics of market decision making. Funds have been provided for the conduct of this research. The instructions are simple and if you follow them carefully and make good decisions you might earn a considerable amount of money which will be paid to you after the experiment.

We are going to simulate a market in which some of you will be buyers and some of you will be sellers in a sequence of 'market days' or trading periods. Two kinds of sheets will be passed out - information for buyers and information for sellers. If you have received sellers' information you will function only as a seller in this market. Similarly, if you have received buyers' information you will function only as a buyer in this market. The information you are to receive is for your own private use. DO NOT REVEAL IT TO ANYONE.

This is a one commodity market in which there is no product differentiation. That is, each seller produces a product which is similar in all respects to the products offered by the other sellers. A seller is free to sell to any buyer or buyers and a buyer may purchase from any seller or sellers.

You will notice that the sheets are identified by a code number. This number is repeated on the attached lapel badge which you should put on so that it can be seen clearly by the Controller. You are to use this code number when bidding.

If you are a buyer with the code number 79 and you wish to buy at 100 you call out "79 is a buyer at 100". Similarly if you are a seller with the code number, say, 84, and you wished to sell at 125 you would call out "84 is a seller at 125". Although you should have in mind the number of units you wish to trade at this price, you do not state it, you call only the price.

The Controller will record on the board only the lowest selling price and the highest buying price, along with the code numbers of buyers and sellers prepared to exchange at those prices. This is continually adjusted throughout the bidding, previous bids and offers being erased and replaced by the latest lowest selling offers and highest buying bids.

While a bid stands (i.e. is on the board) a buyer is obligated to make a contract of at least one unit if a seller should lower his price to meet it, thus forming a contract. The same applies to the seller with the lowest sales offer standing. Any bid or offer that has not been accepted for contract may be cancelled or changed at any time. You are responsible for seeing that the Controller has correctly entered your bid or offer.

When a buyer raises his bid to meet the lowest selling price or a seller lowers his to match the highest buying price a contract is made between the buyer and seller. Their numbers are erased from the board and each fills in a contract slip stating the maximum amount he is prepared to trade at that price. These slips are shown, in silence, to the Controller who will then circle the lowest of the two amounts and this will be the amount actually exchanged, he will then write this amount on the remaining contract slip. If either trader's demands are not fully satisfied by this exchange he can re-enter the market and bid again.

If there should be more than one seller listed against the lowest selling price the seller to gain the contract is chosen at random (according to the toss of a dice). And similarly with multiple buyers.

This process continues with bids, offers and contracts being made all the time. You need not stop bidding while other players are attending to their contracts. The Controller will give warning of the impending close of session and make a call for final bids and offers. The session then closes, the board is erased, record sheets are tabulated and a new session opened. Whether or not you have bought or sold in the previous period you begin afresh at the start of each session or 'market day'.

At the close of the experiment you will total your record sheets and after they have been checked your profits will be available for collection at the Economics Front Office. They should be ready by Friday afternoon.

Except for bids and offers there is to be no communication between participants.

Are there any questions?

Experiment 79-1 | DOUBLE ORAL AUCTION | March 1979

(multiple unit contracts)

(12 inexperienced players, paid lump sum cash)

(equilibrium price = 90; equilibrium quantity = 27-30)

Chronological List of Contract Prices and Quantities

Session 1 p	Session 1 q	Session 2 p	Session 2 q	Session 3 p	Session 3 q
85	3	80	3	73	1
80	2	75	2	75	2
85	2	80	1	80	1
80	2	80	1	90	2
86	4	85	3	87	2
85	5	75	1	85	3
80	3	85	1	85	4
85	2	90	3	90	2
85	4	95	1	85	2
85	4			87	1
				85	4
				78	3
84.00*	31	83.12*	16	81.11*	27

* weighted average

Buyer and Seller Profits (in cents)

	Session 1 Buyer	Session 1 Seller	Session 2 Buyer	Session 2 Seller	Session 3 Buyer	Session 3 Seller
1.	176	24	–	–	103	94
2.	74	–	45	15	58	2
3.	53	24	70	4	–	27
4.	18	25	40	29	79	44
5.	70	10	84	25	69	13
6.	28	39	95	64	95	46
Av.	69.83	20.33	55.67	22.83	67.33	37.67

Experiment 79-2 — DOUBLE ORAL AUCTION — March 1979

(multiple unit contracts)

(12 inexperienced players, paid according to profits)

(equilibrium price = 90; equilibrium quantity = 27-30)

Chronological List of Contract Prices and Quantities

Session 1 p	Session 1 q	Session 2 p	Session 2 q	Session 3 p	Session 3 q
80	4	80	3	84	4
80	1	82	1	84	2
79	2	85	1	85	5
80	1	81	1	85	3
82	1	81	1	85	2
80	5	85	1		
81	1	83	2		
83	1	83	2		
78	1	85	3		
80	2	85	3		
80	4	80	2		
80	2				
80.08*	25	82.80*	20	84.63*	16

* weighted average

Buyer and Seller Profits (in cents)

	Session 1 Buyer	Session 1 Seller	Session 2 Buyer	Session 2 Seller	Session 3 Buyer	Session 3 Seller
1.	100	9	93	30	–	16
2.	109	14	23	22	78	21
3.	117	-16	78	26	84	34
4.	54	27	88	44	60	44
5.	100	19	81	44	94	–
6.	40	30	67	30	–	40
Av.	86.67	13.83	71.67	32.67	52.67	25.83

Experiment 79-3

DOUBLE ORAL AUCTION

March 1979

(multiple unit contracts)

(12 inexperienced players, paid according to profits)

(equilibrium price = 180; equilibrium quantity 27-30)

Chronological List of Contract Prices and Quantities

Session 1 p	Session 1 q	Session 2 p	Session 2 q	Session 3 p	Session 3 q
180	4	190	7	195	4
300	2	195	5	197	2
195	4	196	3	195	1
195	3	190	3	190	3
210	2	200	4	195	1
190	2	190	1	195	3
200	2	190	4	195	4
200	3	200	5		
200	3				
190	1				
202.88*	26	194.16*	32	194.39*	18

* weighted average

Buyer and Seller Profits (in cents)

	Session 1 Buyer	Session 1 Seller	Session 2 Buyer	Session 2 Seller	Session 3 Buyer	Session 3 Seller
1.	38	108	68	270	48	168
2.	26	345	43	183	48	100
3.	78	198	40	310	45	153
4.	58	-	-102	70	66	75
5.	20	200	50	158	88	163
6.	-185	188	38	200	70	178
Av.	5.83	173.17	22.83	198.50	60.83	139.50

CHAPTER 6

THE NUMBER OF TRADERS AND BUYER BEHAVIOUR IN A MULTI-OBJECT SEQUENTIAL AUCTION

CHAPTER 6

THE NUMBER OF TRADERS AND BUYER BEHAVIOUR IN A MULTI-OBJECT SEQUENTIAL AUCTION

Summary

The exploratory study of Chapter 5 showed that the size of the market could be a significant feature in determining market efficiency. That study, however, did not distinguish between market size in terms of the number of competing buyers and size in terms of the aggregate level of demand. In this chapter a simpler experimental and statistical design is used to permit an in-depth analysis of market behaviour when the number of competing buyers is varied but the level of aggregate demand kept constant. The market characteristic breakdown of Chapter 3, namely, information, incentives and opportunities, is used in developing testable hypotheses. Size, in terms of buyer numbers, is shown to be an important determinant of market behaviour and market prices during the disequilibrium, price adjustment phase of the market.

6.1 Introduction

The current study explores the implications for market prices of varying the number of competitors in a market and the effect this has on participant knowledge and performance in the context of a multi-object progressive auction where buyers have capacity limits. Focussing on the process of price adjustment in such auction markets, it demonstrates that the impact that the number of competitors in a market has may differ according to whether the market is, or is not, in an equilibrium state. In particular it will be shown that, during the adjustment process, while markets are in a disequilibrium state, those markets with large numbers of competing buyers may be more inefficient and produce lower average market prices than those in which there are only a few buyers. Large markets are normally presumed to be both more efficient and to generate higher prices. But these predictions and presumptions are based on an analysis of markets in equilibrium.

An explanation of the results obtained is presented in terms of the opportunities and incentives confronting auction buyers at different stages in the adjustment process and in terms of the information generated within the market itself as well as prior to the auction. For this purpose experimental market simulations are employed in which subjects are free to adapt their behaviour to the trading rules provided. The assumption of full value bidding behaviour which is commonly adopted in theoretical and computer-simulated studies, influencing the results thus obtained, is compared with the actual trading behaviour observed in these markets. The speed at which markets with different numbers of competing buyers converge to a stable position, thereby removing themselves from the disequilibrium state, is also examined.

Competitive market equilibria have been the object of much study but the results have shown only that they exist, not the process by which they are achieved. According to Rothschild (1973), '[m]odels of adjustment to equilibrium are weakest where proofs of existence are strongest - in their treatment of individual behaviour' (p. 1285) Such models are particularly unconvincing where they employ behavioural rules that require traders to predict the equilibrium price and then to produce, or demand, the output appropriate to their prediction. Unless the adjustment is very quick, any reasonably intelligent trader will realize that more may be gained by adopting strategies which take advantage of the current disequilibrium. It follows that in situations of imperfect information '... *what sort of equilibrium a market has depends on what its participants know and do*' (*ibid*, p. 1286) (italics added). Moreover, what one buyer does affects what others know and do, consequently an iterative model is required.

Buyer interaction in multi-object auctions has previously been modelled by Oren and Rothkopf (1975) as a multi-stage control process. They rejected an alternative approach which they considered superior, namely to model the bidding process as a dynamic multi-player, non-cooperative game, as this was "too difficult" to handle mathematically. This superior approach can be managed, however, using a gaming method where participants in experimental markets develop their own strategies in response to the market rules, the strategies of other buyers, and to market-generated information. Furthermore such markets can easily incorporate budgetary or capacity constraints. These constraints have important implications for buyer behaviour but they are not often employed in analytical models because the non-linear utility functions they represent rapidly become mathematically intractable, especially when combined with subjective buyer assessments and dynamic feedback considerations. All of these problems, however, are readily accommodated within the experimental framework of this chapter which makes this method extremely valuable for study of behavioural responses.

Section 6.2 contains a brief survey of the related theoretical and empirical auction literature. Section 6.3 describes the experimental market used in the present study and Section 6.4 discusses the hypotheses to be tested. The experiments themselves and their results are detailed in Section 6.5 and the significance of these findings is discussed in Section 6.6. The methodological issues involved in this study are presented and discussed in Section 6.7.

6.2 Background

6.2.1 Theoretical Auction Studies

Single-object auctions were analyzed by Vickrey (1961) who was of the opinion that the theoretical conclusions from the single object case could not easily be extended to the case of multi-object auctions. Barr and Schaftel (1976), however, believe him to be in error in rejecting the applicability of demand pricing[1] to auctions where bidders purchase more than one object and they claim to be able to deal with this case '... via a variation of the optimal assignment problem in linear programming' (p. 293). By employing a recontracting measure, the sequential auction is made to approximate to a simultaneous auction,[2] but this treatment ignores the effect of buyer interaction on the development of bidding strategies.

When there are financial or capacity constraints the behaviour of one's competitors becomes a relevant consideration and it is more appropriate to treat the multi-object progressive auction as probabilistic rather than deterministic. Deterministic auctions require only that a bidder should know his own valuations in order to submit a

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1 Demand pricing in the multi-object auction requires setting the price equal to the n+1th highest valuation when there are n objects to be sold. However Forsythe and Isaac (1980) have shown that this is not a perfectly general extension of the Vickrey hypothesis to the multi-object case and that 'there will not generally exist a demand revealing mechanism with which each bidder will pay the same price for each unit purchased' (p. 2).

2 See Chapter 8 for an experimental study of a simultaneous progressive auction that does not involve recontracting.

rational bid. In probabilistic auctions, on the other hand, rational action requires anticipation of the actions of others, indeed '... it is always rational to bid somewhat less than one's full valuation of an object by an amount that is dependent on one's expectations of his competitors' bids. Here miscalculation can lead to non-Pareto outcomes'[3] (*ibid*, p. 292). Multi-object auctions may best be viewed as a series of linked and sequentially interdependent probabilistic auctions in which the strategy adopted by one buyer will affect not only his present profit but also the strategy adopted by him and by his competitors in successive auctions.[4]

Although there are a large number of studies on auctions and competitive bidding - over 500 titles are listed in Stark and Rothkopf (1979) - a well-defined theory of auction price adjustment involving buyer interaction, strategic response and information feedback does not seem to exist. Partly this is because the subject is so difficult. To quote from Schotter:

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3 Barr and Schaftel are here referring to sealed bid tender auctions at which the bid price is the contract price, what Smith (1967) refers to as a "discriminatory pricing" system. It is, however, applicable to multi-object auctions with constraints.

4 Other studies of multi-object auctions include Weber (1981) who considers both simultaneous and sequential auctions. The case of capacity constraints, however, which is central to the present study, is only illustrated in the Weber article by the relatively simple one unit case. Weber's paper nevertheless is particularly interesting for his introduction of dependent value estimates in the sequential auction situation which give rise to "strategy" plays, which he analyzes in a two-stage signalling model. In commodity auctions where valuations are partially based on one's estimate of their value to others, buyers' values are interdependent. (This is also examined in Milgrom and Weber, 1980.) The present study shows that "strategy" plays can arise even when values are <u>in</u>dependent.

> '*Auctions are exchange mechanisms without a tatonnement or recontracting provision in which the seller is relatively passive and goods are often indivisible.* Each clause of definition should make a good economist cringe, and it is because the rules of allocation by auction raise so many theoretical problems for economists that it has been ignored'.[5] (italics in original) (Schotter, 1976, p. 4).

The other reason is that there are so many sub-varieties of auction in existence (for a good description of these, see Cassady, 1967) and even a slight alteration in the institutional setting or trading rules may affect the price discovery process.

6.2.2 Behavioural Assumptions and the Full Value Bidding Hypothesis

In empirical studies of auction markets researchers, not having data on buyer valuations, have needed to establish some behavioural rule that permits such valuations to be derived from observed contract prices. Sosnick (1965) developed a quite complicated model which took into account whether the buyer had or had not purchased the previous lot and the position of the lot in the sale order. Basically, however, he required the assumption that the buyer would always bid up to his full reservation price, if necessary, on the current lot, regardless of whether there were later sale lots that would suit his purpose equally well and regardless of how many lots the buyer required in total and how many he had already bought. This assumption is referred to here as the "Full Value Bidding Hypothesis" (FVB). It assumes independent bidding in that it does not allow for strategies based on expectations or others' behaviour.

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5 Five hundred titles does not seem as if auctions have really been ignored but many of the studies have been undertaken for other purposes, for example, advice on how to bid, and have been undertaken by non-economists.

6.2.3 Simulated Auction Studies

Two computer-simulated auction studies, one by Whan and Richardson in 1969 and another by Whan and Woodburn in 1973, examined the relation of the number of buyers at auction to the average selling price and concluded that as the number of competing buyers increased so did the average selling price. Their result is closely tied to their assumption of full value bidding. With FVB the contract price is always equal to the second highest valuation in the market or one bid increment above it. Using this bidding assumption it is easy to show that when the number of bidders increases, the contract price is more likely to exceed the average level of valuations.[6]

However, in order to operationalize their model it was necessary to ensure that every buyer was an active bidder for every unit on sale. If a buyer requires, or can afford to purchase, less than the full quantity offered for sale, allowance must be made for him to drop out of the market when he has fulfilled his quota. Thus, although he may have evaluated every sale lot and established a reservation price for each, his reservation prices are no longer applicable to the market once he has bought the number of lots he requires.

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6 Thus if there were only two buyers in the market with valuations of 200 and 210 the average price would be 205 and the actual market price, being the lower of the two values would naturally be lower than the average; if there were three buyers, however, and values were equally distributed about the mean, say 200, 205 and 210, the contract price would be equal to the average valuation - and this would be approximately so if values were drawn from some normal distribution of valuations. Once numbers exceed four the contract price is drawn increasingly from the extreme right of the distribution and is increasingly likely to exceed the average valuation. This effect is not due to changes in the distribution of valuations but rather from the greater number of valuations included in the distribution as the number of competing buyers increases.

Now it is not impossible to design a computer program to simulate a progressive auction using the full bidding assumption and in which stopping rules are incorporated to allow for buyers who have completed their quotas. Indeed such a program has been designed as part of the study reported in Chapter 8. But this was not done in the two computer studies referred to above. Instead Whan and his associates assumed that there were no constraints on any buyer: that is, they assumed that each buyer was prepared to buy, if he could, the entire supply, which would ensure that he would be an active bidder throughout the whole sale. This meant that as the number of participating buyers was increased so was the aggregate market demand. But supply was held constant.

Now regardless of the number of traders in the market, *any* increase in aggregate demand results in higher market-clearing prices if supply is constant. Thus the Whan and Richardson (1969) and Whan and Woodburn (1973) simulations confused two possible causes of higher prices, namely increased demand and increased buyer numbers. Empirically it is difficult to separate the two effects but it must be done if the effect of higher buyer numbers *per se* is to be isolated. That *is* done in this chapter to examine buyer behaviour as a function of buyer numbers. Before doing so, the implications for auction prices of full value bidding, and the empirical evidence for such, are examined.

6.2.4 Empirical Auction Studies and Evidence for the FVB Hypothesis

In a study of bidding strategies employed by buyers, Sosnick (1963) found that 'In practice, buyers - even professionals - do not attempt to protect themselves against discrimination by deliberately scattering their purchases or by consciously estimating their later supply opportunities' (p. 166). After outlining several optimizing techniques that could be employed, he concluded that the informational requirements necessary for such techniques placed too great a demand on buyers, and the impression is created that buyers adopt full-value bidding strategies basically by default - other choices being too expensive or bothersome.

If buyers *did* allow themselves to be pushed to their full valuation limits however, as if no later purchase opportunities applied, then it follows that buyers would become satiated in order of their valuations; those with the highest valuations buying first at prices dictated by the next highest valuations. If multiple objects were auctioned in some order then prices would decline, or at least not rise, throughout the series of auctions. The equivalent of a market-clearing price for all the objects would be reached only on the last item traded, and buyers would have foregone almost all of their buyer surplus,[7,8] defined as the difference between buyers' valuations and the market-clearing price. This is shown as the shaded area in Figure 1.

Such information on within-auction price trends as exists, however, does not suggest such a uniform pattern of price declines across successive auctions. Sosnick (1965) found evidence to suggest that cattle prices tended to decline by .4 of a bid increment when different buyers were involved in consecutive sales and to remain constant when the same buyer was involved in both deals. Although the result was an

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7 This is the result that would be obtained if the buyers faced a perfectly discriminating monopolist, hence the practice is often referred to as "self-discrimination".

8 'Buyer surplus' is similar to the more familiar 'consumer surplus' but is more general in that buyers are not presumed to be the final consumers of the good purchased. The predetermined 'resale value' stands in place of the consumer's marginal utility.

overall price decline, this finding is not generally supported in the literature. Other studies to which he refers (Sosnick, 1963, fn. 3) suggest that no one type of price pattern predominates.[9] The diversity of results suggests either that there is no common application of full-value bidding strategies by auction buyers, or that other factors are involved.

Where price declines *are* observed, however, they need not be the result of full value bidding but may be generated instead by risk aversion. In an experimental auction, Smith (1965) assigned all the buyers the same demand schedule with the same maximum price, and in each of six auction sessions that he conducted, transaction prices approached the equilibrium price from above. This down-trend could not be brought about by full-value bidding since all buyers have identical valuations. But if some buyers are more risk averse than others they are prepared to offer their full reservation price early in the session in order to fill their requirements; others are prepared to risk foregoing a purchase by waiting for a chance to buy cheaper later in the auction.[10] Buyers are thus satiated in order of their risk aversion and this, in itself, produces a downtrend in prices.[11]

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9 In Australia, Payne and Whan (1971) in an examination of price movements during single sales for three individual wool types, found only ten of the 73 series analyzed showing any significant serial correlation at all. More recently Todd and Cowell (1981), examining data from South Australian cattle auctions, found a price trend but one that tended to rise throughout the auction, a pattern somewhat similar to that found in Beruldsen's (1970) study where, however, there were secondary falls in the last quarter.

10 This assumes that the penalties for not fulfilling an order exceed the penalties for paying too high a price.

11 Such auction patterns have been examined empirically by Buccola (1982).

In order to distinguish between risk aversion and full-value bidding in the study of buyer behaviour it is necessary to examine not only the transaction prices but buyer valuations as well. Data on valuations for real auctions are not commonly available. Hence this study will use experimental auctions where valuations and other factors can be controlled.

6.3 The Experimental Market

The experimental market will be modelled on the Australian wool market, which is characterized by principal buyers who transmit quantities and prices to their agents who act for them in the market auctions. Principal and agent will be collapsed into the one role for this exercise and other simplifications will be made. Agents' upper limits may be thought of as the limit prices given them by their principals. Where an agent is required to buy more than one unit his limit price set may be interpreted as a section of his principal's demand schedule. Thus the prices do not represent reservation prices in the sense in which they are usually used by agents in auction markets, that is, estimates of the value of particular lots. In this market goods are homogeneous, which removes the necessity for individual evaluations of, and reservation prices on, each lot.

Consider an agent i who is required by his principal to purchase up to q_i lots if possible from the total available supply of a homogeneous good, S. Each successive lot which he purchases is associated with a given (marginal) utility, V_{i1}, V_{i2}, etc., represented as a "resale value" or the amount for which he can resell the unit to the experimenter, and his instructions are to pay no more for a lot than its marginal utility to him.[12] Marginal utilities decrease with successive lots purchased. These rules constrain the agent's bid to be within the range $0 \leq b_{ij} \leq V_{ik+1}$. The number of the lot on offer, j, may be greater than, equal to, but not less than k, the number of the lots already purchased by bidder i. A bidder may only take part in the bidding if $k + 1 \leq q_i$, that is, if he has not already satisfied his quota. For $k + 1 > q_i$, $V_{ik+1} = 0$.

What is the appropriate bidding strategy for agent i who wishes to buy q_i lots? Clearly if $q_i \geq S$ the agent must attempt to purchase the whole supply and to do this he will need to outbid his competitors on every unit. His optimal strategy is to bid up to his full valuation on every unit. If, however, $q_i < S$ agent i has at least three options:

1) to bid up to his full valuation, $b_{ij} = V_{ik+1}$;
2) to bid an amount somewhat less than his full valuation in an attempt to make a gain on the unit but withdraw if the bidding continues beyond this point, b_{ij}, where $b_{ij} + e = V_{ik+1}$ and e represents the bidder's estimate of the excess of his own valuation over the market clearing price;
3) not to bid at all, $b_{ij} = 0$.

This last option may be exercised by the bidder who is unsure of the state of play of market demand and intends to play a "waiting game" in order to gather sufficient information to allow him to choose option 1 or 2 on later auctions. If $e = 0$ then options 1 and 2 are formally the same. They are still worth distinguishing as a buyer may choose option 1 even if $e > 0$, if he is risk averse. Clearly full valuation

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12 This rules out the possibility of averaging strategies which could change the nature of the demand curve. Such behaviour was possible in the market design used in Chapter 5 and is explicitly examined in Chapter 7.

bidding is but one option open to auction buyers in this market situation, and can no longer be considered a compelling normative bid basis.

In establishing their bidding limits at auction, real agents are influenced by expectations of the going price; if they find themselves mistaken they will be inclined to revise these limits.[13] This is the case also in the present market simulations where an agent's bid may be conditioned by his expectations and he may revise these expectations up or down, although at some stage he will find that his given resale values pose a definite upper limit. If a buyer can withhold from the market knowledge of his own eagerness to buy he may be able to establish lower expectations on the part of his competitors and consequently lower market prices. The cost of establishing these expectations is the risk of failing to fill one's quota. However, the smaller the quota required by bidder i with respect to the total available supply the longer he can delay revealing information about himself while influencing and gaining information from his competitors. To delay is no longer a possible option when the supply has been reduced to q_i.

This strategic behaviour may be contrasted with the full value bidding behaviour discussed earlier and the experimental data will be used to distinguish two effects leading away from full value bidding. These may be termed the *incentive* and the *opportunity* effects. It is reasonable to suppose that the delay procedure outlined in Section 6.3 is more likely to be adopted by buyers who desire only a small fraction of the total supply since risk of non-fulfillment of quota is, for them,

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13 This information was obtained during the debriefing of wool buyers after the experiment conducted at the Australian Wool Corporation, and reported in Chapter 7.

relatively small. This applies to the current experimental markets in which there are *many* buyers. Potential rewards are relatively high and risks are relatively low so that these buyers have a strong *incentive* to adopt a bidding strategy which requires them to delay bidding their full valuations.

On the other hand, when there are only a *few* buyers each has a greater *opportunity* to bid low based on greater information. When the market is composed of only three buyers, with equal-sized orders, each buyer automatically knows one third of the aggregate demand schedule. Each of twelve equal-sized order buyers would only know one twelfth of the total market demand. Thus the fewer the number of buyers the relatively more informed each is before the auction begins. One could reason that this greater information on the part of each buyer would lead them to avoid behaviour, such as full value bidding, which can only be to their detriment, in the sense that each loses most of his buyer surplus. If, instead, they use their greater knowledge to predict market-clearing prices, which they should be able to do more accurately, and bid no more than this, then all intra-marginal and marginal buyers will be able to secure a lot and no extra-marginal buyer will be able to do so - a Pareto optimal position. Prices on early lots will be lower than if full value bidding policies had been applied. This information-related opportunity will be identified as the *opportunity* effect.

6.4 Development of the Hypothesis

Whether the opportunity or the incentive effect should prove stronger in any instance is not immediately evident and needs to be examined. Little can be deduced from existing economic theory. However both effects suggest that the FVB strategy will be adopted by neither small nor large markets.

With FVB contract prices are equal to the second highest valuation (possibly plus one bidding increment) and the mean contract price would be equal to the mean of the second to (S+1)th valuation, where S is the number of units sold and valuations decline linearly. The null hypothesis which is consistent with FVB is that $\bar{P}$, the mean contract price, equals $\bar{P}^*$ where $\bar{P}^*$ equals $(\sum_{i=2}^{S+1} V_i/S)$ or the mean of the second to (S+1)th valuations. The alternative hypothesis is that a delay strategy is applied, therefore H_a is $\bar{P} < \bar{P}^*$. Thus we have

Hypothesis 1: H_O: $\bar{P} = \bar{P}^*$

H_A: $\bar{P} < \bar{P}^*$ for all markets,

which tests whether the FVB assumption can reasonably be supposed to hold in these markets.

The tendency for buyers in small numbers markets to bid low has been much discussed in the literature on collusion. The incentives argument relating to buyers in large numbers markets, however, has been relatively neglected.[14] Hypothesis 2 tests the impact of incentives on market prices. The null hypothesis is consistent with the suggestion that the effect of incentives is equally as strong as the effect of prior information or the opportunity effecrt, thus resulting in no difference over all in the mean contract prices of the differently sized markets. If the null hypothesis is not accepted there are two possibilities, one is that there is a positive relationship between market size and market price, the other that there is a negative one. A positive relationship would suggest that the opportunity effect

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14 It is briefly referred to in Whan and Richardson, 1969, but not used in their analysis.

dominates. That is, the greater *opportunity* to bid low when there are few buyers in the market keeps the average market *price lower in small number markets*. As the number of buyers increases, this opportunity diminishes and prices rise. A negative relationship would suggest that the *incentive* effect dominates. That is, that the greater incentive to bid low by buyers in large number markets keeps *prices lower in large markets* than in small numbers markets. Hypothesis 2 tests the null proposition against both alternatives. Acceptance of either the null proposition or Ha' (the negative relationship) would suggest that the incentive effect is a useful explanation of market prices, with the acceptance of Ha' being stronger support for this proposition. Thus we have:

Hypothesis 2A H_O: $\bar{P}_s = \bar{P}_4 = \bar{P}_6 = \bar{P}_{12}$

H_A: $\bar{P}_3 < \bar{P}_4 < \bar{P}_6 < \bar{P}_{12}$

H_A': $\bar{P}_3 > \bar{P}_4 > \bar{P}_6 > \bar{P}_{12}$

where the numerical subscripts refer to the number of buyers in the market.

Even in the event that both small and large markets turn out to generate lower-than-fvb prices, as has been suggested by hypotheses 1 and 2 above, it may still be the case that market prices are functionally related to the size of the market. It would be useful to develop a measure that would permit a distinction to be made between the differently sized markets that will serve to explain the prices and the price adjustment patterns observed in such markets. To this we now turn.

When the number of buyers is small, the relatively greater level of initial information possessed by each buyer is reinforced by the relatively greater opportunity to observe the behaviour of each opponent. Such buyers may tacitly adopt a restrained bidding approach. "Errors" in this situation, that is, cases where the bidder with highest valuation is not the successful buyer, may be minimized if the group adopts restrained bidding but with buyers still buying in the order of their valuations. In the experimental markets no communication is allowed so only implicit collusion is possible but if there are higher initial information levels, and closer observation of within-market behaviour is possible, implicit collusion may be all that is necessary to generate restrained bidding behaviour with the valuation order of purchase preserved.

When there are large numbers of buyers in a market would not be expected to achieve the degree of tacit group understanding available to a smaller group, for information levels at the beginning of the auction are lower and close observation of many other participants is not so easy. Such markets might be expected to exhibit more independent bidding. If such independence leads to buyers competing more fiercely with one another, as is often assumed, then buyers with the higher valuations are going to be successful purchasers before those who hold lower valuations. That is, bidding behaviour by buyers in large number markets could approach full value bidding. The opportunity effect would thus suggest that correlation between the order of valuation and the order of purchase would be high for both large and small markets but that it would be associated with rather higher average price levels for large numbers markets which would be expected to tend towards FVB.

On the other hand, the incentive effect would suggest that the lower "need-to-buy" of buyers in large numbers markets would reduce the level of competitive bidding-up. Because the delay procedures adopted in large number markets are based on individual assessments of profit and risk, rather than on tacit group behaviour, only if every buyer, individually, adopted the same degree of bidding restraint could the order or purchase and valuation be the same. Since this is unlikely the incentive effect would predict lower correlation between the order of purchase and the order of valuation for large number markets than for markets in which there are only a few buyers. The null hypothesis, that there is no difference between the differently sized markets in terms of the correlation between order of valuation and purchase as predicted by the opportunity effect, is tested against the alternative that the differences are in the order specified by the incentive effect, namely that the smaller the market the greater will be the correlation, or the more likely it will be that the bidder with the highest valuation is the successful buyer. Thus we have:

Hypothesis 3: H_O: $C_3 = C_4 = C_6 = C_{12}$

H_A: $C_3 > C_4 > C_6 > C_{12}$

The greater the disparity between the order of valuation and the order of purchase the greater the possibility of "errors" or market inefficiencies. An inefficient trade, or error, is defined as the sale of an item to a buyer whose valuation of it is less than the equilibrium or market-clearing price. The extent of the inefficiency, which may be measured by the loss of producer surplus, is equal to the gain to be made from re-trading. In hypotheses 4 and 5 the number of inefficient trades (I) and the loss of producer surplus (L) are both considered to be directly related to the number of buyers in the market. The null hypothesis in both cases that there is no difference in efficiency between the markets, is tested against the alternative that the inefficiencies increase with market numbers. Thus we have:

Hypothesis 4 H_O: $I_3 = I_4 = I_6 = I_{12}$

H_A: $I_3 < I_4 < I_6 < I_{12}$

Hypothesis 5 H_O: $L_3 = L_4 = L_6 = L_{12}$

H_A: $L_3 < L_4 < L_6 < L_{12}$

The final proposition to be tested concerns the speed of price adjustment in each market. It is possible to measure adjustment, using convergence measures based on variances (Smith, 1962) but the greater possibility of errors in larger number markets, itself an important learning feature, means that individual outlying valuations would give excessive weight to these measures and could give a misleading picture of the overall adjustment. The somewhat rougher measure adopted here examines the number of contracts that take place at, above, or below the equilibrium values in each market. One measure of the speed of adjustment would be the number of contracts taking place at the equilibrium value in each time period. Let this be A, then we have:

Hypothesis 6 H_O: $A_3 = A_4 = A_6 = A_{12}$

H_O: $A_3 < A_4 < A_6 < A_{12}$

where the null hypothesis is tested against the alternative that larger markets converge faster. If this is correct, it has implications for the interpretation of the other results that will be discussed more fully in Section 6.6.

6.5 The Experiments

Subjects were 46 volunteer students in second year microeconomics at the University of Adelaide who had previously taken part in an experimental market session as part of a course exercise. Subjects were contacted by telephone to advise them of their time and location to minimize the chance of collusive action prior to the experiment. They were paid their game profits, in cash, at the end of the session and the average payoff was about $10 for about 90 minutes participation.

Procedure

Each player was instructed in the rules for bidding at a progressive auction, i.e. all bids had to be improving. The minimum bid increment was 5, and a space of 7 seconds after the last bid was taken to indicate that no one wished to bid further and the unit would be allotted to the highest bidder at his bid price. No one was permitted to bid a value which exceeded his marginal valuation for that unit - the valuations were detailed on a schedule that listed both the number of units that each buyer was requested to purchase and the marginal valuation for each unit.

The difference between the valuation and the purchase price of a unit was the player's profit which was retained by him in cash at the end of the session. In order to provoke trading at the margin - and to represent the exigencies of the real world where quantity requirements are important - there were penalties of 5 for each unit that buyers were requested to obtain and did not. These were deducted from their trading profits.

The auction was run under "repetitive stationarity" rules now common in experimental market analysis (see Smith, 1962); that is demand and supply conditions remained constant for each "day" in the five day trading "week". Purchases or non-purchases on one day did not affect the ability to trade on any subsequent day and no income effects were considered. In both sets of experiments demand capacity, i.e. the total number of valuations, was constant at twelve units and supply was constant at eight units.

At the end of each "week" there was a demand change represented by new schedules with changed valuations. Subjects were told only that there was a change and not its direction or magnitude. Values were randomly re-assigned each week. Each market consisted of five "weeks" or twenty-five auctions.

Previous experimental studies (for example, Smith, 1962, Hess, 1972) have suggested that where price information is uncertain, and especially where it is highly uncertain, bid prices tend to be influenced by the last known contract prices, *even though demand is known to have changed*. Because of this "hysteresis" effect the order in which price changes are made could have a separate effect on learning and strategy adoption. Thus the experimental markets were run under *two* contrasting price change conditions. In experiment 1 demand was increased in week 2 and decreased by varying amounts over weeks 3 to 5. This pattern was reversed in experiment 2 with demand decreasing in the second week and rising thereafter.

Decision time was not restricted in any way other than the seven second final delay before acceptance; each market was allowed to set its own pace and a unit could be sold after only one or many bids had taken place.

The traders' instructions for this market are given in Appendix 1.

Experiment 1

Experiment 1 consisted of four separate markets each representing twenty five individual auctions in five sets or "weeks" of five "days" each. The largest market consisted of twelve buyers, each of whom had a demand for one unit representing one eighth of the total supply. Next in size was a six buyer market where each had a demand for two units or one quarter of the total supply. In the four buyer market each had a demand for three units or three eighths of the supply. The smallest market consisted of just three buyers whose demand for four units required them to try to obtain a full half of the available supply.

The range of three to twelve was chosen because, from observation, this seemed to be the general range of "active" buyer numbers at Australian agricultural commodity auctions. As competitive results had been achieved in experimental markets with as few as eight traders (Smith, 1976b), numbers greater than twelve were thought to be "many" for the purposes of competition. The basic supply and demand curves are given in Figure 1.

In the experiments buyers knew how much their competitors wished to buy but not the price limits that they had to adhere to.[15] These could be learnt however, as the auction progressed. It was obvious to all players from their previous experience that they had a general interest in maintaining prices as low as possible. But against this group interest must be set the interests of the individual buyer as it does not benefit him if, by refraining from bidding up prices, he fails to secure a purchase.

