Testing and Measurement in Competition Models*

by

Timothy Bresnahan
Stanford University

Prepared for the 7th
World Congress of
the Econometric Society,
Tokyo, Japan, August 1995.

Dated: November 22, 2023

* I am indebted to many people for comments at the World Congress and thereafter. Jacques Cremer's wise suggestions deserve special notice.

What is market power? Where is it found in late 20th century markets? Has increasing internationalization destroyed it? What mechanisms support firms' attempts to build market power positions for themselves? What are its proximate causes? What are its deep causes? These are some of the questions on which economic theory has made the most rapid progress in the last two decades. In sharp contrast to the situation beforehand, we now understand at a deep level when to expect price to exceed marginal cost. Significant advances in the theory of imperfectly competitive supply tell us under what circumstances an industry will sell less than the perfectly competitive quantity at more than the perfectly competitive price. Perhaps more importantly, formal theories of imperfect competition, overwhelmingly based in the game theory, offer precise and therfore testable characterizations of the behavior supporting the noncompetitive outcomes. This short-run supply theory is necessarily incomplete. It takes as given the degree to which firms' products within an industry are substitutes, the degree to which firms' cost circumstances are similar, the information structures under which prices and or quantities are set, the number of firms competing, and so on. Theories of the determination of all these objects have been another area of very rapid progress.

The time for empirical work testing all this marvelous theory seems to have arrived. Yet the same ideas which permitted a theoretical revolution-strategy, commitment, and imperfect information in the theory of games, have produced a body of theory dauntingly difficult to test. Game theoretic ideas seem particularly suitable for the generation of COUNTER EXAMPLES, followed by counter examples, until all too soon they are *counter examples*.[1] Empirical work has

[1] Franklin Fisher has been a strong critic of the resulting "exemplifying theory" and its corrosive impact on empirical work: "The principal result of theory is that nearly anything can

responded to this situation in several ways. Some work has very tight integration of theory, econometric model, and data analysis. Other work eschews this tight integration, instead identifying key implications to test. Still other work largely ignores strategic theory or lumps very different (we thought!) theories into equivalence classes.

All of these different modes of using theory appear in very successful empirical work. In what follows, I look at some exemplary papers in three very different literatures; auctions, oligopoly pricing, and entry. I have picked the papers and the literatures to illuminate the variety of ways in which theory can be useful. Also, their centrality has led to empirical work with a great deal of attention paid to econometrics and economic theory. Finally, I picked these literatures because they contain an important shift from "testing theory" to "measuring economically important quantities," a topic to which I return in the conclusion.

Section I: Buyers' Behavior in Auctions

Auctions are a reasonably common institutional mechanism for price determination in markets. They are used by government entities (as in the famous spectrum auctions in the U.S. recently) and also in many private contexts. Auction practitioners have, over the years, built up a set of specific rules for bidding, sellers' reservation prices, etc. Often the participants in any particular auction understand these rules in a deep way. These formalized and well understood

---

happen. This is confirmed by the inconclusive results of empirical studies. Theoretical models are over-simplified and provided questionable guidance in real situations. Empirical work is not informed by theory and is often without a sound analytic foundation. The field needs to study the ways in which the rich context of real situations affects behavior and results." One goal of this paper is to take this challenge head on.

rules has made the analysis of auctions a fertile field for of equilibrium game-theoretic methods.

The theory of competitive bidding at auction is very compelling.[2] There is a tight correspondence between the real world auctions' stated rules and auction theory's rules of the game.[3] Almost all auctions have rules such that the game among buyers would be quite trivial if buyers knew everything there is to know about one another and about the object for sale. The essence of the auction is bidders' incomplete information. Auction theory, drawing on the theory of games with incomplete information, has been very successful in modeling descriptions of what bidders know and do not know and of the bidding rules to bidding strategies and therefore outcomes.

There is still considerable work left for empirical study. First, even though the rules of the game are obvious in auctions, the distribution of bidders' private information and valuations is not. There are large differences between the case where bidders have the same guess about an unknown but "common" value for the for-sale object and the other case where each bidder has her own "private" value. Even more difficult, the shape of the bidder's valuation distribution

---

[2] McAfee and McMillan (1987), Milgrom (1989) and Wilson (1992) survey the theoretical literature.

[3] Where there may be gaps, these often relate to the behavior of sellers, which is a much more difficult subject for both theory and empirical work. Empirical scholars have tended to examine what sellers actually do in practice and make that part of the model of the game buyers play. Another important gap is the theory of complex, multiobject auctions, like those for parts of the electromagnetic spectrum recently conducted in the U.S.

matters in a very important but complex way. And it is not possible to learn about these kinds of issues by examing the institutions theoretically. They must be measured and tested. Fortunately, the theory gives very precise and quantitative guidance on how to map from the underlying private information to strategies.

The other task for empirical work, of course, is that the theory might just be wrong. Two potentially troubling parts of the theory are (1) the assumption of non-cooperative behavior- what about collusive bid rigging? And (2) the assumption of a high degree of rationality -- can bidders really make calculations as complex as those in the theory?[4] In either case, the task of empirical work is to test idiosyncratic implications of the important parts of the theory -- in particular, the "Nash" part of Bayesian Nash Equilibrium against collusive bid rigging and the "Bayesian" part against the not-rational-enough alternative.

