# 1. MARKETS

More than anything else in the history of the development of economic thought, experimental economics is about "the extended order of markets" whose outcomes are not part of the intentions of the participants.

It is accurate to say that markets emerged out of the dim past of social and economic exchange as an inscrutable human social "propensity to truck, barter and exchange," rather than to describe them as having been invented. Even today, as in the experimental subfield of economic system design and testing, although "invention" appears to be prominent initially, all designs are subject to continuous change and adaptation in the light of experience and feedback; first in lab testing, then ongoing in the field. For example, the Chicago Mercantile Exchange has a book of rules, consisting of a three ring loose-leaf notebook, symbolizing the persistence of change based on experience that characterizes institutions. This is the central feature of markets in this Handbook.

## *1.1. Institutional Environments*

### *1.1.1. Properties of the Double Auction*

The double auction is a dynamic, real-time bid/ask continuous trading mechanism. It appears to have evolved originally as a two-sided generalization of the open outcry progressive auction, but was co-opted in the form of various electronic versions beginning in 1976 in both the lab (A. Williams at Arizona) and the field (the Toronto stock exchange). The term itself comes from the "old finance" descriptive literature, and was introduced to economics only through laboratory experiments that, from their inception, had to come to terms with the microstructure of trading. As an institution it continues to be subject to ongoing modification and selection for a great variety of new applications.

The laboratory discovery of the double auction's remarkable convergence properties to static equilibrium and its ability to track random (and other) shifts in the supply and demand environment has invited many experimental investigations supplemented by much data analysis. Plott here summarizes six properties, suggestively and graphically labeled (Sawtooth, Beacon, Pushing, etc.) that characterize some of the endogenous features of this mechanism's facilitation of price discovery. These features spotlight the extent to which empirical discoveries from experiments have greatly outrun the development of adequate dynamic theories of price discovery in economics that are institution-specific.

In asset trading environments, it was found that a positive or negative excess of bids over asks – revealed as a natural part of the trader message interaction process and using a Walrasian interpretation of adjustment – foreshadows movements in contract price formation. Bosserts and Plott exploit this discovery and subsequent elaboration and extension to the within-period and across-period motion of prices on the road to finding the equilibrium in controlled supply and demand experiments. The predictive information content of the bid/ask arrival structure enables one to apply numerical methods (here, it is Newton's) and via successive updated approximations in real time to describe the convergence to equilibrium.

In this development it is crucial to note that convergence processes, like the traders, are completely ignorant of the state to which the market converges. This fact continues to mystify the economics profession, although experimentalists were forced to incorporate it into their thinking long ago. The mystery that remains is to fully characterize this convergence process. How and why the bid/ask arrival process is able to provide the discovery procedure that anticipates price movements and the unknown equilibrium is unknown and not yet formally modeled. It is clear, however, that if the price is below the equilibrium of unknown conditions of supply and demand, the number of buyers who would want to buy at that price exceeds the number who want to sell. Hence is it natural to expect a greater intensity of bid activity than ask activity. At the margin, this differential activity is a correct predictor of change toward the unknown equilibrium.

These articulations are an important step in replacing the standard economic story – market participants need complete information – with the more realistic fact that such information cannot – and demonstrably does not – need to be given to any one mind in order to achieve efficient realizations for resource allocation. The complete information requirement stems from Jevons (1888/1871). If it were otherwise, how could the economy even function in the manner traditionally believed in professional and applied discourse?

A partial equilibrium approach to modeling the bid/ask spread from the perspective of optimal individual trader choice introduces a probability distribution that a contract resulting from any given submitted bid (ask) will be accepted. Consistent with this model, Smith and Van Boening show that a behavioral empirical property of double auction trading is that if you increase uncertainty in the supply and demand environment this increases the observed bid/ask spread standing whenever a contract occurs; i.e., increased uncertainty in the environment increases the bid/ask spread.

Brewer studies further the important finding by Gode and Sundar that institutions carry some of the intelligence that enables individuals to discover equilibrium in a market, relieving them from dependence on full rationality. The finding has been confined to isolated single-commodity markets, and its robustness to multiple commodity markets is unknown. However, Brewer looks at robustness where the buyer/seller limit price bounds are continuously refreshed, and expands somewhat the limited intelligence of the traders who are nevertheless of limited rationality. He also provides a nice guide to the development of this literature including the theoretical work pioneered by Hurwicz and his coworkers.