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15 With equal-sized orders some subjects would probably correctly guess that others' quantity limits would be the same as theirs, some would not. This extra source of uncertainty in interpreting the results is avoided by making quantity limits general knowledge.

The objectives of experiment 1 were to test hypotheses 1 through 6 of Section 6.4.

6.5.1.1 Results and Discussion

Test Statistics

The values in Table 1 and subsequent tables cannot be assumed to be normally distributed; they are necessarily interdependent because of the learning effects; and they have heterogeneous variances. For these reasons parametric tests of significance are not appropiate. It is necessary to turn instead to non-parametric statistics. Two such tests are employed in this chapter, the Spearman Rank Correlation test (Siegel, 1956) and the Jonckheere k-sample test against ordered alternatives (Jonckheere, 1954). The latter tests the prediction that a set of sample results will be in a certain order, against the null hypothesis that there is no order and that all samples could be considered to be randomly drawn from the same population. A combination of the Spearman and Jonckheere tests has been developed to overcome certain difficulties in testing hypothesis 3.

Hypothesis 1: Full Value Bidding

H_o: $\bar{P} = \bar{P}^*$

H_a: $\bar{P} < \bar{P}^*$

where $\bar{P}$ = average market price, $\bar{P}^*$ = average of the second to ninth valuations (see Section 6.4).

In Table 1 market price averages have been expressed as deviations from equilibrium prices to facilitate comparison between the experiments. For the null hypothesis to be accepted at the 5 per cent significance level on a one tail test the average market price would need to be at least 31.7¢ higher than the equilibrium value. (As the values here are each to be compared with a given standard and not with each other, the remarks about test statistics do not apply and the standard t test is employed.) From Table 1 the null hypothesis could only be accepted for the first session of the three player market. For all other sessions and markets it is strongly rejected, at the one per cent signifiance level.

The full value bidding hypothesis must therefore be rejected as a reasonable behavioural assumption for buyers in these markets.[16] A tendency to full value bidding, but imperfect, may however still be present and may vary in strength according to the size of the market. This will be tested in hypotheses 2 to 5.

Hypothesis 2: The Incentive and Opportunity Effects

H_o: $\bar{P}_3 = \bar{P}_4 = \bar{P}_6 = \bar{P}_{12}$

H_a: $\bar{P}_3 < \bar{P}_4 < \bar{P}_6 < \bar{P}_{12}$

H_a': $\bar{P}_3 > \bar{P}_4 > \bar{P}_6 > \bar{P}_{12}$

where $\bar{P}$ is the average market price and the subscripts refer to the number of market buyers.

In order to test these rank orderings the Jonkheere test is applied to the weekly average prices in Table 1, giving five sample sets. (The

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16 A similar test on the data obtained from the same experiments using inexperienced subjects indicated that the FVB hypothesis could be accepted for between 0 per cent and 46.5 per cent of the 15 market sessions in the seven experiments conducted, with an average of 20.62 per cent. Market learning on the part of experienced players has reduced this to almost zero. These experiments are reported in Appendix 3 to this chapter.

TABLE 1

Experiment 1 - Deviation of the Average Market Price from Equilibrium

	Week	Mon	Tue	Wed	Thu	Fri	Average for the Week
3-Buyer Market	1	33.75	21.25	18.13	15.00	10.00	19.63
	2	3.13	0.00	-1.25	-3.75	-1.88	-.75
	3	6.25	3.13	1.25	.63	-.63	2.13
	4	4.38	3.75	3.13	1.25	.63	2.63
	5	6.25	5.00	3.75	4.38	3.75	4.63
			Average Deviation for all 25 Auctions				5.65
4-Buyer Market	1	22.50	13.13	10.00	4.38	2.50	10.50
	2	-6.25	-5.63	-5.00	-3.75	-2.50	-4.63
	3	25.63	18.75	6.88	1.88	0.00	10.63
	4	11.88	8.13	5.63	5.00	4.38	7.00
	5	9.38	-.63	-8.13	-12.50	-10.00	-4.38
			Average Deviation for all 25 Auctions				3.82
6-Buyer Market	1	21.25	8.75	3.13	-1.25	-1.25	6.13
	2	-7.50	-8.13	-7.50	-6.25	-5.63	-7.00
	3	18.13	10.00	4.38	-.63	0.00	6.38
	4	7.50	-1.25	-4.38	1.88	-.63	.63
	5	-8.13	2.50	3.13	1.88	.63	0.00
			Average Deviation for all 25 Auctions				1.2
12-Buyer Market	1	17.50	1.25	-1.88	-3.13	-3.75	2.00
	2	20.63	-.63	1.88	-3.13	7.50	5.25
	3	-1.25	-1.88	-1.88	-1.25	5.63	-.13
	4	7.50	2.50	.63	0.00	0.00	2.13
	5	-23.13	-8.75	-6.88	-1.88	1.88	-7.75
			Average Deviation for all 25 Auctions				.3

obvious learning effects in consecutive weeks do not affect the Jonkheere test.) H_a and H_a' are tested directly and are rejected in favour of the null hypothesis in both cases. The market price averages however, are in the order predicted by H_a' (the 'incentives' effect) and since there are 4! or 24 ways in which these averages could have been ordered the probability that this arrangement should result purely by chance is less than 5 per cent. Nevertheless individual variations in weekly averages make it impossible to make any stronger statement and on the basis of the Jonkheere test it is necessary to accept the null hypothesis. The null hypothesis, however, is consistent with the suggestion that the effect of incentives on buyer behaviour is equally as strong as the information-related opportunity. Thus both incentive and opportunity effects may be considered useful explanations of market behaviour but they must be considered in conjunction with each other.

Hypothesis 3: Correlation between Order of Valuation and Purchase

Hypothesis 3 is concerned with the order in which valuations are ranked and the order in which purchases are made. If buyers adopt the FVB strategy there should be perfect correlation between these two series. It is hypothesized that restrained bidding on the part of collusive small number markets would lead to prices which are lower than average valuations but with a high correlation between the order of valuation and the order of purchase. On the other hand, larger markets are unlikely to be able to achieve such uniformity of restraint so that the successful buyer is less likely to be the one with the highest current valuation. Thus in hypothesis 3 the alternative hypothesis is that the amount of correlation between the order of valuation and the order of purchase in the market declines as the number of buyers increases.

Useful summary statistics are difficult to obtain in behavioural analysis because of the complex nature of the issues confronted. Here a new measure has been devised which uses the basic computations of the Spearman Rank Correlation in combination with the Jonkheere test for ranked alternatives in order to test the strength of correlation over the four market sizes.

The figures in Table 2 measure the extent to which the order of purchase departs from the order of valuations, i.e. the extent to which the purchaser is *not* the buyer with the highest valuation. The values given represent the sum of the squares of the differences between the rank values or order of valuation and purchase. Values less than 30 would be accepted by the Spearman Rank Correlation test as evidence that the two ranked series were correlated and values greater than 30 would be rejected. The larger the value the greater the divergence of the two ranked orderings.

From Table 2 it may be seen that the hypothesis that the two series are correlated, that is, that buyers tend to buy in order of their valuations, is accepted for 22 of the 25 auctions for the small three player market, and for 16 of the 25 auctions for the four player markets, and the proportion decreases as market size increases. For the 12 player market only 6 auctions would be accepted out of the possible 25 and for the 6 player market only 5. The incentive to delay bidding one's full valuation thus could be operational in up to 38 of the 50 auctions in the two large markets and the argument that larger buyer numbers will lead to more competitive bidding up and a tendency to full value bidding cannot be supported.

TABLE 2

Experiment 1 - Rank Correlation between Order of Valuation and Purchase

(Spearman Rank Correlation[1])

	3-Buyer Market					4-Buyer Market					6-Buyer Market					12-Buyer Market				
Week	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri
1	8	10	10	23	34*	6	16	18	36*	21	26	18	22	18	43	10	20	30*	56*	42*
2	10	27	26	30*	22	19	54*	96*	89*	29	150*	74*	60*	77*	36*	22	70*	124*	58*	115*
3	22	21	6	16	38*	18	26	30*	8	20	46*	38*	38*	44	22	90*	102*	89*	106*	116*
4	11	24	26	3	10	24	24	18	24	18	46*	56*	50*	49*	46*	10	14	60*	56*	24
5	10	23	8	2	8	8	32*	56*	68*	57*	30*	48*	46*	42*	54*	102*	170*	108*	157*	126*
No. of Market Sessions for which Correlation is Accepted			22					16					5					6		

[1] The statistics in this table are based on the Spearman Rank Correlation Coefficient,

$$rs = 1 - \frac{6 \sum_{i=1}^{N} di^2}{N^3 - N}$$

and represent the value $\sum_{i=1}^{N} di^2$. When N, the number of correlations, = 8, the critical value for $\sum_{i=1}^{N} di^2$ at the 5 per cent acceptance level is < 30. Accordingly, values *greater* than or equal to 30, here marked with an asterisk, signify a less than 5 per cent probability that the two series, are, in fact, correlated.

Using as the basic data the number of days in each week in which the two series would be considered as correlated by the Spearman Rank Correlation list and taking each week as a sample observation, the Jonckheere k-sample test is employed to test hypothesis 3 below:

$$H_o: \; C_3 = C_4 = C_6 = C_{12}$$

$$H_a: \; C_3 > C_4 > C_6 > C_{12}$$

where C is the number of daily auction sessions in which buyers may be considered to have bought in order of their valuations. By this test, H_o is rejected and H_a accepted at the one per cent significance level, results which are consistent with the alternative hypothesis that the amount of correlation declines as the number of buyers increases, which is predicted by the incentive effect.

Hypotheses 4 and 5: Market Efficiency

Data on hypotheses 4 and 5 concerning trading inefficiencies and loss of purchaser surplus are given in Table 3. The ordering is consistent with the alternative hypothesis in both cases, suggesting greater inefficiency during the adjustment process in larger size markets. Lack of multiple observations prevent the use of statistical tests, thus the data must be considered as illustrative and suggestive only. However, the results are consistent with the results of hypothesis 3 above.

The greater welfare losses in the larger markets may be illustrated by reference to the graphs in Appendix 2 to this chapter which show patterns of contract prices in the four markets. The tendency of buyers in large number markets to avoid bidding their full values can be seen in the rapid "flattening out" of the curve from the second day onwards

TABLE 3

Experiment 1: Trading Inefficiencies

	Number of Inefficient Market Sessions	Average Percentage Loss per Inefficient Market Session
3-Buyer Market	3 out of 25	1.91
4-Buyer Market	3 out of 25	3.06
6-Buyer Market	5 out of 25	10.34
12-Buyer Market	7 out of 25	12.64

as buyers try to estimate the lowest possible buying price. The ability of each buyer in large number markets to delay purchasing, if necessary, until the last unit is put up for sale, results in prices close to and even below the equilibrium values. Where units are sold at prices below the equilibrium value there is, of course, the possibility that an extramarginal buyer, whose valuation is less than the equilibrium price, may succeed in purchasing. When this happens last minute price rises may occur as buyers with intra-marginal values have to compete for the last unit. Such last unit price rises can be seen in week 2, on Wednesday and Friday, week 3 on Friday, and week 5 on Monday and Tuesday. In real auctions the same pattern can be observed. It is often referred to by buyers as "panic buying" and thought to be psychologically induced but there may also be sound economic reasons as in these experimental markets.

Sharp price increases have a large impact on buyers who recognize it as a sign that average prices have been too low.[17] Thus the inefficiencies themselves serve to inform buyers and lead to the necessary price adjustment.

Hypothesis 6: Speed of Adjustment

$$H_o: \; A_3 = A_4 = A_6 = A_{12}$$

$$H_a: \; A_3 < A_4 < A_6 < A_{12}$$

where A is the number of equilibrium contracts and subscripts refer to the number of market buyers.

The values in Table 4 indicate for each market the number of contracts that were made at equilibrium prices and those that were made above, or below, equilibrium prices. If the large scale markets really do equilibrate more quickly this will be revealed in a larger number of contracts at the equilibrium level. This is shown in Table 4 to be indeed the case. Not only do the larger number markets tend to have more equilibrium contracts, they tend to have considerably more below equilibrium contracts which is consistent with the operation of the incentive induced delay strategy. The relatively higher number of above equilibrium contracts in the smaller markets is again consistent with the hypothesis that these markets will tend more towards the risk-reduction practice of full value bidding. However, while Jonckheere tests support the tendency of small number markets towards "above equilibrium" (at the 1 per cent significance level) they do not support the alternative hypothesis in hypothesis 6 that there are more equilibrium contracts in larger number markets.

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17 This may be conscious or unconscious recognition. They may simply register that they do not wish to be similarly "caught out" and thus raise their bid limits in subsequent auctions.

TABLE 4

Experiment 1 - The Number of Trades which were At, Above, and Below Equilibrium Prices

	Mon	Tue	Wed	Thu	Fri	Total	Percentage of all Trades %
3-Buyer Market							
At eq.	7	13	15	17	21	73	36.5
Above eq.	29	24	21	17	13	104	52.0
Below eq.	4	3	4	6	6	23	11.5
							100.0
4-Buyer Market							
At eq.	7	11	12	15	18	63	31.5
Above eq.	28	22	18	14	11	93	46.5
Below eq.	5	7	10	11	11	44	22.0
							100.0
6-Buyer Market							
At eq.	5	12	9	21	25	72	36.0
Above eq.	17	15	15	4	3	54	27.0
Below eq.	18	13	16	15	12	74	37.0
							100.0
12-Buyer Market							
At eq.	10	19	16	22	18	85	42.5
Above eq.	19	8	5	1	7	40	20.0
Below eq.	11	13	19	17	15	75	37.5
							100.0

Thus on the basis of the Jonkheere test it is necessary to accept the null hypothesis of no difference in adjustment speeds between markets. Yet, from Table 2 the 12 player market is within two thirds of a bidding increment in all market sessions after the first day with the exception of five - out of twenty (comparative figures for the 3, 4 and 6 buyer markets are 10, 15 and 8 respectively). This inconsistency arises from the fact that many contract prices in the large number markets are just below the equilibrium level. Figure 2 in Appendix 2 suggests the greater tendency to equilibrium in the larger markets. If it were not for the disrupting effect of the last unit price rises, which are more likely to occur in large number markets, it would be possible to measure the equilibrating tendencies of markets by the rate of reduction in the variance.

6.5.2 Experiment 2

Experiment 2 is a partial replication of the 3, 6 and 12 buyer markets of experiment 1.[18] All the conditions of these markets remain the same with the exception of the sequence of weekly demand changes. In experiment 2 the equilibrium price *falls* in the second week and *rises* in weeks 3 to 5, the reverse of the sequence used in experiment 1.

6.5.2.1 Results and Discussion

As these markets are basically the same as those in experiment 1, the results and discussion here will be limited to outlining and, where possible, accounting for differences and similarities between them.

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18 The four buyer market in experiment 2 was inadvertently run with incorrect schedules and had to be omitted from the analysis.

Hypothesis 1

The results of experiment 2 support those of experiment 1. From Table 5 it can be seen that only two market sessions show any sign of full value bidding, the first in the six player market and the first day of the second week of the 12 player market. For the rest, the null hypothesis that $\bar{p} = \bar{p}*$ is strongly rejected in favour of $\bar{p} < \bar{p}*$.

Hypothesis 2

The pattern of contract prices as revealed in Table 5 show that prices in these markets are considerably lower than in experiment 1, suggesting that there is, in fact, an "order effect". It is possible that the rising sequence of equilibrium prices in weeks 3 to 5 countered, to some extent, the natural tendency of all markets to approach equilibrium from above. The Jonckheere test of H_a and H_a' are rejected in favour of the null hypothesis of no difference in market prices between the differently sized markets.

Hypothesis 3

The results of Table 6 clearly support the hypothesis that correlation between the rank order of valuations and the order of purchases diminishes as the number of competing buyers increases. The Jonckheere test accepts the alternative hypothesis at the 1 per cent significance level. These results are consistent with those of experiment 1.

TABLE 5

Experiment 2 -

Deviation of the Average Market Price from Equilibrium

	Week	Mon	Tue	Wed	Thu	Fri	Average for the Week
3-Buyer Market	1	-8.75	-6.88	-3.13	1.88	-1.25	-3.62
	2	-15.00	-8.13	-7.50	-5.00	-4.38	-8.00
	3	-3.13	3.13	3.75	4.38	2.50	2.13
	4	-7.50	2.50	5.65	6.88	3.75	2.25
	5	8.75	7.50	7.50	5.63	4.38	6.75
			Average Deviation for all 25 Auctions				0.10
6-Buyer Market	1	33.75	13.13	5.00	2.50	1.88	11.25
	2	5.63	3.13	0.00	-1.88	-3.13	.75
	3	4.38	1.25	-1.88	-2.50	-3.13	-.38
	4	-1.88	-2.50	-4.38	-5.00	-2.50	-3.25
	5	0.00	-5.00	-1.88	-3.13	-3.75	-2.75
			Average Deviation for all 25 Auctions				-1.12
12-Buyer Market	1	19.38	0.00	-3.75	1.25	-1.88	3.00
	2	39.38	8.13	3.13	2.50	1.25	10.88
	3	-22.50	-14.38	-6.25	0.00	1.88	-8.25
	4	3.13	3.75	1.88	1.88	.63	2.25
	5	-10.63	.63	-.63	-.63	-1.25	-2.50
			Average Deviation for all 25 Auctions				-1.25

TABLE 6

Experiment 2 - Rank Correlation between Order of Valuation and Purchase
(Spearman Rank Correlation[1])

	3-Buyer Market					6-Buyer Market					12-Buyer Market				
Week	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri
1	34*	8	20	54*	58*	12	4	14	28	36*	26	29	89*	143*	44*
2	32*	27	59*	29	21	48*	24	44*	20	75*	4	30*	26	42*	46*
3	18	30*	28	14	4	29	46*	43*	63*	63*	98*	124*	126*	85*	72*
4	26	43*	22	18	29	82*	88*	44*	36*	22	24	70*	74*	35*	54*
5	8	2	10	12	44*	56*	32*	62*	27	98*	114*	136*	76*	104*	86*
Number of Market Sessions for which Correlation is Accepted			17					9					5		

[1] The statistics in this table are based on the Spearman Rank Correlation Coefficient,

$$rs = 1 - \frac{6 \sum_{i=1}^{N} di^2}{N^3 - N}$$

and represent the value $\sum_{i=1}^{N} di^2$. When N, the number of correlations, = 8, the critical value for $\sum_{i=1}^{N} di^2$ at the 5 per cent acceptance level is < 30. Accordingly, values *greater* than or equal to 30, here marked with an asterisk, signify a less than 5 per cent probability that the two series, are, in fact, correlated.

Hypotheses 4 and 5

In Table 7 the number of inefficient market sessions is not significantly different between the different markets. As suggested by the lower average prices in Table 5 the three buyer market is much more inefficient than the corresponding market in experiment 1 in terms of the number of sessions in which extra marginal buyers secured units, but the actual loss of buyer surplus in these markets is relatively small compared to the 10.66 per cent of the 12 player market. Again no statistical tests can be applied to these figures but overall they suggest greater inefficiency in larger number markets.

Hypothesis 6

From Table 8 the tendency of the large number market to equilibrate faster is clearly shown - and supported by the Jonckheere test at the 5 per cent significance level but the tendency of the smaller markets to "above-equilibrium" contracts and of larger market to "below-equilibrium" contrcts was not supported.

From the graphs in Appendix 2 it is possible to see the strongly collusive pattern of bidding in the first few weeks of the three buyer market in which prices approached equilibrium from below. It would appear that this level of collusion could not be permanently maintained for a "convergence from above" pattern is resumed in weeks 3 to 5 which is similar to that of this market in experiment 1.

TABLE 7

Experiment 2 -
Trading Inefficiencies and Loss of Buyer Surplus

	Number of Inefficient Market Sessions	Average Percentage Loss per Inefficient Session
3-Buyer Market	8 out of 25	1.40
6-Buyer Market	6 out of 25	2.29
12-Buyer Market	7 out of 25	10.66

TABLE 8

Experiment 2 - The Number of Trades which were At, Above, and Below Equilibrium Prices

	Mon	Tue	Wed	Thu	Fri	Total	Percentage of all Trades
3-Buyer Market							
At eq.	5	10	10	12	10	47	23.5
Above eq.	11	15	18	21	19	84	42.0
Below eq.	24	15	12	7	11	69	34.5
							100.0
6-Buyer Market							
At. eq.	15	12	12	15	15	69	34.5
Above eq.	17	13	9	4	3	46	23.0
Below eq.	8	15	19	21	22	85	42.5
							100.0
12-Player Market							
At eq.	9	9	18	22	29	87	43.5
Above eq.	16	15	10	10	6	57	28.5
Below eq.	15	16	12	8	5	56	28.0
							100.0

6.6 Summary of Experimental Results

In summary, seven experimental progressive auction markets were examined to see whether changing the number of buyers in the market, over a range of three to twelve, would have any effect on market price if aggregate supply and demand were held constant. The results suggested that during the disequilibrium or price-adjustment phase of the market, average market prices tended to be rather higher in those markets in which there were relatively few buyers, contrary to standard expectations.

Several hypotheses were developed relating to the market strategies adopted by the buyers. Testing these hypotheses then suggested that buyers in small number markets had greater *opportunity* by virtue of their greater knowledge of the overall demand level, to adopt price-reducing delay strategies whilst buyers in large number markets had greater *incentive* to adopt such price reducing delay strategies by virtue of their lower risk of failing to purchase all they desired. Both incentive and opportunity effects were seen to be important influences on the bidding practices adopted with incentive effects being rather stronger in these experimental markets.

Both effects led to prices being lower than the full-value bidding strategy commonly assumed to be operative in empirical studies. However, whenever demand changes occurred in the market and market generated information was at its lowest (the first trading session of the week) there was a greater tendency on the part of buyers in both large and small number markets to opt for full value bidding practices. These practices may therefore be associated with risk reduction under uncertainty. Higher levels of uncertainty than those generated in the current study, such as would be associated with quality differences in the items sold or unknown supply limits which is a common feature of real markets where sellers apply unknown reservation prices, could therefore lead to different results.

The appropriateness of simplified models such as the homogeneous commodity progressive auction adopted here is examined in the following chapter and in Chapter 8 an exploratory experimental test is developed using heterogenous commodities.

6.7 Methodological Critique

6.7.1 Purpose and Validity

If it is true that the information, incentive and opportunity characteristics of the market determine the type of pricing decision made therein then the selection of the appropriate experimental model is important if the results are to have relevance to problems of real world importance.

The study for Chapter 6 originated in discussions concerning the centralization of Australian wool sales. One of the arguments put forward was that where there were only a few buyers and sellers at an auction the prices tended to be lower than at auctions attended by larger numbers of buyers and sellers. Empirical observation is not, however, able to distinguish between higher levels of demand relative to supply and larger numbers of buyers per se. Nor is it able to deal effectively with the fact that smaller markets may be used by buyers and sellers of lower quality wools or that inability to put together a mill lot from a wide variety of sale lot types in smaller markets could be responsible for discounting practices or non-attendance at such auctions by certain buyers and/or sellers.

The direct impact of buyer numbers in market prices then seemed inherently difficult to test empirically but ideally suited for examination by experimental means. In order to maximize 'external validity' or real world relevance, the experimental market model was chosen to replicate the essential characteristics of the Australian wool market, a progressive oral auction. Several features of the market, however, posed some difficulties; one was the heterogeneous nature of the wool lots sold and the other was the two tier buyer organization whereby the principal buyers remained in their offices, many of them overseas, and were represented on the sale floor by local agents.

The several hundred sale lots available on any one sale day may represent over a hundred different types and wool qualities yet, nevertheless, buyers can perceive similarities that enable them to make sub-groupings within which the wool lots are effectively homogeneous. One way of dealing with heterogeneity, therefore, would be to consider the sale of just one sub-grouping. This is basically what is done in this study and in other, theoretical, studies.

However, unless the buyers themselves fall into similar sub-groupings, being interested only in buying lots within the one sub-group, the price determined for the sub-group will be affected by the prices determined for other sub-groups. The difference that this may make to the results is studied in Chapter 8 where a pilot progressive auction experiment is conducted with quality differentials.

The individual, downward-sloping, demand curve of economic price theory assumes that the owner of the marginal utilities is the one facing the possible range of market prices. In the wool market the buyer-principal, in effect, predicts the wool price levels and gives quantity limits to his agent based on expected prices. The agent, therefore, is not in a position, except insofar as he trades on his own account, to increase the quantity desired if prices should turn out to be lower. If prices should be higher than anticipated he is still largely committed to acquiring his quantity limits. (This is discussed further in the next chapter in which an experimental progressive auction market is conducted with real wool buyers.)

The emphasis on quantity rather than price may change the perceived risk structure of the trader and thus his pricing decisions, particularly whether he should follow the 'safety-first' full value bidding rule. This element of the real market is not replicated in the current study which collapses the role of the buyer and his agent into the one decision-making unit for the purposes of this study. This has the advantage of enabling the use of standard demand schedules and thus comparison with previous experimental results using such schedules but reservations need to be borne in mind when attempting to extend the analysis beyond the laboratory context. In a complex situation like the current one it is necessary to progress one step at a time, first eliminating one source of variation then another. This study then is such a step. The experimental study of Chapter 7 is designed to suggest further steps in the analysis.

6.7.2 Operationalizing Concepts

Both of the problems considered above could equally well be considered as problems in the operationalization of concepts. Another such problem is in deciding how to represent market size. The range of buyers, from three to twelve, was adopted because the general feeling in the wool market was that this set the general range to expected buyer numbers. Numbers greater than twelve were considered to be "many" for the purposes of competition.

Since the problem was to isolate changes in buyer numbers from changes in the level of aggregate demand relative to aggregate supply there were two possible ways of dealing with it. One way would be to maintain the level of individual demand per buyer constant and, as the level of aggregate demand rose with increased buyer numbers, to increase the aggregate supply commensurately. The other would be to keep the aggregate levels constant and reduce the individual buyer demand as buyer numbers increased. If we had, say, three buyers with four units of demand a piece for an aggregate level of demand of twelve units, and an aggregate level of supply of two thirds this amount, or eight units, the first method would require, for the twelve buyer market, twelve buyers each with four units of demand; an aggregate demand, therefore, of 48 and an aggregate supply of 32. The second method, adopted in this study, would require twelve buyers, each with one unit of demand, an aggregate demand of twelve and an aggregate supply of eight. In both cases the buyers in the larger, twelve buyer market would be required to purchase up to one eighth of the total supply and the relative degree of excess demand would remain constant.

The first method, however, would require up to four times the time required to auction the required units as compared with the second method. The major difference is in the number of units the buyers are required to handle. If the absolute number of units is important then the two methods are not equivalent.

6.7.3 Measurement

The use of parametric statistics, common to most economic studies, is rarely appropriate for experimental economic studies. The results from individual market sessions are interdependent because of learning effects, they are not normally distributed and have heterogeneous rather than homogeneous variances. Where little learning takes place for one reason or another and the number of observations is large, as in Chapter 5, standard parametric tests of variance can be applied but more often the number of independent observations are few. Experimental economics is thus closer to behavioural science and psychology in its statistical needs than orthordox non-experimental economics.

In Chapter 6 two non-parametric measures are combined in an unusual way to enable rank correlation of four matrices (Section 6.5.1.1). The Spearman Rank correlation is applied to two data series to provide the basic data on the amount of correlation present and the Jonckheere K-sample test is applied to these figures. This provides a neat and precise test of hypothesis 3.

It is not always possible, however, to find just the right test that the problem demands. This is often the case when the concept to be measured is an "index number" or an aggregate of different quality variables. There are many examples of index number concepts in economics, for example, "the interest rate", "the standard of living", even "price" where price is not unique. In Chapter 6 this problem arises in the measurement of the 'speed of convergence'. On the one hand the ideal measure should measure the rate at which average price approaches the equilibrium and on the other the variability inherent in this average. Where the rate and the variability seem to be in conflict there is the old weighting index number problem. The approach taken in

Chapter 6 was to partially sidestep the variability aspect and try to measure the increased number of contracts occurring at the equilibrium level. This disaggregating procedure was also followed in Chapter 5 where "inefficiency" was disaggregated into separate measures for each type of inefficiency. Disaggregating does not avoid the weighting problem, one still needs to make an overall assessment, but it removes the problem from the measurement to the summation-evaluation stage. It is suggested that this is more appropriate for the micro examination approach of experimental studies.

6.7.4 Controls

Two separate control methods were employed in this study, one for the initial series of "training" experiments which are reproduced in Appendix 3, and one for the final series, using experienced subjects, which was reported in this chapter.

For the initial series of experiments using inexperienced subjects, the subjects, who participated as part of a required course assignment, were motivated by relating their game behaviour to their course results. This was done by assigning an essay worth 10 per cent of their final assessment, on an unknown topic but one relating the subject's theoretical knowledge and experimental experience. The students were advised that their ability to complete the assignment successfully would depend upon their full understanding of the experimental market which in turn was related to the effort expended during the session to maximize their profits, the object of the experimental exercise.

In this way the student subjects were motivated in their game behaviour without their game results directly affecting their course grades, which would be morally reprehensible if some subjects received schedules with high re-sale values and others only low resale values not conducive to such high profits. The alternative for experimenters wishing to motivate student subjects by relating actual experimental profits to course results is to so balance the resale values over the weeks of trading that all have equal opportunities. This, however, is not as fair as it seems, since strong learning effects are apparent in most of these experiments, even with experienced subjects, and thus students who acquire their high values during the last trading sessions are at an advantage compared with those who received high values in the early sessions.

Kormendi and Plott (1980) have adopted an intriguing "duplicate bridge" design in which many replicates of the study are conducted and it is the student's performance relative to others in a similar position in the other markets which determines the grade awarded. This avoids the problems above but requires a large number of replicates.

The advantage of the system used in this study is its flexibility. Schedules do not have to be "balanced" nor are a large number of replicates required. Indeed this motivational method could well be employed with the fractional factorial replication described in Chapter 5.

Subjects can be drawn from this "experienced" student pool to take part in further experiments "for money". (As long as these monetary experiments are conducted *before* the essay topic is announced the essay motivation will not bias the results).

In Chapter 6 the reported experiments used subjects trained by the method above and paid their actual game profits by cheque at the close of the trading session. The results reported herein are thus compatible with results elsewhere using this form of motivation.

It is, however, interesting to compare the "inexperienced" and "experienced" subjects results in these markets. In Appendix 3 the graphs of the inexperienced subject results show strong learning effects. But more than this it shows that the learning effects themselves are related to the number of buyers in the market. Regarding "learning" as the flattening of the contract price curve around the equilibrium value, it can be seen that while the 3 buyer markets (Figures 1 and 5) show no tendency to this flattening, the 12 buyer markets (Figures 4 and 8) show a decided trend to a flat contract curve even in the first week of the experiment and this is even faster in the subsequent periods. In-between buyer numbers have in-between results. Thus the 4 buyer markets show some tendency to curb their downward plunge by week 3 and the 6 buyer markets somewhat earlier, by the end of week 2.

Several reasons may be suggested for this relationship. In the first place buyers in the larger number markets have only one unit to sell, after which they can only sit back and observe until that trading session is finished. So buyers who bid up the price of early units to somewhere near their resale valuations have time to reflect on the widsom of their action while they watch other units being sold for less. In the 3 buyer markets the constant attention to the need to purchase up to four units, which have declining marginal resale values, could obscure the picture, blinding the buyer to the significance of the declining price trend.

Another explanation is that there is a learning "threshhold". If one buyer in a market 'discovers' the optimizing strategy of bidding no more than the predicted equilibrium or "cut-off" level, his actions serve to teach others. The more buyers, the greater the teaching effect. It is a plausible, though unsubstantiated, theory that there needs to be a minimum number of "teachers" before the market itself "learns". if the probability that one such buyer would occur in a market was equal for each market this would however give the advantage in learning to the smaller markets since only two buyers need be 'discovers' for the third buyer to find himself without the need to overbid. However the probability of one buyer in a market discovering the optimum procedure is probably related to the number of buyers in total in that market. It could be further enhanced by the opportunity to observe and reflect which is present in large markets but not in the smaller ones.

Even in the "experienced" markets, graphed in Appendix 2, there is some slight learning effect related to buyer numbers.

These results are consistent with the theoretical attribution of faster convergence to equilibrium prices of "perfect" (i.e., large number) markets.

APPENDIX 1 TO CHAPTER 6

Instructions for Progressive Auction

MARKET INSTRUCTIONS

BUYER

This is an experiment in market decision making.

You are to think of yourself as a buying agent for a company, and you are to buy for them up to a certain number of units as given on your record sheet. The price they are prepared to pay you for each unit you obtain is also listed. Your profit is the difference between this resale value and your purchase price.

You are not obliged to buy the full amount but for every unit that you fail to acquire there will be a penalty of 5¢. (You may like to see this as a monetary equivalent of your loss of face with the company that has relied on you and some indication of your continued employment as their agent). Nevertheless you are not to purchase any unit at a price greater than its resale value.

The measure of your success in this market experiment is the amount of profit (resale value - purchase cost) minus penalties that you are able to accumulate over the trading period. You should try to make this as high as possible.

You are to regard the information listed on your record sheets as private information which must not be divulged to any other player. Apart from bids, directed to the Auctioneer, there is to be no other communication.

AUCTION PROCEDURE

When the Auctioneer declares the auction open, any buyer is free to commence the bidding at any price less than or equal to the value of the first unit in his buying schedule. All bidding is done in cents, thus a bid of $1.09 would be announced as 109 (one hundred and nine). Each successive bid must offer better terms than the preceding bid. Bid increments are to be in multiplies of one cent (i.e., 1, 2, 3 or more cents but not fractions of a cent).

Once a unit has been bought the next bidder is free to make a lower bid. Since he is the first bidder for this unit he can make any bid at all (as long as it is ≤ the appropriate unit in his own schedule). He is not bound to improve the terms of the previous contract. Successive bidders however must improve on the terms offered until a sale is made.

If the highest bid price does not exceed the Auctioneer's reservation price he will announce that the reservation price has not been met and if no further bids are forthcoming the unit will be withdrawn from sale.

If you wish to make a bid call out your bidder number (which is written on your schedule and on the lapel badge you have been given) and the amount of the bid, e.g., "12 bids 82". When no further bids are forthcoming the Auctioneer will declare the unit sold to the highest bidder.

All purchases are to be recorded by the buyer on his record sheet at the time of purchase after which he can re-enter the market if he wishes. An example of a record sheet is attached.

At the end of the auction day buyers total their profits, excluding penalties.

The market then opens, for the next auction day. You should note the values given for each unit. They may or may not be constant from one auction day to the next.

Also note that you cannot carry over any unbought units from one auction to the next. Your total demand in each auction is given on your record sheets, you may buy less but you cannot buy more.

ME CODE NO.

CORDSHEET - BUYER

Name in BLOCK LETTERS (. . . . .

