Demand Shocks, Advance Production, and Market Power: Some Lessons about Markets from the Laboratory

Douglas D. Davis⁺ and K. Ramagopal^{*}

⁺ Department of Economics, Middlebury College Middlebury VT 05753 and School of Business Virginia Commonwealth University, Richmond VA 23284-4000

^{} The School of Business Administration, University of Vermont, Burlington VT 05405*

This paper summarizes some recent research pertaining to laboratory markets, and then discusses some of the implications of this research for applied economics and policy.

Three results are discussed: (a) In one-sided markets where sellers post prices price-tracking response to demand shocks is very poor; (b) Despite the prominence of the Cournot model as a centerpiece for applied research, it is very difficult to construct an environment where Cournot outcomes are observed; (c) Market power, or the capacity of sellers to unilaterally deviate from the competitive prediction, is a prominent characteristic in short run price-setting contexts.

INTRODUCTION

In the forty years since Chamberlain (1948) first reported results of a market experiment, the use of laboratory methods by economists has increased exponentially. Laboratory methods have become a standard research tool in areas ranging from individual decision theory to macroeconomics, and papers reporting experimental research are now commonplace in economics journals. Economists not well acquainted with experimental work may view this trend with some skepticism. Apart from lessons of the most specific sort (e.g., that in a particular context, the notion of a sequential equilibrium organizes the outcomes of a game well) what can be learned from college sophomores playing computer games for cash?

In fact, experimental research has generated a number of results that are relevant to applied contexts. Indeed, in an important sense, the central focus of experimental research is toward applied and policy issues. Policy decisions often stem from economic theories. However, assessing the behavioral relevance of these theories with evidence from the natural world is often difficult or impossible. Experimental methods allow investigators to observe directly the capacity of theories to organize behavior. The implications of several general findings from the laboratory suggest modifications in the way that economists conventionally approach some very standard issues.

Consider, for example, the managerial problem of formulating a strategic policy for a firm in a industry with relatively few competitors. The textbook approach to this problem would involve drawing some inference about a firm's residual demand schedule, typically from past sales. The manager would also make some assessment

regarding the nature of competitive process. If output decisions are fairly flexible, competition is usually viewed as a Bertrand game, and price choices are the focus of interest. On the other hand, if production requires some advance commitments to inputs, competition is judged to be “Cournot,” and the focus of strategic output choices becomes a capacity decision. In this latter case, short run price competition is typically presumed to be of rather secondary interest, and is determined by the market.

The appropriateness of these conclusions turns on the behavioral validity of three important conditions. The first is that relevant information about demand can be ascertained from sales prices. Second, is that the characterization of a competitive process as a Cournot game is appropriate when firms must make binding production decisions. The theory underlying this condition is the well-known demonstration by Kreps and Scheinkman (1983) that Cournot outcomes are a unique subgame perfect equilibrium for a two-stage game, where sellers pick quantities in the first stage, and then compete on the basis of prices in the second stage. This model is routinely used as the basis for justifying the use of Cournot outcomes as the predictions for long-run competition. The third condition is that given short-run capacity constraints, pricing decisions are of secondary importance once production decisions have been made.

Results of recent laboratory research are beginning to raise serious questions about each of these conditions. First, depending on the type of trading rules used in a market, past transactions prices can provide very poor information about demand. Second, the effects of binding advance production decisions on market performance are sensitive to the trading rules used, and in any case Cournot predictions have very little behavioral appeal. Third, the problem of pricing under short run capacity constraints

can be non-trivial. Market power, or the capacity of individual sellers to profitably deviate from the market clearing price very often arises, particularly in posted-offer (retail) markets.

The primary objective of this paper is to describe in some detail the three results just mentioned, and to consider what these results suggest for managerial planning and policy. Additionally, it is hoped this review will help create some appreciation for how laboratory analysis can fit into the economist's "toolbox." The paper is organized as follows. A brief description of the way a laboratory market is created is provided in section 2, along with some discussion of how experiments can be used to approach policy issues. Sections 3, 4 and 5 then review research pertaining to demand instability, Cournot specifications, and market power, respectively. Some final comments are offered in a brief sixth section.

LABORATORY MARKETS: METHODOLOGY AND IMPLEMENTATION

The primary advantages of experimental analysis are replicability and control. *Replicability* is the notion that any researcher can reproduce the conditions described by another, and expect to independently verify the observed phenomenon. As a methodological device, the role of replicability is critical, in that it offers a publicly verifiable standard of observability.¹ As a procedural matter, it requires a specification of methods and procedures sufficient to allow an interested investigator to repeat an

experiment and verify the result. For this reason, it is conventional for experimenters to publish (or at least provide ready access to) their instructions.²

Control is the idea that the researcher is able to construct an environment with enough precision to allow the investigator to conclude that observation of (or failure to observe) a phenomenon of interest is a consequence of the induced incentives, and nothing else. As a methodological device, it is control that allows the researcher to make a claim to results, for example, that a particular theory explains or fails to explain behavior. Procedurally, control requires specification of the environment of interest in a manner that is as precisely related to relevant theory or issue under examination as possible.

Some insight into the advantages of control is gained by examining how a laboratory market is created. Consider the basic theoretical question of whether markets are drawn to the competitive price and output allocations predicted by standard price theory. Evaluating this requires providing participants with incentives that induce a supply and demand structure with pre-specified competitive predictions. Start with the supply side. A collection of participants identified as sellers are assigned costs for one or more abstract “units.” The participants are then invited to sell as many of these units in the market as they desire, under the condition that they keep as earnings the difference between the sales price and the unit cost. For example, in Figure 1, a seller S3, might be induced with a cost of 110 cents for a particular unit. If S3 managed to sell the unit for 135 cents, S3 would keep 25 cents as earnings. Given that 110 cents is a minimum price below which no profits are made, 110 cents represents a minimum willingness-to-sell unit supply price. Endowing several sellers with multiple units, and

ranking the units from lowest to highest in cost generates a market supply schedule.

The step line curve labeled **S**, in the left side of Figure 1, illustrates an induced market supply schedule for six sellers, labeled S1 to S6, each of whom are endowed with two units.

The market demand schedule is constructed similarly. In this case buyers are endowed with a collection of unit values, and are invited to buy units with their redemption values, under the condition that they keep as earnings the difference between the endowed unit value and the purchase price. A buyer B3 for example, might be given a unit valuation of 160 cents for a particular unit. If B3 purchases the unit for 135 cents, B3 would keep $160 - 135 = 25$ cents as earnings. Since 160 cents is a maximum price, above which B3 would earn nothing, this value is a maximum willingness to pay unit demand value. Endowing several buyers each with multiple units, and ranking unit valuations from highest to lowest generates a market demand schedule. The step line curve labeled **D** in the left side of Figure 1 illustrates a maximum willingness-to-pay marginal valuation schedule for a market consisting of six buyers, B1 to B6, each of whom is provided with incentives to purchase two units.

Competitive equilibrium price and quantity predictions follow from the induced market supply and demand structure. As indicated by the dashed lines in Figure 1, a quantity of seven units are predicted to trade, at any prices in the range between 130 and 140 cents. The ambiguity of the price prediction in Figure 1 is a consequence of endowing buyers and sellers with discrete units. Given discrete units, market supply and demand must overlap either vertically, creating a range of prices consistent with the competitive prediction, or horizontally, creating a competitive quantity range. Vertical

overlaps are more conventionally used, since generating the competitive price prediction with a horizontal overlap requires a transaction for which neither a seller or a buyer earns any profits.³

Market sessions typically consist of a number of independent trading periods. At the outset of each period buyers and sellers are endowed with the unit valuations and costs and are invited to trade. Trade proceeds until a pre-announced closing condition is met (for example the expiration of a time constraint), and the market is closed. Following market closure, earnings are calculated, and traders are re-endowed with unit costs and valuations for a subsequent period.