The hypothesis that institutions provide algorithms that assist traders is very powerful. The challenge ultimately is to understand how the algorithmic behavior of traders interacts with institutions as algorithms to yield socially optimal outcomes approximated by what we observe; this interaction occurs outside of anyone's conscious intention.

Smith and Williams demonstrate and articulate the anatomy of the response of double auction markets to external price controls, either ceilings or floors, binding or non-binding. The key discovery from experimental probes by Isaac and Plott was that both binding and non-binding controls slowed convergence to the competitive equilibrium. Why is this? It seemed transparent from traditional static supply and demand theory that the market (1) should quickly lock on to the control price – ceiling or floor – if it is binding and (2) have no effect whatsoever if it is not binding. Both propositions are robustly false and in the report of their work, Smith and Williams show why: it is implicit in the dynamics of the double auction process. In double auction processes, buyers and sellers, not knowing anything about an "equilibrium price" or what might constitute a realizable trade, start from an initial advantageous position of strength – they bid low, and ask high relative to their respect induced values and costs. Then they concede competitively, narrowing the bid/ask spread. But a price ceiling asymmetrically limits the buyer and seller strategy spaces: it has no effect on the capacity of buyers to begin bargaining from advantageously low bids, while sellers can start no higher than the ceiling. The normal tendency to concede then yields contracts lower than would prevail if there were no ceiling. The process is reversed if there is a floor price control. This discovery sheds important new light on the importance of understanding how institutions mediate the market price discovery process. It was only one of the dozens of discoveries that changed the way experimentalists think about economics and markets.

### *1.1.2. Properties of Posted Offer Processes*

Even where alternative institutions yield equilibrium convergence, the dynamics differ greatly, and there is wide variation in the ability of different pricing processes to track changes in the environment.

Posted offer pricing was one of the early trading institutions examined in the laboratory, and it played a central role in alerting experimentalists to the significance and role of institutions in understanding economic behavior in markets. It is the pricing mechanism most often put forward by economists when they seek to model oligopoly behavior or think about market power. Posted offer pricing is particularly visible because of its ubiquity in retail markets.

The simplicity of posted offer relative to double auction trading has invited more theoretical modeling, but in the tradition of standard price theory the models abstract from strategic behavior by buyers; i.e., demand is given and fully revealed by buyers who are (in effect) modeled as robots in the standard theory. This qualification and limitation is not always evident in proposed policy and other applications of market power theory. Relevance is sometimes justified on the basis that in some applications

there are a great many buyers, who by assumption are usually thought to reveal demand. But this assumption has never been tested so far as we are able to determine.

How might buyers, whatever their number relative to sellers, influence seller posted offer prices? There are two ways: (1) sellers may expect that buyers may overreact (retaliate) to an increase in price; (2) buyers may react by withholding demand, particularly at the margin, which has been observed in experimental markets, and prominently in monopoly markets with multiple buyers. As documented in experiments, demand withholding even at the margin has strong disciplinary power in cases of decreasing marginal and average cost (since the marginal units are the most profitable), leading firms to compete brutally for volume.

The first entry in this section deals with an issue concerning possible retaliatory buyer behavior in markets due to perceived "unfairness." It has been found in questionnaire response studies that buyers resist changes in posted offer prices that are not cost justified, that arise from external changes in the environment, because these increases are perceived as "unfair" based on available information. Kujal and Smith manipulate information to investigate this "fairness" argument in a market context, and ask whether fairness affects the path or the equilibrium if the latter is modified for a taste for "fairness" in the sense of preference for more equal outcomes: the path is affected, but "fairness" washes out in determining the new equilibrium which is based on traditional, competitive, profit-maximizing behavior.

In posted offer pricing, where a competitive equilibrium outcome is not supported by a Nash pure strategy equilibrium there is a potential for unilateral self-interested action to lead to behavior that is natural to define as market power. "Edgeworth cycles" are a prominent example, and this suggests the possibility of a mixed strategy Nash equilibrium defined on the premise that buyers have no role in influencing posted prices. Davis and Wilson explicitly consider this approach for characterizing seller behavior in posted offer markets. They find that this approach poorly organizes seller behavior. Since they control for any effects due to buyer behavior by simulating fully revealing buyers, the failure cannot be due to buyer responses.