Let us now examine empirical work on auctions of two very different types. "Structuralist" empirical work specifies everything in economic agents' environment explicitly. In auction work, that means that the distribution of bidders' valuations forms an explicit part of the specification of the econometric model. Further, it is the equilibrium of an explicitly stated economic model which maps the underlying economic environment to observable data. Structuralist econometric models can be complex and difficult to construct, for the high degree of integration of theory and econometrics prevents shortcuts. Yet the econometrics also have a beautiful transparency, as there is literally not any part of the data analysis, not even the error

[4] With appropriate humility, we might also say that the behavior in the theory looks pretty compelling to us as economists but that there might be other elements of human behavior we don't understand yet which belong in the true theory.

term, without an explicit economic foundation. In "implicationist" work, on the other hand, theory and data analysis have more separate roles. The test table implications of a theory, or a cluster of theories, are drawn out. The exact form of the empirical procedure is not derived from a specific theory, the error term especially may be "tacked on" to the model. Implicationist methods pick up in robustness some of what they lose in integratedness, as we shall see in the auctions work.

Section I.1, Structuralist Studies of Auctions

Consider first Laffont, Ossard, and Vuong's (1995) very structuralist approach to descending auctions for eggplants in Marmande, France. These are auctions in which sellers are farmers and buyers are various traders in agricultural goods. They are modelled as first price sealed bid auctions among risk neutral bidders with independent private values drawn from the same distribution, F( ). Each auction is taken to be independent of all others. (The sample is selected to make the latter assumption more plausible.) The solution is Bayesian Nash Equilibrium. Each buyer's bidding strategy determines her bid, b^i, as a function of her value v^i, the reservation price, ρ^o, set by the seller, the distribution function for other bidders' valuations and the number of bidders, I. The form of the strategy is actually quite simple for the bidder to calculate, assuming that she knows what game she is playing and that she knows the distribution of all other bidder's valuations or bids.

$$b^i = e(v^i, I, p^\circ, F) = v^i - \frac{1}{(F(v^i))^{I-1}} \int_{p^\circ}^{v^i} (F(x))^{I-1} dx \qquad (1)$$

This same equilibrium notion provides non-trivial challenges for the structuralist econometrician. One would like to estimate the function F( ) in (1). More realistically, there may be exogenous variables, X (perhaps seasons in this agricultural example), and one would like to

estimate F(· ; x), a family of C.D.F.s. Further, one would like to do this without putting too much restriction on the shape of F( ). The problem is, what is observed is the distribution of bids, not the distribution of underlying values. And those are linked to the data by the behavioral equation of the bidder, which depends itself wupon the unknown distribution. Suddenly the problem seems more complex, as the mapping from the objects we are trying to estimate -- distribution functions -- to the objects we can observe -- distribution functions of another object -- is an integral. The mapping is extremely nonlinear and has other associated numerical complexities. This calls for some quite elegant econometrics.[5] In their paper, Laffont et al. use a simulation estimator.[6]

This structuralist approach does not really offer much of a test of the relevant theory, at least not at this stage. Instead, the approach offers a way to measure the underlying objects in the theory, taking the theory as a given.[7] What we do have at the end of papers like this are estimates that completely characterize the economic (including informational and strategic) behavior and environment of the bidders. Thus, calculations based on these estimates are not

---

[5] Similarly, the need for elegant econometrics arises in other structuralist approaches to private-information games in very different contexts. See Wolak (1994) for a structuralist principal/agent model of regulation.

[6] They simulate the first moment of the observed distribution of winning bids.

[7] Paarsch (1992) offers a test between common-value and private-value variants. Laffont et al. offer some remarks on future testing in their conclusion, and we can hope for developments in that direction.

subject to any "Lucas critique" caveats. In this regard, the structuralist approaches to the empirical study of auctions reach a high level of integration of economic theory, econometric method, and data analysis.

Section I.2 Implications of Auction Theory

The implications of assymetric information auction theory are not confined to a description of the equation determining equilibrium. Instead, the theory is quite full of results! Testing some of these results, by implicationist methods, has been another rich vein for empirical work. An interesting example is Hendricks and Porter (1988). They focus on common-value auctions in which some bidders are better informed than others about the underlying value. These auctions have the feature that, in equilibrium, the uninformed bidders are not as effective competitors as the informed bidders. They also have the feature that the structuralist approach described above would be vastly more difficult, as the distribution of both informed and uninformed bidders' information would form part of the integral equation for equilibrium bids.[8]

Hendricks and Porter proceed by identifying seven distinct implications of the theory for empirical test. Many of these are tightly linked to the information economics part of the theory. Some of them are that

> The informed firm wins the bid at least half the time and makes an expected profit,
>
> That uninformed firms earn zero profits on average, but lose when the informed

[8] While it is wise not to say never, it seems unlikely that nay structuralist investigation of the full Hendricks-Porter model will over come these difficulties anytime soon.

firm bids (it is a secret who bids),

The informed firm's strategy does not depend on the (expected) number of uninformed bidders and

The informed firm, even though its information is strictly better The informed firm bids higher when public information (even though the informed firm's information is strictly better).