Notice how the parsimony of the design facilitates evaluation of competitive predictions. The traded commodity is abstract, and has value only in the laboratory environment. Moreover, those values are strictly specified by the experimenter. Thus, buyer or seller preferences for, or aversions to particular products (say chocolate bars, or coffee mugs) cannot arise as rival explanations for observed behavior.⁴ Deviations from the predicted competitive outcome are (at least largely) a consequence of the failure of the elements included in the design to elicit these outcomes.⁵

The above design, however, is incomplete. It is insufficient to merely provide buyers and sellers with incentives to trade. In order for trading to occur, some rules governing acceptable communications as well the language of contracts must be specified. The specification of such rules define the *trading institution*. One very standard institution is the *double-auction* trading rules that characterize trading in many financial exchanges. Double-auction trading is two-sided and sequential: Sellers make offers to sell, and buyers make bids to purchase. Either side may also accept terms of

trade proposed by the other side of the market. Offers, bids and contracts are centrally and publicly displayed.⁶

The upper right panel in Figure 1 illustrates trade in a sample double-auction session conducted using the market demand and supply arrays shown in Figure 1. Each trading period is represented as a numbered vertical column. In each bar, contracts are represented by dots. The widely dispersed scattering of dots in trading period 1, for example indicates considerable price volatility. Observe further that none of the contracts were within the competitive price band, bounded by the thin dotted lines. As indicated at the bottom of the column, a total of eight contracts were struck in period 1, one more than the competitive prediction. As is also indicated at the bottom of the column, the market was 89% efficient in this period, meaning that 89% of the consumer and producer surpluses (the area between the supply and demand curves) was extracted in the trading process. Much closer conformance to competitive price predictions is observed in periods 2 and 3. In each period the competitive quantity prediction of seven was traded, and all but one of the 14 contracts were struck within the competitive price band. The market was 100% efficient each period.

The rapid convergence to competitive price and efficiency predictions illustrated by this session is typical of double auction exchange (e.g., Smith 1982). Double auction markets tend to generate efficient, competitive outcomes under a surprisingly wide range of circumstances, including unusual “boundary” supply and demand configurations where all the surplus goes to one side of the market or the other (Smith and Williams, 1989), when supply and demand arrays are not stable across trading periods (Davis, Harrison and Williams, 1993), under conditions where sellers are

allowed to engage in explicit conspiracies (Isaac and Plott, 1981; Clauser and Plott, 1993), and even in “thin” markets, where one side of a market has only two or sometimes a single trader (Smith and Williams, 1989; Smith, 1981). In fact, double auctions are so robustly competitive that the observation of deviations from the competitive prediction often merits publication.⁷

Posted offer trading rules define a second very standard institution. Posted offer rules more closely parallel exchange in retail and producer-goods markets, where negotiation costs would be high relative to the value of the traded good. Markets of interest in industrial organization economics are often organized under some variant of posted-offer rules. In contrast to the double auction, trading under posted-offer rules is simultaneous and asymmetric. At the outset of each trading period, sellers simultaneously post prices and maximum sales quantities, under the conditions that the seller must be willing to sell at least one unit at the posted price, and that sellers bear the cost only of units that are subsequently sold. Once all posting decisions are complete buyers are drawn from a waiting mode, one at a time, and are given the opportunity to shop. While shopping a buyer may make as many purchases as desired. The trading period ends when all buyers have shopped, or when all sellers are out of units.

The bottom right panel of Figure 1 illustrates the results of a sample posted-offer market. As illustrated by the dots in period 1, the pattern of contracts in a posted-offer market differs distinctly from that observed in the double auction, with buyers purchasing units from sellers with the lowest posted prices first, followed by progressively higher-priced units. Offers that did not result in trades, illustrated in the

panel as crosses, are the highest priced units. This pattern persists in the subsequent periods, with transactions prices dropping slowly toward the competitive outcome. Notice also the summary information listed at the bottom of each column. In marked contrast to the double auction, competitive predictions are not quickly observed, and efficiency extraction rates are far less than complete. In period 1 only four units traded, generating only 70% of the possible gains from trade. Quantity improved to eight units in period 2, but efficiency increased only to 78%. Efficiency remains low, even after several periods. In period 5, for example, only five units traded, and only 81% of the possible gains from trade were realized.⁸

As with the sample double auction market, the results of the illustrated posted-offer market are very typical. Prices tend to converge to competitive predictions from above. Competitive price, quantity and efficiency extraction rates are generated, but more slowly than in the double auction (see e. g., Plott, 1986). In addition to comparatively slow convergence rates, posted-offer markets are less robustly competitive than double auctions. Posted offer markets are susceptible to “thin market” problems where one side of the market has only one or two sellers (Smith, 1981, Smith and Williams, 1989), as well as explicit collusion (Isaac, et al. 1984; Davis and Holt, 1998). Also, as shown in more detail below, posted-offer markets also respond abysmally to demand adjustments, and are extremely susceptible to market power exercise.

Prior to proceeding, we offer two additional methodological comments. The first pertains to the links between laboratory research and applied or policy economics. The markets created in the laboratory are by needs very simple ones, and the researcher

must be very careful in drawing inferences about natural contexts from experimental data. The most straightforward use of laboratory evidence applies to theory, for in the laboratory the assumptions of a theory can be matched with a controlled precision unavailable in the natural world. If the theory fails in the simple “best shot” environment of the laboratory, it is difficult to see how the theory can explain behavior in more complex natural contexts

The strongest links of experiments to policy making then, are through theory. Policies, after all, are based on theories. The absence of behavioral support for a theory in the laboratory suggests the foundations of the policy are questionable. Relatedly, policy debates often turn on differences of opinion as to the relevance of rival theories. If one of two competing theories in a debate does a better job organizing behavior in the laboratory, the data provide some direct support for the superior performer. Finally, even with qualifications about extensions from the laboratory to natural contexts stated, laboratory results can, in some circumstances, *suggest* (although not prove) important behavioral determinants in natural contexts. When certain elements of a laboratory environment (for example, key features of the trading institutions) have strong and obvious parallels to certain natural markets, laboratory results that turn on these elements invite suggestions about their naturally occurring analogues.

The second comment pertains to the kinds of effects that typically are the focus of laboratory market research. As suggested by comparing the contract series for the double auction and posted-offer markets in Figure 1, market performance is importantly affected by trading rules. These effects apply not only to comparisons between double

auction and posted offer markets, but to variants of these institutions, and to other institutions that are different altogether. The focus of economic laboratory research on institutional effects has considerable appeal, since the costs of evaluating the effects of trading rules in natural contexts dwarfs the costs of generating comparable data in the laboratory. Although examination of institutional variations is by no means the exclusive focus of economic laboratory research, it is a prominent one. For example, two of the applications discussed below are exclusively institutional issues (those pertaining to demand shocks and binding advance-production decisions); while the third (the effects of market power) is importantly affected by institutional details.

MORE ON THE IMPORTANCE OF INSTITUTIONS: NONSTATIONARY DEMAND

Recent research indicates that some of the differences between posted offer and double auction performance noted above (in particular, differences in the price convergence path) are mitigated or even eliminated in more general variants of the standard laboratory implementations of the posted offer and double auction institutions, when trade is conducted under repeated stationary conditions (Mestelman *et al.* 1987, Mestelman and Welland, 1988, 1994). The choice of institutions, however remains critical. One institutional difference that appears fairly resilient to institutional modifications is the dynamic response of posted offer markets to demand side changes.