TRADING WEEK ☐	MON	TUES	WED	THURS	FRI
t Unit sale Value					
rchase Price					
ofit*					
d Unit sale Value					
rchase Price					
ofit*					
d Unit sale Value					
rchase Price					
ofit*					
h Unit sale Value					
rchase Price					
ofit*					
h Unit sale Value					
rchase Price					
ofit*					
h Unit sale Value					
rchase Price					
ofit*					
oss Profits					
less 5¢ for every unit not purchased.					
nal Profit					

*Profit = Resale Value - Purchase Price

APPENDIX 2 TO CHAPTER 6

Graphs of the Progressive Auction reported in Chapter 6, using constant aggregate supply and demand schedules and a variable number of buyers

Experiment 1, 3 Player Market

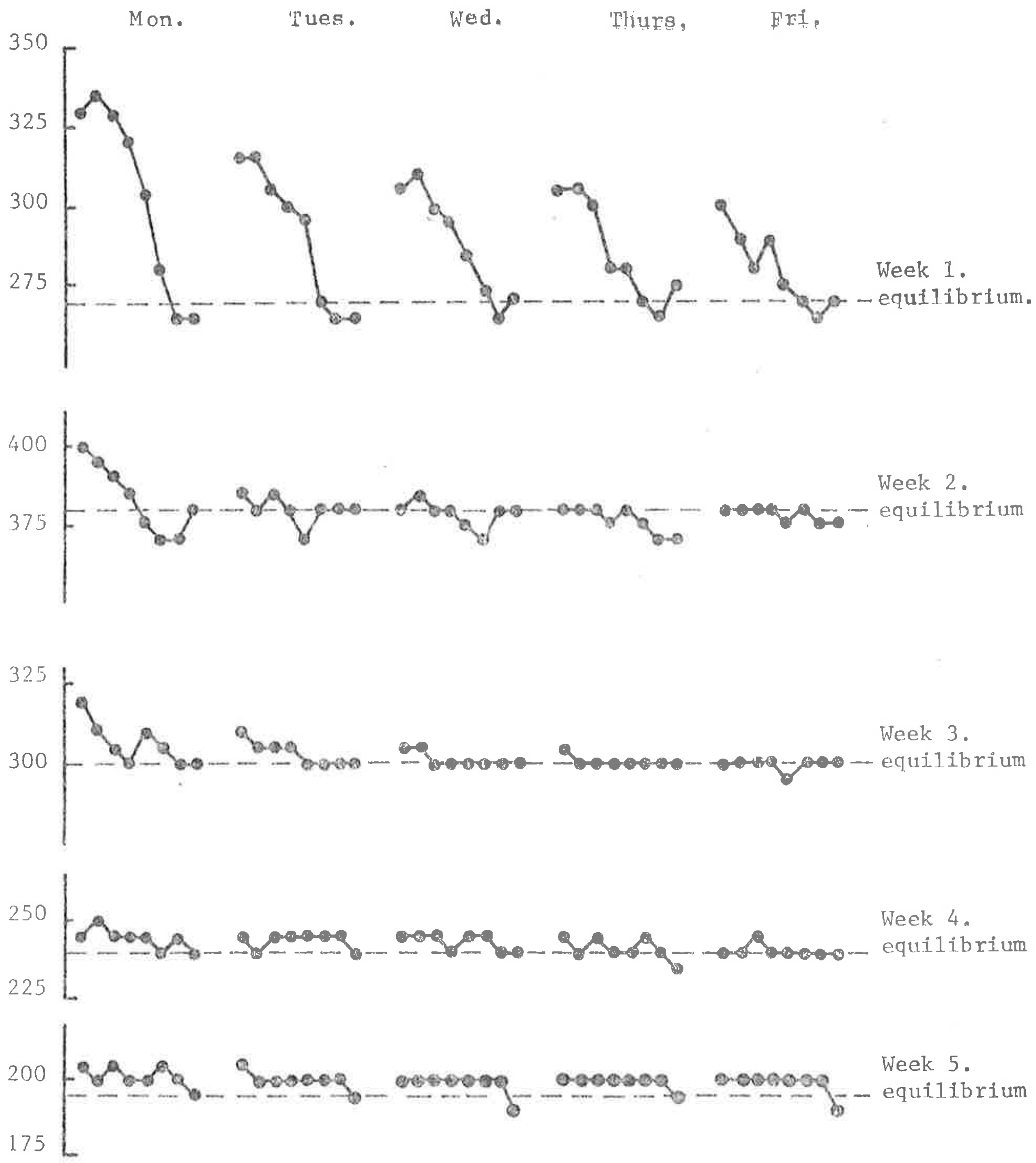


FIGURE 2a.

Experiment 1, 4 Player Market

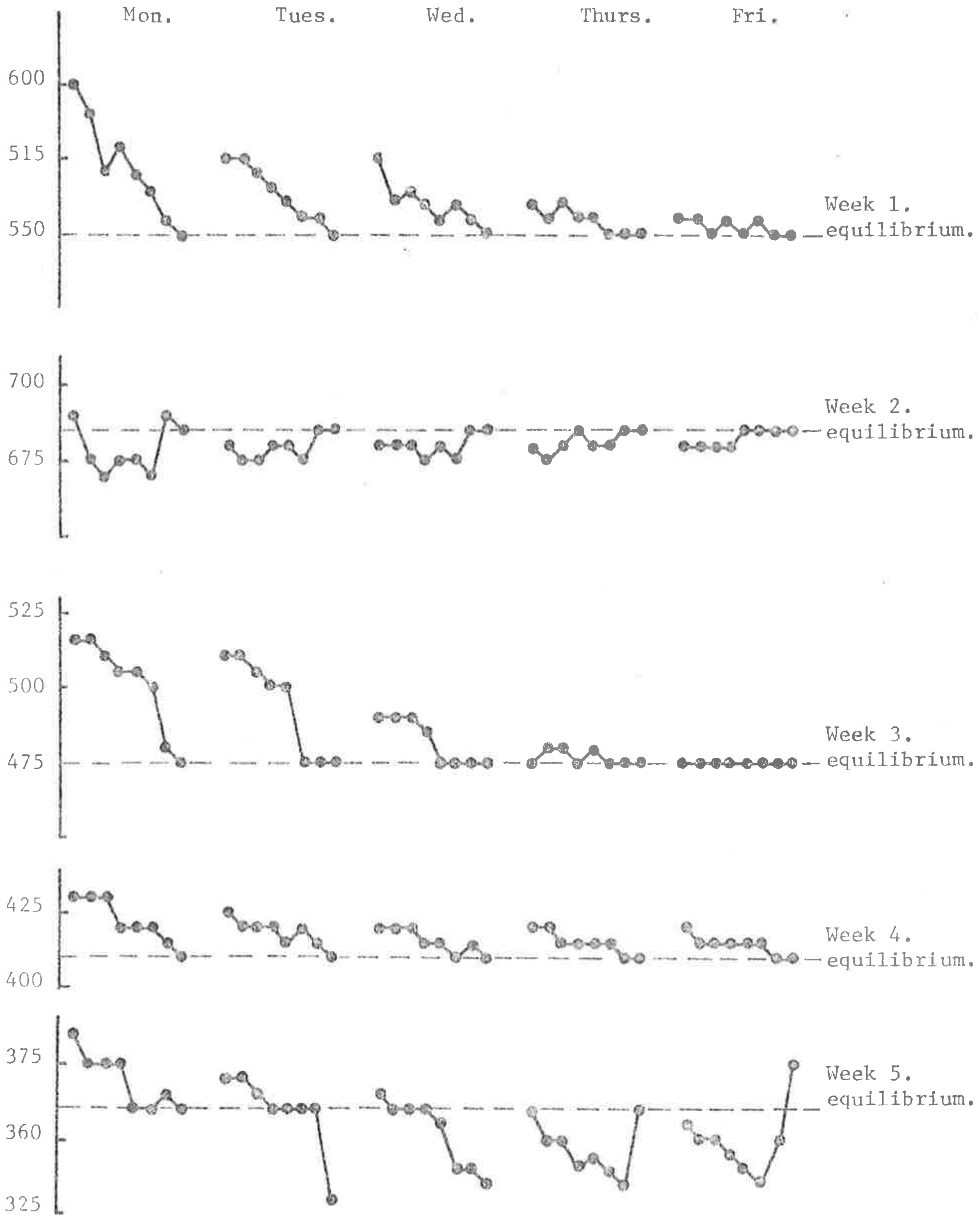


FIGURE 2b.

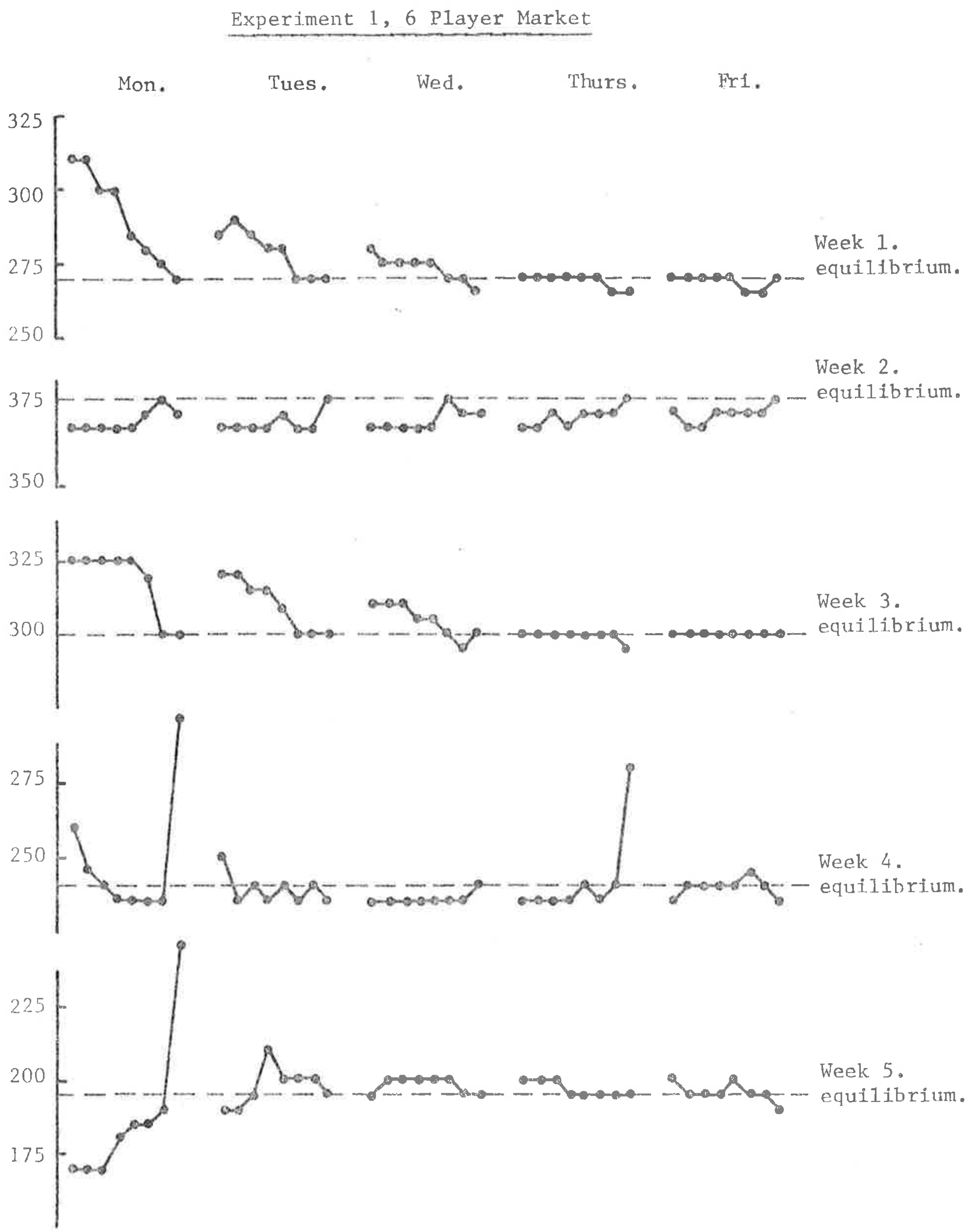

Experiment 1, 6 Player Market
Mon.
Tues.
Wed.
Thurs.
Fri.
325
300
275
250
Week 1.
equilibrium.
375
350
Week 2.
equilibrium.
325
300
Week 3.
equilibrium.
275
250
Week 4.
equilibrium.
225
200
175
Week 5.
equilibrium.

FIGURE 2c.

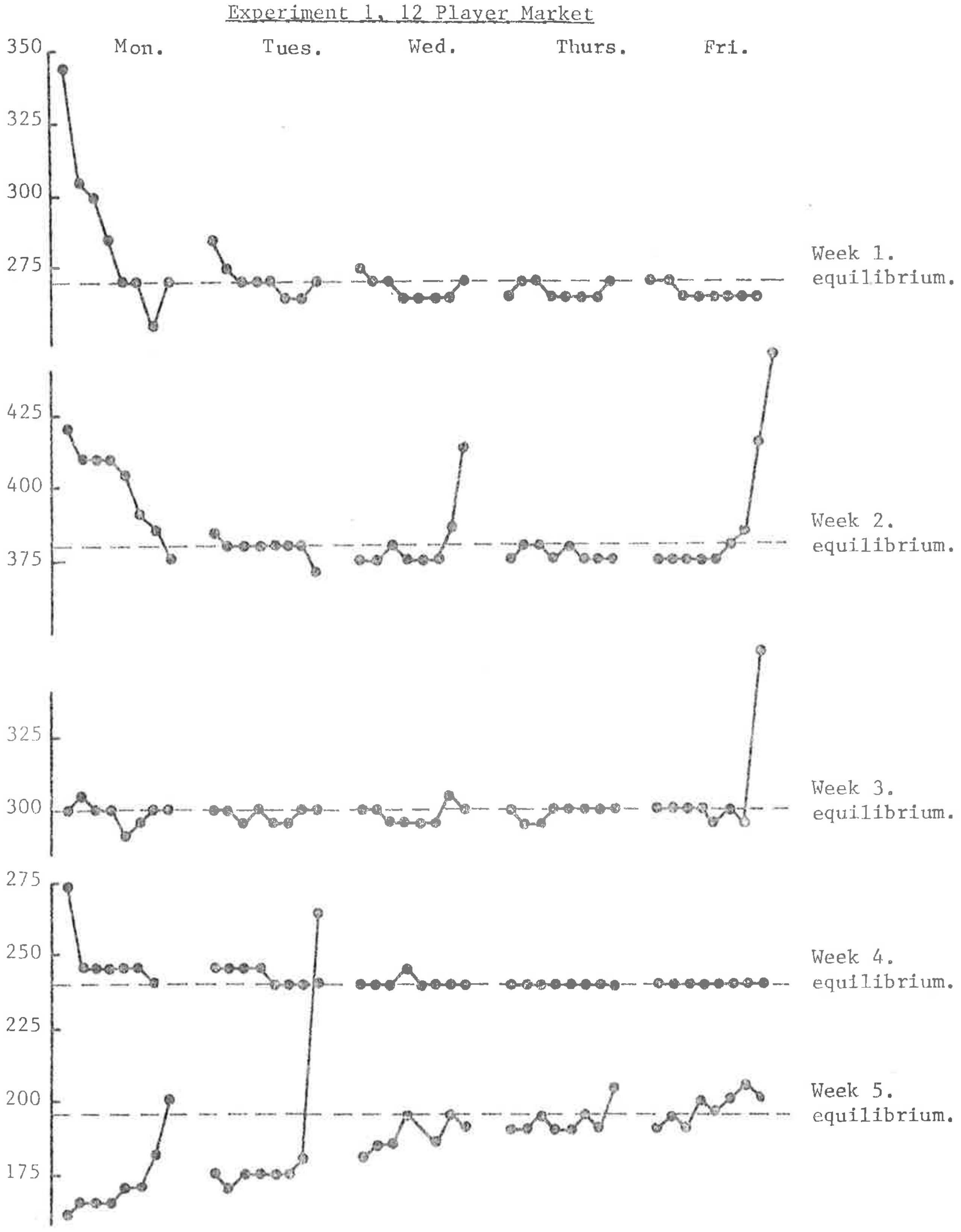

Experiment 1, 12 Player Market
350
325
300
275
Mon.
Tues.
Wed.
Thurs.
Fri.
Week 1.
equilibrium.
425
400
375
Week 2.
equilibrium.
325
300
Week 3.
equilibrium.
275
250
225
200
175
Week 4.
equilibrium.
Week 5.
equilibrium.

FIGURE 2d.

Experiment 2, 3 Player Market

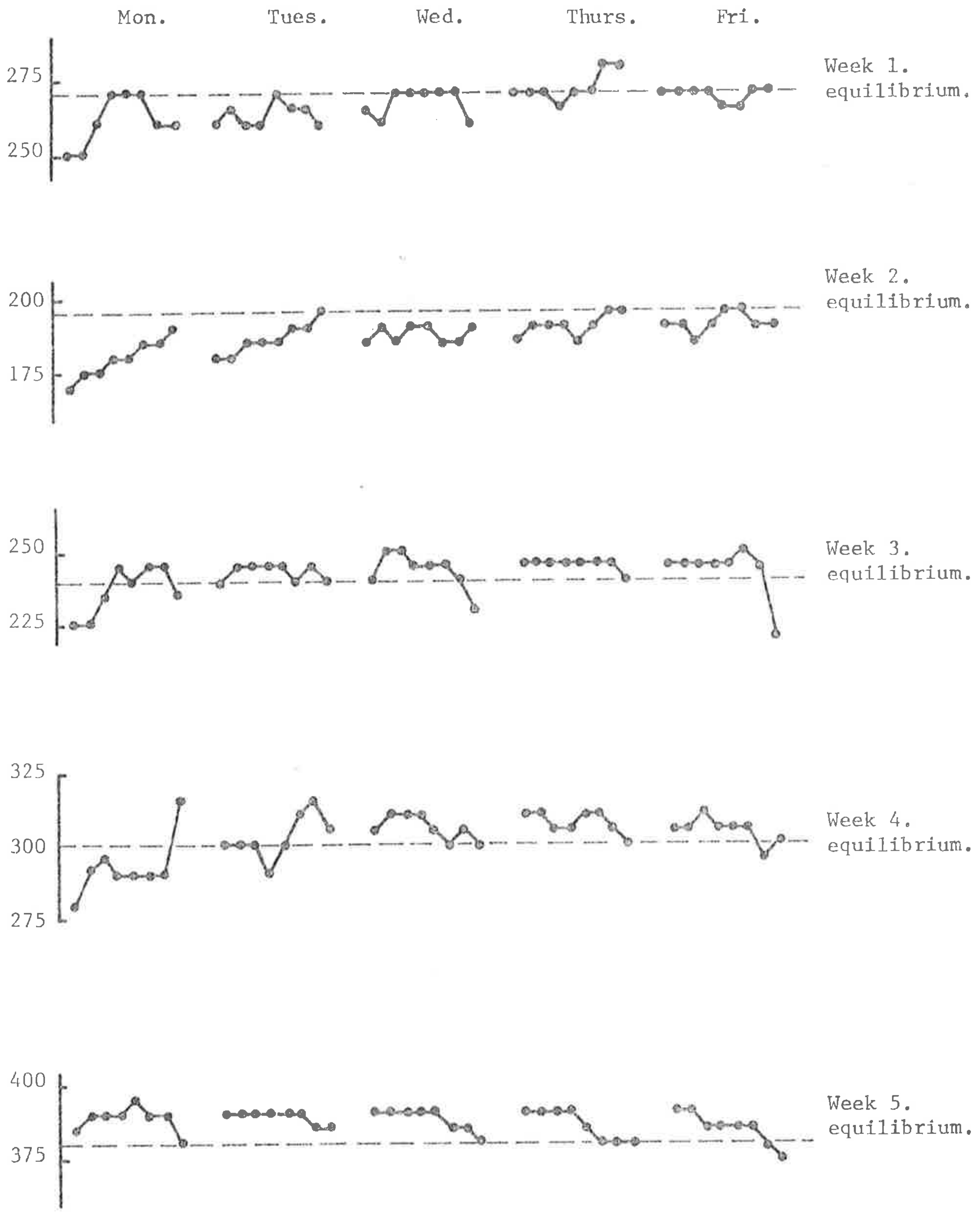


FIGURE 3a.

Experiment 2, 6 Player Market

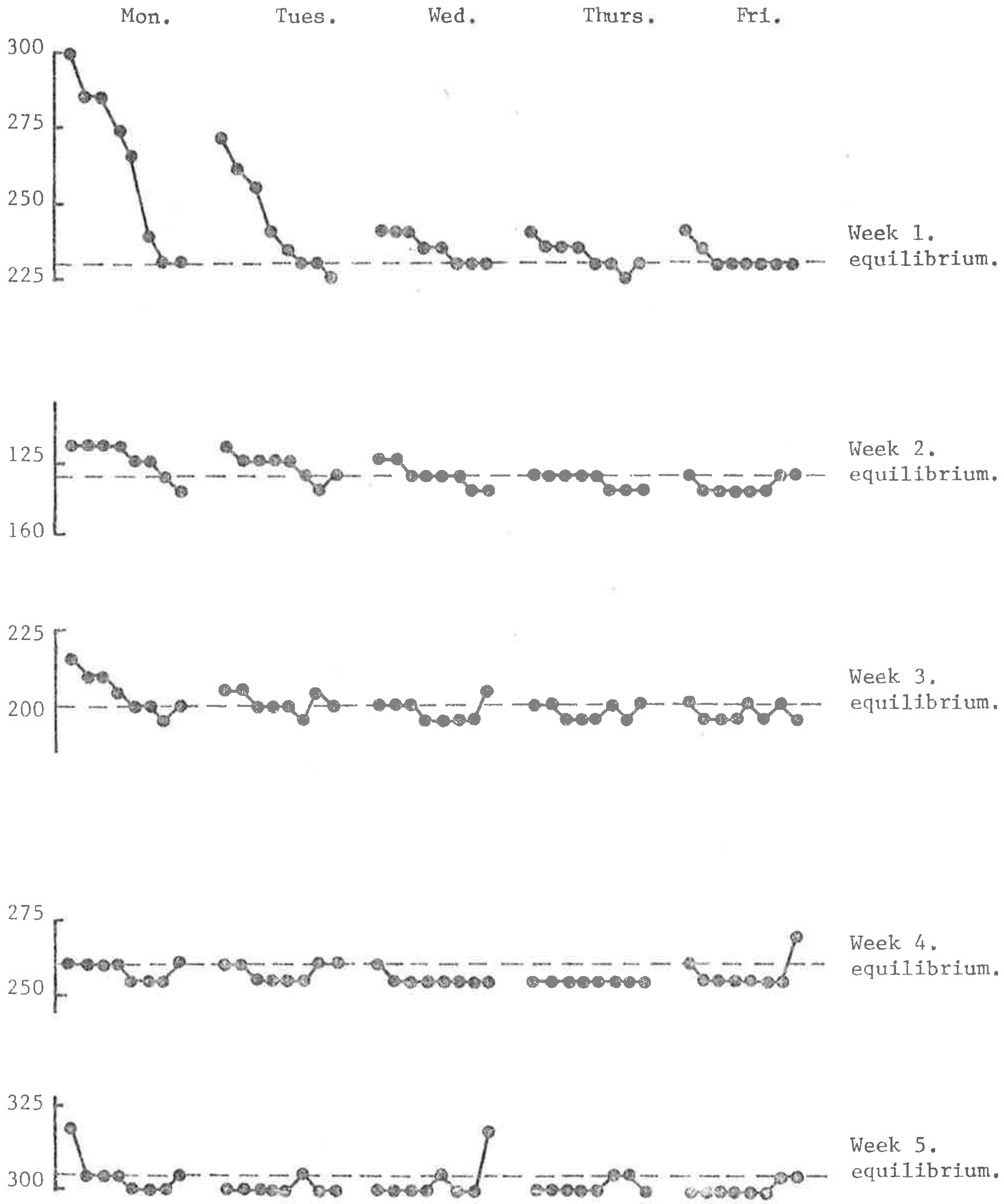


FIGURE 3b.

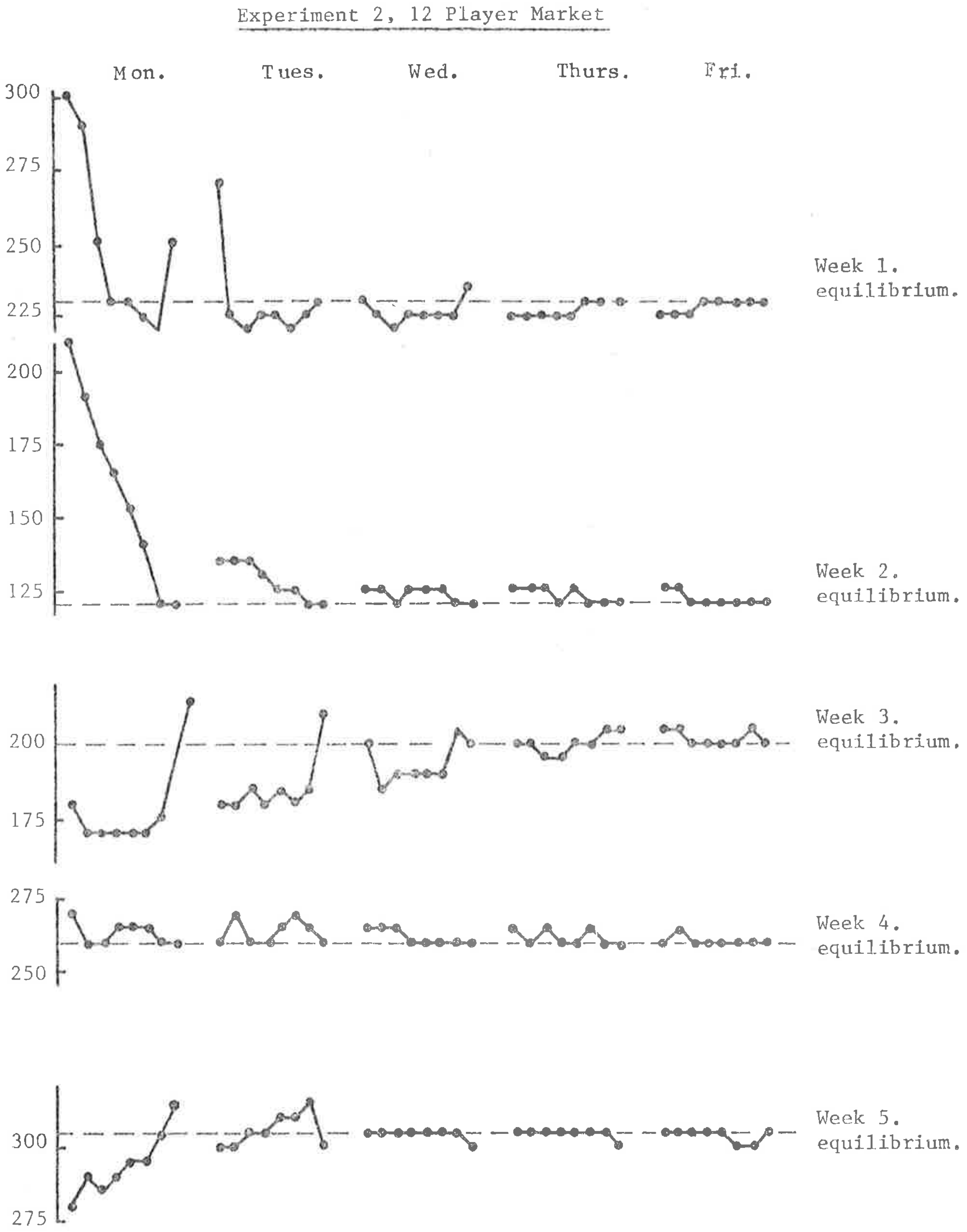

Experiment 2, 12 Player Market
Mon.
Tues.
Wed.
Thurs.
Fri.
300
275
250
225
Week 1.
equilibrium.
200
175
150
125
Week 2.
equilibrium.
200
175
Week 3.
equilibrium.
275
250
Week 4.
equilibrium.
300
275
Week 5.
equilibrium.

FIGURE 3c.

APPENDIX 3 TO CHAPTER 6

Graphs of Progressive Auction Experiments using the same basic aggregate schedule design as those reported in Chapter 6.

These experiments, however, were conducted using *inexperienced* subjects. The contract price patterns are more variable and the rate of market learning appears to be related to the number of competing buyers. Discussion of this point will be found in Section 6.7.3.

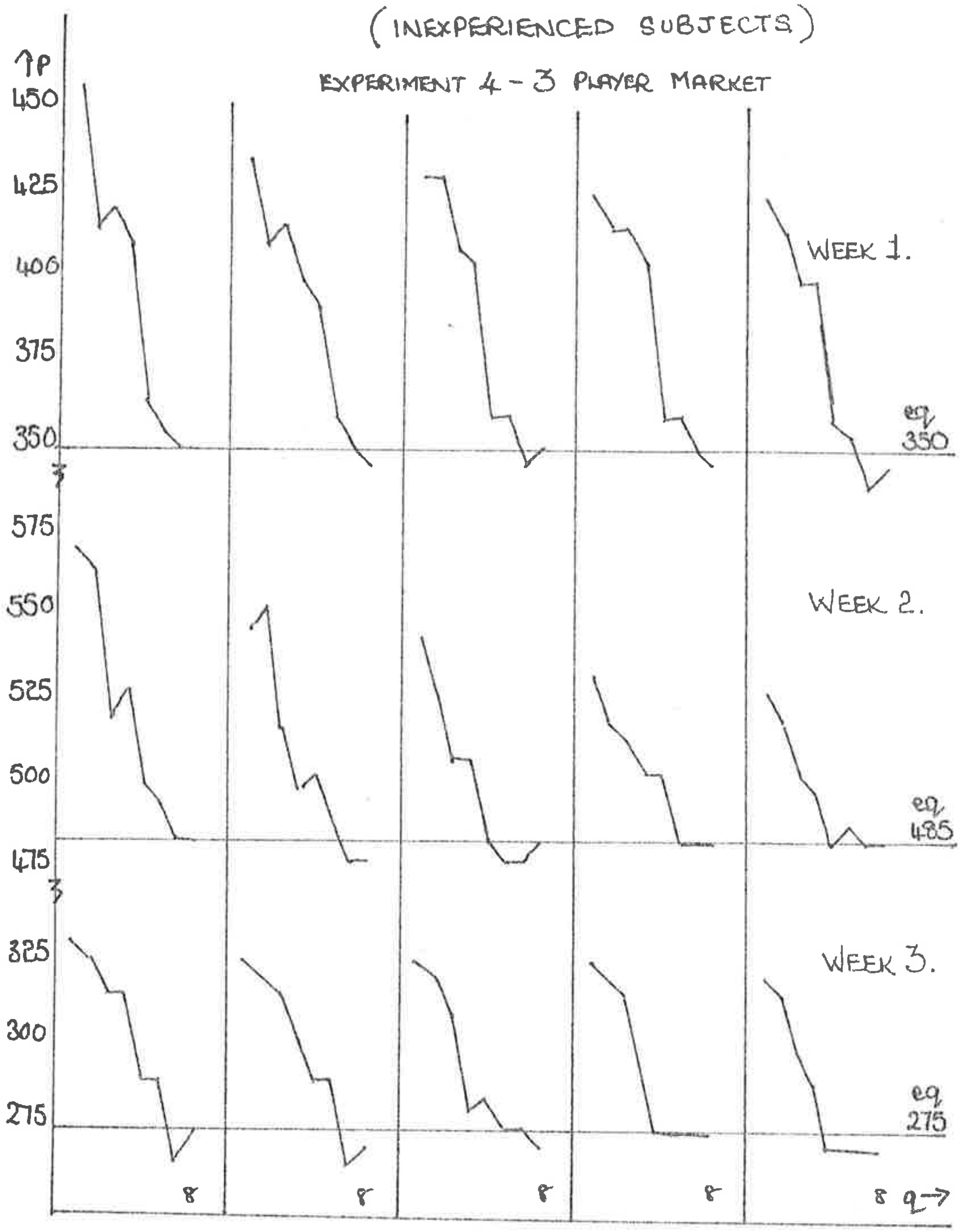

(INEXPERIENCED SUBJECTS)
EXPERIMENT 4 - 3 PLAYER MARKET
↑P
450
425
400
375
350
575
550
525
500
475
325
300
275
WEEK 1.
WEEK 2.
WEEK 3.
eq 350
eq 485
eq 275
8
8
8
8
8 q→

Fig 1

(INEXPERIENCED SUBJECTS)

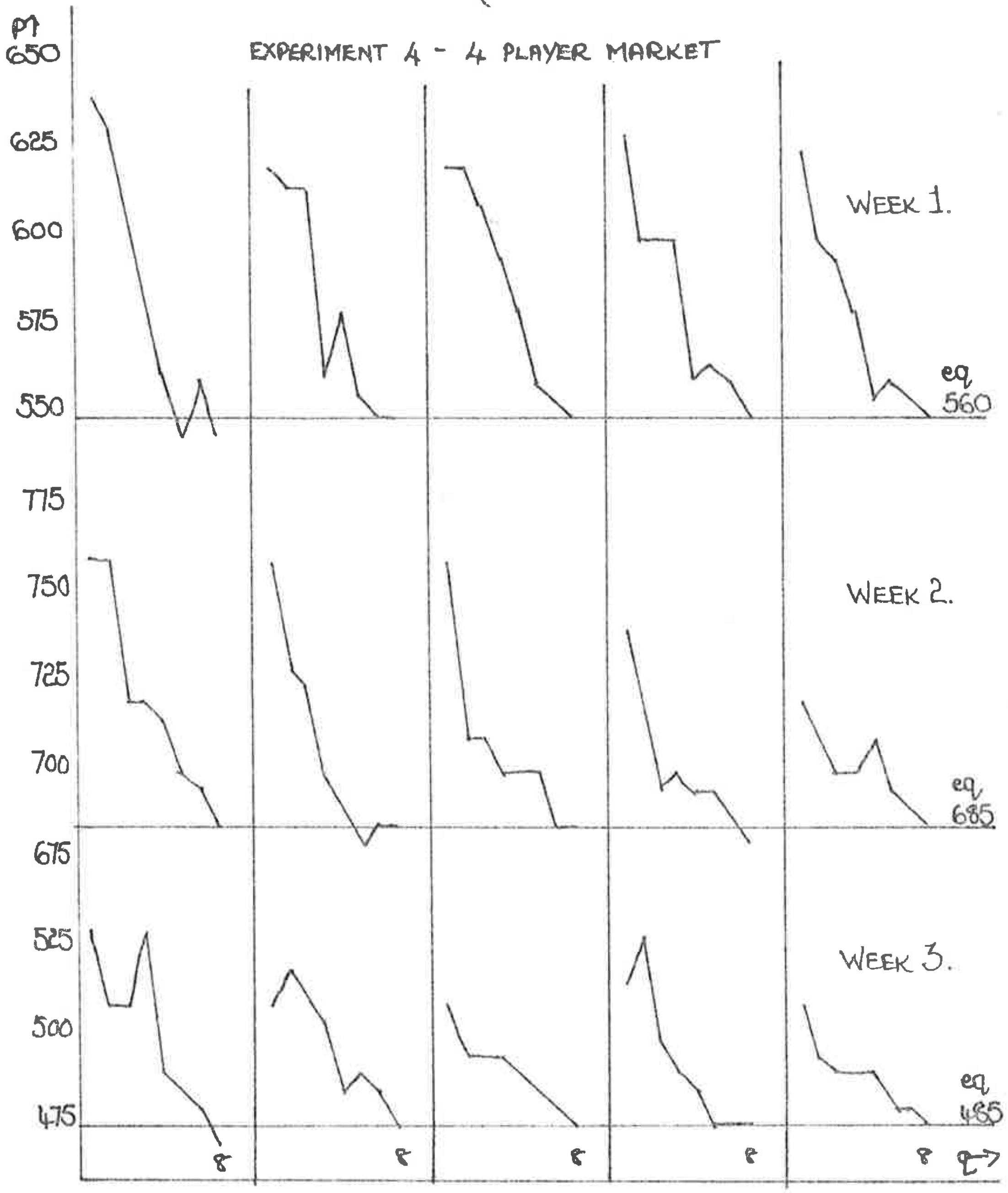
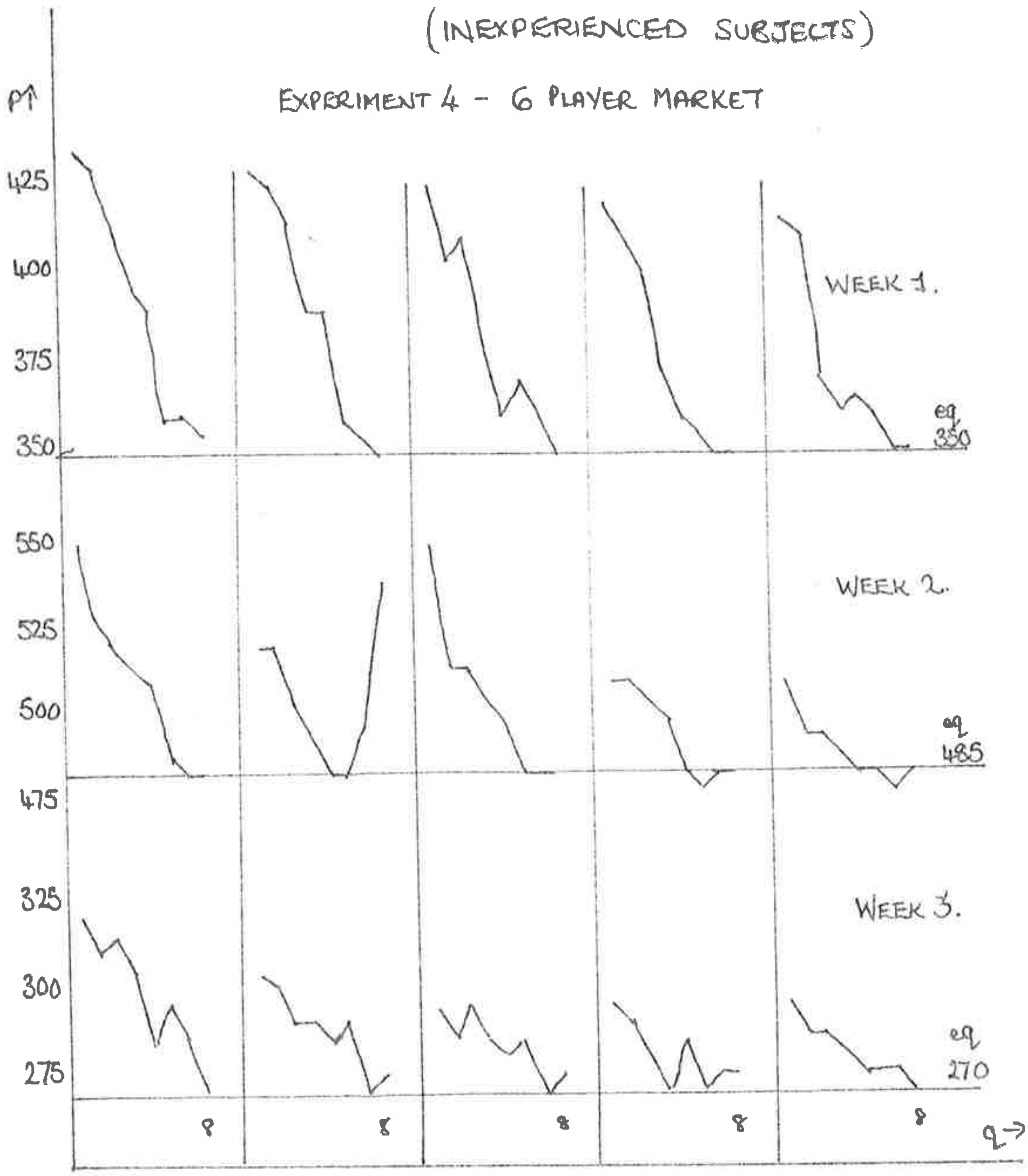