Taken together, these and a few other implications have a strong information economics, equilibrium, and rational actor flavor.

Hendricks and Porter proceed with a very thorough statistical examination of the observed bids on offshore oil leases and how they are shifted by a wide variety of environmental variables. Of particular importance is the assumption about the informed firm. The oil leases are auctioned off in a series of "tracts". Hendricks and Porter take a firm which has already drilled wells on adjacent tracts to be (potentially) better informed than those who have simply been able to perform above-ground research. This key assumption permits testing of many of the key implications of the theory. In particular, they find that the informed bidders make profits, that uninformed bidders bid conservatively to avoid the winner's curse, that informed firms respond somewhat to the (weak) competition from uninformed firms, and several other nonobvious implications of the theory. Given testing of the long list of implications, many tightly linked to the underlying economics of strategy and private information, powerful evidence for the full theory has been assembled.

Auctions: Summary

At the end of these empirical auctions papers, one feels very good about the theoretical revolution in Industrial Organization. The theory of auctions has been a success, not only in

helping us think better about auctions in the abstract, but in predicting phenomena in real auctions. Realization of the theory in empirical papers has taken on two very different forms, each of which has been very successful. Structuralist methods have used theory as a factor of production in measuring deep economic parameters. Implicationist methods have tested the theory, including some nonobvious implications.

Of course, there are some worrisome notes and some things we do not understand yet. Some very interesting papers about bid-rigging in auctions suggest that the phenomenon is empirically important.[9] But the relevant evidence is much less satisfactorally tied to theory. Partly, this is a problem of theory; we do not, and probably cannot, have a theory of bid rigging which is as clean as the theory of competitive bidding. At best, we can hope for a theory of bid rigging which is about as clean as the theory of cartels, one topic of my next section. Another area of difficulty concerns the auctioning of multiple objects and buyer dynamics. Interestingly, this appears to be a topic on which stubborn fact is leading theory, for example, difficult-to-explain price falls for objects auctioned later inthe same day.[10] Similarly, the topic of seller behavior at auctions is likely to be thornier than the topic of buyer behavior. But these are simply the boundaries of success; within the boundary, it is hard to have anything but positive feelings about the economic literature on auctions.

The success in empirical studies of auctions is something of an outlier in industrial economics (and I suspect in economics generally.) The theory of games and the facts of

[9] See Porter and Zona (1993).

[10] For example, Ashenfelter (1989).

auctions are particularly well aligned. The task of deciding what game-theoretic model goes with the world, out of the thousands of different ways to make models of the world, is reasonably direct in auctions. Discovering those same correspondences in other areas is more difficult.

Section II: Oligopoly Pricing Behavior

Let us now turn to a problem that is closely related, oligopoly pricing behavior. In oligopoly, as in bidding at auction, prices are set by complex strategic interaction. The equilibrium observed arises from firms' interactions, which may well be characterized by gaming and all that implies. An auction has rules; these form many of the "rules of the game" which is at the heart of the competitive bidding model. In an open marketplace, however, it is rare that the "rules of the game" will be visible and obvious in market institutions.[11]

This is an embarrassment of rides for the empicial researcher looking at competition

[11] A great deal of effort has been expended in attempting to work out the relationship between market institutions and the rules of the oligopoly game. It has proved difficult to take advantage of this in empirical work. A change in an institution's conditions of commitment or in the exact structure of the information it reveals can have profound implications for the game being played. There was for a while some hope that these subtleties might be resolved by purely logical arguments, but now the "refinement" agenda seems mores like the quest for the holy grail then for the unified field theory. Even had the theory succeeded, we would still face the inherent difficulty of mapping institutions-in-the-world to institutions-in-the-theory. Game-theory models are purely logical objects; they are linked to the world by correspondences between key assumptions and features of observable institutions that might be the same as the assumptions. That correspondence will be, in a real industry, subject to multiple interpretations.

among the few. Whcih of the dozens of available theories to use? What econometric procedures might test for the theory actually in place in an industry? Alternatively, what can be accomplished in market power measurement robustly, i.e., without determing the exact theory of supply? Once again, these questions about the role of economic theory in empirical work appear in the literature as econometric modelling decisions.

Section II.1 Old Work

One response to this challenge has been to limit attention to a small number of explicitly game theoretic models of competition. These can then be tested, each against the other. Holding the model of demand fixed, a variety of econometric models of supply are introduced, each derived from an explicitly stated game.

To the best of my knowledge, my dissertation was the first attempt at this method. In it, there is a vertical product differentiation model of the demand for automobiles. This leads to a demand system

$$Q_j = F_j (P, X, \beta) + \varepsilon_j \qquad (1)$$

where

Q_j	is the quantity demand of vehicle j
P	is the vector of prices of all automobiles
X	is the matrix of observable attributes of all automobiles
β	are the parameters
ε_j	is the demand error

and there is one such equation for each product, j. In the empirical work, the model actually estimated is very restrictive. The vertical product differentiation theoretical model is imposed in a very structural way; each product's demand is a function only of its own and two other product's prices. The defense of this very restrictive specification came from (1) a reading of the automobile literature, (2) conversations with marketers in automobile companies, and (3)

pure expedience.