Consider the inflationary, then deflationary “trend-demand” design illustrated in the left panel of Figure 2. For the first two trading periods, three buyers and three sellers are induced with the supply and demand arrays labeled $\mathbf{S}$ and $\mathbf{D}_{1,2,15}$, respectively. Under the competitive prediction, five units trade at any price in the range between 240 and 250 cents. The quantity prediction, as well as 245 cents, the center of competitive price range, are marked with dotted lines. Prior to starting trading period 3, marginal redemption values for buyers are all increased by 30 cents to create demand curve $\mathbf{D}_{3,14}$. These individual demand incentives are increased privately, and it is only through the responses of buyers to price postings that sellers can learn of the shift. As indicated by the intersection of $\mathbf{S}$ and $\mathbf{D}_{3,14}$, the competitive quantity prediction increases by two units to seven, and the center of competitive price prediction increases by 20 cents, to 265. Similar upward shifts in demand are repeated prior to periods 4 through 8, generating the illustrated series of equilibrium predictions. In period 8 the equilibrium quantity prediction is 17 units and the center of the equilibrium price range is 365 cents. Period 8 incentives are repeated in period 9, followed by a sequence of demand reductions in periods 10 to 15. The resulting equilibrium price path is the stepped “Christmas Tree” shown as the solid lines in upper and lower panels on the right side of Figure 2.

In the three double auction markets, shown in the upper panel, price tracking is far from perfect.⁹ Relative to the solid stepped-line equilibrium price path, the transactions price paths for the three sessions (shown respectively as dotted, dashed and solid lines) tend to lag a bit below the competitive price in early periods of the inflationary regimes (periods 2 to 4) and somewhat above the competitive price in early

periods of the deflationary regime (periods 8 to 10). Nevertheless, mean prices in each session generally follow the underlying movements in prices. These markets also tend to be extremely efficient, extracting more than 98% of the available gains from exchange on average. Note finally that the average of closing prices, illustrated as the series of open circles, provides very useful information. As suggested by the very near proximity of the circles to the equilibrium prediction, closing prices tend to provide a very precise indicator of the underlying equilibrium each period.

In contrast, mean transactions prices for the posted-offer markets, show in the bottom panel on the right side of Figure 2, do not even remotely follow the equilibrium path. Rather, prices tend to drift up slowly through the inflationary regime, and then continue their upward trend until again crossing the equilibrium price several periods into the deflationary regime. When the underlying equilibrium falls below the transactions price, trade tapers off in each market, and finally terminates altogether, as indicated by markers that highlight truncations of each series at some point between periods 11 to 13. Efficiency performance for the posted offer markets parallels the abysmal price tracking performance. Mean efficiency for each of the three markets is roughly 50%.

The very poor price tracking and efficiency performance of the posted-offer markets is a consequence of the one-sided nature of the price-posting process. Each period sellers see only the publicly posted prices as well as their own individual sales. A seller can infer that prices are generally too high only in the unusual case where that seller both posted the lowest price, and sold nothing.¹⁰ In other cases of zero sales, the seller may believe only that sales went to the other lower-pricing sellers, and that the

only price revision necessary is to undercut the prices posted by rivals. Conversely, when the sales volume is positive, the seller learns nothing about the maximum price buyers could pay for units.

Mechanisms in naturally occurring retail-type markets could, in principle, resolve some of these informational deficiencies. In some natural contexts, buyers solicit and receive private discounts from sellers. Also, sellers in natural markets typically get some information about the relation of price to demand by customer reactions: In the event prices are too high, sellers frequently post a second “clearance sale” price. On the other hand, evidence of excess demand is communicated via queues of consumers looking for products at a posted price when the inventory is exhausted. As a first step toward investigating the corrective characteristics of these variations from the standard laboratory posted-offer implementation, Davis and Holt (1997) report an experiment consisting of an additional 12 market sessions. In addition to the three standard posted-offer sessions illustrated in Figure 2, performance in three other treatments was investigated. In a first treatment, buyers were allowed to request discounts from the sellers’ posted-prices. Sellers responded by offering a discount of any desired size (including no discount at all), which the buyer could purchase or reject. This discount was private, and was not revealed to other sellers or buyers. In a second treatment, sellers posted a second “clearance sale” price after all buyers shopped given the first postings.¹¹ In a third treatment, buyers provided excess demand information. After all buyers had completed the shopping sequence, they indicated to each seller how many additional units they would have purchased from a seller at his or her posted price, were extra units available.

Results of these three treatments are illustrated in the three panels of Figure 3. As seen in the figure, price-tracking in each case improved somewhat relative to the baseline. In each treatment prices for one session more nearly followed the rough outline of the movement in the underlying equilibrium path than in any of the posted offer sessions. Price performance, however, remained far inferior to that observed in any of the double auction treatments, and in most instances was not markedly improved over the baseline posted-offer sessions. Efficiency extraction rates similarly improved somewhat in each of these posted-offer variants relative to the baseline. But the improvement was only slight, with efficiency extraction rates averaging between 60% and 69% in each treatment.

These generalizations to standard posted offer rules, of course, are not exhaustive. In natural contexts, for example, sellers could offer multiple “clearance sale” re-postings to clear an inventory. Further the discount, clearance-sale and excess demand techniques may be used jointly. The effects of these combined treatments remain to be investigated.¹² Results of the research conducted to date, however, is highly suggestive: The quality of information generated by past transaction prices is highly sensitive to the type of trading institution from which the prices were drawn. Although prices for goods and services sold on two-sided spot or financial markets may reflect underlying market conditions with some precision (particularly the closing prices), posted retail or producer prices are liable to provide highly misleading information about underlying demand.¹³

ADVANCE PRODUCTION AND COURNOT MARKETS

Although variants of double-auction and posted-offer trading rules comprise the most standard of trading institutions, they are by no means exclusive choices. A wide variety of other auction forms appear regularly in natural contexts. The ascending-bid English or “country” auctions frequently used to auction antiques and paintings, the variants of sealed-bid auctions used for government procurements, and the two-sided “call” markets used in many financial exchanges for opening trade and for floating initial offerings are just a few of the more typical alternatives.

Still other assumed institutional structures derive their importance more from their use as a modeling device for economics than as a mechanism of exchange. In particular, when modeling interactions between a limited number of players, economists frequently presume that competition typically follows a Cournot process. The implicit assumption of the Cournot specification, that sellers compete by posting quantities, is institutionally rather artificial. It is difficult to conceive of a naturally occurring context where prices are somehow set by the interaction of market demand and supply curves. However, the more institutionally appealing alternative of Bertrand price competition is theoretically “unrealistic” in that the market structure is unimportant. Assuming a homogenous product and no effective capacity constraints, price competitors always have an incentive to undercut any common price above the competitive level. Thus, as long a market has more than one seller, only the competitive outcome can be a pure strategy Nash equilibrium.

The most standard theoretical justification for using a Cournot specification is a two-stage game by Kreps and Scheinkman (1983). The game is constructed as a model of a long run competitive process, where sellers pick capacity in the first stage, and then compete on the basis of price in the second stage. Under rather general conditions, Kreps and Scheinkman show that the Cournot outcome is the unique subgame perfect Nash equilibrium for this game.

A number of questionable assumptions must be made for this theory to apply to natural contexts. In particular, the model assumes that buyers make purchases according to an efficient rationing rule.¹⁴ More generally questionable is the relevance of dividing the real-time nature of the natural world into a series of long-run periods where sellers make essentially simultaneous capacity choices, with the intra-period intervals marked only by price competition. An even more fundamental question, however, pertains to the capacity of the Kreps and Scheinkman specification to generate Cournot outcomes.