Kruze directly addresses the issue of buyer influence on seller posted price behavior. She compares posted offers by two sellers in markets using robot demand-revealing buyers with markets using human buyers. Mean posted prices are significantly higher when the robot buyers fully reveal demand.

As a means of having close experimental control on the expression of demand, experimentalists remove the effect of seller inventories on pricing behavior by treating all trades as applying to contracts for sales to order. Since most of the gross national product and a growing share of it are for services, this is not an oversimplification. Nevertheless, it is important to ask how price formation in posted offer and double auction institutions is affected by the need for sellers to manage inventory simultaneously in order to facilitate sales. Mestelman reports many experiments comparing the two institutions in this environment. One important finding is that the advantage that the posted price procedure has over double auction (for sellers) *disappears* when they have to manage inventory to make sales.

Just as price controls, both binding and non-binding, impact the dynamics of market convergence processes, quantity controls or quotas affect market convergence behavior. Kujal summarizes experiments examining this phenomenon in posted offer markets, demonstrating how quotas interfere with the price–quantity equilibrium discovery process.

### *1.1.3. Call Markets and Sealed Bids*

Smith reports a robustly replicable example of a remarkable property of two-sided bid-offer trading institutions. In this example, all trades clear at a uniform price and traders closely approximate the predicted competitive equilibrium: many accepted bids and asks are tied or nearly tied at the equilibrium clearing price. Consequently, the equilibrium is strategy-proof. This emergent property enables each side of the market to "regulate" the ability of the other side to extract more favorable terms. No trader can influence the price by withholding some of his or her units from the market. The market frequently achieves 100 percent efficient allocations, but only 5–10 percent of the induced supply and demand surplus is revealed in the bids (asks).

In this section Cox provides a summary of the theory – various risk preference models – of the first- or high-price sealed bid auction developed in response to experimental tests. All these auctions build upon the pioneering work of Vickery. Cox also summarizes the principal results from experimental tests of these models. Auctions have been a particularly fruitful success story for non-cooperative equilibrium theory after the original models of Vickery were modified for risk aversion.

### *1.1.4. Alternative Market Institutions*

Walras observed in the 1870s that the French bourse used a trading procedure that avoided the occurrence of trades at different prices. Economic theorists thereafter were attracted to studying the dynamic properties of the "tatonnement" mechanism Walras used to describe general multi-market equilibrium determination. The idea was to use an iterative procedure to discover equilibrium clearing prices that would avoid non-equilibrium trades that changed endowments and generated complex path dependent trajectories. The London gold market used the same procedure (adding unanimity as a stopping rule), but it was not an institution adopted in other market applications. This long history was reason enough to invite experimental testing and comparison with the other institutions discussed in this section.

Bronfman et al. and Plott report experiments making it plain that the tatonnement is inefficient and yields volatile outcomes. There is no suggestion that the French were somehow missing something obvious, as Walras's version may well have ignored additional institutional structure supplied by the auctioneer, who was not modeled. The episode is a mystery, leaving unexplained why a procedure with such flawed incentive properties has survived so long.

Friedman and Rich examine an unusual institution which was created by government and other agents without benefit of either an equilibrium theory or a testing methodology. In this case, the "Matching Market" (some versions have been called a "buyers' bid auction") in which the highest remaining bid is matched with the lowest offer in order and filled at the bid price so long as that price is greater than the matching ask. They find this mechanism to be inefficient relative to the uniform price sealed bid-offer clearing market. This contribution illustrates the hazards of market design proposals that are offered without test-bedding their properties to determine if they have undesirable outcomes or are dominated by well-known alternatives.

Plott discusses two methods of implementing the Walrasian adjustment mechanism that have been tested in the experimental literature. Although both have performed satisfactorily in isolated single commodity markets with linear excess demand, neither does well in nonlinear or multiple market settings. Part of the poor performance is a consequence of strategic misrepresentation of the excess demand, and part comes from coordination failure across markets. The problems are especially evident – even in the single market case – where there is no price that yields zero excess demand, although there is a price above which excess demand is negative, and below which it is positive. Such markets converge in the continuous double auction, but fail to do so with the tatonnement.