Expedience dictated simple demand because the supply side was modeled in a very complex way. Costs were simple: the marginal cost of automobile *j* was constant, and depended on observed quality attributes plus an unobserved error as $MC_j = MC(X_j\gamma) + \eta_j$. Supply of each product is modeled by competing competitive interaction models, including Collusion (2) and Bertrand (3):

$$P_j = \arg\max_{P_j} \sum_{\text{all } k} (P_k - MC(X_k\gamma) - \eta_k) \cdot (F_j(P, X, B) + \varepsilon_j) \quad (2)$$

vs.

$$P_j = \arg\max_{P_j} \sum_{k \varepsilon B_j} (P_k - MC(X_k\gamma) - \eta_k) \cdot (F_j(P, X, B) + \varepsilon_j). \quad (3)$$

Where B_j is the set of products sold by the firm selling j. The goal of the empirical work is to test among competing game theoretic models of supply, i.e., tell (1) and (2) from (1) and (3).

The principle empirical findings are two. First, as theory predicts for a vertically product differentiated industry, price-cost margins are much larger for larger automobiles whether (2) or (3) is in effect.[12] The other is that both collusive and competitive pricing regimes were observed (in different years) in the period under study, the mid 1950's. The latter finding

[12] This finding was later replicated from another more recent period by Bresnahan (1981). More importantly, it has been replicated by Berry, Levinsohn and Pakes (1995) in a model which does not impose the vertical product differentiation structure. Indeed, the Berry Levinsohn, Pakes model imposes only very weak restrictions on the pattern of substitutability. This superior structure comes with the requirement of more difficult econometrics.

follows from non-nested tests of the model with Bertrand pricing against the model with Collusive pricing, and vice versa. Very similar ideas, and better method for testing among the distinct theories, have been used by Gasmi, Laffont, and Vuong (1992) in a study of the packaged soft drink industry covering strategic advertising as well as strategic pricing.

These papers investigate the consequences of strategic interaction for pricing one period at a time. The methods work well for theories that are quite distinct: Bertrand vs. Collusion vs. Stackelberg leadership by a specific firm are good candidates. Also, the methods can detect large shifts in the pricing rule over time.

II.2 Early Work on Repeated Play

Once those different theories of supply in any particular period can be distinguished, we can turn to the dynamics. Switches between competitive and collusive regimes are a core element of dynamic oligopoly theory under uncertainty, a key insight of Green and Porter (1984). Substantial progress was made in detecting such switches by Porter (1984), who measured two distinct pricing regimes, each repeated many times, in his study.

In Porter's study of an 1880s railroad cartel, Q_t is grain shipped by rail from Chicago to the East Coast, measured in tons. The time index t refers to a week between the first week of 1880 and the sixteenth week of 1886. The price data, P_t, are based on a weekly poll taken by the cartel of its members; given the possibility of secret price cutting, P_t is probably to be interpreted as if it were a weighted average of list prices. The demand function takes the constant elasticity form.

Since there is some entry and some acquisition activity during the sample period, Porter adds structural dummies S_t to supply. Furthermore, it is assumed that the probability of successful collusion is $1 - \pi$. After a transformation, the supply relation ultimately estimated

takes the form:

Supply relation	Probability	
$\log P_t = \Gamma_0 + \alpha^a + \Gamma_1 \log Q_t + (\Gamma_2, S_t) + \varepsilon_{cit}$	π	(4)
$\log P_t = \Gamma_0 + \alpha^a + \alpha^b + \Gamma_1 \log Q_t + (\Gamma_2, S_t) + \varepsilon_{cit}$	$1 - \pi$	

where α^a is a transformation of the conduct parameter in periods of successful collusion, and α^b measures the change in conduct when collusion breaks down. Of course, it is clear that α^a cannot be separately estimated from Γ_0 on the basis of estimating these equations, but there is considerable interest in estimating α^b, the percentage amount by which a breakdown in the cartel changes prices. As the form of (4) suggests, Porter estimates the supply and demand system by "switching equations" methods, in which the probability π as well as the regular parameters are estimated from the data. He finds that there are two pricing/quantity determination regimes, and that they correspond to very distinct supply behavior.

I recount this early history of the field not just to remember our youthful excitement at actually testing theories. The many compromises embedded in the econometric specifications of the papers left important economic issues unresolved. The two sources of market power are steep (firm and industry) demand curves and less-than-competitive conduct. Even my brief account of these early papers shows restrictive demand systems and an incomplete model of conduct. Ensuing work has attacked both problems with widely varying results.