Fig. 2



(INEXPERIENCED SUBJECTS)
EXPERIMENT 4 - 6 PLAYER MARKET
p↑
425
400
375
350
WEEK 1.
eq
350
550
525
500
475
WEEK 2.
eq
485
325
300
275
WEEK 3.
eq
270
8
8
8
8
8
q→

Fig. 3

(INEXPERIENCED SUBJECTS)

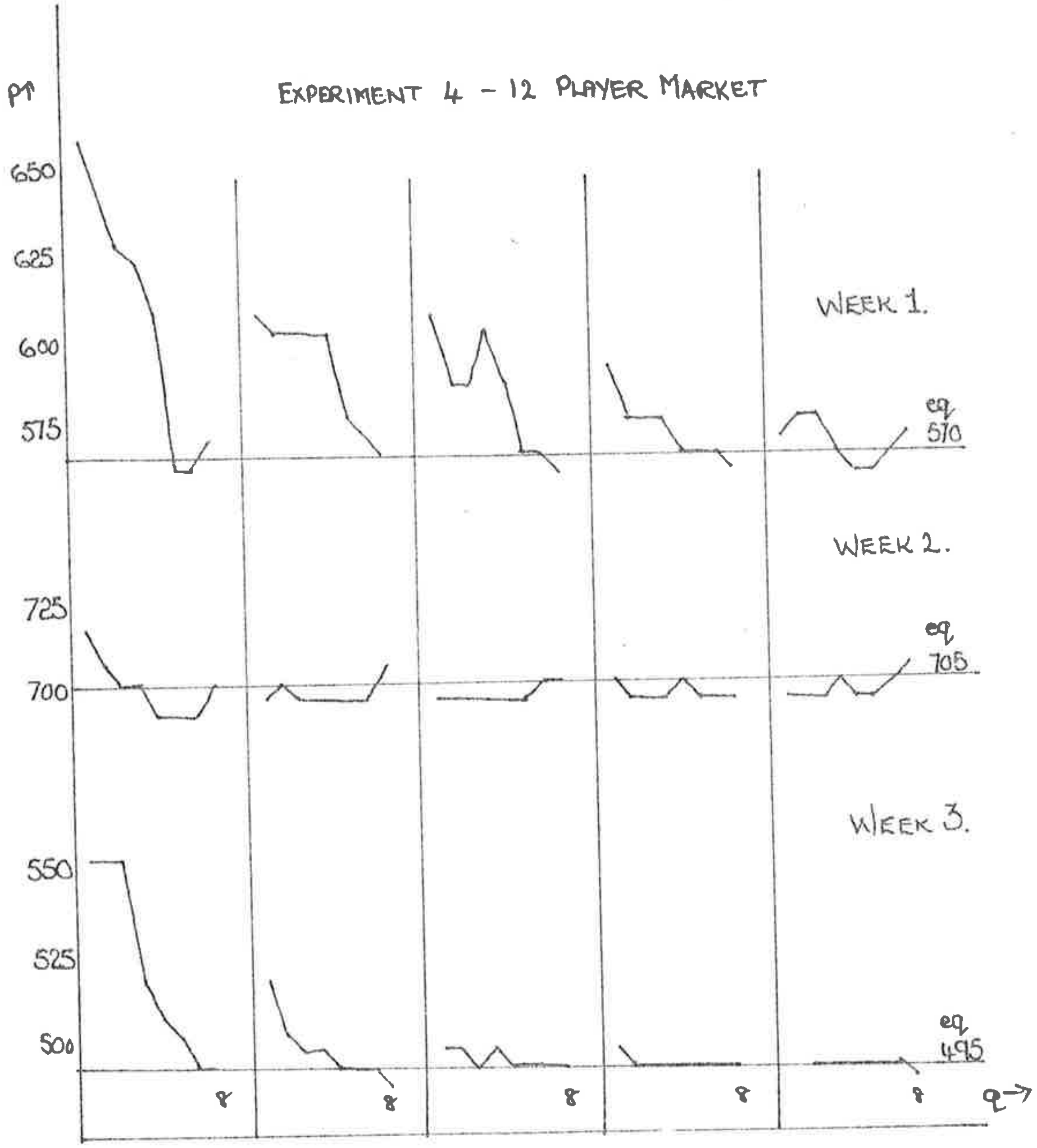


Fig. 4

(INEXPERIENCED SUBJECTS)

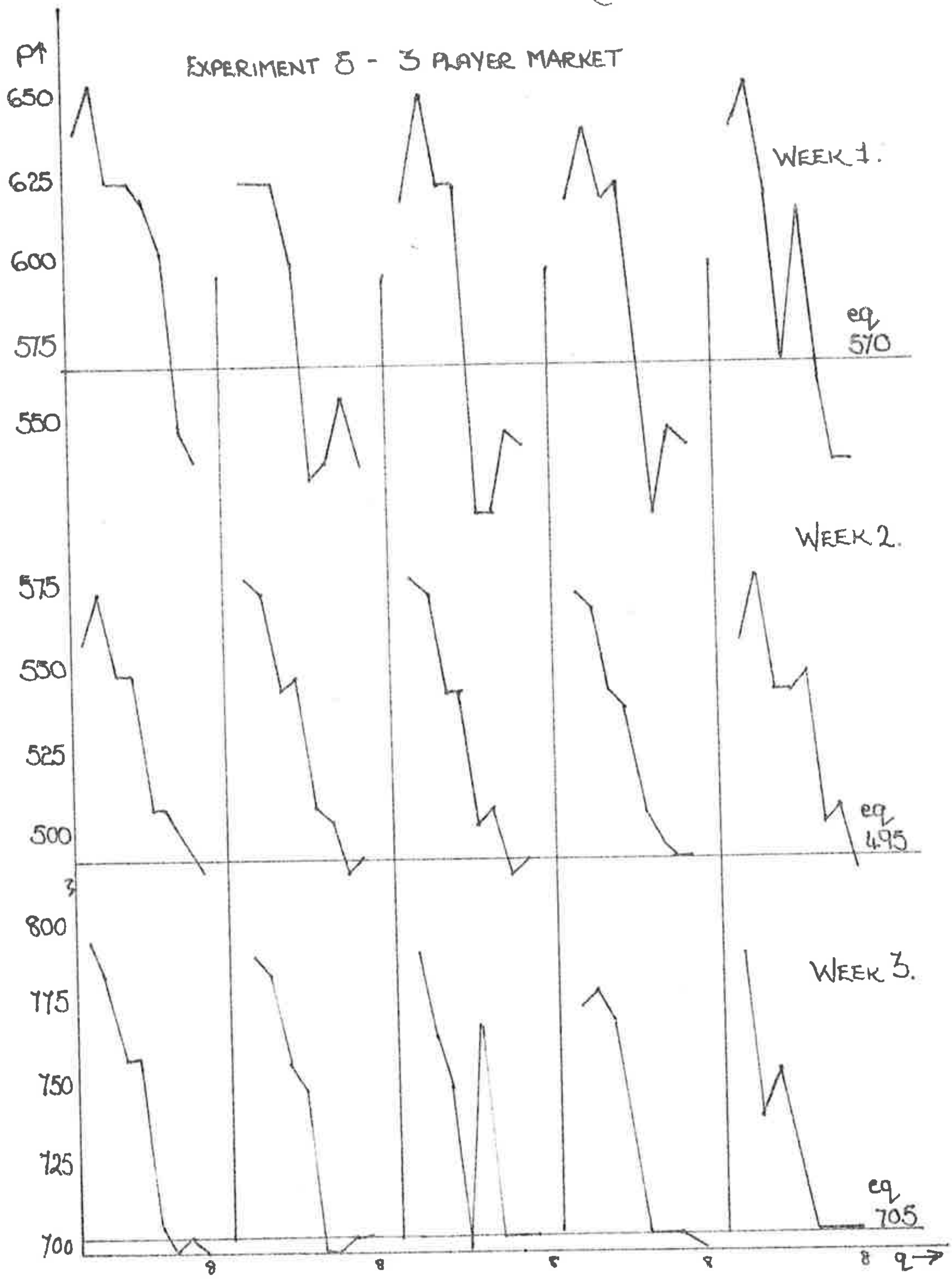


Fig. 5

(INEXPERIENCED SUBJECTS)

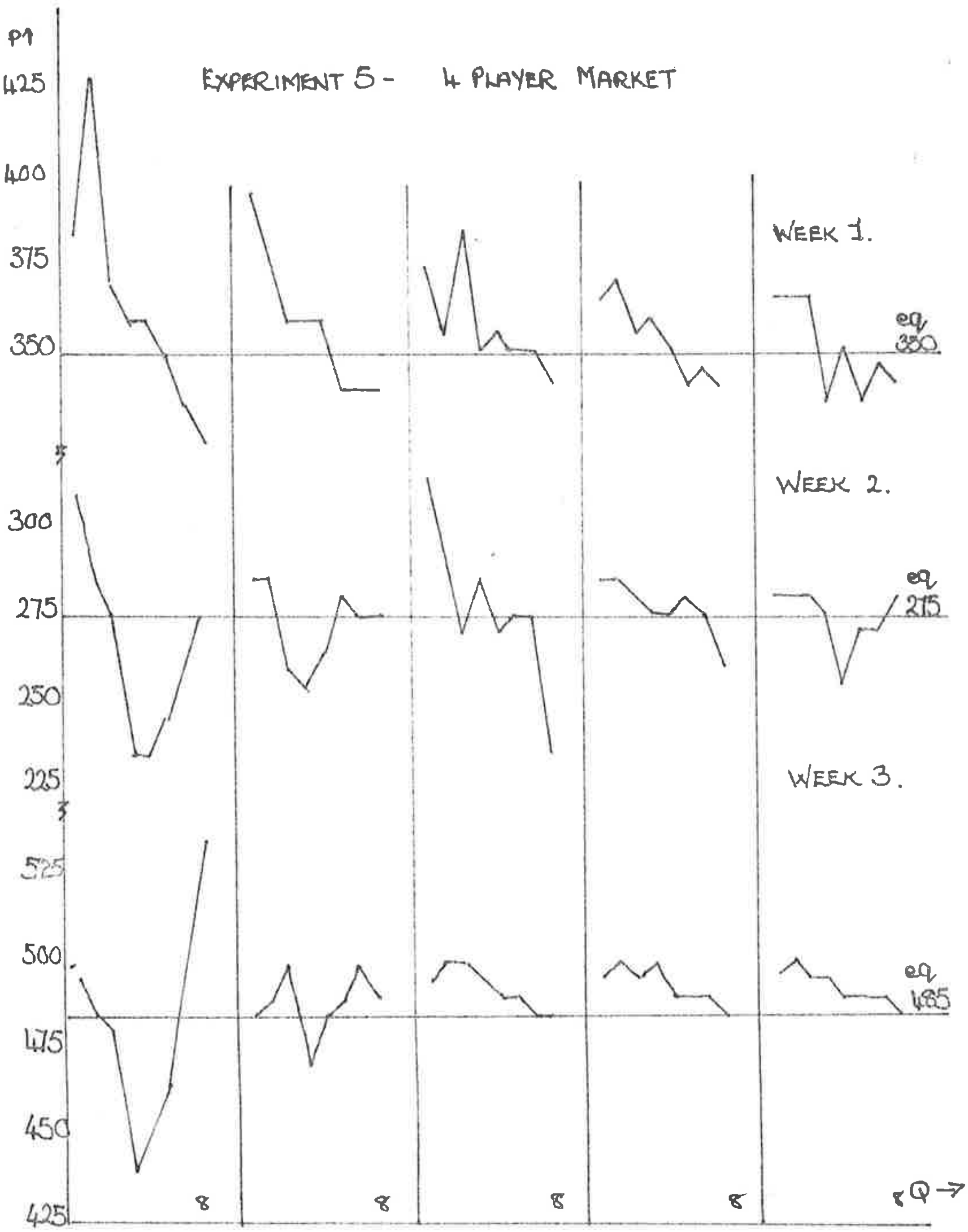


Fig. 6

(INEXPERIENCED SUBJECTS)

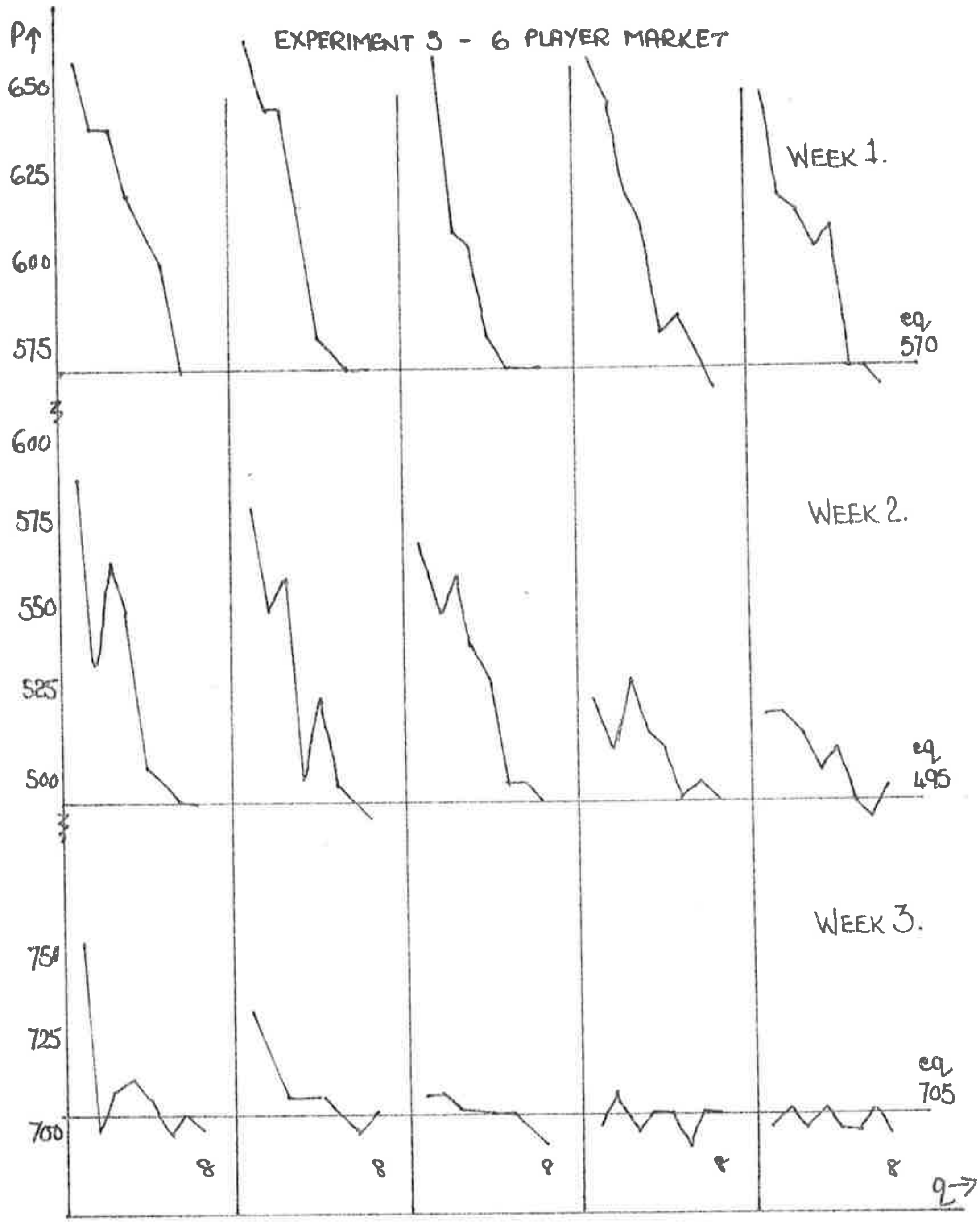


Fig. 7

(INEXPERIENCED SUBJECTS)

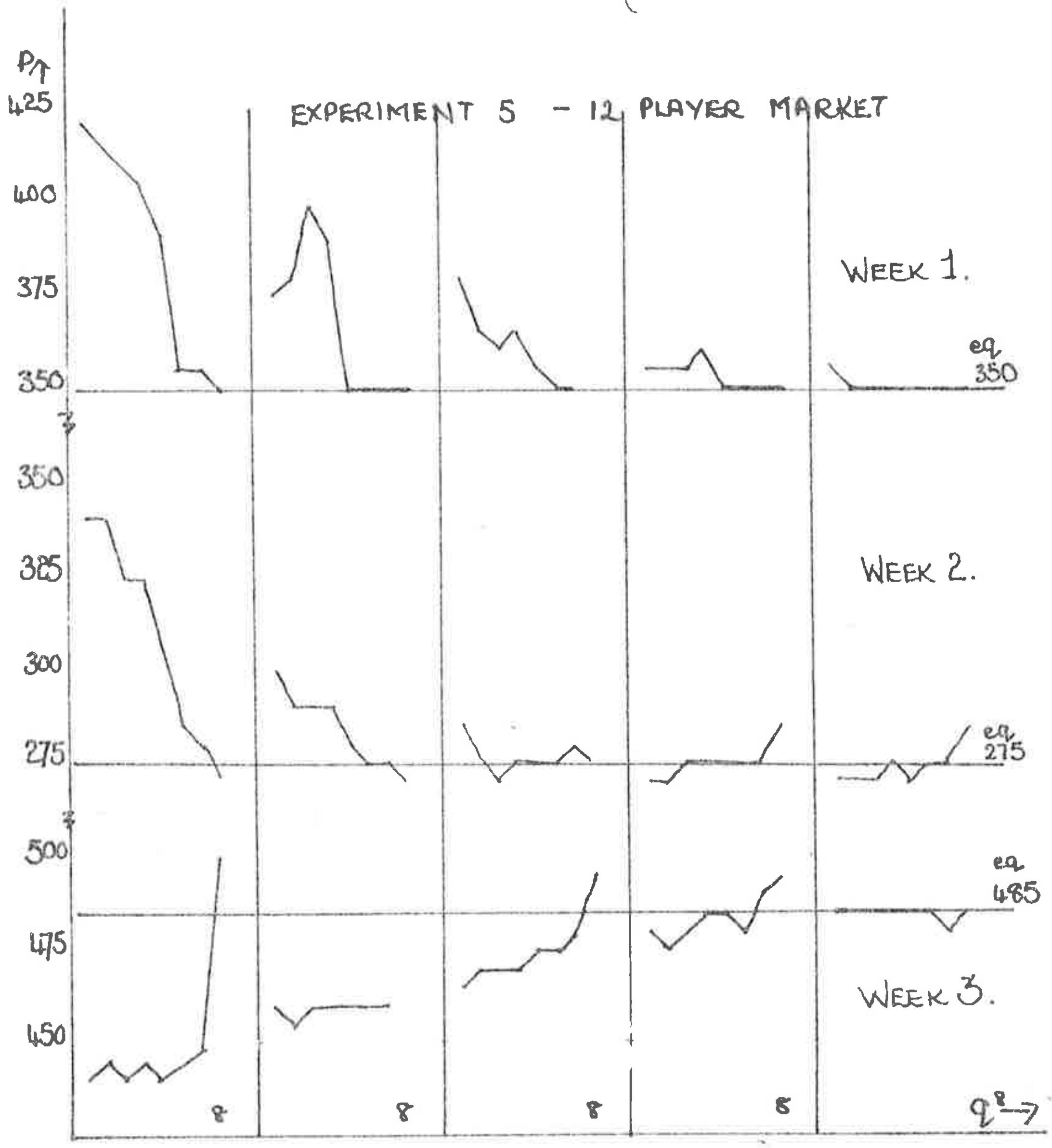


Fig. 8

CHAPTER 7

EXPERIENCE AND DECISION-MAKING: A COMPARISON OF STUDENTS AND BUSINESSMEN IN A SIMULATED PROGRESSIVE AUCTION

CHAPTER 7

EXPERIENCE AND DECISION-MAKING: A COMPARISON OF STUDENTS AND BUSINESSMEN IN A SIMULATED PROGRESSIVE AUCTION

Summary

This study compares the price strategy choices of inexperienced student subjects with those of highly experienced wool buyers. The students are shown to choose the profit-maximizing alternative whilst the wool buyers choose the full value bidding option with its emphasis on attaining quantity requirements. The wool buyers' choice is shown to be related to their experience and to the conditions operating in the actual wool markets with which they are familiar. This difference in strategy choice raises the issue of what is "appropriate" experimental design and subject selection. The current study utilizes a progressive oral auction with homogeneous commodities.

7.1 Introduction

In simulated auctions experienced experimental subjects usually recognize and adopt optimal profit-maximizing procedures more quickly than inexperienced subjects which leads to faster market equilibration and higher efficiency levels. This was illustrated in Chapter 6 (Section 6.7.4) and is supported by several other experimental studies.[1] Is the experience of the experimental market which these subjects acquire, strategically 'equivalent' to the knowledge of, and

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1 For example, Williams (1978) and Smith and Williams (1979) amongst others.

facility with real markets that traders acquire in *their* daily practice? This is an important issue for, while most experimental economic studies to date have been conducted using University students as subjects, critics have objected to this practice on the grounds that students are 'unrepresentative' of the business community for whom they may be regarded as proxies. The level of business experience and attitudes to risk are the two areas of difference commonly cited, with student subjects being regarded as less experienced and (therefore?) less risk averse than businessmen,[2] particularly at the low levels of payments provided.[3]

Reward mechanisms however may be designed that encourage various degrees of risk-aversion or risk-seeking on the part of experimental subjects whatever their natural propensities[4] and the basic problem is not with the student subjects as such, or any other group of subjects, but rather that too little is known about risk-taking in the business community generally. The same may be said for the effects of experience. The present study may therefore be regarded as an information-generating experiment. It is designed to compare and contrast the bidding behaviour of a group of experienced buyers with that of a group of inexperienced student subjects. The model used is a progressive oral auction with homogeneous commodities and the emphasis

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2 The one study comparing risk aversion by age and experience (Binswanger, 1980) showed that there was only a slight difference between young, inexperienced subjects and older, experienced subjects and that, if anything, the young were *more* risk averse.

3 Experimental payments are typically much lower than equivalent amounts in real markets, however payment levels need to be seen in relation to the current income of subjects and traders if a judgement is to be made relating to incentive and risk-taking.

4 Schotter and Braunstein (1981).

is on differences caused by the *levels of experience*; questions of risk and the appropriate level of monetary motivation are not directly addressed.[5]

Section 7.2 describes the two subject pools being compared and Section 7.3 outlines the three trading strategies the experiment is designed to examine. The trading results are presented in Section 7.4 and Section 7.5 takes a closer look at the wool buyers' strategies in the light of buyers' previous experience. For this the experimental results were supplemented by an informal discussion with the wool buyers immediately after the experiment and a telephone interview which was conducted two days later. Section 7.6 then discusses the consequences of these findings for experimental design and subject selection. Section 7.7 summarizes and concludes the substantive part of the study and Section 7.8 discusses some of the methodological issues involved.

7.2 The Experimental Subjects

Nine experienced wool buyers were recruited by the Executive Officer of the Australian Wool Corporation and asked to take part in 'an experiment being conducted by the University of Adelaide'.[6] Everyone contacted agreed to take part in the experiment which was conducted at the Corporation's salesrooms during the wool selling season but on a day during which no sales had been scheduled. Four of the buyers were

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5 A separate study would be needed to decide what would be comparable levels of monetary payment between the two disparate groups.

6 I am very grateful to Allan Harris, Executive Officer of the A.W.C. for his help in this matter and for 'sweetening the pot' for his volunteers by providing food and drinks for the informative discussion session that followed. My thanks also to all nine wool buyers and my colleague and assistant on this occasion, Dr. Janice Gaffney.

officers of the Corporation while the remaining five represented the leading wool broking houses. Each had an average of 35 years experience and all were senior buyers.

Funds were not provided for this exercise and motivation was by mobilizing the buyers' natural competitiveness. This was done by announcing that the "best" trader would be revealed at the end of the session. It was clear that there was quite some rivalry between the buyers from the Wool Corporation, the "ruling body", and those who represented the broking houses, even to the extent that they naturally chose to seat themselves on opposite sides of the room. But even between individuals on the same "team" there was much competition.

Two groups, of nine students each, were chosen for the student subject replicates. The subjects had taken part in one experimental market, not a progressive auction, the year before and had therefore some facility in reading schedules and following instructions; they were, however, inexperienced in the trading rules for this particular market.

Students were second year micro-economics undergraduates who took part in the experiments as part of a course exercise for which an essay was assigned worth 10 per cent of their final assessment. The subject of the essay was not known in advance so that it could not influence the students' behaviour. Instead the students were advised that only by striving to maximize their profits would they gain the understanding necessary to successfully complete the assignment.

In this way both groups were motivated by a desire to succeed in their chosen field, the buyers to be revealed as a "successful" buyer, the students to succeed in their studies.

7.3 The Experiment

A progressive oral auction with homogeneous commodities, similar to that adopted in Chapter 6, was chosen because it most closely approximated the market structure facing the wool buyers. In another environment, say a double auction or a sealed bid tender auction, the wool buyers could not be considered as "experienced".

7.3.1 Examination of Three Trading Strategies

The trading rules of this auction were designed to examine whether buyers chose one of three main bidding strategies. They could choose to *maximize their profits* by attempting to predict the market equilibrium or "cut-off" point and bidding at this level; or they could choose to *maximize their purchases*, subject to not making a loss, by bidding at the level of their average valuation; or they could follow-out some bidding rule such as the *full value bidding* rule described in the last chapter by bidding up to their full valuation, if necessary, on each item.[7]

In Table 1 the buyer valuations are given for each of the three trading weeks. Only Lot 1 and Lot 2 values were actually presented to the buyers; the average values in column 3 were not given but could, of course, be calculated by the traders. The "expected" price is the price that the market would eventually tend towards if all traders were to follow the same strategy and conditions remained constant long enough. So, for example, if all buyers were to attempt to maximize profits the market price would be expected to tend towards the

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7 These represent the major strategies, other variants were also possible but not considered in this exercise.

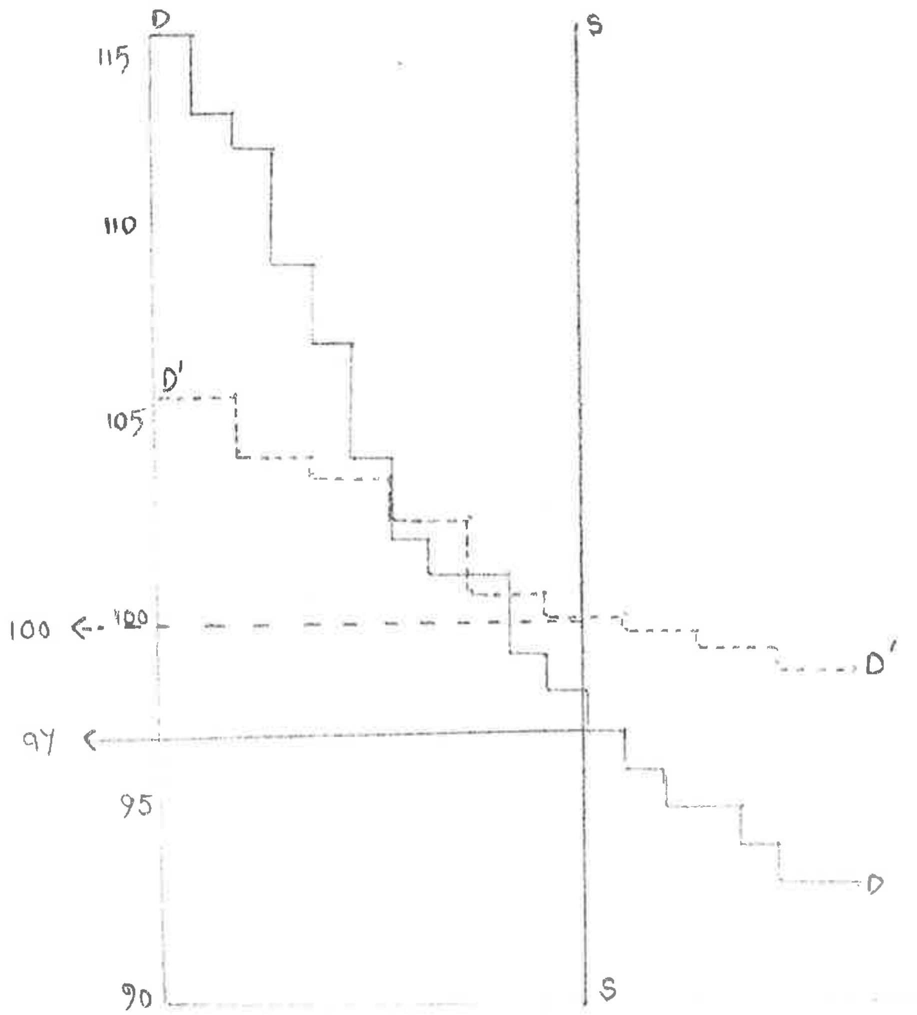
TABLE 1

Buyers Valuations

Buyer	Week 1 Lot 1 1.	Week 1 Lot 2 2.	Week 1 Av. 3.	Week 2 Lot 1 1.	Week 2 Lot 2 2.	Week 2 Av. 3.	Week 3 Lot 1 1.	Week 3 Lot 2 2.	Week 3 Av. 3.
1	115	96	105 1/2	96	93	94 1/2	114	97	105 1/2
2	113	95	104	95	92	93 1/2	111	96	103 1/2
3	112	95	103 1/2	94	91	92 1/2	109	95	102
4	109	94	102 1/2	109	90	99 1/2	106	95	100 1/2
5	107	93	100	107	89	98	104	101	102 1/2
6	104	93	98 1/2	106	89	97 1/2	103	100	101 1/2
4	102	99	100 1/2	103	88	95 1/2	102	99	100 1/2
8	101	98	99 1/2	101	87	94	117	98	107 1/2
9	101	97	99	98	87 1/2	5	115	97	106
Expected average of market price (= equil. value) if marginal values are used			97			91			99
Expected average market price (= equil. value of column 3) if average vaues are used			100			94			102
Expected average market price (= average of 2nd to 13th valuations) if full value bidding is used			103 1/4			97 1/4			105 1/4

FIGURE 1

Demand and Supply Schedules*



* Schedules graphed are for week 1, weeks 2 and 3 are simply rescaled.

theoretical equilibrium or demand-supply intersection. On the other hand if buyers bid according to their average values this would tend toalter the demand schedule to that shown as D'D' in Figure 1. This demand schedule, being flatter, intersects the supply schedule at a higher price. This intersection then is the "expected" price if all buyers calculate average values.

The third strategy considered is the full value bidding strategy by which traders compete on every item, even though they may require only a small fraction of the total supply. This results in the price for each item being equal to the second highest valuation of those buyers left in the market at the time at which the item is put up for sale. Consistently followed by all traders, this practice would lead to a different price being quoted for each item of the homogeneous supply and the expected average market price would be equal to the average of the second to $n + 1^{th}$ valuation, where n is the number of items for sale and the valuations are ranked in decreasing order of value.

It was not assumed that all the buyers in the market *would* necessarily adopt the same strategy but the valuations were chosen so that there would be a clear demarcation between the various "expected" prices and thus any tendency on the part of the market to move towards one or the other could be observed.

In each market every buyer had a demand schedule covering two units, the second of which returned him a lower re-sale value than the first (see Table 1), representing a downward sloping individual demand curve. The rules of the market were that every bid must be an 'improving' bid, there was no stated minimum increment but all bids were to be in whole units. When no bid had been entered for five seconds the item was declared sold to the highest bidder. Fifteen auction sessions were conducted, five in each "week" of trading. During each week demand and supply conditions were held constant and traders were informed that this would be so. At the beginning of each new week demand was changed and traders were informed of the direction but not the magnitude of this change. Full instructions and schedules are given in Appendix 1.

7.3.2 Profit Maximization, Quantity Constraints and Penalties

Buyers were given the general instruction to 'maximize profits' but how this was to be done was left to them. They were not, for example, instructed to bid no more for a unit than its marginal resale value to them.[8] This would have prejudiced the buyers' strategy choice away from the average price strategy and for this exercise it was desirable that these choices be open.

In previous studies penalties have been adopted in place of commissions as a method for stimulating marginal trading for this has proved to be a more powerful incentive where monetary payments are not actually involved (see the discussion on this point, in Section 5.4). Penalties (of 2 per untraded unit) were also adopted in the current study, partly to stimulate marginal trading but partly also because they represent a very real factor in the wool markets where the requirement to obtain one's full demand quota is taken very seriously. The impact of these quantity requirements in real markets is thought to be responsible for the adoption of non-profit maximizing strategies such as average pricing or full value bidding. Thus an important aspect of the

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8 This is an instruction commonly incorporated in experimental instructions to ensure that traders react to the induced demand schedules.

current study was to observe the impact of the penalties on the bidding behaviour of both the wool buyers and the student subjects.