Davis (1997) reports an experiment designed to investigate this latter issue. The experiment consisted of twelve triopolies, conducted under the supply and demand arrays illustrated on the left side of Figure 4. As suggested by the numbers identifying sellers, listed below cost steps on the market supply schedule, the design consisted of three symmetric sellers, each of whom could offer a maximum of six units for trade; A first unit costs 5 cents, followed by a second unit costing 45 cents, two units at 65 cents, and two units at 80 cents. Buying behavior was simulated by the experiment monitor. Following the posting of prices and quantities by sellers in each period, the

monitor mechanically made all purchases profitable as a single purchaser, induced with the marginal value incentives listed as demand schedule **D**.

Half of the twelve sessions were conducted under standard posted offer rules, with sellers making simultaneous price/maximum quantity choices each period under the condition that production quantity choices were not binding: Sellers, that is, incurred the cost of producing units sold only in the event that the units sold. Under these conditions, competitive sales quantity $Q_e = 12$ and price $P_e = 80$ cents define the unique pure-strategy Nash equilibrium for the stage game.¹⁵ Per seller earnings are 140 cents.

The remaining six sessions were conducted identically, except that prior to making a price decision sellers made a binding quantity choice. Following the argument made by Kreps and Schienkman (1983), this shift in rules changes the unique Nash equilibrium for the stage game from the competitive outcome to the Cournot prediction $P_c = 140$ cents and $Q_c = 9$ units. Per seller earnings under the Cournot outcome are 300 cents.

The intuition underlying this result is straightforward, and is illustrated in Figure 5. Once the first-stage capacity decisions are made, production costs are sunk. Therefore, the optimal price choice in the second stage is simply the revenue-maximizing choice. Under most circumstances this is the price that will clear the market quantity that has been produced. Suppose, for example, that all sellers select the Cournot quantity of three units, and consider incentives for seller S3, shown in Figure 5. Since unit costs are sunk, cost assignments may be rotated as desired. Thus, S3's units are placed furthest to the right to highlight the effects of a unilateral

deviation. At the market clearing price P_{cl} revenues ($abdc$) are maximized. Any price below P_{cl} will decrease revenues for each of the three units sold. Given the discrete demand steps, the most profitable possible price increase will be to P' , the highest price consistent with the sale of all units at the next demand step. At P' revenues on two of the three units will increase, (shown as the striped box $a'b'xa$), but at the typically higher cost of revenues foregone from the sale of an available unit, (shown as the dotted box $xbdd'$). Thus prices are mechanically determined at the market-clearing level, given first-stage quantity decisions, and the game is essentially a quantity choice game.¹⁶

To facilitate evaluation of the underlying theory, each of sessions was conducted under conditions of full and common information regarding costs and valuations.¹⁷ Also, to give the sellers sufficient experience with the environment, each the market consisted of at least 35 trading periods.

Despite the fact that the competitive and Cournot predictions are unique Nash equilibria in their respective environments, adherence to Nash predictions differed markedly across treatments. As seen in the upper panel on the right of Figure 4, the posted-offer markets were uniformly drawn to the competitive price prediction. For example, in the final 10-period block common to all sessions, highlighted by the thin vertical bars, the average price was about 82 cents. The treatment was also competitive in other dimensions. Over periods 26-35 average earnings were about 138 cents and the average transactions quantity was 11.5 units.

In contrast, convergence to the Cournot prediction in the advance-production sessions, illustrated in the lower panel on the right side of Figure 4, was far less than

complete. As suggested by the thick line representing the average for all six sessions, it is clear that relative to the posted-offer sessions, prices are higher. Stable Cournot outcomes, however, are never observed. First, prices are too low. For the six sessions, the mean price over periods 26-35 is 111 cents, almost exactly midway between competitive and Cournot predictions. Earnings and output, at about 206 cents and 10.5 units respectively were similar about halfway between Cournot and competitive predictions. But, as is further suggested by the figure, prices in the advance production sessions were also persistently volatile. Unlike the posted offer markets there was no indication in any session that sellers were “settling down” to a particular behavioral outcome.

It is interesting to consider why the predictions break down. Nash-Cournot predictions do not break down because sellers fail to realize that setting the market clearing price is optimal when there is no excess capacity. For example over periods 26 to 35, roughly 85% of price choices were essentially at the market clearing level. Rather, predictions fail because of the instability of Cournot incentives themselves. The instability of Cournot incentives is a predominant characteristic of numerous previous experiments conducted using a Cournot specification (see, e.g., Fouraker and Siegel, 1963, and Rassenti *et al.*, 1996).

The potential instability of Cournot incentives has been known for some time. Theocharis (1961) observed that given linear demand and constant costs, Cournot games were dynamically stable only in the case of two sellers. With three sellers, oscillating cycles are generated, and with four or more sellers the market is explosively unstable. However, Fisher (1961) and others observe that a variety of factors tend to

enhance stability, including in particular increasing costs, and less than full-adjustment best responses. In part, results illustrated in Figure 4 suggest that the responses of Fisher and his colleagues should not lead economists to dismiss easily the instability issue raised by Theocharis. However, from a behavioral perspective, Theocharis was right, but for the wrong reason. Although participants convincingly learned the wisdom of posting the market clearing price in the second stage, participants did not make best-response outcomes at the outset of the sessions, nor did they learn to do so by the session's end. Over the last 10 periods common to all sessions, less than 20% of quantity choices were consistent with best-responses. An understanding of how participants respond in such circumstances remains an important open question.¹⁸ Alternatively, it may be the case that some variant of the capacity choice/price choice game does generate Cournot outcomes.

But neither of these observations detract from the implications of the central result: Binding advance production decisions may create strategic opportunities, and may result in higher average prices and lower average output than in comparable Bertrand environments. Nevertheless, Cournot predictions provide a very poor basis for planning, and an unstable reference for policy decisions. At the least, when firms compete on the basis of quantities, economists should think about acknowledging the extreme variability of possible outcomes.

CAPACITY CONSTRAINTS AND MARKET POWER

Consider again the second stage pricing phase of the advance production game, shown in Figure 5. As a general rule, once all sellers have made production decisions, the pricing decision is mechanical. Since production costs are sunk, sellers simply maximize revenues. But the market-clearing price does not always maximize revenues. Suppose, for example, that after collectively posting the Cournot quantity of nine units, the market demand curve shifts in to D_L . Avoiding for the moment the issue of how sellers would learn of the demand decrease (discussed above in section 3), note that any seller can increase revenues by posting a price P'_L above the market clearing price P_{cl-L} . For specificity, consider again incentives for seller S3. At price P_{cl-L} , S3 sells three units, to earn area $efdc$. Raising the price to P'_L , S3 foregoes revenues from the sale of an already produced unit ($yfdd'$), but more than makes up for this loss by doubling revenues on the two units that are still sold ($e'f'ye$). Since the sellers are symmetric, S1 and S2 have similar incentives. The incentive for sellers to unilaterally deviate from the intersection of market supply and demand curves is the key to the notion of *market power*, developed by Holt (1989). Market power arises when the competitive equilibrium for a one-period market game is not a Nash equilibrium.

Nash equilibrium calculations are typically far from a trivial matter, even in highly structured posted offer markets. Given multiple buyers and sellers, each with the unique set of cost and value incentives necessary to generate “usual” supply and demand structures, specifying the complete structure of incentives becomes rather complex. However, it is generally not difficult to identify when market power exists in posted offer markets. Further, it is possible to construct designs where the relevant Nash equilibrium calculations are also tractable.

Davis and Holt (1994) report one such experiment. The purpose of the experiment was to isolate the effects of market power as an explanation for supra-competitive prices. The principle design manipulation involved two treatments. In each case market supply and demand schedules are held fixed, as are the number of sellers. The treatments differed only with respect to the presence or absence of market power.