Section II.3 Moving Toward Testing Dynamic Implications

Those papers tested only a subset of the implications of modern oligopoly theory. On the positive side, they provide evidence for switches among different pricing regimes in highly concentrated oligopolies. The gross size of the changes in supply behavior within the same

industry over time, with reversals, itself provides strong evidence for the importance of strategic considerations as a part of oligopoly supply. More critically, however, the papers did not examine the causes of these changes in behavior over time. It is reasonable to look within the dynamic-oligopoly framework and ask whether the full implications of the Stigler theory of oligopoly, as realized by Green and Porter (1984) or Abreu et al. (1990), have been tested. Since incomplete information about demand is at the heart of the theory, one could ask whether it really was true that downward demand shocks predict changes to a "punishment" regime. Since there are alternative theories (as one should always expect with dynamic games in an incomplete information environment), such as that of Rotemberg and Saloner, one could ask which of the theories is true. Since the theories turn on repeated play to enforce the cartel contract, one could ask whether the changes in regime are frequent enough, endogenous enough, and matter enough for flow profitability to enforce cartel compliance. One could ask, somewhat outside the box defined by the theories, whether firms appear to be observing the contract (e.g., is there actual secret price cutting in equilibrium) or whether some "social" rather than rational mechanism enforces the market power. All of these things are well worth asking.

They are, however, very difficult to answer.

The basic difficulty here lies in the theory itself. Dynamic game theory, at least for oligopoly, has had strong elements of "threat/enforcement" logic. This arises directly from the structure of oligopoly pricing, in which firms have individual incentives to depart from the high prices that are collectively profit maximizing. It is harder to measure a threat (probablistic reversion to a low-price regime[13]) than it is to measure the behavior that the threat enforces

[13] Or of continuation in it, in the fully-optimal version of the theory provided by Abreu

(cooperation in the high-price regime). The distinction is empirically important. The behavior that the threats enforce, or more generally plays in the stage game of a repeated game, are first-order implications of the theory. We can see these behaviors, test for them, measure them. The threats themselves may be much less visible implications of the theory. We see them only when they are actually carried out, as when the regime changes. In the specific circumstances of dynamic oligopoly, there are two problems: regime switches in a reasonably successful cartel will be rare, and the events that cause the regime switch are theorized to be invisible. These are unpromising conditions for systematic statistical investigation.

The importance of these more dynamic and information-intensive issues has drawn scholarships to the problem regardless. Roberts and Samuelson (1988) have investigated firms' dynamic responses to one anothers' advertising decisions, using a dynamic-games framework. Baker (1989) has examined what may be a cartel enforcement scheme in steel, using the special circumstances of the Great Depression as a backdrop to high-markup behavior enforced by the threat. A series of papers has followed up on Porter's railroad study[14]. A second basic implication of the theory, that the pricing regimes tend to persist over time, was verified by Cosslett and Lee (1985). The question of what triggers price wars, perhaps the key one in understanding the game dynamics, has been taken up by Porter (1985) and Ellison (1994).

Since the railroad cartel used a quota system, Porter's idea was to see if deviations of market shares from the nominal quotas predict price wars; there seemed to be inadequate information in

---

et al. (1990).

[14] See Porter and Lee (1985) Berry & Briggs (1988), and Hajivassilou (1989).

the data to determine whether this is the case. Ellison, using a more unified measurement framework based on close attention to the Markov structure of regime transformations, and to the dynamics of the serially correlated demand error, is able to go farther. Though the amount of information in the data somewhat undercuts the empirical finding, there do appear to be trigger strategies at work. Interestingly, there also appears to be some actual cheating on the cartel of the secret price cutting form.

These papers, taken as a group, are not all that encouraging about the future of testing dynamical, informational implications of oligopoly theory. The railroad-cartel dataset, just over a century old, is by far the best we have, and approaches the limits of what we could hope to have. Weekly data, public information, and a cartel that acted above board (it was then legal) are extraordinary assets. Yet, even with this data richness, the ultimate statistical evidence about the different hypothesis is more "consistent with" than " compeling for" a theory. Another century might well pass without a dataset that supports a better statistical investigation of cartel enforcement.

There are some first-order implications of oligopoly theory that are quite testable in real-world data environments. Collusive oligopolies will have monopoly-like pricing behavior (i.e. pricing behavior that depends on marginal revenue) in their cartel regime. Collusive oligopolies working in imperfect information environments will sometimes revert to more competitive pricing regimes. Since we have built measurement methods that are good at (1) telling static monopoly from more competitive static supply behaviors (like Cournot or Bertrand or perfect competition) and (2) detecting regime switches in supply behavior, these implications of the theory can be seen in reasonable data environments. These are also the first-order implications of the theory for welfare analysis. It is an accomplishment worth having to know

how much like monopoly, and how often like monopoly, oligopolies are. We will know less, by statistical means at least, about the reasons for oligopoly cooperation.

All this points to a shift in scholarly emphasis from the intensive margin of industries where a theory a be deeply tested to the extensive margin of investigating strategic pricing outcomes in a wide variety of interesting and important contexts.

Section II.4 More Flexible Demand Systems with Product Differentiation

Market power measurement with flexible demand assumptions has been an area of rapid and convincing progress. Consider again the demand systems in the papers discussed. One paper uses an extreme version of the VPD model, in which only three prices affect the demand for any particular product in a product-differentiated industry. The other assumes a constant-elasticity demand curve (in a market-power assessment context!) While these types of illustrative functional form assumptions may be fine for theoretical purposes, they are very restrictive for use in empirical work.