7.4 The Results

The results of the wool buyer experiment and the two student replicates are graphed in Figures 2, 3 and 4 and summarized in Tables 2 and 3 below.

The average daily price of the wool buyer study for the first week was 102.6 and although it declined a little over the week it was closer to the full value bidding (F.V.B.) price of 103.3 than to either of the other alternatives, that is, the average pricing value of 100 or the profit-maximizing value of 97. The sharp fall in price throughout the auction day, which is evident in Figure 2, also suggests that an F.V.B. strategy was being followed here rather than, say, an averaging strategy that took the penalties into account. The latter strategy would have led to a contract price curve which flattened throughout the week centering on the cut-off point of 100 plus two (see Figure 1). This was not the case for the wool buyer study.[9] Moreover, the same price pattern was consistently followed in weeks 2 and 3. In both these weeks the average price was just a fraction under the F.V.B. price.

The student replicates show a rather different picture (Figures 3 and 4). For the first day of the first trading week there is a downward sloping contract price curve similar to that of the wool buyers in Figure 2 but the curve flattens out towards the end of the week with more contracts being at, or close to, the theoretical equilibrium value

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9 Only one buyer out of the nine adopted the average pricing strategy.

TABLE 2

Results of Wool Buyer and Student Auctions

	Average Market Price		
	Wool Buyers	Students # 1	Students # 2
Week 1			
Day 1	102.3	102.3	100.3
Day 2	103.2	101.3	100.6
Day 3	103.2	99.8	99.4
Day 4	102.3	98.8	98.5
Day 5	102.0	98.2	97.9
Average	102.6	100.1	99.3
Week 2			
Day 1	97.3	94.2	94.3
Day 2	96.6	93.8	92.4
Day 3	96.8	93.2	91.8
Day 4	96.4	92.7	91.3
Day 5	96.1	92.4	91.0
Average	96.6	93.2	92.2
Week 3			
Day 1	105.4	99.4	100.3
Day 2	104.3	99.3	99.8
Day 3	105.3	99.3	99.8
Day 4	104.1	99.4	99.8
Day 5	103.8	99.5	99.7
Average	104.6	99.4	99.9

Expected Prices*
(from Table 1)

	Week 1	Week 2	Week 3
Expected Price (Profit-Maximization)	97	91	99
Expected Price (Average Pricing)	100	94	102
Expected Average Price (Full Value Bidding)	103¼	97¼	105¼

* Exclusive of penalties.

TABLE 3

Trader Profits*[10]

	Wool Buyers	Student #1	Student #2
Week 1	60	229	270
Week 2	54	276	339
Week 3	61	387	357

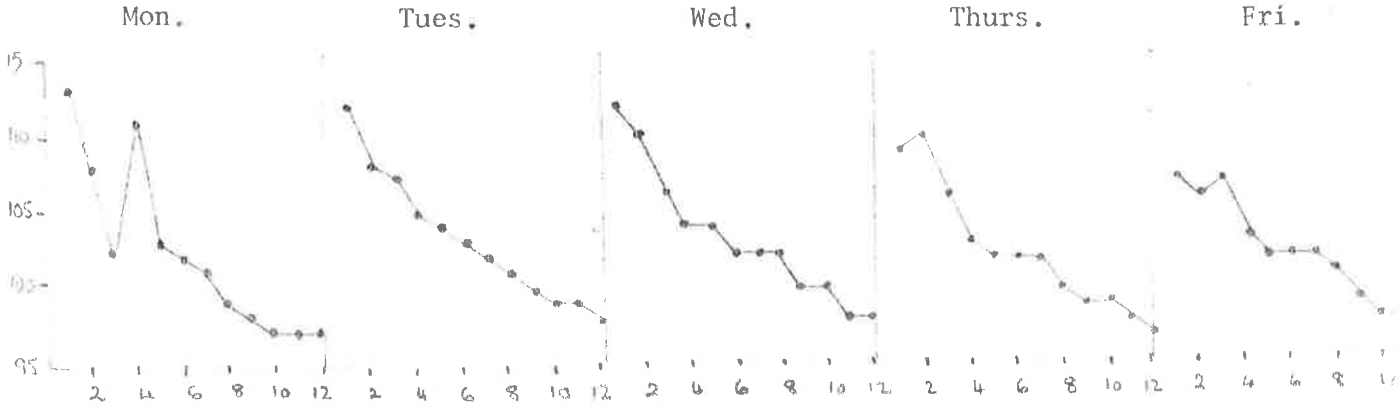
* Potential profits were 410 each week.

10 Only buyer profits have been recorded for this progressive auction as sellers have delegated their responsibilities to the auctioneer and therefore take no active part in the auction. However if seller profits were included total market profits would have been close to 100% in all markets. Only 3 extramarginal trades were recorded in the 30 student auction sessions. 13 were recorded for the 15 wool buyer sessions but 10 of these were due to the one buyer who adopted a predominantly average-pricing system.

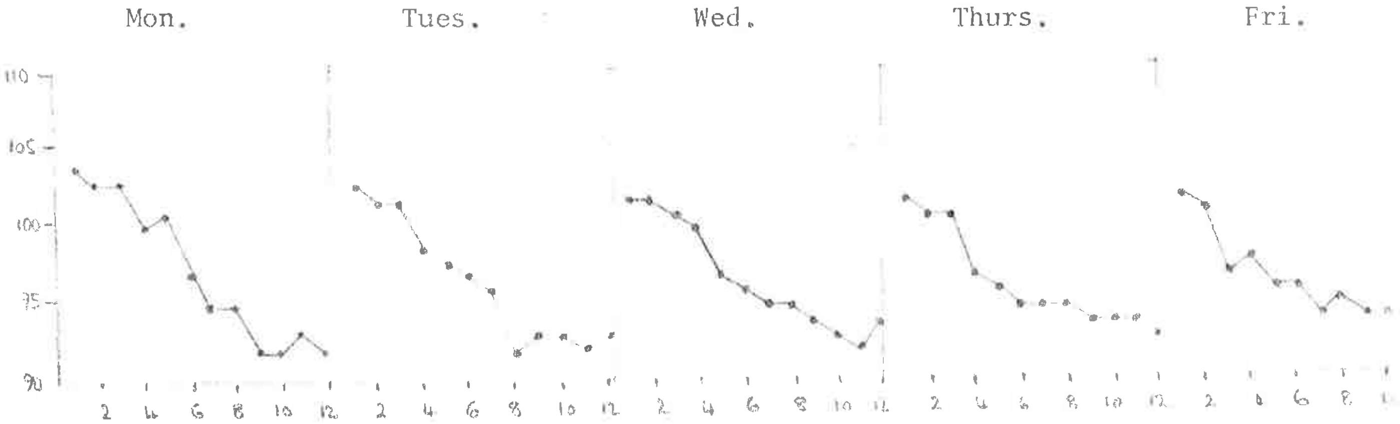
FIGURE 2

Experienced Wool Buyers

WEEK 1



WEEK 2



WEEK 3

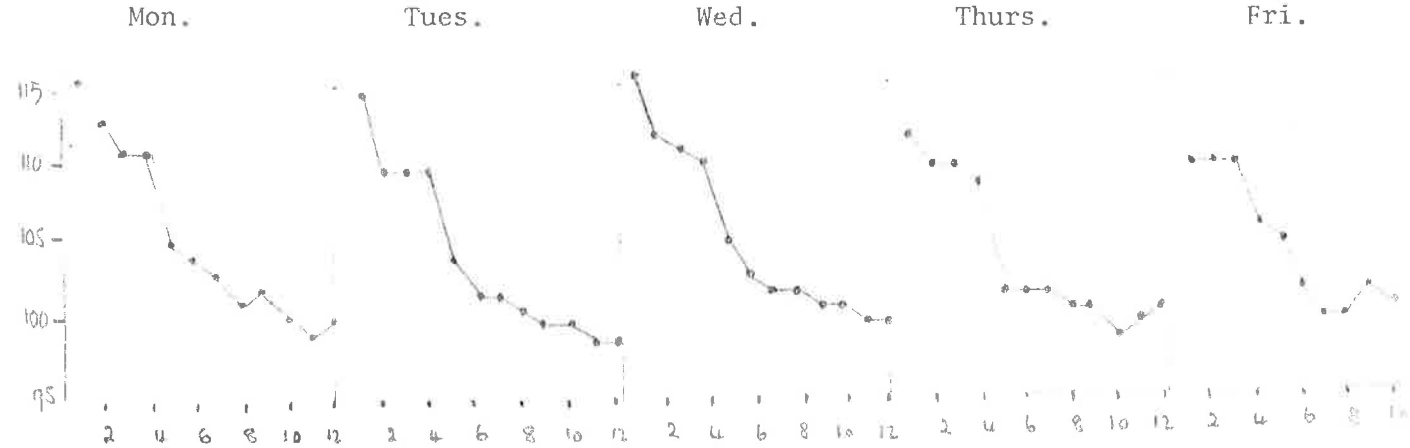
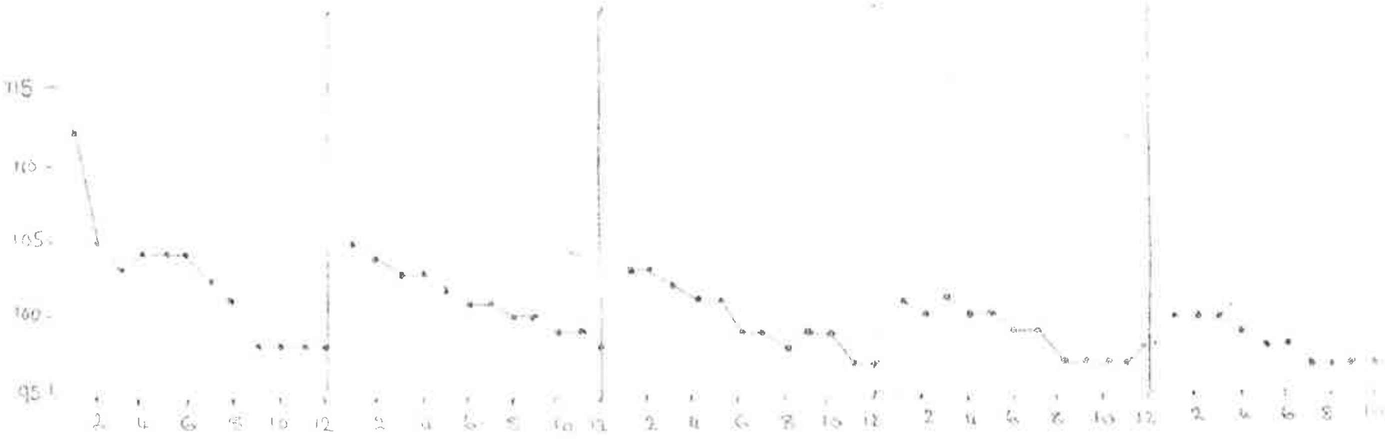


FIGURE 3

Student Replicate #1

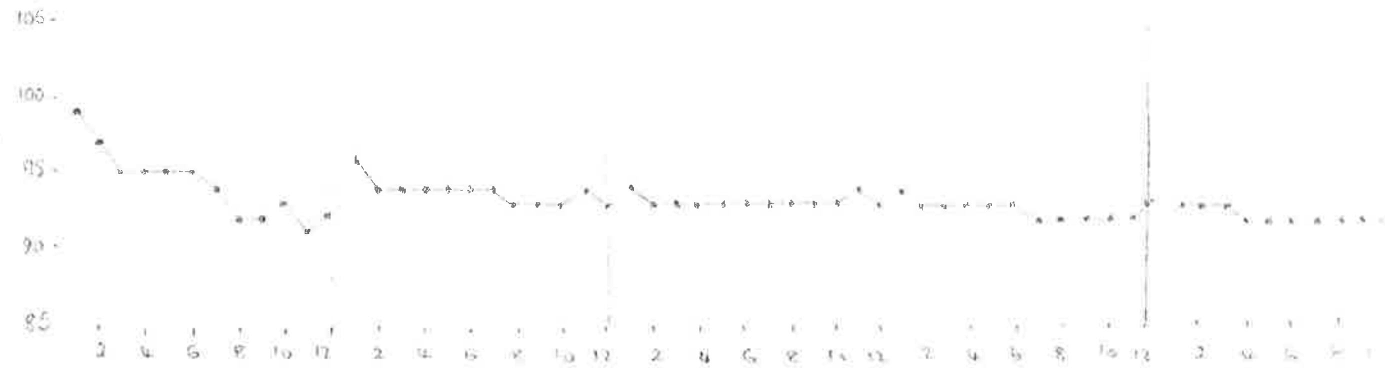
WEEK 1

Mon. Tues. Wed. Thurs. Fri.



WEEK 2

Mon. Tues. Wed. Thurs. Fri.



WEEK 3

Mon. Tues. Wed. Thurs. Fri.

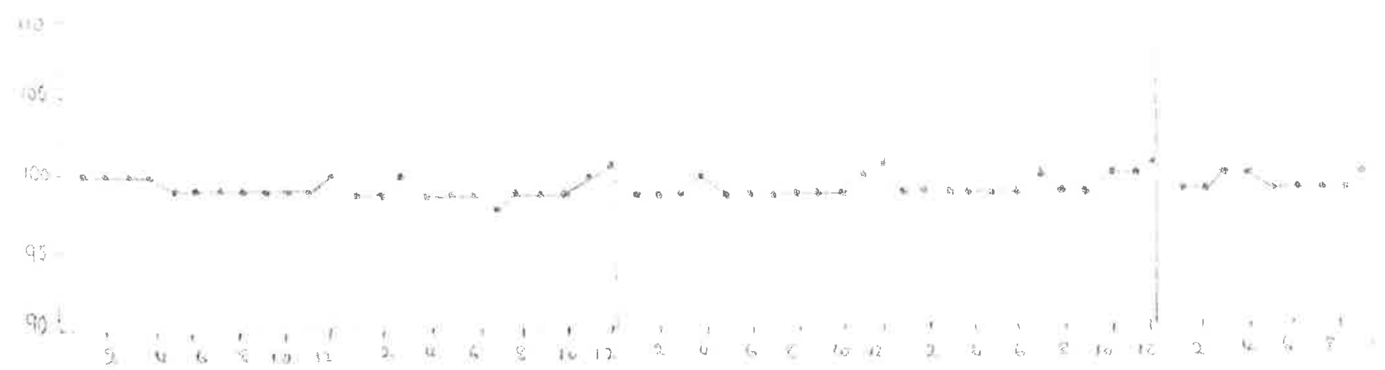
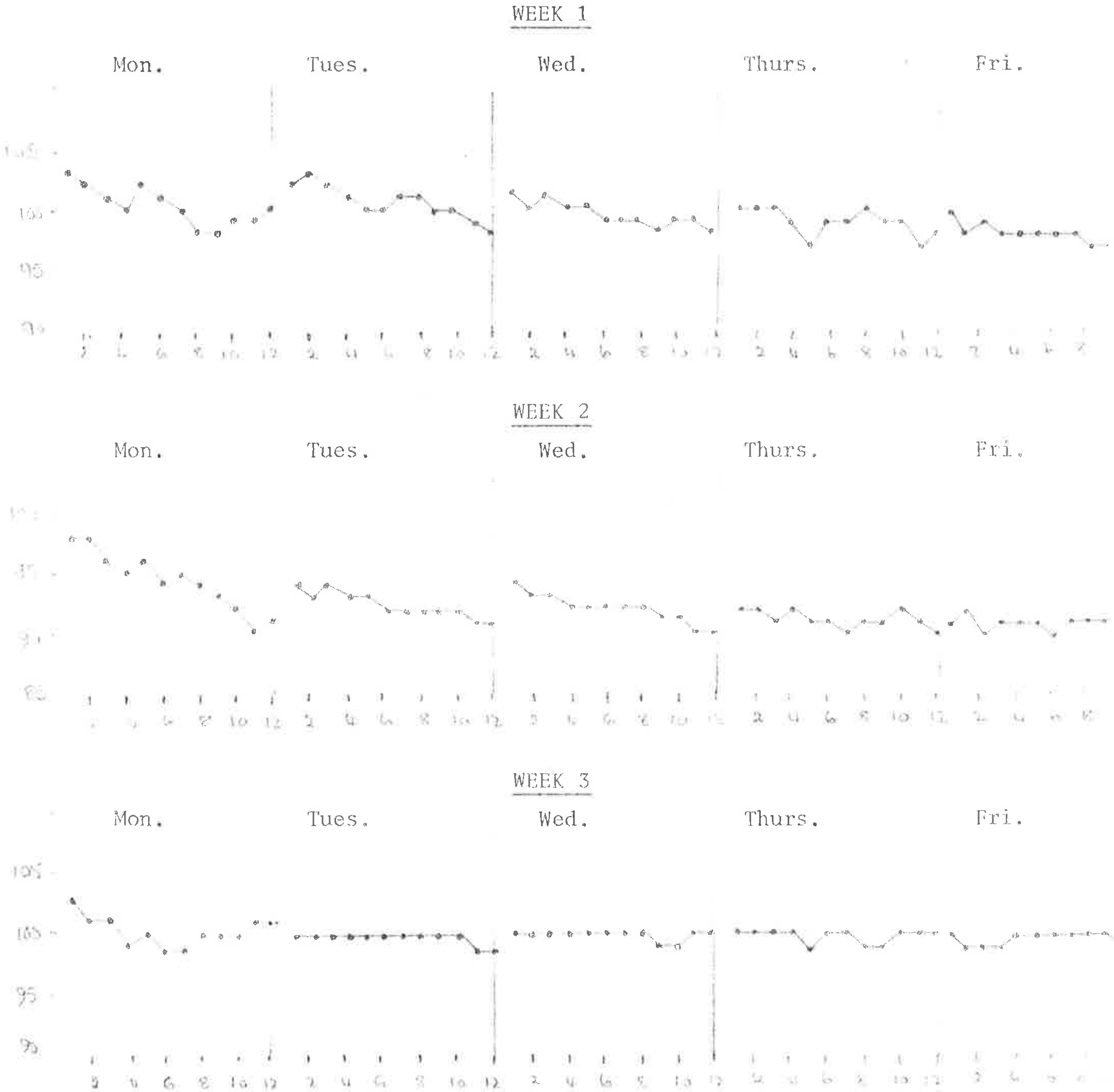


FIGURE 4

Student Replicate # 2



of 97. In each successive week the period of adjustment to equilibrium prices grows shorter, indicating rapid market learning on the part of student subjects.

In general the penalties make only a muted impact on prices in the student replicates, with maybe the last sale item or last few sale items increased above the non-penalty equilibrium value by one unit, not the full two of the penalty. In the wool buyer study, on the other hand the full two unit penalty is frequently invoked. This is consistent with the wool buyers' greater familiarity with the concept of penalties in their previous trading experience.

Not surprisingly, given the strategies adopted, the students make far more profits than the wool buyers, as can be seen in Table 3. The student results are consistent with previous experimental studies which show that students are adept at discovering and adopting the profit-maximizing strategies. Although inexperienced at progressive oral auctions the students quickly learned to operate profitably in the trading environment. The wool buyers did not. Why did the students, who were relatively inexperienced at the market game and had no experience at all in actual auction trading, adopt the profit-maximizing option and the wool buyers do otherwise? To understand this it is necessary to look more closely at what determines the bidding policies of the wool buyers.

7.5 A Closer Look at Wool Buyers' Strategies

The information on which this section was based was gathered from a lengthy discussion held immediately after the wool buyer experiment and a structured telephone interview of all nine buyers two days later.

(See Appendix 2 for the administered questionnaire). From this several important issues emerged.

The first of these is that although this was only an experimental market, a "game", the wool buyers reacted as if it were "the real thing". The buyers were told at the very beginning of the instructions that this was a simplified model of auction trading and different in several respects from the kind of markets with which they were familiar. In particular all the lots on sale could be considered to be of the same quality. The buyers were obviously ill at ease with this concept of a homogeneous good. And with reason. All of their skills, over many long years of trading, have been developed for the purpose of detecting and valuing fine shades of quality differences. The fundamental absurdity of a sequential auction for a homogeneous good was clearly obvious to them, although student subjects never seem to see this and are certainly not affected by it.

In the initial question time the buyers asked whether they could operate cartels (theoretically outlawed but, in practice, still used), whether they could spread their weekly lot requirements over the week, and whether they could "average" over lots, meaning here their practice of acquiring a mill lot of a given average quality from smaller lots of different quality wools. This practice is an important aspect of a wool buyer's work but not at all relevant to the experimental task where there are no quality differences. *In general where the rules of the experimental market conflicted with the market rules that they were used to, the buyers instinctively chose the latter.* This was well summed up by one buyer who commented, 'with us it is a reflex action, possibly others could orientate themselves more quickly'. These reflex actions are important in understanding market behaviour in those transitionary periods between one set of market rules or institutions and another and we return to this in Section 7.6 below.

Past experience not only conditions the rules to which buyers relate but also the information that they recognize and absorb (or interpret and act upon). As Figure 2 shows, each auction session featured a sharp decline in prices, of about 15 per cent, over the session. When they were asked if they had noticed that prices fell during the trading day, seven out of the nine buyers said that they had not. Despite its consistency over 15 consecutive auction sessions *they had not seen the price fall!*

Why had these astute and experienced buyers not noticed such an obvious price pattern? The answer must be given in terms of what happens in the real markets with which they are familiar. Price variation at an ordinary wool auction is to be expected given that different quality lots are put up for sale in successive lots. Price variation of itself, therefore, does not alert the buyer to the possibility of a declining, or a rising, price *trend*. Although records are kept as a matter of course, the actual bidding proceeds at too rapid a pace to allow bidders time to absorb and analyze trends during the auction itself. This work is frequently done by the principal's head office, often nowadays by computer, and if there are any changed instructions these are passed to the agents at the beginning of the next auction day. Moreover the task of record-keeping for subsequent analysis is the work of a junior in the firm, not the senior buyer who was represented in this experiment. Given these facts it is not difficult to understand why the buyers failed to see the price trend; their prior experience had, in fact, "conditioned" them not to notice it. The students lacked this conditioning and so were able to observe, and subsequently to take advantage of, the price fall.

A third feature of the buyer's bidding strategy was their habit of bidding up the price of lots that they were not interested in acquiring and they would frequently bid up another player even after they had acquired their two lots. They acknowledged that this practice was also common in their normal trading 'just to keep the others honest' as they put it. It was a key determinant in their market pricing and largely accounted for prices being close to the F.V.B. limit. Competitive "bidding-up" is frequently observed in the early stages of experimental markets with student replicates, even when monetary payments are used. It seems some subjects are more interested in preventing the success of another than in securing their own. This "perverse" behaviour in student experiments has, however, real world significance in the wool market, on two accounts. First, competitors in the current market are most likely to meet again in any future resale market. By allowing another, now, to buy a lot cheaper than he himself has been able to do will permit that competitor to undercut his price in the resale market. (While agents buy on commission, they also purchase on their own account for future speculative selling). And secondly, it makes a buyer look incompetent to have bought at a price above the going level. In the competitive agency world this may not only mean a loss of face but also the loss of a job. On the other hand agents are not encouraged to seek prices lower than the valuations they have placed on the lots; to the extent they succeed the profits are not theirs and, to the extent they fail to acquire a unit they could have afforded to buy, they reap their principal's displeasure. As one buyer put it, if a lot was sold to another buyer at his own upper limit price the principal 'would want to know the reason why'.

It would appear that the buyers valuations in practice are quite close which puts a premium on being 'the first in with a bid'. Among the nine buyers one was recognized by the others as their superior, not on account of securing lots more cheaply than others but on account of being extremely fast in bidding.

Taking an overall look then at the trading experience of the buyers we can see four features of that experience that encourage full value bidding. First there is the added risk of not securing a required lot when there are *quality differences* in the lots on offer and an uncertain demand for any particular lot. Secondly, there is the *speed* of the auction which makes strategic planning difficult. Thirdly, there is the *competitive bidding-up* aspect and fourthly there is an *emphasis on quantity* rather than price when the bidders are agents for others.

Students, lacking this experience, do not react in the same way. Is this an advantage or a disadvantage?

7.6 Subject Selection and Experimental Design

The wool buyers, in this experiment, reacted *not* to the opportunities and incentives present in the experimental market but to those present in other situations with which they were familiar. If the object of the experiment therefore is to measure reactions to the *experimental* conditions and objectives it is unproductive to choose as subjects those whose prior experience is contrary to the current design requirements; for they will have difficulty in adjusting to a new frame of reference with consequent sub-optimal behaviour. This behaviour will eventually change as more knowledge of the new system is acquired but it may require a lengthy learning or transitional period.

Sometimes, however, this transitional behaviour may itself be the focus of attention as, for example, when the U.S. Treasury considered changing the basis of its sealed bid tender for Treasury bills from discriminatory to non-discriminatory pricing.[11] In this case the experimenter will be better able to control knowledge conditions if subjects with no particular expertise are used, first adjusting fully to one set of conditions and then being exposed to the new rules or conditions. The use of businessmen experienced in one set of rules introduces many unknowns which may confuse the issue and make interpretation impossible.

The major role that experienced businessmen or traders can play is in *model development* or the design of the experimental market itself. Where it is desirable to model a particular market institution the comparison of the performance of an unbiased subject group, such as the students used here, with the performance of the experienced business group, can point up issues of importance to the model that the theoretician may miss. A thorough de-briefing or post-experimental discussion is essential to this task.

7.7 Summary of Experimental Results

The results of the three auction market experiments reported in this chapter strongly suggests that the experience possessed by the wool buyers as a result of their years of trading activity is not strategically equivalent to the kind of experience being simulated, in general, in these experimental markets. An experienced market player

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11 An experimental examination of both systems and, *inter alia*, the transitional phase, is found in Smith (1967).

operates more efficiently within the simulated environment because of his experience is relevant to the current task. Not only was the wool buyers' more detailed and complex experience not relevant, they were in a worse position than novice students in that the nature of their experience retarded new learning.

The major benefit of experimental market models is that they can be used to examine aspects of market behaviour under very simplified market conditions - as restricted, indeed, as the market theories they are designed to test. It is this very simplification that makes experienced market traders inappropriate subjects. However, in simplifying market structure for the purpose of theoretical examinations, it is necessary to eliminate inessential elements and the choice of what is inessential is determined by the theory being adopted. Here the use of experienced market buyers may be of great value. Where the relevance of the theory is in doubt the use of a comparison study may suggest new areas of investigations and modifications to, or replacement of, the theory.

7.8 Methodological Critique

Chapter Seven has been a study in experimental method to a large extent and thus most of the methodological issues have already been discussed. This section, therefore, will be quite brief. Two points, however, should be noted.

The first is the necessity to distinguish clearly between the various different choices. This has not always been done in previous experimental studies,[12] partly through poor experimental design but

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12 This was a problem, for example, in Friedman and Hoggatt (1980).

mostly because the nature of experiments often means that the experimenter only gradually becomes aware of the different possibilities. Here the expected prices have been clearly separated for each strategy choice. Since it was possible for the group as a whole to have mixed strategies, or, indeed, to switch from one strategy to another as the learning process progressed, it was necessary to supplement the average price distinction with observations on the price contract curve which shows the pattern of adjustment of prices over each auction session. This, for example, made it possible to rule out the likelihood that the average price of 102.6 obtained in the first week of trading for the wool buyers was obtained by a policy, on their part, of averaging their two values and adding on the plus two penalty. As pointed out in Section 7.4, this would have resulted in a price contract curve which initially followed the rather flatter demand curve D'D' (Figure 1) and which became progressively flatter as the market became aware of the appropriate cut-off point. Instead the curve was steeply downward sloping in all auction periods supporting the F.V.B. hypothesis.

The magnitude of demand changes from one weekly period to the next was kept within the range of ±10 per cent because, from observation, this was the common limit to fluctuations that could be expected in wool auctions from one week to the next. Cumulative weekly changes could, of course, account for much larger swings over a wool selling season. As the objective of the exercise was to maximize the opportunities for the experienced wool traders to reveal the effects of that experience the magnitude of demand swings was less than is generally the case in experimental markets. In the event this seemed to make it easier for the student subjects to adjust to the changes rather than the wool buyers. It is important to recognize the compromises that often need to be made in experimental design with requirements of one objective being traded off against another, and to note the effects that this may have on the results obtained.

APPENDIX 1

EXPERIMENTAL AUCTION MARKET.

INSTRUCTIONS.

The experimental auction market in which you are about to participate has not been designed to model any specific market, such as wool. In fact in two key respects it differs quite considerably from markets with which you are familiar. The first of these is that all the units available for sale in this auction are identical in terms of quality. The second is that you are required to buy a given number of units (which is detailed on the accompanying schedule) but each successive unit is worth less to you than the preceding one. Thus you may be told that you will be paid $50 for the first unit you acquire, $47 for the next, $43 for the next, etc. These are your 'resale values', that is, the values for which you can theoretically resell your units to the experimenter.

The aim of the experiment is for you to attempt to make as much profit as you can. To make a profit you must pay, in total, less than the sum of the resale values for the units that you have purchased. For example, using the values above, if you had been able to buy two units for a total of $80 your profit would be $50 + $47 - $80 = $17. However there will be a penalty of $2 for every unit that you were asked to purchase and did not. Thus, in the above example, if you had been asked to purchase 3 units and bought only 2 then your final profit would have been $17 - (Penalty of $2) = $15.

PROCEDURE.

The auction works this way: at the beginning of each auction 'day' the auctioneer will announce the number of units that are available for sale and the starting bid level whereapon the floor will then be open for bidding. Each bidder will call out his bid, minimum increment $1, and when a space of 4 seconds elapses without a bid having been entered the auctioneer will declare the unit sold to the highest bidder at his bid price and the next unit will be put up for sale/ When all units have been sold that is the end of the first auction day. The market straightaway opens for the next auction day. For the first five days, 'Monday' through 'Friday', the values for each buyer remain constant. Instructions are daily instructions and the request to 'buy 3 units' refers to each individual auction day. A unit not purchased on one day cannot be bought later in the week. Similarly advance purchases cannot be made. At the end of the week buyers values change. You will then be told whether there is an increase or decrease in demand. Trading will continue for several weeks. In order for the auctioneer to tell the buyers apart, every buyer will be given a buyer number to be used when bidding, thus "No. 5 bids $42" or, more simply, "5 - 42'. All bids will need to be recorded so please speak clearly.

PLEASE DO NOT REVEAL YOUR BUYER VALUES TO ANYONE.

Are there any questions?

NAME................................

BUYER NO..........

You are requested to purchase units

		First Unit	Second Unit	Third Unit		
MONDAY	Values				Total Value	
	Costs				Total Cost	
					Profit	
					minus Penalties	
					Net Profit	
TUESDAY	Values				Total Value	
	Costs				Total Cost	
					Profit	
					minus Penalties	
					Net Profit	
WEDNESDAY	Values				Total Value	
	Costs				Total Cost	
					Profit	
					minus Penalties	
					Net Profit	
THURSDAY	Values				Total Value	
	Costs				Total Cost	
					Profit	
					minus Penalties	
					Net Profit	
FRIDAY	Values				Total Value	
	Costs				Total Cost	
					Profit	
					minus Penalties	
					Net Profit	

Total Profit (Net) for the Week. | |

APPENDIX 2

Questionnaire for the Wool Buyers, June 9th, 1981

1. What did you think you were going to be asked to do when you agreed to take part in the game?

2. Did you understand the rules of the game (a) in the beginning? (b) later? (c) not at all?

3. The experiment differed in many ways from the trading you are used to. Which ways did you think were the most important?

4. Did you take the game seriously (a) from the start? (b) later? (c) not at all?

5. Did you notice that the prices fell during the day? What conclusions did you draw from this?

6. How did you feel when you found that you could not buy your second unit? What did you do then?

7. What was the penalty for not buying the full two units? Did you ever consider that just buying one and taking the penalty would make more profit for you?

8. What was your main objective? To increase profits, or to get your two lots?

CHAPTER 8

QUALITY DIFFERENTIALS AND FULL VALUE BIDDING BEHAVIOUR IN TWO AUCTION MARKET SIMULATIONS

CHAPTER 8

QUALITY DIFFERENTIALS AND FULL VALUE BIDDING BEHAVIOUR IN TWO AUCTION MARKET SIMULATIONS

Summary

An exploratory study of the effects on buyer behaviour of including quality differentials in auction market simulations. Two auction markets are examined: a traditional sequential progressive auction and a new resource allocation mechanism - the simultaneous progressive auction. Monte Carlo simulation is combined with experimental market analysis to bring out the implications of the two auction types under quality differentiation.

8.1 Introduction

The experimental studies reported in previous chapters have been concerned with the assumptions which may reasonably be made about buyer behaviour at auction. Chapters 6 and 7 focussed on the English, or progressive, auction and, in particular, on the assumption of full value bidding (FVB) at such auctions. Chapter 8 continues the examination of FVB behaviour but it does so in the more realistic market setting of a progressive auction with heterogeneous commodities.

Laboratory experimental studies to date[1] have assumed homogeneity

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1 As at October 1982 I know of no laboratory experimental market using heterogeneous commodities although I believe that T. Ledyard and others have been working on experimental studies with two inter-linked markets. The principle of market interdependence would appear to be common to both studies.

in the hypothetical trading unit as a simplification. For some market conditions this may be a reasonable procedure, for example, treasury bills are homogeneous and sold by auction - a simultaneous, sealed bid, tender auction. But selling homogeneous commodities by a *successive* auction, such as the English auction examined here, is absurdly inefficient. More to the point, making such a simplistic assumption as homogeneity in a successive auction may obscure a vital element of real auctions, namely the uncertainty that heterogeneity produces.

Theoretically one can deal with heterogeneity by grouping reasonably similar commodities into homogeneous sub-sets of the heterogeneous market and dealing with each sub-set as if it were a separate market.[2] This is acceptable if buyers, too, can be grouped into the same sub-sets. At a cattle auction, for example, if buyers of two-year-old Friesian heifers are interested only in that sub-grouping and no other, the sub-group could be considered a separate market.[3] However, if buyers are also interested in other types and ages of cattle, especially if they have financial or capacity limits, then the price decided in any one sub-market is a function of the prices being determined in every other and it is no longer possible to deal in terms of independent homogeneous sub-sets. Such interdependence adds greatly to the complexity of the decisions that need to be made by buyers if optimal profit-maximization strategies are to be employed and Sosnick (1963) has suggested that this complexity could be a major reason for

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2 For example, see the theoretical (non-experimental) study of heterogeneous markets by Schwartz and Wilde (1981).

3 Although one might well wonder if a more efficient sale method could not be devised which would prevent buyers wasting their time in attending the auction of cattle in which they were not interested.

the use of the simpler FVB rule.

In the first part of this chapter, Section 8.2, Sosnick's conjecture that the complexity of heterogeneous commodities will lead market traders to adopt full value bidding is tested using laboratory markets with heterogeneous commodities. The implications of FVB for the level and variance of prices of heterogenous commodities sold by sequential auction are examined in Section 8.3 which leads to the development, in Section 8.4, of a new resource allocation mechanism, the simultaneous progressive auction. This mechanism is designed to avoid the disadvantages shown to be associated with sequential auctions but to retain the advantage of progressive bidding. In Section 8.5 computer simulations compare the performance of the simultaneous and sequential auctions. This is followed by a second laboratory experiment in which the behavioural assumptions underlying the new simultaneous progressive auction are put to the test. Both experiments, which incorporate heterogeneous commodities, should be regarded at this stage as pilot experiments only. Discussion of their findings and future research directions comprise Section 8.7, and Section 8.8 deals with several of the methodological problems involved in the studies.

8.2 A Progressive Auction Market with Heterogeneous Commodities

8.2.1 Introducing Quality Differences

In the wool market, and the same is true of other commodity and resource markets such as those for cattle or oil leases, an item may be valued differently by different buyers because the various physical attributes it possesses are of varying importance for the different end uses the buyers have in mind. In addition there may be "errors of estimation" associated with each assessment. Estimation errors have been well discussed in auction literature, under the rubric of "winners curse". This is a well-known feature of auction buying whereby the successful buyer is the one who has over-estimated the true worth of the commodity by the greatest amount. In the current study such estimation errors are considered not to exist. Instead, differences in valuations occur solely because of different end uses.