### *1.2. Imperfect Competition*

The theory of perfect competition stemming from W.S. Jevons specified conditions so restrictive and impractical that both theory and public policy were destined to deal extensively with market imperfections in the achievement of static market equilibrium. Although Jevons imagined that complete information on supply and demand was essential for market participants to reach a competitive equilibrium, neither he nor his followers have produced a theorem showing that competition prevails with such information and fails in its absence. Instead we have a proliferation of cases in which competition is compromised depending upon the dearth of firms, market power, whose conditions depend more critically on the intra-firm cost-capacity structure than the number of firms, collusion, various information asymmetries, entry barriers, and so on.

Contestable markets theory and laboratory experiments independently brought new insights to the notion that the world was inherently non-competitive. The former focused on the cost of entry relative to its value to the entrant thereby linking competition in a completely natural way with decision in the context of opportunity cost. The world defined the opportunity set of the firm whose location-entry decision was in response to everything in the environment that could potentially yield benefits in excess of the cost of entry. Industrial organization went dynamic, but also returned to fundamental economic decision-making as it applied to entry and exit.

Experimental economists discovered: (1) complete information on the conditions of supply and demand, as proposed by Jevons and thereafter accepted, are not necessary nor even sufficient for agents to discover a competitive equilibrium; (2) the institution

of trading significantly impacted competitive outcomes through its implicit information revelation properties; (3) competitive outcomes were mediated by agent choice governed by opportunity cost comparisons in single markets that varied the cost of entry, and multiple market participation choice by buyers and sellers; (4) the predicted potential for profit to be left on the table because of information asymmetries were overcome by reputation formation, warranties, and participant monitoring of those who had the inside asymmetric information, as agent behavior signaled the need for more comprehensive models of the role of information in equilibrium; (5) contestable market theory performed as predicted; (6) it was difficult to show that concepts of rational predatory pricing described observed behavior in market experiments.

These developments together had straight-forward implications for public policy: reduce all artificial entry barriers such as restrictions on trade foreign or domestic, impediments to new business formation, nontransferable management and worker benefits, and so on.

### *1.2.1. Market Power*

Fehr and Gachter use laboratory experiments to examine two models that have been offered to explain the persistent residue of inter-industry wage differentials after controlling for job, worker and demographic characteristics. Is the residue a consequence of not having identified all the factors determining the differentials or a failure of the law of one price in a market? Experiments control for "other characteristics," and therefore provide an independent approach to hypothesis testing. Fehr and Gachter test two versions of the theory of efficiency wage differentials: reference fair-wage effort, and shirking, where the wage differential is paid to reduce shirking. Both versions survive the laboratory tests. For example, firms with better profit alternatives (higher value for the work) pay wages above the competitive wage to induce more effort (or to prevent shirking).

The paradox of power is that in many instances, such as in the distribution of income, the strong do not grow ever more powerful relative to the weak. Thus the poor who have more votes than the rich have not appropriated any substantial share of the latter's resources. Durham, Hirshleifer and Smith test a Nash–Cournot model resolving the paradox in terms of diminishing returns to appropriative effort. The results show good conformance with the several predictions of the model.

The paper by Davis and Holt provides the basic primer on market power, its definition and manifestation in experiments, and the emergence of collusive behavior by market participants. Since entry cost is infinite by experimental design, these partial equilibrium exercises demonstrate the mischief that can persist in the complete absence of any discipline of entry.

Bosch-Domenèch and Vriend examine the path-breaking early literature on oligopoly behavior (1959–1961) summarizing the effect of information and institutional form (quantity vs price adjusting) on the occurrence of cooperative or competitive outcomes.

This literature not only launched experimental economics, but it also defined the laboratory protocols that continue to influence how experiments are designed and executed.

Cox and Isaac's entry shows how and why institutions, contestability, and incentive designs can matter in the decentralized restraint or control of monopoly behavior. It was this theme – institutional design for monopoly control – that originally inspired Vickrey's investigation of incentive compatibility, and his contributions to auction theory.