Attention to the demand side of the specification also derives from some important realities of modern economic life. The driving forces of economic and industrial change, at least in the developed world, in the late twentieth century have not particularly centered on cheaper production of the same body of goods. Instead, a steady process of new-goods and new-industries creation has been a critical shaper of events. As a result, the places in the modern economy where one would most like to assess market power are in product differentiated industries. Consumer products industries with brand names; information technology industries with technical standards; pharmaceuticals and the health care sector itself, with complex therapeutic outcomes; retail trade with service and stockouts; these are fairly good representatives of likely locuses of market power in the present. Whether one thinks that the

market power in them is a social ill, because of deadweight losses, or a social good, because the monopoly profits pay for the economic change, is of little import for the question of appropriate empirical methods. The fact is, this part of the economy is where the action is.[15]

Accordingly, a series of recent papers has estimated very complex oligopoly demand and pricing models. This includes some papers that are innovative in terms of measurement methodology, including those by Goldberg (1995), Berry, Levinsohn, and Pakes (1995), Trajtenberg (1986) and Hausman (1994). The first two of these papers consider the automobile market, and both bring substantially more data and a substantially less restricted specification to the demand side than the work discussed above. Hausman and Trajtenberg, working in very different industries and with different purposes, are also careful to make unrestrictive demand assumptions.

In Goldberg's paper, individual household microdata are used. This already permits a less restrictive specification of the aggregate demand elasticities. Different kinds of households are permitted to prefer different kinds of vehicles. The rich like big, fancy cars; young families show more of a preference for station wagons over convertibles than do young singles, and *vice versa*. Parameters that measure the impact of the observable heterogeneity in demand behavior, plus the sampling distribution of household types, permit an extremely unrestricted specification of the elasticities of substitution between products of different types.

Berry, Levinsohn, and Pakes are more concerned with the flexibility of the functional form for the demand system, since they use aggregate data on quantity demanded. Their

[15] In the next section, when I turn to the LR analysis of the determinants of market structure, this same remark will return in force.

approach is to start from an individual-choice demand model, but to permit the unobserved heterogeneity of consumer preferences to lie in a five-dimensional space. Thus, different automobiles can be "neighbors" in the product space in any of five dimensions. (The dimensions are defined by observable characteristics of the automobiles.) The work is careful to demonstrate that the pattern of elasticities of substitution and cross-elasticities of substitution among different products is unrestricted, showing the resulting implications for the patterns of which products and firms compete with which. These elasticities also determine the equilibrium market power, measured by markups, in Bertrand equilibrium.

We see the same set of concerns in a closely related literature on assessing the contributions of a new good to social welfare.[16] A steep single-product demand curve is the hallmark of market power in product differentiated industries. It is also the hallmark of large consumer surplus from the invention of a new good.

[16] See Trajtenberg (1986) and Hausman (1994).

This literature has turned away from game theoretic models of the supply side. Sellers are modeled either by static multiproduct Bertrand, or go unmodeled.[17] There are three main reasons for this. First, these papers are difficult enough econometrically as it is; we progress by steps. Second, it is a perfectly reasonable position that, in product differentiated industries, the slope of the single firm demand curve is the main source of market power.[18] Third, and most important, is the idea that strategy is important in these industries; product introduction strategy, advertising strategy, and product positioning strategy, not pricing.

Section III: Studies of Equilibrium Industry Structure

Let us now turn to a third area of enquiry. This is the area of studies of the determinants of industry structure. Its relationships to the immediately proceeding body of knowledge is one

---

[17] With the observation that product differentiation is the key, why do we need new measurement method in Industrial Organization? The focus of these papers is on measuring buyer behavior, not testing seller behavior. While the outcome of that process is a market power or similar assessment, the process itself would seem to belong in another field. The answer arises because of the potential endogeneity of prices (or of other marketing variables) in the demand system. There is a substantial role for the Industrial Organization theory of supply to play in revealing why it is that the demand system is identified and how it should be estimated. Without an assumed model of supply, none of the demand systems would be identified. See Bresnahan, Stern and Trajtenberg (1995).

[18] This idea has even became fairly important to U.S. antitrust enforces stirred by Baker and Bresnahan (1986).

of complementarily. Given that competition among the few can be quite uncompetitive as a pricing mechanism, what determines the "few?"

The part of economic theory supporting this area of enquiry is difficult and complex. It includes the theory of entry barriers, of predation, and (before we forget) of nonstrategic competitive entry. This is a set of literatures in which a great deal rides on specific strategic interactions. Large differences in outcomes may very well turn on small differences in circumstances, ones that are obvious to industry participants but very difficult to detect by the analyst. John Sutton, in a landmark book and in another paper in this session, ably describes the difficulty of this body of theory, so I will not repeat the argument here.

Empirical researchers, cognizant of the difficulties of a direct statistical attack on the objects central to the theory, have used eclectically implicationist methods. Sutton, building upon his synthesis of a wide variety of theories set out to test their implications using a "bounds" approach. This means attempting to characterize the robust implications of a wide variety of strategic theories. The theories themselves are thrown into an observational equivalence class -- distinctions not related to the robust implications are not tested nor measured. Sutton's two equivalence classes are industries with Endogenous Sunk Cost (ESC) and Exogenous Sunk Cost (XSC) characteristics. Roughly, in the ESC industries some strategic variable offers very considerable room for strategic interplay in the entry game. In XSC industries, only the rate at which competition causes prices to fall, the "toughness of price competition," matters for equilibrium industry structure. (Fixed costs in both contexts).