To simulate this situation the buyers in the experimental market were presented with ten lots of a commodity called wool, which they were assumed to have examined and appraised. Each lot could with modification (say extra scouring or bleaching) be made suitable for the buyer's needs. However modifications cost money and therefore the more pre-processing the lot required in order to attain some desired standard the lower would be the price the buyer would be prepared to pay for it.

Since the buyer could purchase any lot the difference between his own lot valuations represented the differential costs to him of processing the wool. Between buyers, different end uses would account for different buyer assessments of the same lot. This representation of quality differences in the market resulted in the matrix of valuations given in Table 1 where a row represents one buyer's estimation of the value of all lots and a column represents a particular lot and the varying assessments made of it by all buyers.

8.2.2 Experimental Design

The instructions and schedules for this market are given in Appendix 1. They are similar to the rules for the progressive auction experiments of Chapters 6 and 7. In brief they were: progressive oral bids, no buyer permitted to bid more than his resale value, and each buyer to acquire up to two lots of the commodity with penalties attached to lots that were 'commissioned' (i.e., listed on the demand schedule) but not purchased, as explained in previous chapters.

The primary object of the experiments was to determine whether, when faced with quality differentials in the sale commodity, buyers would opt to follow full value bidding practices. In previous experiments using homogeneous commodities (Chapter 6), the FVB rule had, in general, not been adopted.

Those experiments had also suggested that certain market variables had a significant effect on market prices, namely the number of market buyers, the relationship of average quota to the overall supply, and the level of "excess demand". Excess demand was defined as the percentage by which the sum of units listed on the individual demand schedules ("aggregate demand") exceeded the given and fixed supply ("aggregate supply"). As a secondary objective then, the present study aimed to throw more light on the significance of these variables. Unfortunately, conducting the experiments as course assignments over which little control on numbers could be exercised, let to a limited range of buyer numbers - between 7 and 9. However, as each buyer was required to try to obtain either one or two units according to the schedule he was given, by manipulating the proportions of buyers with one and two unit demand schedules it was possible, even with a restricted range of buyer numbers, to vary the level of excess demand.[4] The average buyer quota

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4 Given the excess demand value, the average buyer quota and the level of aggregate supply, the number of market buyers is automatically determined. Any 3 of the 4 variables determines the fourth.

TABLE 1

Schedule of Buyer Valuations

WEEK 1 — LOT NO. AND VALUATION

Buyer No.	1	2	3	4	5	6	7	8	9	10
1	99	93	98	88	97	95	92	98	92	101
2	99	90	100	86	98	96	93	100	94	98
3	102	93	98	87	98	92	95	99	95	99
4	99	96	96	88	95	95	92	98	92	100
5	99	90	100	89	100	92	89	98	91	101
6	98	93	98	92	96	94	89	97	93	95
7	99	94	95	91	98	97	95	99	93	99
8	96	94	95	85	95	94	93	96	93	98
9	101	90	100	89	100	95	93	103	90	102

WEEK 2

Buyer No.	1	2	3	4	5	6	7	8	9	10
1	98	91	91	88	81	85	93	93	91	102
2	96	86	95	88	79	85	92	95	94	99
3	96	85	93	87	80	86	93	94	90	97
4	99	88	89	90	84	86	95	96	91	99
5	94	92	90	89	83	85	99	95	91	95
6	101	91	94	87	85	84	93	94	87	100
7	95	90	91	90	82	95	92	91	89	98
8	94	90	91	90	83	87	95	94	91	98
9	98	90	89	86	80	88	95	93	93	102

WEEK 3

Buyer No.	1	2	3	4	5	6	7	8	9	10
1	99	102	92	90	96	89	94	92	90	93
2	100	99	87	87	100	93	98	94	92	91
3	98	102	90	86	97	90	95	91	92	94
4	98	98	85	87	94	87	92	89	94	90
5	99	97	85	88	97	90	95	89	88	92
6	102	100	88	84	97	90	95	89	91	93
7	100	98	87	85	99	92	97	90	90	97
8	96	98	89	85	97	90	98	88	91	97
9	96	101	91	84	96	89	97	92	93	94

Note: That in the first experiment reported, the sequential progressive auction, 15 auction sections were conducted, that is five auction 'days' for each of the three weeks given. In the second experiment, the simultaneous progressive auction, 4 sessions were run, two for each of the first two weeks' conditions given above.

was constrained to be between 1 and 2. The results are presented in the tables in increasing order of excess demand and buyer quotas.

8.2.3 Experimental Results

Because the appropriate full value bid is the second highest valuation of all buyers currently in the market, plus any bidding increment that may be necessary, the rate at which buyers complete their quota requirements and drop out of the market affects the bid level. Table 2 indicates the relationship of the full value bid (exclusive of bidding increments) to the second highest valuation on each lot as ascertained before the auction commenced. The greater the level of excess demand the greater the number of buyers who are active throughout the entire auction and the higher the full value bid limit. It is true that the greater the number of buyers, irrespective of aggregate demand, the potentially greater the value of the second highest bid, since the number of valuations per lot is increased. However, the effect of buyer numbers was not as significant as the level of excess demand as can be seen from Table 2.

In Table 3 the average contract or market price for each of the four experimental markets is shown as a percentage of the relevant full value price. It is seen that as the level of excess demand increases the market price as a percentage of the full value bid price rises significantly. In the case of market 4 with 60 per cent excess demand the average market price actually exceeds the full value bid price indicating that buyers in this market frequently found it necessary to exceed the second highest valuation by the bidding increment. Although, given the range of values, the evidence is slight, there also seems to be a tendency for the average market price to rise as the average buyer quota increases (markets 2 and 3 in Table 3). From Table 2 we see that this effect is *not* due to increased buyer numbers, for the number of buyers actually decreases (from 9 to 7) over the two relevant markets.

The most important result from these markets is the fact that *all* of them are close to the full value bid limit. The market prices are averages over the three trading weeks, or fifteen daily auctions in all so that FVB is seen to occur even in the face of market learning. This is in stark contrast to the results of Chapter 6 and it would seem that Sosnick's conjecture is borne out by these simulations. This being so it is worth examining the implications that full value bidding has for price levels and variance in sequential or successive auctions with quality differentials.

8.3 Effects of FVB on Prices and Variance at Successive Auctions

Assume that there are x lots of a commodity for sale and for simplicity, that the size dimensions of each lot are approximately equal, that is, we always have the same number of cattle per pen or the same number of bales of wool per lot - so that we may standardize for, and thus ignore, quantity differences. Each lot is qualitatively different from the next; the differences, however, are not extreme so although the lots are not perfect substitutes there is a high level of cross elasticity between them. Each of the y buyers has a valuation for each of the lots on offer, determined by their assessment of the worth to them of the differing quality characteristics inherent in each lot. Finally whilst any lot may be considered substitutable, at a price, for any other, no buyer requires more than z units of the available total supply ($z \leq x$; $zy > x$). The problem is to allocate the different lots to the different buyers in order to maximize total market utility - that is, total seller receipts plus buyer profits.

TABLE 2

The Full Value Bid Level as a Percentage of the Second Highest Valuation

	Level of Excess Demand %	Percentage of Second Highest Valuation %	No. of Buyers
Expt. No.	1	2	3
1	10	99.1	8
2	20	99.4	9
3	20	99.3	7
4	60	99.8	8

TABLE 3

Average Market Price as a Per Cent of the Full Value Bid Price and its Relationship to the Level of Excess Demand and Buyer Quotas

	Level of Excess Demand %	Buyer Quotas	Average Market Price as a Per Cent of FVB Price %
Expt. No.	1	2	3
1	10	1.37	97.5
2	20	1.33	99.3
3	20	1.71	99.9
4	60	2.00	100.4

The lots are to be sold by a sequential progressive auction. According to the full value bidding rules each buyer is prepared to pay up to his full valuation to secure a lot and will do so until he has obtained his full quota, at which time he will cease to bid in the market.

In a sequential progressive auction the price cannot be higher than the second highest valuation, plus a bidding increment because when the bidding rises to the level of the second highest valuation there is only one buyer left in the market who is able to bid. If his is the current outstanding bid he will secure the lot at the second highest valuation, if not he will bid once more and secure it. For simplicity we have chosen to ignore the bidding increment in these examples and thus to assume that it is the highest bidder who first places his bid at the second highest bid level.[5]

It can readily be seen that the distribution of the lots amongst buyers and the average price received by sellers is crucially dependent upon the order in which the lots are sold. In the following examples there are five lots on offer and three buyers, each of whom requires two lots. Supply is thus five, total demand capacity is six and there is a small, but positive, level of excess demand which ensures that a rationing problem does, indeed, arise.

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5 This assumption does not destroy the generality of the argument. In some markets, e.g., the South Australian cattle auctions, the actual selling price is the last bid price minus one increment. The intent here would seem to be to ensure the achievement of the pareto optimal position that Vickrey (1961) has shown to be the case with unique item second price bids.

8.3.1 Examples of Price Variation and Distribution

Example 1:

		Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
		Buyers' Valuations by Lot				
1.	Buyer 1	83	79	83	84	85
2.	Buyer 2	82	76	85	81	78
3.	Buyer 3	77	81	80	76	82
		Result of Auctions by Lot				
4.	Market Price	82	79	83	81	78
5.	Purchaser's No.	1	3	2	1	3

Average Price 80.6

In Example 1 each lot is sold to the buyer who has the highest valuation (row 5) but at the price of the next highest valuation (row 4). When Lot 1 is auctioned buyer one is willing to pay the most (83) and is able to obtain the lot at the second highest bidder's valuation (82). By the time the fifth lot is put up for auction, buyer one has already purchased the two items he required and has withdrawn from the market, consequently lot 5 is sold at the second highest valuation *of those buyers left in the auction*, i.e., buyers two and three, in fact to buyer number 3 at a price of 78.

If the same goods were sold to the same buyers, with the same valuations *but* the order of lots was changed so that lot 5 is now the first to be sold, the rest remaining in the same order as before, we notice several important differences.

Example 2:

		Lot 5	Lot 1	Lot 2	Lot 3	Lot 4
		Buyers' Valuations by Lot				
1.	Buyer 1	85	83	79	83	84
2.	Buyer 2	78	82	76	85	81
3.	Buyer 3	82	77	81	80	76
		Results of Auctions by Lot				
4.	Market Price	82	82	76	80	76
5.	Purchaser's No.	1	1	3	2	2

Average Price 79.2

Table 4 below, shows that where the order of sale is changed only lot 1 remains unchanged in price from example 1 to example 2.

TABLE 4

Market Prices (Purchasers No. in Brackets) By Lot

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Example 1	82(1)	79(3)	83(2)	81(1)	78(3)
Example 2:	82(1)	76(3)	80(2)	76(2)	82(1)

The last lot to be sold suffers from a relative lack of competing buyers so that the effect of moving lot 5 to the head of the queue serves to increase its price from 78 to 82, and moving lot 4 to the end serves to *decrease its* price from 81 to 76.

Not only do prices change which is of significance to the individual sellers who are thus benefitted or disadvantaged by lot position, but the *distribution of lots* amongst buyers also changes. In example 1 buyers one and three received their full quota requirements of two units each and buyer two received only one. With a slight re-arrangement in the order of lots buyers one and two are now the successful buyers, and buyer three receives only half of his requirements.

These figures have been chosen purely for demonstration purposes. With them it is possible to show the situation where the lot arrangements see two of the three buyers buying the first four units leaving no competition at all for the last unit. This is the case in example three. By the time that Lot 2 is offered for sale buyer 3 is the only buyer who has not completed his quota. He faces no competition. The price in this case is likely to be determined by the auctioneers starting value. In the absence of such a starting value price is theoretically undefined. This is so because price is a rationing device. Where no rationing is needed there is no price. Although in actual fact, if the price is not determined by the auctioneer or by a reserve price set by the seller, other buyers might speculatively buy over their lot limits if prices fell low enough.

Example 3:

		Buyers' Valuations by Lot				
		Lot 5	Lot 1	Lot 3	Lot 4	Lot 2
1	Buyer 1	85	83	83	84	79
2	Buyer 2	78	82	85	81	76
3	Buyer 3	82	77	80	76	81
		Result of Auctions by Lot				
4	Market Price	82	82	80	76	Un-defined
5	Purchaser's No.	1	1	2	2	3

Average Price (if we assume lot 2 would be sold at the starting price plus one increment, assumed here to be 76) is 79.2

8.3.2 Disadvantages of the Sequential Progressive Auction

The variety of these results suggests that the bidder might consider departure from the policy of bidding up to his true valuation. However buyers are not directly aware of this variety since the order of sale is predetermined and of course, the lots are sold only once and not varied as we have done here for illustration. All the empirical evidence, and now the experimental evidence of heterogeneous commodity markets from the previous section, suggests that buyers do, in fact, bid up to their full valuation.

If they do not - if, for example, buyers bid low on the first few lots to get a 'feel' for the market - then there will be relatively more competition for the lots coming later in the auction than for early lots. Whichever bidding pattern develops it is clear that with sequential auctions, *the order of sale* makes an important difference to the prices received and to the distribution of lots amongst buyers and that depending on the distribution of valuations, some items may receive little competition.

There is no assurance that any unit will go to the buyer whose comparative desire for it is the greatest. Thus in the examples given it would always pay buyer number one, *if he knew it*, to purchase lots 4 and 5 rather than any other combination since his 'pure profit' or 'rent', (the difference between his and the next highest valuation) is greatest for lots 4 and 5 (three units each) compared with lot 1, say, where the difference is one only. In the absence of full information any attempt by buyers to hold off in their bidding, competing, say, only on particular lots which seem especially favourable to them, will not necessarily result in any better distribution of lots but may generate overall lower prices.

The lack of uniqueness in outcomes arises basically because the lots are traded *in sequence*. The progressive nature of the bidding reveals the strength of competition for the current lot but not for future lots. Since the markets for different lots are interdependent this involves the strategizing decision maker in estimating the strength of demand for later lots in order to know the extent to which he should bid on the current lot. The strategies that may arise as a result of this and their impact on realized market prices were discussed in Chapter 6. Here we consider what would happen if we were to develop a simultaneous selling system, which avoided the need to bid strategically but incorporated the flexibility of the progressive bid (thus differentiating it from a simultaneous sealed bid auction which lacks the opportunity for bid revision).

8.4 An Alternative Resource Allocation Mechanism - The Simultaneous Progressive Auction

In a simultaneous auction,[6] bids are opened on all sale lots simultaneously. In this sense it is not unlike the organized financial share markets except that there is no scope for seller offers.[7] Bids are made progressively on all lots until prices have risen sufficiently to eliminate enough of the buyers who have lower valuations, so the

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6 Raikes and Dippold (1977, 1978) designed but did not test a simultaneous progressive auction. Their focus was on the possibilities of such an auction for multiple price determination and they did not compare prices and profits established at sequential and simultaneous auctions.

7 There is no reason why, with an electronic trading system, it should not be possible to include this option, although available experimental evidence (e.g., Smith 1964, Williams 1973) suggests that this need not be beneficial to the sellers.

remaining demand is equal to the number of lots available. At this point bidding ceases and the various lots are awarded to their highest bidders. One advantage of this system is that the strength of competition on each lot is always known. A buyer does not have to guess whether later lots will go at a discount or a premium. This eliminates much, if not all, of the strategy plays that can reduce realized prices. A major advantage is that buyers can select the lot which is relatively the best buy for them.

8.4.1 An Illustration of the Simultaneous Progressive Auction

As an illustration of how such a system may work let us take the values given in the first three examples. Any of these examples may be used as the order of lots is not important in a simultaneous auction.[8]

Buyers' Valuations by Lot

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Buyer 1	83	79	83	84	85
Buyer 2	82	76	85	81	78
Buyer 3	77	81	80	76	82

Let us suppose that the auctioneer opens the bidding at some level, say 75, and each buyer is then able to bid for the number of units which he desires. For simplicity of exposition let us assume that each buyer makes two bids in sequence and each bid involves a minimum increment raise. (The consequences of changing these assumptions will be explored in Sections 7 and 8). Thus buyer 1 would choose to open with a bid for

8 In very small number markets such as the one reported here there may be slight differences when there is equal rent to be had from several different lots and there is a choice to be made from them.

lots 4 and 5, since these maximize his surplus from the market. Buyer 2 would choose lots 1 and 3. When it is buyer 3's turn to bid on his most favoured lot, lot 5, it has already been bid for. Nevertheless, given the alternative choice, it pays him to raise the bid for lot 5 (as well as placing a bid for lot 2).

It will always pay a buyer to bid for the lots which maximize the difference between his valuation and the current bid. This need not, of course, be the lot for which he has the highest valuation because the current bid price on each lot will be determined by the strength of the competition for it. As the valuation-bid gap closes on one lot he will move to another. In this example buyer 1 ends up with lots 4 and 5 at prices of 78 and 82 respectively, which gives him a pure profit of 9 units instead of only 4 units had he purchased lot 1 instead of either of these, which in a sequential auction with full value bidding he would have done.

Notice that in the simultaneous auction no bidder drops out of the market until all prices are determined or until his valuations are no longer competitive. Each buyer will always have an incentive to bid for any unit as long as the profit to be made on it is at least as great as his next best alternative. Thus *the amount of competition in the market is spread evenly over all lots.*

Chart 1 below illustrates the process of a simultaneous auction for the values and buyers given above in a step by step fashion. Wherever two lots yield a buyer the same pure profit it is assumed here that he will take the first. Once the initial bids have been placed no further action need be taken by a buyer unless he is overbid. For each round an asterisk indicates that the buyer is staying with the bid made in a

CHART 1

<u>Progressive Bidding in a Simultaneous Auction for Five Lots and Three Buyers, Each with a Demand for 2 Lots</u>

Buyer/Lot	1	2	3	4	5
Round 1					
1				76	76
2	76		76		
3		76			77
Round 2					
1				*	78
2	*		*		
3		*	77		
Round 3					
1				*	*
2	*		78		
3		*			79
Round 4					
1	77			*	
2	78		*		
3		*			*
Round 5					
1				*	80
2	*		*		
3		*	79		
Round 6					
1				*	*
2	*		80		
3		*			
Round 7					
1				*	*
2	*		*		
3		*			81

CHART 1 (continued)

Progressive Bidding in a Simultaneous Auction for Five Lots and Three Buyers, Each with a Demand for 2 Lots

Buyer/Lot	1	2	3	4	5
Round 8					
1	79			*	
2			*	77	
3		*			*
Round 9					
1	*			78	
2	80		*		
3		*			*
Round 10					
1				78	82
2	*		*		
3		76			
Contract Price	80	76	80	78	82
Buyer No.	2	3	2	1	1

previous round. While he is the outstanding bidder he cannot alter his bid price or rescind his bid. In this example there is only a small level of excess demand so that the number of new bids per round is low. This makes the process easier to follow but the speed of adjustment would be faster if there were more excess demand.

8.4.2 Market Efficiency

In order to compare the market efficiency of the simultaneous auction procedure with the more traditional sequential auction we must decide what characteristics an efficient market would have.[9] The first of these should be the ability to generate average prices close to the theoretical market clearing level with no decided bias. (One-sided markets, such as auctions in which only buyers bid, have been shown in previous studies to have potential biases which may favour or disfavour the bidding side according to the trading rules adopted.[10]) Secondly, given an unbiased average, the efficient market should also ensure that the range of prices around the average is small. Failure to do this could result in inefficient allocation of commodities in that a buyer whose valuation of the good is intra-marginal, i.e., above the clearing level, fails to purchase while an extra-marginal buyer, with a valuation below the clearing level, succeeds. Traders must then incur the costs of retrading to exhaust all gains from trade.[11]

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9 A summary of various efficiency measures is included in Buccola (1982).

10 Smith (1964), Williams (1973), Plott & Smith (1978).

11 Note this means only that the immediate market is inefficient. In a more global sense it may be cheaper to re-trade than incorporate measures to ensure the exhaustion of all gains in the primary market. However, this can only be decided after the costs of such measures have been determined. It is not reason for not attempting to design them.

It is not difficult to determine the theoretical market-clearing price for a homogenous product market; it is the point at which the supply and demand schedules intersect. But when commodities are differentiated the market-clearing level is not easily discovered. Where there are many commodities, all slightly different, the price of each is determined by the demand for each commodity *relative* to the demand for all others.

With the explicit trading rules for the simultaneous progressive auction given in section 5 we can determine a unique equilibrium solution set, namely prices of 80, 76, 80, 78, and 82 for the 5 lots, respectively, with an overall average of 79.2. This average is less than that in example 1 but the same as example 2. Buyer profits in the simultaneous auction are much higher than in either of the two sequential markets for which all prices were fully defined, 21 as against 12 and 19. Also, the total utility derived from the market (i.e., buyer plus seller surplus) is higher - 417 for the simultaneous auction against 415 for both examples 1 and 2 of the sequential auction. If buyers were not constrained to bid for the first (or lowest numbered) lot when the valuation-bid margin was equal, but instead could choose between equally profitable lots at random, then there would be no unique equilibrium solution. Rather a set of solutions could exist and there is no reason why each member of the set should generate the same total utility.[12]

Although its solution is not unique, a simultaneous auction should generate an equilibrium price set. A simultaneous auction thus

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12 One could further define a sub-set of equilibrium solutions which would maximise total utility but the sub-set itself could consist of several solutions.

generates a reference standard against which to compare the performance of any existing sequential auction. Would the prices, on average, be higher or lower than those in sequential markets with full value bidding? And what of buyer profits? As suggested earlier, the prospects for better matching of buyers' needs in the simultaneous auction system gives reason to suspect that trader surpluses would be higher in this system. Another aspect of interest is the variance in prices and profits. *A priori*, one would expect that price variance under the simultaneous selling system would be less because of the effect of spreading the total competition more evenly over all lots. Increasing the overall level of buyer profits could be accompanied, however, by either increased or decreased variance. By their nature these questions lend themselves to analysis by computer simulation. Such an analysis is discussed in the following section.

8.5 Computer Simulated Sequential and Simultaneous Auctions

Computerized simulations were designed for both the sequential and simultaneous auctions and applied to 270 data sets representing a range of buyer numbers, lot numbers, buyer quotas and excess demand levels. Analysis of these variables suggested that none was statistically significant in determining price, profit or variance under either market system and thus the data were considered as a whole and presented that way in Table 5. Half of the simulations, 135 data sets, used a range of buyer valuations that were distributed normally about the mean with a standard deviation of two. This is referred to as the 'narrow' valuation range. In the remaining 135 data sets the buyer valuations were more dispersed, still distributed normally but with a standard deviation of 3. This is the 'wider' valuation range. This distinction did prove to be statistically significant and is shown in Table 5.

TABLE 5

Summary of Computer Simulated Auctions

	Small Valuation Range (a) $	Large Valuation Range (b) $
Average Price Per Lot		
: Sequential	100.81	104.85
: Simultaneous	101.06	104.99
: Difference	.25*	.14*
Average Profit Per Lot		
: Sequential	1.07	2.61
: Simultaneous	.99	2.97
: Difference	-.02	.36*
Average Utility Per Lot		
: Sequential	101.88	107.46
: Simultaneous	102.05	107.96
: Difference	.17*	.50**
Price Variance		
: Sequential	8.70	14.18
: Simultaneous	8.57	12.64
: Difference	.13†	1.54**
Profit Variance		
: Sequential	1.00	5.20
: Simultaneous	1.05	5.48
: Difference	-.05†	-.28†

(a) Buyer estimates distributed normally around the mean with a standard deviation of 2.

(b) Buyer estimates distributed normally around the mean with a standard deviation of 3.

* Significant at the .05 level.

** Significant at the .01 level of significance for a one-tailed test using the Wilcoxian Matched-Pairs Signed-Rank Test.

† Not significant.

8.5.1 Simulation Design

The design of the sequential auction basically followed the process outlined in sections 8.2.1 and 8.2.2 above. A random number generator was used to create the 'mean' values per lot. A rectangular distribution gave equal probability to all integer values between 96 and 105. Once these mean values had been established for each lot the individual buyer estimates were selected on the assumption that they were distributed normally about the mean, with a standard distribution of 2 for the narrower distribution range and 3 for the wider.

For the sequential auction it was necessary to establish that the individual buyer estimates or values were only taken into account while the buyer was active in the market. Once the buyer had bought his allotted quota he withdrew from the auction and his values for all subsequent lots were withdrawn from consideration in future sales. Failure to do this had marred previous attempts to simulate a sequential auction (see comments on papers by Whan and Richardson and Whan and Woodburn in Chapter 6). Because this process altered the listing of buyer values in the computer program a duplicate set of initial values was established at the beginning of the program, before the operation of the sequential auction, for use in the simultaneous auction. This latter auction design followed the pattern set out in section 8.4 above. The computer programs and data sets used are given in Appendix 1.

8.5.2 Results of Computer Simulations

The computer simulations show that the simultaneous selling method produces higher prices for sellers. This was significant at the 5% level for both the narrow and wide range of buyer estimates. The average utility per lot (that is buyer plus seller surplus) was also significantly higher under the simultaneous selling system for both valuation ranges, but the utility gains were higher when the distribution of buyer valuations had a greater variance about the mean. This suggests that the use of a simultaneous auction is more valuable when there is greater variability in end uses amongst buyers or perhaps when there is greater variability in processing costs for the same end use - as when different buyers have differing transport costs perhaps.

Price variance, which is not significant with the smaller range of valuations, is significant at the 1% level with the wider valuation range, and the simultaneous selling system yields smaller price variation as predicted. The difference in the variance of profits is not significant under either valuation range.

Average profits per lot would appear to be about the same under both selling systems with the smaller valuation range but is significantly greater for the simultaneous auction with the wider valuation range.

Overall, a sequential auction, with buyers adopting full value bidding, would appear to be more efficient relative to the simultaneous auction reference standard when buyers are likely to make closely similar estimates than when their estimates differ considerably. In practical terms this would suggest that a simultaneous progressive auction would be of greater benefit to, say, a cattle sale where valuations are more dispersed, than to a wool sale where they are very similar.[13]

8.6 Simultaneous Auctions - Experimental Evidence

Computer simulation is a useful device for testing likely performance in new systems but they are limited by their *a priori* behavioural assumptions. For the sequential auction the use of the full value bidding hypothesis was validated by experimental test; now it is necessary to establish the behavioural assumptions underlying the simultaneous progressive auction simulation and put them to a similar test.

The computer simulation assumed that buyers always bid on the lot, or lots, that maximized the difference between their valuation and the market price. This assumes that buyers are astute and continually aware of changing opportunities. The following experiment is designed to test actual buyer response in simultaneous markets.

8.6.1 Market Design

Four market simulations were conducted under the rules of simultaneous progressive auctions as described in Section 8.4. Each buyer had a schedule listing the resale value to him of each of the ten

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13 A computer based system for sale by description of beef cattle, which is basically a simultaneous progressive auction using telex, is currently undergoing trails in Armidale, N.S.W. The bidding is based on farm gate prices and buyers are responsible for transport. Transport differentials thus provide the basis for wide variations in buyer valuations, the conditions which this Chapter has shown to be favourable to simultaneous selling. In the wool market, however, where buyers valuations are thought to be much less dispersed, a recent attempt to introduce a centralized and computerized wool selling system, "Woolnet", with many of the characteristics of the simultaneous progressive auction, proved in 1981 to be unsuccessful.

lots on offer. He was required to buy either one or two lots as directed. The buyer valuation matrices were as in Table 1 but only the first two weeks values were used. In each of these market simulations two rounds or market periods were conducted using week 1 prices followed by two periods using week 2 prices. The auction rules stated that each buyer, in turn, would place a bid for either one or two lots, depending on his quota requirements. If, when his turn to bid came around, he was already the outstanding bidder for any lot this was taken as one of his bids - in other words he was not required (nor permitted) to raise his own bid. Bidding continued until all buyers had signalled a 'pass', either by virtue of being no longer able to bid or by being the highest outstanding bidder on their preferred lot/lots. Each buyer was given a worksheet on which to record the current price and/or profit margin to himself of each lot; this was to be kept as a running record throughout the auction. In actual fact whilst some buyers did keep the necessary records, others preferred to concentrate on the current prices as recorded on the overhead transparency maintained by the experimenter.

If buyers operated optimally in all markets one would not expect much variation in prices between repeated rounds under the same market conditions, nor between different groups facing the same market conditions. (Experiments A and B in Table 6 are replicates). Some slight variation might arise since when two or more lots offered a buyer the same profit margin the choice could be assumed to be random in the experimental simulations whereas with the computer simulation the choice was always the lowest numbered lot. Variations in average price between successive rounds of play with the same market conditions and players would therefore not be zero but would be expected to be quite small.

8.6.2 Experimental Subjects

The subjects were second year microeconomic students who had had some limited exposure to experimental markets in the previous year. They were familiar with the mechanics of schedules, etc. but had not had experience with this particular market form. Motivation was by linking performance in the experimental market to their grade average via an essay as explained in Chapter 6.

8.6.3 Experimental Results

The average price per round for each of the four markets is given in Table 6 along with average buyer profit. The price level from one round to the next varies from a low of .1 in week 1, market A to a high of 2.5 in week 1 market B. This level of between-market variation for the two replicates A and B is however due largely to learning errors on the part of one subject in market B who stopped bidding at a level short of her valuations in both rounds in week 1. Successive rounds in week 1 market C cannot be compared as the level of excess demand was increased at the end of round 1. For week 2 the price differences between round 1 and round 2 are small for all markets, with differences of between .3 and .9. This lower level of variation is what would be expected given the lack of obvious strategizing options.

Equally significant is the fact that, with market learning, the level of utility increases between round 1 and round 2 in nearly every market. Gains in utility are measured by the increase or decrease in selling price, which represents a gain or loss to sellers, plus the increase or decrease in profit, which represents a gain or loss to buyers. In Table 7 below the total utility gains and their distribution

TABLE 6

Summary of Simultaneous Auction Experiments

		Average Market Price		Average Profit Per Lot	
		Rnd 1 $	Rnd 2 $	Rnd 1 $	Rnd 2 $
Expt. A	Week 1	96.6*	96.5*	1.4	1.2
	2	91.8*	92.7*	1.5	1.1
B	Week 1	93.3*	95.8*	3.7	2.2
	2	92.6*	92.3*	.9	1.3
C	Week 1	96.2*	97.2	1.9	0.0
	2	94.7	94.3	2.4	3.0
D	Week 1	95.4	(a)	2.1	(a)
	2	93.0	93.7	1.2	0.4

* Excess Demand = 20%, otherwise = 80%.

(a) This week not repeated in expt. D.

TABLE 7

UTILITY GAINS WITH MARKET LEARNING IN REPETITIONS OF SIMULTANEOUS AUCTIONS

	Gains to Sellers	Gains to Buyers	Total Gains
Market A. wk 1	- .1	- .2	- .3
wk 2	+ .9	- .4	+ .5
Market B. wk 1	+2.5	-1.5	+1.0
wk 2	- .3	+ .4	+ .1
Market C. wk 1	na	na	na
wk 2	- .4	+ .6	+ .2
Market D. wk 1	na	na	na
wk 2	+ .7	- .8	- .1

between buyers and sellers is shown for successive rounds in each market. Only in the first week of market A and the second week of market D does utility not increase with buyer experience. Interestingly, this increase is not all distributed towards the buyers themselves but rather evenly distributed, on average, between both buyers and sellers.

The computer simulations assumed that there was no "strategic" play, that is, moves being made conditional on expectations of others. Bidding therefore was completely deterministic. Theoretically this is also true of the experimental simulation given the two rules that, one, limited the number of bids that could be made at any one time to the extent of the buyer's quota and, two, constrained bidders to bid in a prescribed sequence. The relaxation of either, or both, of these rules would introduce possibilities for strategic play.

One modification to the rules was made which did open the market to strategic play. This was to allow buyers to bid more than one increment at a time. This use of "jump raises" was not allowed for in the computer simulation. When initially introduced it had the effect of causing some buyers to bid more than the competition really required. This was so because, given that it was advantageous for the highest value buyer to be the first to bid the second highest value (and therefore to avoid being forced to pay the increment) buyers would try to estimate this value and raise their bids quickly to it. Sometimes they overestimated. With repeated use of jump raises it was noticed that the average amount of the jump declined.

Even with the one-increment-at-a-time rule, it was noticed that several players adopted different bidding practices, "strategies", such as withholding their bid from favoured items until the last moment. The structure of the market did not encourage or reward this behaviour. That the simultaneous auction gave little support for strategic play is also suggested by the relationship between market structure, in terms of excess demand, and consistency of bidding. The proportion of lots being sold to the same buyer in repeated rounds did not differ with the level of excess demand as it had for the experiments conducted with sequential trading.[14]

8.7 Summary of Experimental Results

Two sets of exploratory experiments were discussed in this Chapter. The first utilized the traditional sequential progressive auction market; the second introduced a new auction method, the simultaneous progressive auction. Both incorporated quality differences in the commodity traded. The object was to test the appropriateness of certain assumptions concerning buyer behaviour. They were not designed as a comparative study of the two auction mechanisms used and as the number of buyers and level of market demand varied between the

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14 The extent to which buyers purchased the same lot in successive auctions when the lots were sold sequentially is given in the following table. This suggests that buyers are less prepared to bid under their valuations in the hope of doing better later in the auction when the level of overall competition for lots rises. With the simultaneous progressive auction no significant differences in uniformity of allocation (a measure of buyer 'strategizing') was detected when comparing different levels of excess demand, an indication of the lower scope for strategizing in simultaneous auctions.

		Buyer Strategizing in Sequental Auctions	
Expt/No	Excess Demand	Buyer Quota	Uniformity of Allocation (%)
1	10	1.37	65
2	20	1.33	72
3	20	1.71	79
4	60	2.00	83

experiments run as sequential auctions and those run as simultaneous auctions the results cannot, in fact, be compared.

In the limited case examined in this pilot study the assumption of no strategic behaviour on the part of buyers in simultaneous auctions would apear to be relatively accurate. The full value bidding assumption was shown to be an accurate reflection of buyer behaviour in a sequential auction with quality differentials. It is also non-strategic, that is, deterministic behaviour.

A full investigation of the strategic properties and possibilities of simultaneous auctions would need to take into account options which permitted buyers to bid on any number of lots regardless of their buying requirements and opportunities to bid out of a given sequence. Also it seems certain that any practical implementation of a simultaneous auction system would require extensive computerization with buyers having access through their own terminals. With such a system, having buyers bid in sequence would not be impossible but it is likely to generate suspicion of foul play and suggestions of cheating in the allocation of the actual buyer sequences. Both of these variations could, in fact, be dealt with experimentally; the latter with some simple electronic devices for deciding which buyer 'had the floor' (a prototype has been designed by the author after the fashion of buzzers used in quiz shows). These initial pilot experiments suggest that more experimentation needs to be undertaken before appropriately realistic behavioural assumptions can be built into computerized simulations of simultaneous auctions.

The importance of incorporating quality differences in future auction market studies has been shown by the consistency of these experimental results with the existing theoretical and empirical literature, a consistency that was not obtained with markets using homogeneous commodities. It also suggests that more studies should be undertaken to examine the effects of different types of risk on buyer behaviour, and thus, consequently, on auction price levels.

8.8 Methodological Critique

8.8.1 Purpose

The purpose of the present Chapter, as with Chapter 5, was basically exploratory. Unlike Chapter 5, however, where the market design - the double auction and private treaty negotiation markets - had been previously developed and tested (Smith, 1962, 1967, etc. and Chamberlin, 1948) and the objective was to examine the theoretical implications of time pressures, the present Chapter has been concerned with the development of new market designs - the use of quality differentials and simultaneous as opposed to sequential bidding practices. When, as here, the exploration takes the form of new market design the initial experiments must, of necessity be regarded as tentative, pilot studies only. The reason for this is that, prior to conducting the experiments, too little is known to enable the designer to fully estimate his measurement and control needs. The object of the exploration was to discover how buyers would react to the greater uncertainty levels that the quality differentials would introduce. In particular, given the results of the experiments conducted previously without quality differentials, would this change be sufficient to produce the auction market behaviour that both theoretical and empirical studies have assumed to apply - the tendency of auction buyers to bid their full estimation values?