The supply and demand arrays shown in the left panel of Figure 6 illustrate. In the “no-power” variant, sellers S1, S2 and S3 are each endowed with one low-cost unit, and two high-cost units, as illustrated by the numbers printed below the cost steps on the supply curve. Small sellers S4 and S5 are each endowed with a single unit. The relevant demand curve is the solid line marked **D**. In the competitive outcome, 11 units trade at a price of P_c . No seller has market power in this design. Since an excess demand of three units exists at any price at any price above P_c , any unilateral deviation from P_c will reduce sales for the deviator to zero.

Market power may be introduced by reallocating S3’s two high cost units to S1 and S2, as indicated by the italicized numbers printed below the high cost step. Given a capacity of four units, S1 and S2 each find a unilateral deviation from P_c profitable provided that the limit price r deviates sufficiently from the competitive prediction. By raising price to r , sales for S1 or S2 would fall from four units to one. But profits would increase as long as $r > 4P_c - 3c$.

Notice that r is not a Nash equilibrium for the market “stage-game.” At a common price of r either S1 or S2 could increase sales from one unit to four by posting a price slightly below r . Incentives remain for S1 and S2 to undercut any common

price until earnings from selling four units as the low pricing seller no longer exceed the certain earnings available from posting the limit price r and selling a single unit. In terms of the parameters of the model, incentives to price shade persist until $P_{\min} = (r - 3c)/4$. The unique equilibrium for this market involves mixing over a range of prices bound by r and $(r - 3c)/4$. The large sellers (S1 and S2), and the smaller sellers (S3, S4 and S5) mix over different distributions. Calculation of these mixing distributions is rather complicated, and is unnecessary for the present purpose, but two features of the distributions merit comment. First, the entire range of both distributions involve prices above P_c . Thus, market power unambiguously raises prices. Second, the mean of the mixing distribution for the larger sellers, $P_{1,2}$ is fairly close to $P_{\min}$, indicating that most of the density in the predicted distribution is concentrated at the lower end of the price range.¹⁹

The experiment consisted of six sessions. Each session consisted of 60 trading periods, 30 in each treatment condition. To facilitate evaluation of the game-theoretic predictions, the markets were conducted under conditions of full information. Further, buyer behavior was simulated as a single fully revealing buyer. Also to control for possible order-of-sequence effects, the order of the market power and no-power treatment was alternated across sessions.

The effects of market power are clearly illustrated by the average price paths for the three no-power/power sessions and the three power/no-power sessions, shown in upper and lower panels on the right side of Figure 6. As is evident from a comparison across the panels, the adjustment to the P_c prediction is less than complete when the no-power treatment follows the power treatment. Nevertheless, in either case, prices

clearly tend to be higher in the market power sessions than in the no-power sessions. In fact, for each of the six sessions, the average transactions price for the last 10 periods of the power treatment exceeded the average transactions price for the no-power treatment.

Davis and Holt also conducted an additional six sessions to investigate the effects of a pure “numbers effect.” In these sessions, the allocations of sellers S3, S4 and S5 were consolidated into a single seller. This adjustment leaves power unchanged, since the randomizing distributions for the sellers is unaffected, but reduces the number of sellers. Results further support the hypothesis that market power, rather than the number of sellers in a market is the primary explainer of supra-competitive pricing: Although prices were slightly higher in the three-seller sessions with power than in the five seller sessions with power, the difference was slight.

Market power of this sort has several very practical implications. First, of course, is the almost pedestrian observation that price competition, once capacity choices have been made is a far from trivial matter. Due either to miscalculations in the capacity choice stage, or to changes in demand, strategic opportunities can arise in the pricing stage.²⁰ More generally, the notion of market power also provides a very useful basis for public policy. Consider, for example, the standard antitrust problem of assessing the likely anti-competitive effects of a horizontal merger. The rather poor explanatory power of Cournot predictions suggests that the predicted links between the number of sellers and price-cost mark-ups form a questionable basis for policy. On the other hand, attention to a pure Bertrand process (without capacity constraints) forces the policy-maker into the highly speculative business of assessing the likelihood that the

allowed merger will, in the future, entice competitors into collusive agreements. Alternatively, market power focuses on *unilateral* activity. A merger should be proscribed if it allows a seller to profitably deviate from competitive outcome.²¹

The notion of market power has been the focus of considerable recent policy-oriented experimental research. In closing this section, we consider two dimensions of market power that have been investigated recently in the laboratory: market power as an explanation for countercyclical mark-ups, and the possible effects of market power in markets for pollution permits.

Market Power and Counter-Cyclical Mark-Ups

The first application pertains to “price-stickiness.” A sluggish response of prices to demand changes has been hypothesized to be a factor contributing to real output fluctuations. A variety of explanations have been offered. One explanation that has received considerable attention recently is a theory of optimal collusion, (e. g., Rotemberg and Saloner 1986). In periods of recession, low prices reduce the gains from cheating on a collusive agreement, so colluding firms find it optimal to raise mark-ups. Although this theory is broadly consistent with sluggish price-adjustment performance at the macroeconomic level (e.g., Rotemberg, 1982), it requires the behaviorally unpalatable assumption that collusion (either explicit or tacit) is an endemic characteristic of U. S. industrial performance.

Reynolds and Wilson (1997) develop an alternative explanation for countercyclical mark-ups that relies on unilateral market power rather than collusive activity. The model adapts the Kreps and Schienkman (1983) capacity choice/price

choice game reviewed above in Section 4, to allow for demand uncertainty. Given demand uncertainty, production to expected demand may result in market power in low demand realizations. In terms of Figure 5, for example, if **S** was selected as the optimal response to an uncertain demand, the demand realization **D_L** would result in market power. As a consequence the equilibrium for the second stage pricing game would involve mixing over a range of prices above the market clearing level.²²

Wilson (1996) evaluates some implications of this theory using two and three digit SIC data for seventeen industries, and finds support for the market power hypothesis. In addition to the sluggish price-adjustments observed previously by Rotemberg (1982), factors specific to the market-power hypothesis receive some support. Prices are more variable in periods of low demand (since firms are mixing in low demand realizations). Moreover, the distribution of prices is skewed in recessions (predicted since the bulk of the equilibrium randomizing distribution involves prices near the lower bound of the mixing range).

Although supportive of the market power hypothesis, tests with naturally occurring data can provide no direct evidence of market power. Wilson (1996) reports a clever variant of the Davis and Holt (1994) market power experiment to generate relevant direct evidence. Rather than reallocating units among sellers, the principle treatment in Wilson's experiment involved a shift between a low demand condition, illustrated in Figure 6 as demand curve **D**, where market power was present, and a high demand condition, illustrated by the dotted-line demand curve D_h , where all unit valuations were 100 cents higher. Market power is absent in the high demand

condition, because earnings on high cost units are sufficiently high to make a unilateral deviation from the competitive price unprofitable.

Wilson's principle treatment consisted of six sessions, each consisting of a pair of 30-period power and no-power treatments, as in Davis and Holt. To facilitate evaluation of the theory, sellers were provided full information about the structure of underlying costs as well as demand. Market power effects similar to those reported by Davis and Holt were observed: Markets tended to competitive outcomes when the competitive equilibrium was a Nash equilibrium. But supra-competitive pricing was observed when market power was present. The difference, of course, is that in Wilson's experiment, the demand-side market power led to countercyclical price mark-ups, since competitive outcomes were observed in periods of high demand.