Sutton argued that a key implication of ESC was that, even in very large markets, concentrated structure will arise. Further, an important implication of the bounds approach is that no such relationship exists for XSC industries? For this core idea, then, Sutton pursued the

empirical analogy; could failure of industry structure to converge to competition be found in larger markets, and would it be found in contrast to XSC industries. In his study of consumer products industries, he found that the behavior of different classes of industries was indeed quite different. As a systematic matter, XSC industries tend to be far less concentrated in large national economies. ESC industries are roughly equally concentrated across a wide range of market sizes.

Industry narratives, rather than systematic statistical work, pursued some of the details of the synthesis. By examining a wide variety in the toughness of price competition induced by government intervention, Sutton was able to verify that the toughness of price competition does indeed matter greatly in XSC industries. Further, he provides a series of narratives about market structure determination in the ESC industries. These suggest (1) that the forces at work are indeed those suggested by the theory and (2) that the primary problem of the theory, very subtle differences in strategic interaction in similar circumstances, also arises in the world. A wide variety of strategic mechanisms seemed to come into play in very similar industries, e.g., in the same industry in different countries.

In a related approach to the same issues, Peter Reiss and I and Stephen Berry took up the problem of equilibrium market structure determination statistically. In them, the guiding concept in the model was a latent profitability variable, Π_n, for the n_{th} firm into a market. We applied the model to a sample of very concentrated markets, so it was Π_1, Π_2, etc., literally monopoly, duopoly, and triopoly profit that were modeled and estimated. Working independently of Sutton, we also focused on the size of the market as the key regressor.

In this framework, it is possible to examine specific entry games. Holding constant the cost and demand environment, specific models of entry and entry deterence have distinct

implications for observables. Examples in the literature include detecting leader/follower models with an observably distinct class of leaders (Bresnahan and Reiss (1990)) and discriminating among potential entrants of different types (Berry (1992)). These examples, in which strong assumptions about the normal form of the game linked to observable variety in potential entrants, reveal as much of the difficulties of model ing the game among entrants as they do about its potential payoffs.

The framework uses the size of the market, S, as the key exogenous observable. The latent profit to the n_{th} firm into the market is modelled as

$$\Pi_n = (P(n) - mc)\, q(n) \cdot S - F - B(N)$$

The first term is per-firm variable profit, modelled as linear in S.[19] The variable q is unit sales to the representative consumer made by each firm, so $q \cdot S$ is per-firm unit sales. The toughness of price competition appears as P(n) (with q(n) following along by a demand calculation). The outcome of the entry game is buried in the to-be-estimated parameters B(n). If $B(2) > B(1)$, we infer that something is going on to keep second firms out of the market, but cannot say much about what it is.

These statistical models have two interpretations. The first one is structuralist. If the entry game can be written in normal form, hypotheses about simultaneous-move versus leader-follower equilibrium, or more generally about strategic heterogeneity among potential entrants, can be stated and tested.[20] The problem here is that much of the relevant theory resists

[19] The linearity is relaxed in later papers, but I retain it here for clarity in exposition.

[20] Bresnahan and Reiss take up the question, in a study of rural automobile dealerships,

statement in normal form; the underlying extensive forms are quite complex. This leads to an implicational reinterpretation. The parameter B(N) is taken to be the reduced form of the theoretical model: whatever strategic interaction leads to unnaturally concentrated structure, we measure it. Obviously, this idea of B(N) as a portmanteau statistic is closely related to Sutton's bounds ideas.

The portmanteau statistic and the bound strike many as diffuse. Yet, quite a good deal has been learned. It may be very hard to learn (statistically) how sunk costs permit strategic manipulation of entry, exit, etc. Yet we have very good evidence, from very different contexts, that sunk cost, especially ESC, permit it.

There have been several analytical advances in knowledge despite these difficulties. We now know that there are a variety of industries in which the determination of entry and industry structure is strategic. Sunk costs have been implicated in the strategy, in the sense that industries where costs are more sunk and/or the sunk costs are more endogenous tend to have more concentrated structure. The latter inference, however, has a very reduced form flavor. Little progress has been made in illuminating the exact mechanisms by which sunk costs, or exogenous sunk costs, enable strategic determination of market structure. Indeed, the very logic of the "bounds" approach is that it may not be possible to learn the exact mechanism.

Second, there may be alternative hypotheses of great power that it is extremely difficult to reject. In both my paper with Peter Reiss (1990) and Berry (1992), consideration is given to

---

of whether General Motors dealers are more frequent monopolists because they are leaders in a game where Ford dealers are followers. Berry examines the variety induced in airlines' entry behavior by their distinct pre-entry positions.

the possibility that different potential entrant's profits (should they enter) are correlated. The correlation parameter is quite badly estimated in both analyses. Worse, the correlation parameter is very difficult to distinguish from the parameters measuring the extent of strategic limitations on competition. While this may sound like an econometric detail, the correlation is actually an important parameter. If entry calls for a great deal of skill or rare firm capabilities, that would appear in this context as weakly correlated profits across potential entrants. Potential entrants' profits will be strongly correlated if there are many firms with the capacity to enter. Presence or absence of a large body of capable entrants is an alternative, purely efficiency-based, theory of concentrated structure.