### *1.2.2. Collusion*

Cason provides a brief but comprehensive discussion of results in the literature on price signaling, conspiracies and their often observed transient impact on competitive outcomes He also reports that the airline industry, which has been plagued by profit troubles, uses its multiple market participation to squeeze some profits from collusion. Airlines are an interesting example in which specific airlines dominate certain airports, but most have persistently failed to convert such apparent market power into profitable operations.

Gomez, Goeree and Holt report the results of laboratory experiments designed to elicit predatory pricing behavior. The question is whether an incumbent can gain by temporarily pricing below marginal cost, drive out the entrant, and then enjoy an unmolested and profitable monopoly. It turns out that such behavior was difficult to find. They report three replications of a single contrary experiment that yielded predation, found none, and then report a simpler design in which predatory behavior emerged. The theoretical and experimental literature on predation is deficient in failing to fully model entry/exit cost: for example the effect of predatory behavior on the target firm's asset value. Thus, where the sunk cost of an entrant is high because of specialized, long-lived capital, predatory behavior destroys asset value by forcing its resale price to be discounted by the predation, and any new buyer (public policy should not allow purchase by the incumbent predator) enters at a lower cost so that it can effectively compete against predation. Otherwise – hat is, when there is a low entry cost and high contestability – predation carries little advantage: every price increase after effective predation attempts to pick its monopoly fruits and invites new highly contestable entrants whose entry cost is low.

Sherstyuk provides an extensive discussion of the literature dealing with the special anti-competitive issues arising in multiple unit progressive auctions because of incentive incompatibility ("demand reduction") arising in a naturally occurring institution. She also indicates how these effects can be mitigated by redesigning the institution and eliminating the signaling culprit – open bidding by the agents – for example by using English clock procedures including the combinatorial clock. This work illustrates the principle that less information and a truncated message space may improve performance. For example, "jump bidding," in which bidders raise the standing bid by more than the bid increment, is eliminated by the English clock. A high degree of uncertainty regarding identity and number of bidders is particularly important for efficiency and the control of collusion.

### *1.2.3. Non-classical Cost Environments*

Traditionally, non-convexities have been thought to undermine the efficiency properties of the competitive model as derived in the neo-classical synthesis. Where an industry was characterized by scale economies that were large enough to exhaust all demand, natural monopoly was thought to be the state that would emerge. J.B. Clark (1904) stated the idea of potential competition but failed to develop its full analytical implications: the plant that is not built but could be built provides a limit on price. Contestable market theory formally introduced the concept of "hit and run" entry, with prices limited by entry opportunity cost.

Plott reports the results of competing firms that choose between two markets. One market is characterized by scale economies, and he finds that among the various possible imperfect competition models, a single firm emerges in the industry, and prices are Ramsey competitive as predicted by contestable markets theory.

But certain non-convexities can create severe price discovery problems in certain institutions, such as double auction, that in classical environments are exceptionally effective. The problem is at the foundation: any institution that converges to yield the law of one price in a market will fail to be efficient because no price line or hyper plane cleanly separates the two sides of the market. Efficiency requires nonlinear, disjoint or multi-part pricing such as might be included in directly negotiated contracts.

Van Boeing and Wilson summarize experiments providing a particularly compelling example of non-convex supply in which firms incur only avoidable fixed costs – costs that do not vary with the level of output, but must be incurred if any output is produced. The structure is such that demand passes through a gap in the supply function. With double auction trading, convergence to a single price allows a higher cost firm to enter, but demand cannot support the entry, and market allocation is inefficient. The authors preclude entry, which can (but need not) provide a solution in some parameterizations. Indeed, entry cost itself can be an avoidable fixed cost. How behavior in their environment would evolve if the troublesome "entrant" in their market had an outside option is an open question.

## *1.3. Dynamics of Market Adjustments*

In this section, the papers report work on market price stability, market disintegration, asset market price bubbles and entry decision coordination.

Hypotheses governing adjustment in price–quantity space and the stability of competitive equilibrium points in that space captured alternative modes of thinking about agent responses in disequilibrium states. Supply quantity lags behind the current price, the current price change depends on excess demand at that price, or the current quantity change depends on the gap between the demand and supply prices (marginal surplus) for that quantity. Since traditional economic theory was not institution-specific, this void was filled in by the experimenters. Plott uses the double auction to test the quantity and

price adjustment hypotheses in an environment with multiple equilibria, each stable or unstable by one or the other hypotheses tested.