This direct evidence that market power can drive the hypothesized price/cost mark-ups, at least in a simple environment, is an important complement to Wilson's empirical work. The combination of supportive characteristics from naturally occurring markets, and direct observation in a controlled laboratory context place a considerable burden of explanation on those supporting the rival "collusive" markup theory. Perhaps discrimination between the collusive and market power variants of a theory of countercyclical markups could be even more sharply delineated with an experiment where collusive opportunities (either explicit or tacit) were present, but market power was absent.²³

The sluggish response of posted-offer markets to demand shifts observed above in Section 3 also motivates considerable price "stickiness," even in the absence of market power. Apparently, the explanations differ in the expected duration of effects.

In the trend-demand design, demand continually shifts, and adjustment fails because sellers never obtain relevant information. In the environment explored by Wilson (1996), sellers were subjected to a single shock, under conditions of complete information. The relevance of these different observations merits further investigation, but likely depends on the stability of demand in natural contexts.²⁴

Market Power in Markets for Tradable Pollution Emission Permits

Market power is not uniquely a characteristic of posted-offer markets. Deviations from competitive predictions attributable to market power in laboratory markets have been reported by Holt *et al.* (1986), and Davis and Williams (1991). But market power effects tend to be much smaller in double-auctions than in posted-offer type markets. Nevertheless, as shown in this second application, market-power can also impose sizable inefficiencies in some double auction contexts.

The application pertains to the establishment of markets for emission permits. In recent years emission permit markets have gained widespread recognition as an effective way to minimize the social abatement costs of pollution. When markets are competitive, the efficiency-enhancing effects of permit markets are readily apparent: Firms requiring emission-intensive processes to produce goods that are highly socially valued can profitably purchase permits from firms that produce less valuable products, or that find switching to less emission-intensive processes less costly.

In some potential markets, however, a single firm accounts for a sizable portion of the total emissions.²⁵ Popular proponents of emission markets dismiss market power concerns, arguing that market power effects are likely to be small, and in any case,

even an emission market distorted by market power will function more efficiently than the “command and control” alternative, where the state assigns emission rights.²⁶

A second argument that market power considerations are of secondary importance is that the choice of an appropriate market trading institution will mitigate any power created by the market structure. As observed above in Section 2, laboratory double auction markets are so robustly competitive that competitive outcomes were often generated even with monopolies (Smith, 1981, Smith and Williams, 1989, Ledyard and Szakaly-Moore, 1994).

Recent experimental work impressively refutes both of these arguments. Godby (1997a) shows that the double auction institution is not alone sufficient to generate competitive outcomes. Market power was regularly and successfully exercised in double auction monopolies with a large, but diffuse “fringe” of permit buyers. But the exercise of market power in a permit market is not alone enough to suggest that market power could make an emissions market less efficient than the state assignment pollution rights. If downstream product markets are competitive, manipulation of permit prices will only distort the distribution of earnings for market participants.²⁷ However, further experimental results by Godby *et al.* (1996), and Godby (1997b) show that efficiency losses relative to nontradable permit assignments arise regularly as a behavioral matter when a firm has market-power both in the market for permits, and in the down-stream product market. The extent of inefficiencies depend on the initial assignment of permits. But if the dominant firm is granted a large initial endowment of permits, the firm can not only distort prices in the permit market, but can also purchase permits to exclude the fringe in the product market.

The policy implications of these results are again direct. Although markets can improve efficiency, the reservations of those worried about details like structural considerations are not just the protestations of pessimistic naysayers. If relatively unsophisticated students are able to detect and exploit market-power as “dominant firms” in two-hour laboratory markets, there is considerable reason to believe that the far more experienced and sophisticated dominant players in natural markets will be able to exploit their position. Both in theory and in practice, market power can undermine the benefits of creating a market.

CLOSING REMARKS

Despite the fact that the typical subject pool is college students, laboratory analysis has several lessons to offer economists, even to those with very applied interests. Market experiments, conducted in their very simple environments yield valuable insights into the way that different market organizations affect performance. These insights force us to consider carefully which models are better guides to market performance.

The very encouraging results of initial market experiments, largely that competitive outcomes were generated with some regularity, were not trivial exercises demonstrating something that every reasonable economist knew to be true. Neither are the persistent deviations from theoretical predictions observed here an indication that the experiments have been done incorrectly. Rather, theory alone is an imperfect guide

to human behavior, and policies based on theory alone can be no more useful than the theories upon which they were based. Experiments, in their simplicity, cannot replace analysis of data from the natural world. But experimental data clearly has a role in policy analysis. They can help guide economists to when and under what circumstances theories work and when they do not. They can help economists discriminate between those theoretical observations that are important shortcomings of a theory, and other observations that are largely curiosities. In short, experiments can help give some behavioral grounding to the theory-laden, and sometimes ethereal study of modern economics.

ACKNOWLEDGEMENTS

We thank, without implicating Rob Godby, Stuart Mestelman, Bart Wilson and an anonymous referee for helpful comments. Financial support for this research was provided by the National Science Foundation (grant SBR 9319842)

NOTES

- ¹ We wish to emphasize that replicatory experiments should be funded, and that the results should be published, even when they disagree with previous findings. The possibility of replication imposes a critical discipline on experimental research.
- ² Instructions for more common experimental environments are available in standard references. For example, see Davis and Holt (1993), chapters 3 and 4 for instructions for the double auction and posted-offer markets discussed below in this section.
- ³ To induce the trade of such marginal units traders are often paid a small trading commission. But essentially such commissions generate a slight upward shift of the demand schedule, and a slight downward shift of the cost schedule, and thus create a vertical overlap of the type shown in Figure 1. In the case of commissions, however, the overlap is rather artificially constrained in that traders cannot negotiate over the terms of the final trade.
- ⁴ The theory of induced valuation does not apply to all issues that may be examined with laboratory methods. For example, in some circumstances, the research question pertains to the values individuals place on items in natural contexts (such as environmental quality). Inducing incentives in such cases would defeat the purpose of the investigation.
- ⁵ Although it is important to maximize control, control is never complete when free individuals are making decisions. Participants may not understand the instructions. Moreover, while paying participants reasonable cash earnings increases control,

occasionally a participant maximizes something other than earnings. These deviations are fairly rare.

⁶ Although a number of variations of double auction trading exist, it is conventional to also impose two additional rules: (a) Only the lowest bid and the highest offer are given standing, and (b) bids and offers that do not have standing are rank queued by order of proximity to the standing bid/offer spread. Incidentally, condition (a) corresponds to rules 71 and 72 of the NYSE (Leffler and Loring, 1963)

⁷ See, for example, Holt *et al.* (1986), Davis and Williams (1991) or Van Boening and Wilcox (1996).

⁸ The drop in efficiency in period 5 relative to periods 3 and 4 is a consequence of the random selection of buyers from the waiting queue. In period 5 buyers B1 and B2, with low unit valuations were drawn early in the period, leaving some buyers with high value units unable to make purchases. Had this market been continued for more periods, efficiency would have improved: The ordering of the shopping sequence becomes irrelevant as all sellers post prices close to the competitive prediction.

⁹ The design for the illustrated double auctions differs slightly from the supply and demand arrays shown in Figure 2. Supply and demand arrays intersected with horizontal rather than vertical overlaps, and to induce the trade of the marginal zero surplus units, traders were paid a five cent commission for each trade. Also, four rather than three traders were on each side of the market. The institutional effects illustrated are unaffected by these design differences. The transactions price paths for four posted-offer markets conducted under conditions used for the double

auctions are virtually identical to the posted-offer results illustrated (see Davis *et al.* 1993). The design and posted-offer sequences were chosen for compatibility with results of the posted-offer variants shown in Figure 3.