8.8.2 Validity

In terms of external validity, that is the extent to which the market design can be said to be representative of the real world, the introduction of quality differences is clearly a significant step forward. The simplified nature of the market, with repetitive constancy, still means that there are limits to the extent to which the results may be generalized to a wider setting or compared with empirical studies, but the confidence with which such generalizations can be made must be increased. A further source of validation is consistency, with both the existing theoretical and existing empirical studies. As far as the sequential auction is concerned this has now been achieved, with the results of full value bidding being consistent with the theoretical arguments concerning tendencies to self-discrimination at progressive auctions, and with observations of actual buyer behaviour (Sosnick, 1960) and evidence of declining price trends (Buccola, 1982).

Lack of empirical studies on the simultaneous auctions - there has been some theoretical work by Raikes and Dippold (1978) - emphasize the need to stress the internal logic of this new resource mechanism. Any behavioural assumption will serve the purpose of consistent internal logic, but for wider application, the internal logic has to be combined with *appropriate* behavioural assumptions - the object of this study.

8.8.3 Operationalizing Concepts

Section 8.2.1 gives a detailed account of the method used to introduce quality differentials in the market commodity. In order to explain the nature of such differentials and make them meaningful for the subjects it was necessary to give the commodity a 'name', in this case we used 'wool'. The use of a named rather than hypothetical commodity carries with it certain problems in that subjects may then endow the commodity with attributes, real or imagined, that have nothing to do with the market being modelled but affect the outcome. An illustration of this point is a demonstration double auction market conducted with first year economics students in 1972. The commodity again was 'wool'. Despite the extremely bright prospects for wool sellers in 1972, and very high current market prices, the student sellers in this market felt themselves disadvantaged by the illiquidity of their commodity. As one seller said afterwards "The buyers could take their money and go elsewhere, we would be stuck with wool". The market result was that prices tended to be below the equilibrium level. This attribute of illiquidity, while it may be important in real markets, was not part of the market design in which both buyers and sellers had, in fact, the same advantage - cards with values written on them. An important study by Simon (1972) of the effect on subject behaviour of different scenario presentations shows that this is more than an academic quibble. However, in market simulations, as in all things, trade-offs must often be made, in this case between giving subjects the necessary understanding for operating in the market and the possibility of bias. As the bias in the double-auction had been a seller bias the use of buyer-only one-sided auctions in these experiments may have minimized any tendency to bias in this case but the experimenter needs to be aware at all times of the problems that "reality" might bring.

8.8.4 Measurement

A wider range of valuations in the experimental markets would have made the results clearer but, as the computer simulations reveal, the valuation range is itself a variable with significant impact on prices and variance. The use of selected values as, for example, in the demonstration examples of Section 8.3.1, would be useful in the experimental auctions. The common use of randomly selected values, albeit from a defined distribution, is a suitable method for operations involving large numbers of observations, say from computer simulations. But it may be very inefficient to apply to small number studies such as experimental market analysis. The significance of using selected values is well illustrated in a recent study experimental of labour search by Schotter and Braunstein (1981). Selected values can illustrate the *range* of possibilities. More work, possibly using random values or at least values with a certain conditional probability, will have to be done to be able to tell how likely are any of the results which occur within this range. This is an ideal opportunity to combine successfully computer simulations with experimental market analysis.

8.8.5 Controls

Imposing controls on markets often limits the number of variables that can be considered but insufficient controls have the same effect, as illustrated by the present study. In some cases, of course, variables may be interdependent in which case no level of control can effectively separate the different effects. A more detailed discussion of general control problems is taken up in the next Chapter.

APPENDIX 1 TO CHAPTER 8

EXPERIMENTAL AUCTION MARKET RULES

- (Quality Variation)

The experimental auction market in which you are about to participate has been designed to model markets where many units of a similar kind are being sold but where each unit differs somewhat in its quality characteristics. (Real World examples would be different grades of tobacco or different qualities of cattle or wool.)

You are to imagine that you have examined all the lots that have been put up for sale. Each lot requires some sort of preliminary processing to get it to the standard that you require. You have assessed the cost of such processing for each lot offerred and taken this into account in establishing your valuations. You are now indifferent between each lot if you can get it at your valuation. That is, if one lot costs you $10 more than the others in processing costs you will be content with it if you can get it $10 cheaper.

Your aim is to buy 'x' lots of the ten lots on offer and to make the greatest possible profit for yourself in doing so. This will not necessarily mean buying at the cheapest price. For example, if lot A is valued by you at $85 and lot B at $75, lot A, if you can purchase it at $70 will give you a $15 net profit whereas, lot B purchased at $65, although cheaper, will give you a net profit of only $10.

Your valuations and the amount you wish to purchase are listed on the schedule to be given out in a moment. A sample schedule is attached.

AUCTION PROCEDURE - (sequential selling)

The auction works this way: The auctioneer will announce the lot no. to be sold, the starting bid level and ask for offers. Each buyer will call out his bid, minimum increment is $1 and all bids are to be improving. When no bid has been entered for the space of 5 seconds the lot is deemed to be sold to the highest outstanding bidder at his bid price. The successful bidder then enters his costs and the next lot no. is put up for sale, and so on until we have sold all lots. That is then the close of the first auction day. Every bidder will be asked to tally his purchases, costs and profits and then the auctioneer will announce the opening of the second auction day. For the 5 'days' of the first trading 'week' all conditions remain constant - same purchase requirements, same valuations. Purchase or non-purchase on any day does not affect subsequent trading. At the end of the week conditions will change. Trading will continue for several weeks.

The valuations on your schedule are upper limits, you may equal but <u>not exceed</u> them. The same applies to your quantity requirements with the proviso that if you fail to purchase your full requirements on any one auction day there will be a penalty of $2 for each lot that you wished to acquire and did not. This represents your costs of delay and rescheduling required in the production processes.

Each buyer will use his buyer number in the bidding, thus no. 12 will call '12 bids $200' or, more simply, '12 - 200'.

Attached are two worked examples showing you how to record your profits on the schedules.

YOUR VALUATIONS ARE FOR YOUR EYES ONLY. PLEASE DO NOT REVEAL THEM TO ANYBODY.

Any questions?

AUCTION PROCEDURE - (simultaneous selling, in order)

The auction works this way: All the ten lots will be put up for sale simultaneously. Each buyer will, in turn, be called apon to nominate up to two lots for which he wishes to bid. This will have the effect of increasing the price of that lot by $1 and the buyer's bidder number will be entered on the board alongside the unit as the highest outstanding bidder. A buyer may, if he wishes, nominate only one unit or he may 'pass' altogether. This may happen if he is already the current outstanding bidder for the lot or lots which he wishes to purchase or if the bid prices have exceeded his valuations. When all buyers pass in succession the auction shall be deemed closed and the lots sold to the highest outstanding bidders at their bid prices. The auction will then open for the second auction day. At the end of each day all buyers will be given a moment to tally their purchases, costs and profits. For the first 5 'days' of the first auction 'week' all valuations remain constant. Purchase or non-purchase on any day will not affect subsequent trading. New valuations will be given for weeks 2,3, etc. Trading will continue for several weeks.

The valuations on your schedule are upper limits, you may equal but not exceed them. The same applies to your quantity requirements with the proviso that if you fail to purchase your full requirements on any one auction day there will be a penalty of $2 for each lot that you wished to acquire and did not. This represents your costs of delay and rescheduling required in the production processes.

Attached are two worked examples showing you how to record your profits on the schedules.

YOUR VALUATIONS ARE FOR YOUR EYES ONLY. PLEASE DO NOT REVEAL THEM TO ANYBODY

Are there [illegible] questions?

Name .... buyer No [illegible]

BUYER SCHEDULE

Lot No.	1	2	3	4	5	6	7	8	9	10
Valuation	99	98	87	84	97	87	95	94	91	92

You wish to purchase [illegible] units

Day 1

	1	2	3	4	5	6	7	8	9	10
cost		95				82				
profit		3				5				

(bought required 2 units ∴ no penalties)

costs	[illegible]
profits	8
less penalties	–
net profit	8

Day 2

	1	2	3	4	5	6	7	8	9	10
cost					94					
profit					3					

(one unit short of required amount, ∴ penalty of 2)