Organized exchanges in Chicago, New York and elsewhere have rules prohibiting or controlling the occurrence of "off floor" trades, that is, outside the designated hours and locus on the exchange floor. Are these rules functional in terms of market performance and maintenance, or are they only an obvious manifestation of the exchange firm's desire to collect its service fees? The problem posed for study by Smith and Van Boening is described by a parable:

> In the beginning, traders were dispersed in space and time, and it was transaction-costly for the traders to find each other and to negotiate private trades; a fee-for-trades exchange firm was formed where traders congregate to negotiate, and the multilateral double auction was born with public display of prices in real time; traders are now in close proximity to each other and find it natural to defect from the exchange and trade bilaterally at low negotiation cost since they can free-ride on the prices discovered by the market (such information being a public good). This compromises the viability of the exchange firm in facilitating central markets.

Smith and Van Boening report experimental results in which subjects in electronic double auction exchange are given the opportunity to easily make bilateral "off floor" trades that bypass the organized market. A growing number of such trades occur over time. These trades tend predominantly to split the available gains from exchange at prices inside the standing bid/ask spread. Moreover, the standing bid/ask spread tends to widen, and prices become more volatile, as the price discovery process fragments.

Price bubbles are as old as asset trading, and have characterized organized stock markets since their inception in the nineteenth century. This phenomenon motivated the idea of creating a "transparent" asset trading market where shares had a well-defined, intrinsic value based on common trader information concerning share expected, or average, dividend value. Using these experimental results as a baseline, the research program originally was expected to inquire if price bubbles – trading away from intrinsic value – could be created by controlling information or other elements.

But a funny thing happened at the very beginning: the baseline environment generated huge price bubbles and the research program turned to questions of replication and to the study of a great variety of treatments that were conjectured might mitigate the phenomena These treatments include experience within or across diverse groups; homogeneity of endowments; the imposition of price change limits based on the previous period's close; subject sophistication (business executive and even over-the-counter market makers); allowing subjects to buy on margin and to sell short; futures trading; dividend certainty; recruiting subjects who were required to bring their own money to mitigate an alleged "house money" effect; varying the supply of money relative to shares; preventing resale of previously purchased shares; and so on.

Replication by others proved that it was not a peculiar "Arizona" phenomenon and none of the mitigating treatments eliminated bubbles except one: experience in the same group – bring the same group to the lab three times, and prices in the third session

deviate little from dividend value and volume slows to a trickle. Some of the treatments reduced somewhat various measures of the severity of the bubble; others made the bubble worse on one or more measures. For example the bubble is smaller or greater depending on whether subjects are endowed with less or more cash, confirming the observation that the stock market is sensitive to changes in monetary policy; futures trading is accompanied by a reduction in spot share price bubbles, consistent with the hypothesis that there is a problem with common dividend information being sufficient to induce common expectations. Bubbles are exacerbated by margin and short trading, but are nevertheless eliminated by experience across three sessions of experience.

The results reported by Williams, Porter and Smith, by Fisher and by Noussair and Plott document many of these findings. Not all of the reported treatment effects range across all three levels of experience.

Rapoport and Seale study a class of (0, 1) entry games in which the average number of entries tracks with remarkable if not perfect accuracy the Nash equilibrium. These results look "like magic" to Kahneman who introduced the game to cognitive psychologists, and "like magic" to economists. They look this way to anyone who accepts the implicit hypothesis that desirable individual and social outcomes are unattainable except by cognitive self-awareness, focused attention and prolonged deliberation. Welcome to the world of experimental economics: this Handbook is filled with examples of this kind of "magic" replicated over and over in a great variety of contexts during the last half century. Rapoport and Seale find these particular entry game results replicable and robust with respect to a number of treatment and parameter changes. It is like the bubble results, intransigent, but here the results support "rational" economic performance.

It is not magic. Rather, it is simply not understood by any of the constructivist models in the standard toolkits of either economists or psychologists because those models deal with outcomes not processes. Asking the subjects does not help, for they do not understand it either, any more than they can tell you how they are able to drive a car while thinking about their term paper.

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