- ¹⁰ In some variants of the posted-offer institution, total market sales are provided as public information. The effect of this variant on market performance remains to be explored.
- ¹¹ In a repeated-stationary environment, a variant of this clearance sale treatment was very effective in reducing differences between posted-offer and double auction performance (Mestelman and Welland, 1994).
- ¹² Although differences across experiments impede comparability, the results of an experiment by Davis and Williams (1997) suggest that it is the one-sided nature of the posted-offer institution rather than the simultaneous nature of the price-posting process that causes the poor demand response. Davis and Williams report results of a two-sided “call” auction, where both sellers and buyers post reservation prices. Price tracking and efficiency performance of the call markets rivals that observed in the double auctions.
- ¹³ An interesting experiment by Cox and Oxaca (1995) suggests a very similar conclusion. These authors conducted a series of double auction and posted offer markets where supply and demand schedules were subjected to random shocks between periods. The authors then used various econometric techniques to estimate the underlying supply and demand arrays from the observed price data. One of their most prominent conclusions was that the estimates are highly sensitive to the trading institution.

- ¹⁴ As pointed out by Davidson and Deneckere (1986) Cournot predictions break down when other rationing rules are used. See also Herk (1993).
- ¹⁵ Although unique, the competitive outcome is a weak Nash equilibrium. No seller can gain by posting a price above 80 cents, if sellers collectively offer at least 15 units. But at a price of 80 cents, they are individually indifferent between offering 4, 5 or 6 units.
- ¹⁶ Although this intuition is correct it is incomplete, since posting the market-clearing price will not maximize revenues for all possible quantity combinations. (An exception for Demand curve D_L is illustrated in Figure 5, and is explained in the text below.) When posting the market-clearing price is not a dominant strategy, the equilibrium for the stage-game involves mixing. To establish that the Cournot quantity is the unique subgame perfect Nash equilibrium for the two-stage game it must be established that all allocations that involve mixing in the second stage are not subgame perfect. This condition holds because expected earnings in the mixing equilibria are always below earnings for those instances where posting the price is a dominant strategy.
- ¹⁷ Provision of such information is typical when evaluating game-theoretic predictions. (Cost and value information was also provided in the market power experiments discussed below.) Although this information condition is unrealistic in many natural contexts, satisfying it allows a cleaner test of the relevant theory.
- ¹⁸ One possibility suggested in a recent study by Rassenti *et al.* (1996) is that participants are motivated by dynamic considerations. Certain participants “play tough” in order to force others into accepting their relatively large quantity choices,

and earnings shares. This possibility is consistent with the data from the results summarized in Figure 4. A second possibility is that the Nash equilibrium is too strong a solution concept in this context. With some experience, decisions tended to cycle in the range of outcomes consistent with the notion of rationalizability, identified separately by Pearce (1984) and Bernheim (1984). For example in periods 26-35 (the last 10 periods common to all sessions, 96% of choices were consistent with rationalizability.

¹⁹ Small sellers try to price below the large sellers, in order to avoid being excluded from the market altogether. Thus the bulk of density in the mixing distribution for the small sellers is even closer to $P_{\min}$ than for the large sellers.

²⁰ Market power, in fact, can be insidious. Notice, for example in the aggregate supply and demand arrays shown in Figure 1, that S1 has some market power: Under posted offer rules, eight units are offered at $P_c = 1.40$, and seven will sell. But this is not a Nash equilibrium. If S1 raises price from 1.40 to 1.50, S1's last (zero-surplus) unit will not sell with certainty. But unless it is buyer B1 who happens to be drawn from the shopping sequence last, S1 will sell a single unit at 1.50. Since $5/6(150-130) = 16.67$ exceeds the 10 cents S1 is certain to earn by posting $P_c = 1.40$, S1 finds unilateral deviation from P_c profitable, and thus has some market power.

²¹ This is consistent with the approach taken in the 1992 DOJ Horizontal Merger Guidelines. Recent prosecutorial action by the FTC and the DOJ are consistent with this policy. For example, key to the FTC's case against the planned consolidation of Staples and Office Max, was the argument "that the combined company would have

enough market clout to boost its prices by as much as 10%” (Dow Jones, July, 2, 1997).

²² We thank Bart Wilson for pointing out that the equilibrium for the capacity-choice game with stochastic-demand has not yet been characterized for the cases where the number of sellers exceeds two.

²³ Results of previous laboratory research involving collusion in posted-offer markets suggests that although it may be possible for explicitly communicating sellers to exploit demand changes, it is highly unlikely that any sort of less explicit arrangement will generate supra-competitive profits, regardless of the demand conditions. Given opportunities to communicate, posted-offer sellers appear fairly capable of earning collusive profits (Isaac *et al.* 1984, Davis and Holt, 1997b). However, absent opportunities for verbal communications, sellers find coordinating activities exceedingly difficult (Holt and Davis, 1990; Cason, 1995).

²⁴ An additional 12 sessions reported by Wilson (1996) suggest that incomplete demand information may have persistent effects, even when sellers have considerable response time. These latter sessions were conducted identically to those reviewed in the text, except that sellers made decisions under conditions of incomplete information. Sellers were told neither cost or value information, but were told only that demand changed prior to period 31. In these latter treatments, Wilson reports considerable “hysteresis” effects: absent information, supra-competitive prices tend to remain after power has been removed, and that previously observed competitive prices tend to persist after power is introduced.

- ²⁵ Godby (1997), for example, notes that in one recently proposed NOx market in Canada, a single firm accounts for 50% of total emissions.
- ²⁶ This despite theoretic work indicating that market power effects can hamper seriously the benefits of success in such markets (Misiolek and Elder, 1989).
- ²⁷ But even confined to the permit market, market power exercise imposes dynamic efficiency costs, since it damps incentives for the large polluter (the dominant firm) to develop and/or adopt less emission-intensive technologies.

REFERENCES

- D. Bernheim (1984). Rationalizable Strategic Behavior. *Econometrica*, **52**, 1007-28.
- T. N. Cason (1995). Cheap Talk Price Signaling in Laboratory Markets. *Information Economics and Policy*, **7**, 183-204.
- E. H. Chamberlain (1948). An Experimental Imperfect Market. *Journal of Political Economy*, **46**, 279-338.
- L. Clauser and C. R. Plott (1993). On the Anatomy of the 'Nonfacilitating' Features of the Double Auction Institution in Conspiratorial Markets. In *Double Auction Market: Institutions, Theories, and Laboratory Evidence* (edited by D. Friedman, and J. Rust) Reading MA: Addison-Wesley.
- J. C. Cox and R. L. Oxaca (1995). Using Laboratory Market Experiments to Evaluate Econometric Estimators of Structural Models. Manuscript, University of Arizona.
- C. Davidson, and R. Deneckere (1986). Long-Run Competition in Capacity, Short-Run Competition in Price, and the Cournot Model. *RAND Journal of Economics*, **17**, 404-15.
- D. D. Davis (1997). Advance Production and Cournot Outcomes: An Experimental Investigation. Manuscript., Virginia Commonwealth University.
- D. D. Davis, *et al.* (1993). The Effects of Nonstationarities on the Convergence to Competitive Equilibria. *Journal of Economic Behavior and Organization*, **20**, 305-26.

- D. D. Davis and C. A. Holt (1998). Conspiracies and Secret Discounts in Laboratory Markets. *Economic Journal*, forthcoming.
- D. D. Davis and C. A. Holt (1997). Price Rigidities and Institutional Variations in Markets with Posted Prices. *Economic Theory*, **9**, 63-80.
- D. D. Davis and C. A. Holt (1994). Market Power and Mergers in Laboratory Experiments with Posted Prices. *Rand Journal of Economics*, **25**, 467-487.
- D. D. Davis and C. A. Holt (1993). *Experimental Economics*, Princeton: Princeton University Press.
- D. D. Davis and A. W. Williams (1997). The Effects of Nonstationarities on Performance in Call Markets. *Journal of Economic Behavior and Organization*, **32**, 39-54.
- D. D. Davis and A. W. Williams (1991). The Hayek Hypothesis in Experimental Auctions: Institutional Effects and Market Power. *Economic Inquiry*, **29**, 261-74.
- F. Fisher (1961). The Stability of the Cournot Oligopoly Solution: The Effects of Speeds of Adjustment and Increasing Marginal Costs. *Review of Economic Studies*, **29**, 125-35.
- L. E. Fouraker and Sidney Siegel (1963). *Bargaining Behavior*, New York: McGraw-Hill.