costs	94
profits	3
less penalties	-2
net profit	1

Day 3

	1	2	3	4	5	6	7	8	9	10
cost										
profit										

costs	
profits	
less penalties	
net profit	

Day 4

	1	2	3	4	5	6	7	8	9	10
cost										
profit										

costs	
profits	
less penalties	
net profit	

Day 5

	1	2	3	4	5	6	7	8	9	10
cost										
profit										

costs	
profits	
less penalties	
net profit	

profit for the week

```
EEEPBUU,T100.
FTN5.
LGO.

      PROGRAM SIMSEQ
      DIMENSION IAV(50),IX(75,50),IS(75,50),INO(75)
      DIMENSION IP(50),IB(50),ID(75,50),IPR(75)
      DO 3 L =1,25
      READ 14,NL,NB,LIM
14    FORMAT(7X,3I4)
C   IAV(I)  = ↑TRUE↑ PRICE VECTOR
C   IX(J,I)= VALUATION OF LOT I BY BUYER J
C   IS(J,I)= STORED VALUATIONS
C   INO(J)  = NUMBER OF LOTS THAT J HAS BOUGHT ALREADY
C   LIM(J)  = MAXIMUM NUMBER OF LOTS THAT J CAN BUY
C   IP(I)   = SECOND HIGHEST VALUATION
C   IB(I)   = INDEX OF BIDDER WHO PURCHASED LOT I
C                (HIGHEST VALUATION BUYS THE LOT)
C   IPR(I)  = BUYER↑S PROFITS ON LOT I
C   NL      = NUMBER OF LOTS
C   NB      = NUMBER OF BUYERS
      CALL AUCTION(IAV,IX,IS,INO,IP,IB,ID,IPR,L,
     +NL,NB,LIM,XBAR,SD)
3     CONTINUE
      STOP
      END
      SUBROUTINE AUCTION(IAV,IX,IS,INO,IP,IB,ID,IPR,L,
     +NL,NB,LIM,XBAR,SD)
      DIMENSION IAV(50),IX(75,50),IS(75,50),INO(75)
      DIMENSION IP(50),IB(50),ID(75,50),IPR(75)
      CALL RANSET(RANSEED)
      RANSEED=L/100
      DO 305 J=1,NB
      INO(J) = 0
305   CONTINUE
C   CALCULATE IAV(I), THE ↑TRUE↑ VALUES
      DO 10 I=1,NL
      IAV(I)=RANF()*10+95
2     FORMAT(5X,2I5)
10    CONTINUE
C   CALCULATE VALUATIONS DISTRIBUTED NORMALLY ABOUT
C                            ↑TRUE↑ VALUES
      DO 40 J=1,NB
      DO 30 I=1,NL
      T=0
      DO 20 K=1,12
      T=T+ RANF()
20    CONTINUE
      IX(J,I)=(T/12.0)*24-12+IAV(I)+0.5
C   THIS UTILIZES THE CENTRAL LIMIT THEOREM TO APPROXIMATE THE
C                                  NORMAL DISTRIBUTION
      IS(J,I)=IX(J,I)
30    CONTINUE
40    CONTINUE
C FIND OUT WHO BOUGHT AND AT WHAT PRICE
      DO 80 I=1,NL
      M5=0
      DO 50 J=1,NB
      IF(IX(J,I).LE.M5) GO TO 50
      M5=IX(J,I)
      IB(I)=J
50    CONTINUE
      J=IB(I)
      INO(J)=INO(J)+1
      M6=0
      DO 60 J=1,NB
      IF(IB(I).EQ.J) GO TO 60
      IF(IX(J,I).LE.M6) GO TO 60
      M6=IX(J,I)
60    CONTINUE
      IP(I)=M6
      J=IB(I)
      IF(INO(J).LT.LIM) GO TO 80
      DO 70 K=1,NL
      IX(J,K)=0
70    CONTINUE
C IF ORDER FILLED THIS SETS VALUATIONS OF J TO ZERO
80    CONTINUE
      PRINT 4,L,NL,NB,LIM
4     FORMAT(5X,I2,↑ NL = ↑,I2,↑ NB = ↑,I2,↑ LIM = ↑,I2)
      PRINT 5
5     FORMAT(5X,↑SOLD SEQUENTIALLY,AV PRICE AND SD WERE↑)
      CALL CALC (IP,NL,XBAR,SD)
      PRINT 6
6     FORMAT(5X,↑AND THE AVERAGE BUYER PROFIT AND SD WERE↑)
      CALL PROFIT (IP,IS,IB,IPR,NL,NB,XBAR,SD)
```

```
C                        SIMULTANEOUS AUCTION
C  RESET VALUATIONS
      DO 160 J=1,NB
      DO 150 I=1,NL
      IX(J,I) = IS(J,I)
150   CONTINUE
160   CONTINUE
C  SET ALL BIDDER INDEXES BACK TO ZERO
      DO 170 I=1,NL
      IB(I)=0
170   CONTINUE
C SET STARTING PRICE INDEX
      DO 180 I=1,NL
      IP(I) = 90
180   CONTINUE
C  BIDDING IS SEQUENTIAL BY BUYER. EACH BUYER
C     MAY MAKE UP TO IZ BIDS WHERE IZ= LIM -
C     NUMBER OF OUTSTANDING BIDS
C  TO SELECT IZ
500   ICOUNT=0
      DO 200 J=1,NB
      IW=0
      DO 210 I=1,NL
      IF(IB(I).NE.J) GO TO 210
      IW = IW+1
210   CONTINUE
      IF(IW.EQ.LIM) GO TO 310
      GO TO 315
310   ICOUNT=ICOUNT+1
      GO TO 200
315   IZ=LIM-IW
C  GENERATE A VECTOR OF DIFFERENCES,ID(J,I) =
C     IX(J,I)-IP(I) SETTING THE DIFFERENCE FOR
C     ANY UNIT FOR WHICH J IS THE HIGHEST OUT-
C     STANDING BIDDER TO ZERO SO THAT HE WON*T
C     BID FOR IT AGAIN.
      M2=0
      DO 220 I = 1,NL
      ID(J,I) = IX(J,I) - IP(I)
      IF (IB(I).EQ.J) GO TO 320
      GO TO 325
320   ID(J,I)=0
      GO TO 220
325   IF(ID(J,I).LE.0) GO TO 220
      M2 = M2+1
220   CONTINUE
C  HOW MANY BIDS IS THE BUYER ABLE TO MAKE+
      IF(M2.EQ.0) GO TO 330
      IF(M2.LT.IZ) GO TO 327
      GO TO 335
330   ICOUNT = ICOUNT+1
      GO TO 200
C TO SELECT THE IZ HIGHEST POSITIVE DIFFERENCE
327   IZ=M2
335   DO 230 K=1,IZ
      M3=0
      DO 240 I = 1,NL
      IF(ID(J,I).LE.M3)GO TO 240
      M3 = ID(J,I)
      M4 = I
240   CONTINUE
C  INCREMENT THE UNIT BID FOR
      I = M4
      IP(I) = IP(I)+1
C  RECORD THE BUYER AS THE CURRENT OUTSTANDING BIDDER
      IB(I) = J
C  AND SET THE VALUE OF I TO ZERO
      ID(J,I) = 0
230   CONTINUE
200   CONTINUE
      IF (ICOUNT.LT.NB) GO TO 500
      PRINT 7
7     FORMAT(5X,*SOLD SIMULTANEOUSLY,AV PRICE AND SD WERE*)
      CALL CALC (IP,NL,XBAR,SD)
      PRINT 6
      CALL PROFIT (IP,IX,IB,IPR,NL,NB,XBAR,SD)
      RETURN
      END
      SUBROUTINE CALC (IP,NL,XBAR,SD)
      DIMENSION IP(50)
      G1 = 0
      G2 = 0
      DO 700 I = 1,NL
      G1 = G1 + IP(I)
      G2 = G2 + IP(I)*IP(I)
700   CONTINUE
      XBAR= G1/NL
      SD=(G2-G1*G1/NL)/(NL-1)
```

```
      PRINT 13,XBAR,SD
13    FORMAT(10X,2F8.2)
      RETURN
      END
      SUBROUTINE PROFIT (IP,IX,IB,IPR,NL,NP,XBAR,SD)
      DIMENSION IP(50),IX(75,50),IB(50),IPR(75)
      DO 900 I=1,NL
      J = IB(I)
      IPR(I) = IX(J,I) - IP(I)
900   CONTINUE
      CALL CALC(IPR,NL,XBAR,SD)
      RETURN
      END

        10   4   3
        20   8   3
        30  12   3
        40  16   3
        50  20   3
        10  11   1
        20  22   1
        30  33   1
        40  44   1
        50  55   1
        10  15   1
        20  30   1
        30  45   1
        40  60   1
        50  75   1
        10   5   3
        20  10   3
        30  15   3
        40  20   3
        50  25   3
        10   6   2
        20  12   2
        30  18   2
        40  24   2
        50  30   2

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CHAPTER 9

EXPERIMENTAL METHOD

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EXPERIMENTAL METHOD

For many years beginning economic students were informed that experimentation in economics was "impossible". Thus for most of the current generation of economists, unless they have had a side interest in psychology or engineering, the techniques and limitations of experiments are unknown. The current chapter is not designed as a 'how-to-do-it manual', rather as a check list for points that should be kept in mind by those theorists attempting to assess the value of experimental results and those who are considering incorporating them in their own theoretical studies. The detailed methodological points discussed after each of the experimental chapters in Part 2 are briefly summarized. In addition there are several issues common to all the experiments which are discussed here at rather more length. A knowledge of the technical state of the art is considered an essential pre-requisite for an understanding of the current place of experimentation in economic theory.

9.1 Purpose

Clarity of purpose is a major requirement of a well-directed experimental study as the purpose will determine the type of model to be used, the subject to be employed and the nature of the statistical analysis required.

9.1.1 Purpose and Design

It is possible to conduct an experiment without a well thought out purpose, to select a market model and then 'try this and that and see what happens'. But such an unstructured approach generates results that are difficult to interpret, there being no testable hypothesis or standard of comparison. At best they may suggest another, more structured, experiment. At worst they lend themselves to ad hoc theorizing.

Sometimes an experiment designed to examine one problem will throw up interesting results that suggest a theoretical development in some other area. For example, in an early study of the tendency of markets, constructed as double-auctions, to converge to the theoretical equilibrium (Smith, 1962) a one-sided double auction (in which only buyers were allowed to bid) seemed to bias the average market prices below the theoretical level. Before conducting this experiment no hypotheses had been proposed and the conclusion that the market structure led to a price bias was a rationalization of the observed results. Smith, therefore, used this result to design another experiment with the explicit purpose of examining the market bias. In the introduction to this latter experiment he remarked, *a propos* of the previous result 'The results of such a posteriori testing and theorizing based largely upon unreplicated experiments should be considered highly tentative until such results have been confirmed by further experiments designed specifically to test the particular hypotheses in question' (Smith, 1964, pp. 181-2).

9.1.2 Limits

Laboratory experimental markets may cost from several hundred to several thousand dollars depending on the number of subjects and the length of the experiments. The real cost limits, however, are the effort costs of the experimenters in terms of organization and administration. This has been the major benefit of the computerized markets designed by Arlington Williams (1978) and others. With the computer taking on the administrational efforts experiments can be conducted more easily and more frequently.[1] The effort of manually run experiments however imposes a valuable discipline on experimenters who are thus forced to consider very carefully the marginal value of the 'extra' experiment added on 'just to see what happens'.[2] There is, however, the associated danger of trying to make a limited number of experiments do too much. For example, to justify the costs involved one may be tempted to overload the experiments with variations or to develop an experimental market that has both teaching and research applications. The latter attempt is rarely successful because of the conflict of interests involved and the attempt to introduce too many variables into a design may mean that none of them are sufficiently controlled.

Many studies which, correctly, require several variables may, to save expense, examine an ad hoc selection of them, one or two at a

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1 It is believed that computerized markets are now held weekly at the University of Arizona and can be designed and made available to different theorists for the testing of theories related to market structure and market pricing.

2 It is perhaps worth noting that all the experimental studies adopting the unstructured approach discussed in the section above that have come to the author's notice have had access to computerized market models at low cost.

time. It is far better, where a factorial design is called for, to use a statistical design which permits coverage of all cells than to make an *a priori* judgement on which cells should be examined. This point is discussed in Chapter 5.

9.1.3 Exploration

All experiments are exploratory in one sense; they either tell us what we don't know or seek to tell us whether we really know what we think we do. The latter experiments are theory-testing experiments of which Chapters 6 and 7 are examples. This thesis reserves the term 'exploratory' for the non-theory testing experiments. There are two examples of such exploratory experiments in Part 2. In Chapter 5 the experimental market models have been well established (the double auction, Smith, 1962, 1964, 1965, and the private treaty market, Chamberlin, 1948) and are used to explore an area where the theory is deficient or empirical or behavioural data is lacking. In Chapter 8 it is the experimental market model that is untried and the experiment seeks to develop an understanding of the market institution and its possible implications. In the initial stages of development insufficient is known about the model itself to permit the experimenter to develop the most appropriate control and analysis techniques. For this reason these studies are referred to as "pilot studies". They serve to pave the way for other, more developed, experiments. Clearly there is little to be gained by attempting to apply detailed statistical analysis to the results of pilot experiments. The purpose determines the analysis.

9.2 Validity

It is rarely possible to check the results of an experimental simulation against real world events since if the needed information was available from real world data the experiment would not have been undertaken in the first place. In addition, the value of experimental models, as with any model, is in its simplification. A simplified model enables one to develop an understanding of a part process that is obscured by the complexity of the world itself. The validity of an experimental model must therefore be a matter of subjective assessment. In making this assessment, however, we can direct our attention to two questions; *one*, how sure are we that the results obtained are the consequence of the treatment applied and not the result of chance or artefact, and *two*, how relevant are the results to a wider context, in other words, how far can they be generalized? These two questions, which may be termed "internal" and "external validity" questions respectively were taken up in Section 5.8.

9.2.1 Internal Validity

Considerable research using different subject pools and controllers/experimenters have now established the basic result of the double auction viz:- any market constituted as a double auction will, with repetitive constancy, approach the theoretical equilibrium level of price and quantity, with as few as four buyers and four sellers (Smith, 1976b). These results have also been extended to include seasonal markets and it has been shown that, even where buyers and sellers know no more than their own schedules, prices and quantities will tend towards the intertemporal equilibrium when carry over costs are zero. Convergence to the equilibrium values has also been shown to be faster with experienced rather than inexperienced subjects.

These results are now known with some confidence, however hardly any research[3] has been undertaken on the significance of the various design elements that have now become standard practice. Several of these design elements have potential as design artefacts, systematically biasing observed results. For example, it is a common practice to allocate multiple units of the exchange commodity to the subject traders with instructions to buy (sell) no more than one unit at a time and that unit for no more (no less) than ts marginal value. If each subject has, say, 4 units to trade and only the last is a marginal or extra-marginal unit then, unless some subjects trade very much more quickly than anyone else, for the first three quarters of the trading session only intra-marginal units will be capable of being exchanged. As it is early in the trading session, when market generated information is low, that extra-marginal units would normally be most likely to be exchanged this design element loads the dice in favour of low extra-marginal trades and therefore high market efficiencies for such double-auction markets (where efficiency is measured by the relative absence of extra-marginal trading). This potential bias could be eliminated either by allowing traders to trade in multi-unit deals or by varying the number of intra-marginal units allocated to each trader. Both of these methods were combined in Chapter 5 and the level of efficiency was predictably lower.

"Repetitive constancy", or the re-establishment of the initial demand and supply conditions at the beginning of a number of consecutive market days, is now a well-established practice. Smith, who introduced it says 'It is only through some learning mechanism of this kind that I

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3 At least little published research.

can imagine the possibility of equilibrium being approached in any real market' (Smith, 1962, p. 114, fn. 5). However real markets are not repetitively constant and market models incorporating changed market conditions in successive periods (Hess, 1972) and models in which changes are introduced after a period of stability and the changed conditions are themselves allowed to remain constant for several periods (Smith, 1979) show very different behaviour patterns. One must ask which model and behavioural response is the most appropriate for generalization to wider contexts.

Other design features which need further examination are the number of market participants and the possibility of subject bias. Whilst competitive results have been achieved with as few as eight traders there is some indication that larger numbers generate market prices that are lower than equilibrium values. Thus in the study of the effects of market organization (Smith, 1964) in which two group sizes were used and the larger group size (28 subjects) generated lower prices under all market conditions compared with the smaller group size (20 subjects). Different subjects participated in each of the 6 experiments. In this instance the demand and supply schedules for the larger group were grossed up by adding 4 extra-marginal buyers and sellers to each schedule. In a later paper using a posted price system, Williams (1975) used 18 subjects in one group session and 14-16 in another session. A comparison of the sessions in which 18 and 14 subjects took part reveals lower average prices for the larger group. This time the schedules were grossed up by interpolating values in the smaller schedules. The difference in schedule treatment suggests that it is the number of market participants itself which is resulting in this downward price bias. Recent studies however have used quite small groups - the 'eight' earlier refered to - and therefore this issue has not been further examined. In the double auction study in Chapter 5 there was no systematic price bias associated with the larger group size which was included in that study to help illuminate this problem. Other experimental studies in Part 2 incorporating different numbers of market participants have been one-sided buyer markets and the asymmetry feature in these markets means that the results obtained cannot be generalized to explain the double auction results.

Subject bias has not received much attention although Chamberlin (1948) concluded that only a subjective bias on the part of his seller subjects could account for the fact that the average price was lower than the equilibrium price 39 times and higher only 7 times in his 46 studies. Higher than equilibrium levels of sales were explained by the fact that, with a range of prices obtaining in the market, some extra-marginal buyers and sellers would have a chance to make a contract that would not have been possible if all sales were at the equilibrium price. This however does not account for the overall lower prices.

Chamberlin suggested that his student subjects would be unfamiliar in the selling role and perform rather better as buyers or that students' market experience with retail, rather than wholesale, markets, where prices are set by sellers, would lead subject sellers to regard their lower limit as 'the price'. While this seems hardly less reasonable than expecting buyers to accept the sellers' offers on the grounds that this is customary in retail markets it does raise the problem of what knowledge and attitudes we can expect on the part of our subjects, especially students, who make up by far the largest percentage of experimental subjects used. Chapter 7 examined this issue with interesting results.

A recent computerized version of the Chamberlin model was constructed by Berczi (1979). In this model Berczi randomly paired buyers and sellers and whenever the pairing led to a possible exchange, that exchange took place at the mid-price. His results showed that actual quantity exchanged exceeded the theoretical equilibrium by about 50% but that the average price approached the theoretical price. From this he deduced that Chamberlin's assumption about seller bias on the part of trader subjects was correct, since the only difference between his and Chamberlin's original model was the absence of trader subjectivity.

Direct tests of this subject bias which were conducted by the author, however, failed to substantiate this claim. One such test involved setting up a market in which all traders could be buyers and or sellers and could switch from one role to the other any number of times. In this market all traders were issued both money and commodity shares. Each trader was given a value for the commodity share which was different between traders but constant over the number of shares acquired. If the current market value exceeded his share value he could offer to sell, if it fell short he could ofer to buy. But equally he could offer to buy or sell at some new price level. It was thus always open for traders to choose to make a buying or selling offer at any given moment. If Chamberlin's assumption was correct and students felt more at ease in the buying role one would have expected a preponderance of buying offers but this was not the case. Buying and selling offers were more or less the same.

Another test involved asking students, 36 of them, whether they would prefer the buying or selling role in the double auction in which they were about to take part. 31 of the 36 had no preference at all.

And yet there may be a form of seller bias to the extent that students empathize with the problems of sellers in the real world who need to produce in advance of sales. After a demonstration wool trading market (not used for research but for teaching purposes) in which the buyers clearly made more profits than sellers, a group of sellers remarked that they were disadvantaged because they had wool which was an illiquid commodity whilst the buyers were favoured with money. Both groups, in fact, had only a set of representative cards.

The issue of possible biases is too important to discard without further thought. One design feature that has received considerable attention through studies of excess rent (Smith, 1965) and price controls which serve to truncate one of the schedules, (Isaac & Plott, 1981; Smith & Williams, 1981) is the question of asymmetric schedules. In general though, much more exploratory work needs to be done in the area of possible design artefacts to ensure internal validity.

9.2.2 External Validity

The question of the representativeness of a particular experimental model can best be discussed in three parts; the required complexity of the model relative to the real world, the appropriateness of the market design chosen, and congruence with existing theoretical and empirical studies.

9.2.2.1 Complexity

It has been argued quite convincingly by Smith (1977b) and by Plott 1979) that, at least when testing a theory, that the model used be no more complicated than the theory itself. If the theory fails to be supported by the experimental market thus constituted to give the theory "its best chance" this throws strong doubt on the ability of the theory to predict in more complicated situations. However if the theory is supported the experimental market has done nothing more than provide a working model of the theory; in itself it says nothing about the possibility of generalizing to a wider context. And this is true no matter what level of simplicity or complexity has been adopted.

While simple models provide useful benchmarks against which to judge the performance of more complicated markets, simplicity may be deceptive. For example it was shown in Chapters 7 and 8 that the use of the simplifying homogeneity assumption led, in effect, to model mis-specification in that it eliminated the important element of buyer risk. When this element was introduced the behavioural responses changed completely.

It is always difficult to know what is merely a simplifying assumption and what is a distorting one. This is true of any theory or model development, not merely experimental economics. Fortunately there are methods that can be employed in experimental economics to check the appropriateness of the model design as was indicated in Chapter 7.

9.2.2.2 The Appropriateness of Model Design

For model results to be generalized to a wider context the model needs to have appropriate real world characteristics. In speaking of representativeness Smith refers to the concept of "parallelism". This is basically the *assumption* that what is true of the model in its limited context is true also in a wider context.

The validity of this assumption increases as the model is more appropriate to the real world, thus studies of motion in a vacuum would be less generalizable than a study which incorporated the element of friction. In the context of experimental markets it is suggested that the economist's traditional emphasis on price above other market variables may not well represent real markets and real market buyer behaviour. To the extent that the incentive structure in the experiment rewards price decisions and/or fails to provide scope for non-price decisions the model may be mis-specified. Support for this suggestion comes from two sources. One, the emphasis of real wool buying agents on quantity and the attainment of buying quotas, has already been examined in Chapter 7. The other is an experimental study by Fleming (1969) who compared the decision making of academic subjects and business manager subjects. The primary objective of the exercise he set was to transport some trade brochures urgently to a convention some 200 miles away. The academics saw the secondary objective as doing this at minimum cost but the managers instead looked to the reliability of the transport as the next most important consideration, thus placing the emphasis on quality. The difference in approach between the two groups was statistically highly significant.

9.2.2.3 Congruence

'Testing' model results against real world observations is not always possible because the reason for setting up the experiment is frequently the lack of readily observable real world data. It can happen however that a study undertaken in advance of some real world event may be validated by the results when the event is recorded. The results of an early experimental study of the likely effects on Treasury revenues of a proposed switch in the pricing practice applied to their sealed bid auctions of treasury bills (Smith, 1967) were later supported by an empirical study after the price change had taken place (Tsao & Vignola, 1977).

But congruence can also imply consistency of the experimental results with previously accepted theory. Thus the theoretical assumption of self-discriminatory buying practices by buyers at progressive auctions was consistent with the experimental results of Chapters 7 and 8 but not those of Chapter 6 (and the student replicates of the auction in Chapter 7).

Sometimes experimental markets can help to develop a theoretical explanation for observed empirical phenomena. Thus in Chapter 8 it was observed that the simultaneous auction seemed to yield improved gains to both buyers and sellers in those cases where there was a wide range of buyer estimations of the commodity value. Where a similar simultaneous telex auction was tried with a cattle market in Armidale, New South Wales, the system was "felt" by the buyers and sellers to be advantageous to them and the system has expanded. Because they have no standards of comparison to know how well they would have fared under an alternative system with similar demand and supply conditions the traders have to react to a "gut feel" for the market. But this reaction is supported by the experimental study since, with the effect of transport costs, buyers estimates of the value of cattle to them vary quite widely. A similar scheme mooted for wool buyers where buyer estimates were very close failed to gain trader acceptance. Although this was only a pilot study there would seem to be the potential for theoretical developments to explain real world reactions.

9.3 Operationalizing Concepts

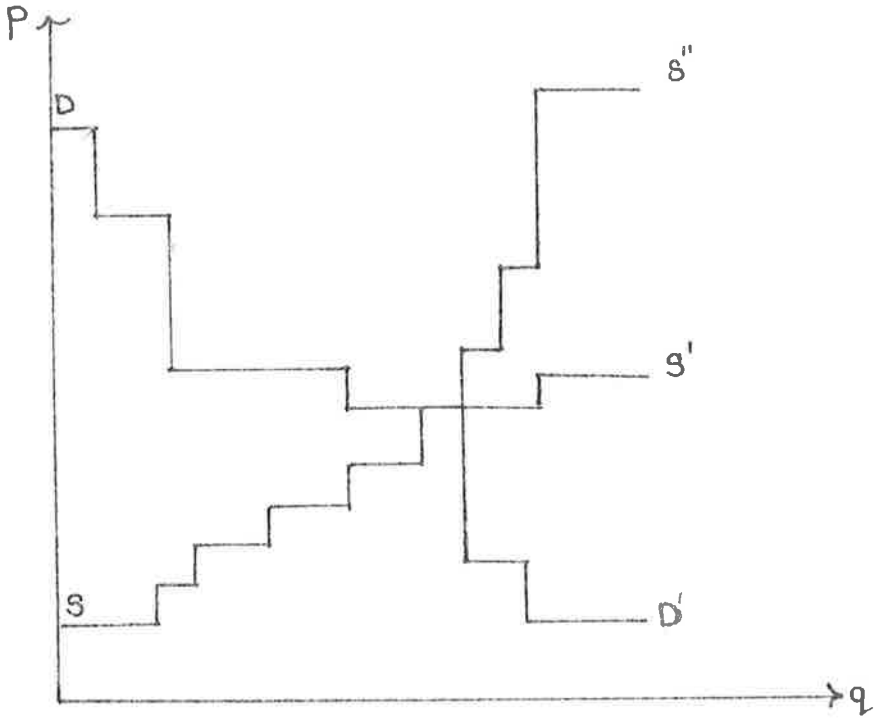
Operationalizing concepts or translating a theoretical concept into a practical equivalent could be termed the "art" in the "science" of experimental economics. There are many alternatives to translate most theoretical concepts and the results achieved are not independent of the method adopted. A study by Simon (1972) showed that subjects were sensitive to the context in which the design was set and would deliberately limit the set of strategies they adopted according to their interpretation of the setting. The same basic strategic design, the allocation of two resources across three sectors so as to maximize a given output, was presented in an economic context, a war context and in an abstract context. For the economic setting the two resources were two different types of advertising the three sectors were three market regions. For the war setting the two resources were ground troops and air support and the three sectors were three war zones. There was a much greater tendency to allocate all resources to one or two zones in the war context than in the business context because of the possibility of rationalization in terms of the scenario itself. Even in the "neutral" abstract context however there was the possibility for subjects with, say, an economic background, to see in the abstract scenario a related economic setting. And there is the possibility of a greater range of such "related settings" in an abstract presentation. Nevertheless it is reasonably common practice to try to avoid involving subjects' prior knowledge by presenting most of the market simulations as an unidentified market for a hypothetical commodity. This avoids the problem mentioned in Section 9.2.1 of the wool auction where buyers adopted a certain attitude because of conceptions about the wool market. Sometimes, however, making the commodity explicit is unavoidable, given the need to ensure that subjects understand the operations of the market. In Chapter 8 it was felt that without a rationalization in terms of some real commodity subjects might fail to understand the nature of the quality differentiation built into the model. Trade-offs like this are not uncommon in experimental design. Another example is the choice of the magnitude of price changes in the wool auction in Chapter 8 to suit the knowledge conditions of the subjects acting as "experienced buyers". More attention has been paid to this aspect of game design by researchers in socio-political aspects of game usage (for example, in the pages of the journal, "Simulation and Games") than by experimental economists.

9.4 Measurement

9.4.1 New Measures

The advantage of experimental models is their ability to directly observe and measure the factors of interest and not have to distill them from generalized data. This however requires the experimenter to develop the measures he needs since many of them do not exist as yet. An example of this need is a measure of the extent to which the model is "at risk".

When different market organizations are compared, one factor in the comparison is usually the degree of market efficiency which is basically Pareto efficiency, or the extent to which the market trades all of its intra-marginal units and avoids trading extra-marginal units. Plott and Smith (1978) devised a measure of this efficiency by using the ratio of actual profits to potential profits. The level of potential profits is determined by the shape of the sections of the supply and demand schedules to the left of the intersection point, the area shaded in the figure below.



Actual profits are determined by the number of extra-marginal trades that take place. This will be determined in part by the scope for such extra-marginal trades. Thus SS' has a high potential for extra-marginal trades since all of the extra-marginal sales units *could* be matched with an intra-marginal buyer whereas although SS" has the same number of extra-marginal units there is less possibility that any of them will be traded since most are beyond the buying power of the majority of buyers. A market which has the supply schedule SS' is thus potentially more "at risk" of incurring inefficiency in market allocation.

If markets are tested for efficiency using schedules like SS" all measured efficiencies will be quite high - and the low level of possible variation may make it difficult to assess different market institutions.

The necessity to make theoretical models operational requires many new measures to take into account aspects like the above. In this case it could be done quite simply by measuring the potential for XM trades (each XM selling unit weighted by the number of potential IM buyers) and comparing the actual with the potential.

9.4.2 New Statistics

Equally necessary is the development of new statistical techniques suitable for use in experimental economics. These may be drawn from other disciplines with experimental expertise as, for example, with the fractional factorial approach adopted in Chapter 5 or drawn from existing behavioural techniques as in the example of the Jonkheere-Rank test in Chapter 6. Or they may need to be developed afresh.

The major difficulty for economists assessing experimental results is that they are basically not familar with the techniques for analysing non-parametric models.

9.5 Controls

9.5.1 Subject Selection

The great majority of experimental market studies that have been carried out to date have utilized tertiary students as subjects.[4] This subject pool has numerous advantages in that the subjects are intelligent and easy to motivate, relatively homogeneous, even across different institutions,[5] and administratively easy to assemble. Critics of experimental models frequently object to the 'unrepresentative'

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4 Fleming (1969) is an example of an experimental study which uses non-academic subjects.

5 However Johnson and Cohen (1967) have shown that different career aspirations and training may generate differences in group behaviour.

nature of these experimental markets on the grounds that real buyers and sellers would not behave in the same way as student subjects. But this can be only guesswork since if the behavioural reactions of real market traders to the situation modelled in the experimental market were known there would frequently be no need to conduct the experiment! Where such information is available, it can be parametrized in the model, but to select the behaviour of a 'representative' sample of real world traders is not without problems itself. Kagel et al. (1979) have pointed out that the characteristics required of the representative sample are dependent on the theory being examined and unless the theory is *empirically well developed* this information is not available. The fact is that most economic theories have not reached such a stage of empirical sophistication.

Where the characteristics required of a representative real world sample are unknown, criticisms of student subject populations as being 'unrepresentative' must be matters of opinion only. The burden of proof must lie with the critic who will need to point to some aspect of their behaviour which can be shown to be contrary to that of the business populations being simulated.

9.5.1.1 Volunteers or Captive Subjects?

Whether to use student populations is one question, how to use them is another. For example, should they be volunteers or captive subjects? In an early work, Smith (1964) wrote, 'I never used volunteers. Volunteers were more likely to have heard something about "those experiments conducted by the economics department", and were more likely to have superior motivation, which was not necessary for these experiments', (p. 184). Now, however, the majority of his subjects are volunteeers. There are clearly advantages on both sides.

Using an already assembled class is administratively convenient and it may serve to reduce the psychological 'elite' effect of being selected for an experiment, an effect well documented in the literature as a result of the Hawthorne experiment.[6] The use of an entire captive class of students, reduces the selection bias associated with volunteer subjects and generally presents the experimenter with a relatively homogeneous background with known characteristics. Furthermore it may be the only way to assemble a sufficient number of subjects when they are not to be subject to monetary motivation. However, unless the class or group can be used as a whole, some of these advantages are lost, and where comparability of studies requires that the number of participants be equal over the different experiments this is difficult to achieve if working with differently sized pre-arranged groups.

Another disadvantage is the use of the class 'hours', generally 50 minutes. This period is too short to gather sufficient usable data once allowance is made for learning effects. The initial study by Smith (1962), using captive subjects in a regular class hour, suffered from the lack of comparability between the different experiments which were run for a varying number of market sessions, from as few as two to a maximum of only five. A further disadvantage is the lack of control over motivation. Even if subjects are paid their game profits there is no guarantee that they will all be motivated by monetary rewards which can be more or less assumed for subjects who volunteer.

Solutions to such problems may be found which renders the use of

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6 See Roethlisberger and Dickson (1939).

captive subjects viable. For example, captive subjects may be motivated by a reward structure tied in with their main objective - to pass in the course for which they are originally assembled. This makes the reward system 'meaningful' for all participants. And captives can be used outside of the normal class hour.[7]

There are also control problems in working with volunteers. Volunteers are subject to certain biases which have been well documented by psychologists (see Rosenthal and Rosnow, 1969 and 1973), who have observed that volunteers for social psychology experiments tend to be of higher socio-economic status and more interested in the subject under investigation than non-volunteers. Volunteers also tend to be 'good' subjects in that they try to co-operate in making the experiments work by behaving in ways which are consistent with the hypothesis being examined, independent of the experimental variables being studied.

A difficulty with volunteers for laboratory experiments, not generally found with real world experiments such as the electricity study, is that unless they have had some prior experience in laboratory markets, their decision to volunteer may be based on a faulty assessment of what is involved, which may affect their reaction to the design features of the experiments. They may find the experiments, for example, too boring or too complex, and alter the rules under which they are supposed to be operating, unbeknown to the experimenter. This of course is true of captive students also and to some extent this is a problem to be overcome by the controls built into the game design and the reward structure, but it can also be countered at the subject

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7 For example, many psychology departments arrange to have students take part in experiments for course credits outside of class hours.

selection level.

On the other hand, with prior experience it might be supposed that volunteers would tend to be drawn predominantly from the most successful participants[8] in previous markets. In the sense that unsuccessful businessmen withdraw or are forced to retire from the market, the bias towards expertise that this generates may not be disadvantageous.

The choice between volunteers and captive subjects is not clearcut. It will depend largely on the ease with which they may be assembled, the need for a relatively homogeneous population and two issues which have not yet been mentioned - the need to have experienced subjects, and the problems of motivation.

9.5.1.2 Experienced or Inexperienced Subjects

It is almost standard practice in psychological experiments to use naive, i.e. inexperienced subjects, and this practice was, for a while, adopted in economics experiments also. However the typical economics experiment is more demanding of the subject than the prisoner dilemma games and similar used in psychology and learning effects of inexperienced subjects, as they adjust to the game rules and discover the incentives and opportunities that exist may extend for a reasonably lengthy period of time. This caused considerable variation in data during the course of the experiment which could sometimes overwhelm the behavioural patterns of interest.[9] Some games also seemed to have a

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8 In experimental markets conducted in the Adelaide Economics Department some students making small or no profits have shown great willingness to try again. Presumably they consider they will do better next time.

9 For illustration of this point compare the behavioural patterns of inexperienced buyers with those of experienced buyers in Appendices 2 and 3 to Chapter 6.

high novelty[10] value for subjects which could lead to non-profit maximizing behaviour. Where interactive strategies needed to be developed, inexperienced subjects were slower to register information and react to it.[11] Markets in which inexperienced subjects took part were slower to converge[12] and the experienced subjects were more likely to be influenced by extraneous factors.

Real markets are composed of traders with many different levels of experience ranging from the raw beginner to the experts with 40 or more years of trading behind them. Except perhaps in boom times when there are many openings for new businesses, the proportion of completely inexperienced traders in the market would be very small and these would have the benefit of being able to observe and learn from the actions of others. There is no analogy in the real world to the experimental market situation consisting of completely inexperienced traders. The experience gained in an experimental market may, in some respects, be considered equivalent to experience in a real market in that it allows the trader to abstract from the novelty and learning aspects of the situation and apply himself to the problem of profit seeking.

There is the possibility that bias may be introduced from previous knowledge of game behaviour. However, if the game accurately models the relevant aspects of the real world, similar behavioural reactions could also be expected from real world traders and to omit them would be to distort the model.

In very simple prisoner dilemma games it has been found that

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10 Smith (1979a).

11 See Appendix 3 to Chapter 6.

12 Smith (1979a).

behaviour changes after extensive exposure.[13] Time to reflect on one's behaviour may be just as influential as the opportunity to practice, however, where students are used on several occasions, which allows them the opportunity to communicate outside of the experimental situation, this could lead to collusion between participants and loss of control for the experimenter.[14] This risk may be minimized if the number of experienced players available is large, subsets chosen at random, and subjects individually and privately notified.

Experience which comes from operating within the limits of the experimental market is thus a valid practice if we are attempting to replicate a normal business situation. But where subjects have knowledge of the objective of the experiment and possible solutions, they could be encouraged to try to fit their behaviour into some prescribed mode.[15] And where previous experience is well entrenched it may delay or prevent understanding in the current market situation. This experience is to be avoided for it reduces the control the experimenter has over the outcomes.

9.5.2 Subject Motiation

'In credible economics experiments real people must make real decisions about objects or activities that have real value' (Smith 1967, p. 3).

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13 See Chertkoff and Esser (1976).

14 See Lieberman (1971).

15 See Lieberman (1971).

9.5.2.1 Monetary Motivation

One way to motivate subjects is to tie their decisions to the level of monetary reward. This is perfectly acceptable if the subject's utility is a monotone increasing function of the reward medium and the subject is either autonomous or is prevented by the experimental design from being altrustically interested in the rewards of others. However these provisos may not apply.

At low levels of return the game may lack sufficient challenge for the better players who may then seek alternative or supplementary goals. Johnson and Cohen (1967) reported that their graduate business students readily saw the possibility for profits given by co-operation at the joint maximization position but some chose not to take advantage of them as the following comment by one of the players reveals. 'We both would have made more money had we settled at a constant level of 3.5, but it would have taken all the fun out of the game for both of us' (p. 367). Low levels of payment then combined with a simple game structure may produce boredom in the better players.

High rates of return are not necessarily the answer, either, quite apart from the strain they place on the experimental budget, for risk attitudes and the level of co-operation appear to vary with the size of the reward system. Experiments with payment levels using a variant of the prisoner dilemma model revealed that under the high reward system (payments ten times greater than the low reward system) co-operation was about 30% higher than in the low reward system. While a large increase in payments was required to get the 30% increase in co-operation these results (McClintock and McNeel, 1967) show that behavioural response is not independent of payment levels. Marwell and Ames (1980) have shown that high levels of payments are associated with more risk averse behaviour. This is consistent with Buccola's (1982a) observation that at low levels of payments most subjects are risk takers. These factors suggest that it is just as possible for rates to be set too high as for them to be set too low.

The appendix to Chapter 5 reports a study of a double auction using three payment levels. The objective was to observe whether higher payment levels encouraged more efficient market behaviour on the part of subjects, as suggested by Smith (1976a). The results suggested that with inexperienced subjects the motivation level is not an important behavioural factor. However the question is still open for experienced players.

With non-student subjects monetary motivation takes on added complexity. To motivate business managers, for example, with reward levels that would provoke the normal level of risk taking behaviour may be exhorbitantly expensive. At the other end of the scale, payments to the general public, who would vary considerably in their attitudes to money, may generate quite erratic experimental results. Student volunteers are usually highly motivated by money, having little of it and a high demand at the margin for what money can bring. Thus monetary motivation with student subjects may be more reliable than with non-student subjects.

A problem no matter what form the motivation takes is that to tie the level of the reward to the decision made requires the experimenter to make a prior decision of what is a "good" or "bad" decision. Thus in most market experiments a decision leading to greater profits is "good" and is rewarded by a higher level of the reward medium. In some experimental models, for example in experiments on validating revealed preferences for public goods it may not be so easy to determine response on a "good-bad" scale. Any attempt to do so could bias the model.

9.5.2.2 Incomplete Monetary Rewards

An economizing measure utilizing the motivating force of monetary rewards is the device of incomplete rewards whereby only some traders are rewarded. Smith (1965) has shown that if rewards are allotted to traders randomly this is equivalent to all traders adjusting the reward level by the probability of being the one rewarded. This probability is not related to any game decision. The result, therefore, is that no higher level of motivation is achieved than if the rewards had been set initially at the average payout rate. Moreover random payouts, especially if the probability of not receiving is greater than the probability of receiving, may encourage subjects to attempt to minimize the level of payouts to others and this is *not* the same as maximizing payout to themselves unless the model is designed as a zero sum game which, by and large, most markets are not. This then leads players to adopt market behaviour which is inconsistent with profit maximization.

A compromise between random and full payouts is the "prize game" where only the top profit owner/s is/are rewarded, i.e., "win the prize" which may be money but need not necessarily be. This economizes on payouts but still keeps rewards tied closely to market behaviour. Theoretically a system of money prizes should encourage more profit maximizing behaviour since profit 'satisficers' will also need to adopt maximizing behaviour if they are to achieve any return at all. The effect of a prize is to attach that level of reward to all marginal decisions.

9.5.2.3 Non-Monetary Motivation

So far only pecuniary motivation has been discussed. However economic decisions are being made every day by people who do not have a direct pecuniary interest in the end result. To say that only monetary motivation is suitable for economic experiments is equivalent to reducing all economic problems to the owner-manager paradigm. For many businessmen, making profits or sales is a goal in itself. The fact that we can show that, under certain assumptions, this is equivalent to a profit maximizing goal does not detract from the point that profits enter into the decision process only indirectly.

Profits can be 'real' for experimental subjects to the extent that they are linked to a reward medium which is meaningful for them. This might take the form of status, marks towards a grade average or, in token economies,[16] the right to an hour's television or permission to go on an excursion. Whatever it be, it must be something desired by the subject and a commodity with which he will not be readily satiated, at least within the range provided by the game.

The level of non-monetary rewards are not limited by budget considerations (although there may be other limits to be observed) and greater flexibility can be achieved.

9.5.2.4 Losses

No-loss reward structures avoid the moral hazard which occurs when relatively low income subjects, for example students, put in positive

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16 For the literature on token economies see Kagel and Battalio (1980).

effort in terms of experimental time, for a negative return. This can be finessed by giving a starting sum and limiting losses to this amount, but even zero income seems too severe a penalty for a subject's positive contribution to the experiment. Game designs are thus frequently arranged to pay out a minimum amount equal to, or greater than, some fair payment for time input. This restriction may bias the results obtained. Duopoly studies with price ranges that included loss positions (Murphy, 1966) invoked considerably more co-operation between traders than with price ranges that did not (Fouraker and Siegel, 1963). Whereas the latter study indicated that the duopolists would undercut each other until the point of zero profits for each had been reached the Murphy study showed that when the duopolists were aware that undercutting would result not merely in zero profits but in actual losses this encouraged them in some tacit degree of co-operation. However once a limited co-operation had been learnt it was but a next step to seeking co-operation at the joint profit maximizing level. Since the need to avoid losses was the catalyst in this case a market design without loss provisions would understate the capacity for co-operation.

9.6 Conclusions

There are many aspects of subject selection and motivation that may still need to be examined although in this respect, more so than in the other elements of design and control discussed earlier, the experimental economist can capitalize on the research conducted by the psychologists. The key areas for further research in the methodology of experimental economics are the development of statistical techniques of analysis suited to small number experiments and the close examination of design structures for possible artefact bias. Experimental economics provides almost unlimited scope for the precise measurement of variables which are of interest but it is probable that new disaggregated measures will need to be developed to take advantage of its microeconomic approach.

CHAPTER 10

EXPERIMENTATION AND ECONOMIC THEORY: CONCLUSIONS

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10.1 Summary and Conclusions

The main aim of this thesis was to examine the relationship of experimental method to economic theory and the potential of experimentation for theoretical development. In the process four experimental studies were developed and examined. The major results from these studies were:-

Experiment 1 (Chapter 5)

Time pressures on decision making lead to market inefficiencies which are related to the institutional environment in which trading takes place. The information-rich double-auction market is not necessarily superior in terms of efficient price adjustment to the information-poor private negotiation market when decision times are short.

Experiment 2 (Chapter 6)

At a progressive auction for multiple units of a homogeneous commodity the number of traders taking part determines the nature of the price adjustment process. Specifically, with aggregate demand constant the greater the number of buyers the lower the average price during the adjustment period because of the adoption of information-seeking delaying strategies. This reversal of the normally accepted relationship between market size and price is the outcome of examining disequilibrium rather than equilibrium dynamics.

Experiment 3 (Chapter 7)

Under certain, common, institutional arrangements quantity and quality may be of equal or greater importance to traders than price. A misplaced emphasis on price in modelling progressive auctions such as the Australian wool market is shown to lead to model mis-specification.

Experiment 4 (Chapter 8)

Buyers at progressive auctions, who tend not to self-discriminate when faced with homogeneous commodities, do so when faced with a commodity in which there are quality differences;

and

Selling commodities, in which there are quality differences, simultaneously by progressive oral auction leads to greater benefits for both buyers and sellers than selling them sequentially, but the difference is greatest when there is a wide variation in buyer estimates of the commodity values.

All of these studies testify to the importance of the institutional framework when examining the process of market price adjustment. This is not the view that has been traditionally adopted. In fact institutional economics has generally had a very low status-ranking with economic theorists, being regarded as more descriptive than analytic. Chapter 2 considered why this has been true in the past and outlined the path that economic theory has taken so far. It emphasized the difficulty of obtaining reliable and relevant data and the consequent construction of mathematical mdoels that avoid, as far as possible, any recourse to empirical or institutional data whatsoever. Chapter 10 now uses the experimental framework developed in Chapter 3 and the results of the experimental studies conducted to show why this situation has changed and why micro economic price theory cannot be developed fully in its present institutional vacuum. Furthermore, it shows, following on from the detailed study of methodology in Chapter 9, how the techniques of experimentation can lead to developments in economic theory by posing new questions and opening up new lines of enquiry and how it is uniquely able to explore some of the problems of disequilibrium dynamics. Finally it considers where experimentation now stands and where it may go in the future.

10.2 Price Formation

In Chapter 3 price discovery was distinguished from price determination per se. The theoretical equilibrium or "market-clearing" price was defined as the intersection of the demand and supply schedules that apply at the beginning of the market session. Whether, and if so how, their price is discovered in the market place has been a main objective of experimental investigation.

10.2.1 Experimentation and Price Formation

Smith's initial (1962) enquiry into the relevance of the theoretical equilibrium position under constant market demand and supply conditions and the nature of the price adjustment process, set the stage for much subsequent investigation and discovery. With markets 'repetitively constant', as previously defined, and designed as double auctions in which both buyers and sellers are able to submit and accept bids and offers, numerous experiments now testify to the fact that (1) the theoretical equilibrium, that is the intersection point of the supply and demand schedules obtaining at the start of the market day, is a good predictor of the average market price despite the constant re-writing of these schedules as disequilibrium trades involving extra-marginal buyers and sellers take place and (2) that equilibrium prices can be achieved with quite small markets, in fact as few as eight traders and (3) that it is not necessary or sufficient[1] for traders to know more than their own trading schedule.

In summary, the equilibrium price can be obtained in real markets without the usual assumptions of perfect knowledge,[2] infinite commodity divisibility, or large numbers. The experiments reported in Part 2 show that these results can also be extended to markets organized as progressive auctions if there is a homogeneous commodity. This evidence, from many experimental market studies, contradicts much of the theoretical literature on this point.

From Walras, who assumed that the equilibrating process worked itself out through the action of impersonal forces, but did not specify how, to Marshall and Wicksteed, who assumed that all traders knew the entire Demand and Supply schedules and thus automatically chose the intersection point as the only point acceptable to both buyers and sellers, the literature has been long on assumptions and short on explanation.

Price theorists, in general, have not seen the price determination

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1 Full disclosure of the schedules of other traders sometimes promotes altruistic behaviour on the part of subjects which tends away from the competitive position, see Smith (1976a).

2 Thus presenting factual opposition to existing theory, using probability-based models, which have shown that incomplete information can cause Pareto-inefficient equilibria or complete market breakdown (Akerlof, 1970; Spence, 1974; Stiglitz, 1975).

mechanism as dependent on the market institutions and trading rules within which the exchange takes place. Indeed, much of the historical price determination literature has sought to show that prices are determined independently of market institutions and rules.

10.2.2 Tatonnement Market Theory

Tatonnement markets, for example, may operate as if some central authority or set of rules guided the market but such intervention is deemed not, in actuality, to take place. In a detailed study of the tatonnement literature Walker (1962) has shown that the tatonnement properties which are supposed to secure equilibrium market prices lead to an incomplete model. These properties are that (1) there is only one price ruling in the market at any one time (a fact that makes it possible to calculate excess demand) (2) there is an information dissemination and collection process (by which traders know the one price and can indicate their demand or supply) and (3) no disequilibrium trades take place and the price quotation process continues until a price is determined at which Supply equals Demand.

What is missing from this model is any mechanism for enforcing these properties. How is it possible, without a central authority to guide them, for large numbers of traders to acquire the information they need, and to whom do they communicate their demand or supply requirements at each price and how is it ensured that no disequilibrium trades take place? These questions remain unanswered.

To avoid the necessity to answer them, Knight, and Stigler postulate certain basic conditions that would, in fact, generate the properties of a tatonnement model as derivative outcomes without assuming the existence of a central authority. The conditions they set out are now often taken to *define* the competitive market itself, namely an indefinitely large number of traders, perfect divisibility of the commodity, complete absence of frictions and, while not perfect, at least statistical knowledge of the Supply and Demand curves, that is, the knowledge of the quoted price and all buy and sell offers at that price. However, these conditions result in a situation where all traders are price takers and none of them price makers, which invokes the question (asked by Arrow, 1959) as to who changes the price when the underlying market forces change? This model thus avoids rather than solves the problem of price adjustment by positing the equilibrium price as the set price.

10.2.3 Recontract Models

Recontract models, such as Edgeworth's, in which arrangements made between buyer and seller are regarded as tentative only, until such time as all traders have had time to compare all offers and renegotiate a more favourable outcome, also fail to take account of the information dissemination problem. Since any information would lead to new, recontractable, arrangements, how would traders know when the market was finally closed and the negotiated transactions could take place?

10.2.4 Completing the Model

The models may be closed by introducing a price setter. Either an omniscient price setter who knows everyone's individual supply and demand schedules and uses this knowledge to calculate market demand and supply and hence the equilibrium price, or an informed price setter who posts a price, receives all buyer and seller limits at that price, calculates the excess and posts a new price until the equilibrium, at which Supply equals Demand is reached. But this is equivalent to introducing a central authority or institutional trading rule.

Thus we can see that, not only are the tatonnement properties themselves insufficient to secure equilibrium market prices, but they are shown, by experimental evidence, not to be necessary at all. Equilibrium prices can be achieved despite there being a range of prices in the market at any given time, despite the occurrence of disequilibrium contracts, and in the absence of calculations of excess demand. What is shown to be necessary, however, is the institutional setting.

10.2.5 Small Number Markets and Game Theory

In Chapter 2 reference was made to the game theoretical approach which sought 'to establish satisfactorily ... that the typical problem of economic behaviour become strictly identical with the mathematical notions of suitable games of strategy' (Von Neumann and Morgenstern, 1944, p. 2). However the optimal solutions of game theory frequently take the form of a solution set rather than a unique point and to learn where in the set people land, *institutional information* is required, according to Von Neumann and Morgenstern.

For all these reasons, one arrives at:-

> *Conclusion One:* *For both competitive and small number markets price adjustment cannot be considered apart from the institutional setting in which it takes place.*

A corollary of this is that the impact of experimentation on the development of theory will be to change its direction - away from disembodied price mechanisms and towards institutional related processes.

10.3 New Techniques, New Directions, New Questions

10.3.1 Experimental Framework

Given the unlimited number of institutions that are, or could be, devised this directional change could be seen as a retrograde step, productive of little more than descriptive listings, if it were not for the ability of experimental economics to classify and analyse the information generated.

This thesis has suggested one such classificatory framework based on the *opportunities* that traders face, their *incentives* and the *informational structure*. In Chapter 6 changes in buyer behaviour were shown to be consistent with predictions made on the basis of this classification and the other features of the market being simulated.

10.3.2 Detail in Design and Analysis

Productive answers are the result of *insightful* questions and it is often just as difficult to devise an appropriate question as it is to answer it. In this respect experimental markets have been a boon to economic theorists. In Chapter 4 several examples were given of experiments which, designed to answer one question, gave rise to several others. In part this arises from the need to specify theoretical concepts clearly enough in order to make them operative; this often forces the experimenter to cope with questions, such as the effect of time on decision making, that previously may not have been thought important. And in part it arises from the greater detail in the information provided, particularly about the processes by which the end results are achieved. For example in Chapter 5, when examining the effect of time pressures on trader behaviour it was possible, not merely to measure the profitability of their decisions, but to examine in detail the kind of errors that were being forced upon traders by the lack of decision time.

10.3.3 Exploratory Designs

The key advantage in developing new directions and new questions, however, must lie with the exploratory model designs. Experiments may be designed to yield information in areas that have as yet been underdeveloped in the theoretical literature. Frahm and Schrader (1970) gave this as their reason for the use of experimental analysis in their comparative study of pricing under English and Dutch auction conditions and it was the basis of the exploratory design presented in Chapter 5. Some of the questions raised by that study were (1) the effect on trader behaviour as trader numbers increased under different institutional arrangements (a question that was answered in the context of the progressive oral auction in Chapter 6); (2) the opportunities for market learning under different institutional arrangements and how these were affected by market size; and (3) whether strategies changed as decision time changed, apart from the effects of learning.[3]

Another exploratory model is that designed to yield operating information for institutions that have as yet no real world counterpart,

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3 Both of these latter questions have since been addressed or are being addressed in other studies).

for example the study of a simultaneous progressive auction in Chapter 8. Only computer simulations could provide a similar range of information and then only for pre-designed behaviour patterns. The advantage of experimental markets is that behaviour cannot be specified before hand, and is allowed to respond to the institutional features and trading rules, the opportunities, incentives and informational structure of the market.

Interesting questions being often more prized than (expected) answers, even 'failed' experiments can be extremely valuable and productive, hence

> *Conclusion Two: The major contribution of experimental method to the development of economic theory will be through the generation of new directions and lines of enquiry.*

10.4 Disequilibrium Dynamics

Not exactly a new line of enquiry but certainly one in need of more theoretical development is the whole area of disequilibrium dynamics. The emphasis on mathematical modelling has tended to stress equilibrium models at the expense of disequilibrium models. Proofs of the existence of equilibrium positions abound in the literature but models of adjustment to those equilibrium positions are generally weak. Frequently the models employ behavioural rules that require traders to predict the equilibrium price and then to produce, or demand, the output appropriate to this prediction. This ignores the fact that unless the adjustment is very quick, there will be the opportunity for any reasonably intelligent trader to adopt strategies that take advantage of the (temporary) disequilibrium.

10.4.1 Adjustment Takes Time

When the equilibrium price changes, through a shift in demand or supply conditions, it takes time for traders to recognize and react to this change. During the first phase of the adjustment there will be considerable dispersion in the price, reflecting different assessments of the new equilibrium level. At this time an astute, or lucky, trader can make disequilibrium contracts that favour himself. There is an incentive to seek out such trades. Even if he should be able to predict the new equilibrium there is no incentive for him to contract at this level as long as he can do better. As more bids and offers are made, and agreements found, the market learns something of the new demand and supply parameters. Traders come to recognize certain bids as absurdly low and certain offers as ridiculously high, thus there develops a feel for the 'appropriate' price level for this market. This does not mean that traders learn the Supply and Demand curves, merely that they come to have a better appreciation of where the intersection point lies. As this learning occurs, the price range diminishes and the opportunity for profitable out-of-equilibrium contracts diminishes - and with it the incentive to seek for such opportunities. In this way changes in the level of market information affect the opportunity-incentive structure of the market. This structure, and the rate at which it changes as information is acquired, as well as the information and market learning levels themselves, are functions of the institution and trading rules being modelled. Being able to observe and analyze processes of adjustment makes experimental markets an appropriate tool for studying disequilibrium dynamics.

10.4.2 Signalling and 'Mistakes'

Disequilibrium contracts and the signals they produce are the measures by which the market learns to adjust. In a progressive auction for example, if prices are held too low, that is, below the equilibrium level, it is very likely that an extra-marginal trader will secure a unit of the commodity at the expense of an intra-marginal trader whose valuation is higher. This disequilibrium transaction will frequently result in several intra-marginal traders being forced to bid up the price of later units. When this happens traders, either consciously or unconsciously, register that it is dangerous to delay bidding till the end of the auction and raise their bidding levels to secure an earlier unit. This has the effect of returning the market to an appropriate price level. Conversely if prices are initially too high and fall away as the auction proceeds, buyers who contracted early in the auction will observe that had they been less eager they could have bought for less, thus they learn to moderate their demands and prices fall towards the equilibrium position. These disequilibrium movements are therefore part of an equilibriating process. Only analysis of different market structures will be able to tell whether the movements will be sufficient to bring about an equilibrium *state*. The speed and direction of change is particularly significant in a non-stationary world since if prices tend to approach the equilibrium position systematically from above, prices will be biased above the equilibrium most if not all of the time. Experimental market analysis has shown that this one-sided approach to equilibrium is especially likely where schedules or conditions are asymmetric. For example, if supply elasticity exceeds demand elasticity, prices are likely to approach equilibrium from above, and if price ceilings are established, even at levels above the equilibrium price, market prices will approach equilibrium from below.

10.4.3 Market Constancy and Equilibrium

Experimental studies have shown that under certain institutional arrangements market prices will tend towards the equilibrium level if market supply and demand conditions are constant. To ensure the constancy condition all traders who participate in the market are assumed, upon resumption of trade the next day, to hold their pre-trade stock of assets. This 'repetitive constancy' condition is usually assumed to be derived from Marshall (Smith, 1962) but originates in Edgeworth's discussion of the effect on asset distributions and prices as the number of traders is progressively increased (Edgeworth, 1881, pp. 31, 42, cited in Walker, 1973). Marshall thought this contancy condition resulted from his assumption of the constant marginal utility of money but this is not so (Walker, 1969).

If, instead, at the start of each new day, traders who participated in the market the previous day are assumed to begin the new day with the asset distribution resulting from the previous day's trading it is difficult to see how constant market conditions can prevail. The new asset distribution will imply a new pair of market supply and demand schedules, the intersection of which need not be the same as the previously established equilibrium level.

To overcome this problem, the exchange markets analyzed may be assumed to refer to flow-supply and flow-demand. The scope for such applications, however, maybe more limited than is normally supposed. Take a labour market for example. The constancy conditions may apply to the supply schedule - since the 'capacity of a worker to undertake labour is the same at the beginning of each new day', and 'they can have no accumulated stock of past labour to bring to the market' (Walker, 1973, p. 142) but the same clearly does not apply to labour demand. Moreover it is somewhat doubtful as to how far it applies to labour supply since the willingness of suppliers to supply labour could well be a function of their cash reserves or asset distribution which, in turn, is affected by their participation in the market on previous days.

While market constancy has enabled initial development to be made and has established certain benchmarks, the analysis of price adjustment requires extension to changing market conditions in which equilibrating processes may nevertheless not result in a static equilibrium state. What the constant market experiments have established is the ability to equilibrate under constant conditions, the same ability may operate under changing conditions or it may not.

10.4.4. Markets in a State of Change

Our economic system is in perpetual and permanent disequilibrium. Conditions are not constant as is often portrayed, thus 'The gains obtainable by guessing better and acting sooner are not a mere will-o-the-wisp, luring the actors toward inevitable frustration in equilibrium, but are the crucial motive power and adaptive mechanism of a system that is permanently in disequilibrium' (Nelson and Winter, 1977, p. 271). The ability of experimental markets to catch and to analyze this 'motive power and adaptive mechanism' is the key to future developments in the theory of disequilibrium, which leads us to:

Conclusion Three: *Experimental economics is uniquely adapted to analyze problems in disequilibrium dynamics.*

10.5 Future Directions

The initial economic experiments established a method, or technique for examining economic issues which involve subjective judgement and complex feed-back mechanisms, issues not generally amenable to standard methods of analysis. Since the beginning in the 1960s experimental analysis has grown quickly. Techniques have been polished, initial results verified, and new topics opened up. At this point of time it would be correct to say that experimentation has established itself as a viable analytical procedure. It is certainly more than a mere data-generating mechanism. Nelson and Winter comment, a propos of computer simulation, that 'It is, in short, a very pernicious doctrine that portrays simulation as a non-theoretical activity, in which the only guiding rule is to "copy" reality as closely as possible. If reality could be "copied" into a computer program that approach might be productive - but it can't, and it isn't' (Nelson and Winter, 1977, p. 273). And *a fortiori* for experimentation.

10.5.1. Benchmarks

What experimentation has produced so far are a set of benchmarks against which more complicated or more advanced experimental results may be judged. While the conditions of market constancy do not apply in the real world, the ability of experimental studies to do what is impossible in empirical studies and keep markets constant, enables the basic abilities of different market institutions to be established.

10.5.2 Historic Irreversible Time

The next step is to establish how far these results need to be adjusted to make allowance for the fact that competitive processes take place in historic time, generating changes which are irreversible, an issue that Joan Robinson has pursued many times. At one point she writes 'Never talk about a system *getting into* equilibrium, for equilibrium has no meaning unless you are in it already. But think of a system *being* in equilibrium and having been there as far back towards Adam as you find it useful to go ... so that every *ex ante* expectation about today ever held in the past is being fulfilled today. And the *ex ante* expectation today is that the future will be like the past' (Robinson, 1974, p. 144). The implication is that the concept of equilibrium has no meaning except in a stationary state. Stationary states, in essence, are what are being examined, partially, in experiments with repetitive constancy.

Constant conditions generate an idea of equilibrium adjustment similar to the swings of a pendulum around some centre of gravity. The type of equilibrium, in the sense of a position to which the market is tending, for a real and changing world might rather be likened to a dog chasing its master on a bicycle. The bicycle follows a certain route that is followed, with many stops, sideways deviations and diversions by the dog, nevertheless, the dog does have a focus. That focus changes in historic time. Moreover the adjustments that the market needs to make at any particular time depends not only on the path of the bicycle but also on the past movements of the dog. In this sense every market experiment in historic time may generate individual adjustment paths. The aim should be both to establish the effect of institutional arrangements on the path taken and how far the path may be predicted (and altered), knowing some (or more) of the early adjustment moves.

10.5.3 Institutional Change

Once allowance is made for the effect of historic time, institutional change can not, nor need, be ignored. The twin advantages of experimentation is that transactions take place in real, though condensed, time, and are conditioned by the institutional arrangements and trading rules being modelled which makes it possible in the future to take the next step - to model institutional change.

Previously it has been argued that when the incentives for profitable action facing traders are not met with enabling opportunities this will set up the desire for change. One way in which such changes may be examined is to permit subjects, after a period of operation according to one set of rules, to vote on one change which will then apply during a further operation period. The changes that are suggested, the profitability for traders of these changes, the stability of the new institutional arrangements, are all possible areas of investigation.

Indeed the possibilities are unlimited.

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