- R. Godby (1997a) Market Power in Emission Permit Double Auctions. *Research in Experimental Economics*, vol. 7 (edited by C. A. Holt and R. M. Isaac), Greenwich, Connecticut: JAI Press (forthcoming).
- R. Godby (1997b). Market Power, Vertical Markets and Laboratory Emission Permit Double Auctions. Manuscript, McMaster University.
- R. Godby, *et al.* (1996). Market Power in Pollution Permit Markets: An Experimental Investigation. Manuscript, McMaster University.
- L. F. Herk (1993) Consumer Choice and Cournot Behavior in Capacity-Constrained Duopoly Competition. *RAND Journal of Economics*, **24**, 399-417.
- C. A. Holt (1989). The Exercise of Market Power in Laboratory Experiments. *Journal of Law and Economics*, **32**, s107-30.
- C. A. Holt and D. D. Davis (1990). The Effects of Non-Binding Price Announcements on Posted Offer Markets. *Economics Letters*, **34**, 307-10.
- C. A. Holt *et al.* (1986). Market Power in Oral Double Auctions." *Economic Inquiry*, **24**, 107-123.
- R. M. Isaac and C. A. Plott (1981). The Opportunity for Conspiracy in Restraint of Trade. *Journal of Economics Behavior and Organization*, **2**: 1-30.
- R. M. Isaac *et al.* (1984). The Effects of Market Organization on Conspiracies in Restraint of Trade. *Journal of Economic Behavior and Organization*, **5**, 191-222.
- D. M. Kreps and J. A. Scheinkman (1983). Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes. *Bell Journal of Economics*, **14**, 326-37.

- J. O. Ledyard, and K. Szakaly-Moore (1994). Designing Organizations for Trading Pollution Rights. *Journal of Economic Behavior and Organization*, **25**, 167-96.
- G. L. Leffler and C. F. Loring (1963). *The Stock Market*. New York: Ronald.
- S. Mestelman, *et al.* (1987). Advance Production in Posted-Offer Markets. *Journal of Economic Behavior and Organization*, **8**, 249-64.
- S. Mestelman and J. D. Welland (1988). Advance Production in Experimental Markets. *Review of Economic Studies*, **55**, 641-54.
- S. Mestelman, and J. D. Welland (1994). Price Flexibility and Market Performance in Experimental Markets. *Economic Theory*, **4**, 105-29.
- W. S. Misiolek and H. W. Elder (1989). Exclusionary Manipulation of Market for Pollution Rights. *Journal of Environmental Economics and Management*, **16**, 156-66.
- D. K. Pearce (1984). Rationalizable Strategic Behavior and the Problem of Perfection. *Econometrica*, **52**, 1029-50.
- C. R. Plott (1986). The Posted-Offer Trading Institution. *Science*, **232**, 732-38.
- S. Rassenti *et al.* (1996). Adaptation and Convergence of Behavior in Repeated Experimental Cournot Games. Manuscript, University of Arizona.
- S. S. Reynolds and B. J. Wilson (1997). Market Power, Price Markups and Capacity Investment under Uncertain Demand. Manuscript, University of Arizona.
- J. Rotemberg (1982). Sticky Prices in the United States. *Journal of Political Economy*, **90**, 1187-211.

- J. Rotemberg, and G. Saloner (1986). A Supergame-Theoretic Model of Price Wars during Booms. *American Economic Review*, **76**, 390-407.
- V. L. Smith (1982). Markets as Economizers of Information: Experimental Examination of the 'Hayek Hypothesis'. *Economic Inquiry*, **20**, 165-79.
- V. L. Smith (1981). An Empirical Study of Decentralized Institutions of Monopoly Restraint. In *Essays in Contemporary Fields of Economics in Honor of E. T. Weiler, 1914-1979* (edited by J. Quirk and G. Horwich) 83-106, West Lafayette: Purdue University Press.
- V. L. Smith and A. W. Williams (1989). The Boundaries of Competitive Price Theory: Convergence, Expectations, and Transactions Costs. In *Advances in Behavioral Economics, vol. 2.* (edited by L. Green and J. Kagel) Norwood, N. J.: Ablex Publishing.
- R. D. Theocharis (1961). On the Stability of the Cournot Solution on the Oligopoly Problem. *Review of Economic Studies*, **27**, 133-34.
- M. V. Van Boening. and N. T. Wilcox (1996). Ride the Double Auction Roller Coaster: A Fixed Cost Exception to the Hayek Hypothesis. *American Economic Review*, **86**, 461-77.
- B. J. Wilson (1996). What Collusion? Unilateral Market Power as a Catalyst for Countercyclical Pricing. Manuscript, University of Arizona

Figure 1. Supply and Demand Arrays, and Contract Sequences for a Sample Double Auction, and a Sample Posted-Offer Market. *Data source:* Classroom exercises conducted by Davis and Holt

Figure 2. Supply and Demand Arrays for the Trend-Demand Design, and Mean Contract Price Paths for Double Auction and Posted-Offer Markets. (Key: In the panels on the right-side, the solid step-line is the equilibrium price path. Dotted, dashed and solid curvilinear lines illustrate mean contract paths for individual sessions. Hollow circles in the upper panel represent average of per-period closing prices. Markers in the lower panel indicate breaks in the series due to zero sales volume.) *Data source:* Upper right panel, Davis, Harrison and Williams, 1993; Left and lower right panels, Davis and Holt, 1997b.

Figure 3. Mean Contract Price Paths in the Trend-Demand Design for Three Posted-Offer Variants. (Key: In each panel, the solid step line is the equilibrium price path. The dotted, dashed and solid curvilinear lines illustrate the mean contract path for individual sessions. Markers indicate breaks in series due to zero sales volume.) *Data source:* Davis and Holt, 1997b.

Figure 4. Supply and Demand Arrays and Mean Contract Price Paths for an Advance-Production Experiment. (Key: On the left, the numbers printed below cost steps represent seller identities S1, S2 and S3. In the panels on the right, the thin lines represent the mean transactions price path for a session. The bolded line is the average for the session as a whole.) *Data source:* Davis, 1997.

Sample Second-Stage Decisions

Figure 5. Sample Second-Stage Pricing Incentives for seller S3. Suppose each seller produces 3 units. Given demand D , S3 maximizes revenues by posting the aggregate market clearing price P_{cl} and earning $abdc$. Any unilateral decrease will decrease revenues without affecting quantity. A unilateral increase by S3 to P' will reduce earnings to $a'b'd'c$. Given demand D_L market clearing price P_{cl-L} no longer maximizes revenues for S3. Posting P' will increase S3's revenues from $efdc$ to $e'f'd'c$.

Figure 6. Supply and Demand Arrays and Mean Contract Price Paths for a Market Power Experiment. (Key: In the right panel the numbers printed below cost steps represent seller identities, S1 to S5. Power is created by reallocating the underlined units for S3 to S1 and S2, as italicized. In the panels on the right, the thin lines represent the mean transactions price paths for individual sessions, and the bolded line is the average for the treatment as a whole. p_c is the competitive price prediction and $\bar{p}_{1,2}$ is the mean of the mixing distribution for S1 and S2.) Data source: Davis and Holt, 1994.