Despite these difficulties, we have learned a bit about some of the causes of concentrated industry structure. Certainly, the toughness of price competition is capable of measurement. Accordingly, we could move to systematic statistical work more of the task of measuring the extent to which industry structure is concentrated because of purely strategic considerations arising in the entry game. For this purpose, concentrated structure that arises because prices fall with entry would not count. This promising line is already associated with a small literature.[21]

Another method by which we could learn more about the causes of concentrated structure, and investigate more specifically the mechanisms, would be in the use of the insider perspective. This is the approach of Burns (1986). He searched the records of the tobacco trust of a century ago for internal admissions that the trust was engaged in predation. (Predation was thought to be legal at the time; the records come down to us through the lawsuit which changed

[21] This literature was originated by Reiss and Spiller (1989). Bresnahan and Reiss (1991) provides further data along these lines.

that.) He then regresses the price paid by the trust for various competitors it acquired, and finds that predation led to cheaper acquisitions. Similarly, many of Sutton's detailed industry studies in his chapters tell us the story of how strategy worked to lead to, or not lead to, concentrated structure in the industries he covers. I am not yet convinced that "bounds" is all we can get.

Of course, these more detailed studies have gone forward in extremely fact-rich environments. With modern antritrust laws, we will not frequently be able to collect data the way Burns did. Nor do many scholars have Sutton's exquisite timing, undertaking field research in a body of industries just as the business people who built its structure are contemplating retirement. The use of case studies and other insider-perspective methodologies may be a very promising route to deeper knowledge.

Section IV: The State of Knowledge

The recent theoretical advances in Industrial Organization established the theoretical possibility of strategic forces mattering in industry economics. No longer could the possibility that entrants were too few, prices too high, or strategy relevant be ruled out as a matter of pure logic. The literatures reviewed here have pushed that frontier farther. For some specific industries, we know that these are more than theoretical possibilities, they are marketplace realities.

In this chapter, I have examined three areas in which strategic interaction theories have been tested or strategic aspects of competition have been measured. One striking feature is the widely varying role of formal theory in the analysis. In some of the studies, there is a very high level of integration; every object in the theory is measured, every object in the empirical work has an explicit structural foundation in the Bayesian Nash Equilibrium theory. In the oligopoly pricing work, an initial phase of empirical work focussed on testing strategic supply theories,

also with game-theoretic foundations. More recent efforts have shifted emphasis to the demand side, however, and the vast majority of recent developments in the theory play no role. In the industry structure work, theories are grouped into (large!) equivalence classes, and analytical distinctions once taken to be important are suppressed. Only the robust, common implications of a wide variety of theories are tested. The second striking thing about these literatures is their emphasis on appropriate data analysis; a single industry or a group of closely related industries, price, quantity, entry and exit (not profit) as the dependent variables, and a focus on measurement method.[22]

Why did empirical work in Industrial Organization move from a model of theory testing to a model of using theories to interpret measures of economic quantities? Why haven't the deepest dynamic and informational aspects of the theory been tested? When we were working out strategic competition theory using models based on the theory of games, it was appropriate to put large weight on certain logical distinctions. As we turn to using the theory as one of the tools in making knowledge, the emphasis shifts. Theories are elegant when they cleanly make right the logical distinctions; useful when they predict the important phenoma. I view it as a sign of maturity in our subdiscipline that a wide variety of approaches to studying phenomena, drawing on theory in a wide variety of ways, are in use.

---

[22] One of the more valuable off shoots of the new IO theory has been this refocus on careful industry studies. The theory leads us to expect both SR and LR competition to be complex, and to vary complexity across industries. It also leads us to expect industry details and institutions to be important. Now, competition studies are starting to catch up to regulatory ones in scholars' depth of knowledge of their industries.

For all the accomplishments of the papers covered here, they and others like them cover only a tiny fraction of the economy. That fraction has also been selected more for analytical convenience than, necessarily, for economic importance.[23] The challenge of going beyond them is twofold. First, there is work to do. Second, we will need to be more careful about the welfare economics as well as the positive economics, a topic which will take us back to the formal theory for more help.

[23] This criticism applies to me, author of a study on rural dentists' exit, as much as to anyone.

Bibliography

Abreu, Dilip; Pearce, David; Stacchetti, Enni (1990). "Toward a Theory of Discounted Repeated Games with Imperfect Monitoring." Econometrica 58 (5), September 1990, pp. 1041-63.

Ashenfelter, Orley (1989). "How Auctions Work for Wine and Art." Journal of Economic Perspectives, 3 (3), pp. 23-36.

Baker, Jonathan (1985). The Gains from Merger or Collusion in Product Differentiated Industries. Oxford and New York: Blackwell.

Baker, Jonathan (1989). "Identifying Cartel Policing Under Uncertainty: The U.S. Steel Industry, 1933-1939." Journal of Law and Economics, 32 (2), pp. 47-76.

Berry, Steven (1992). " Estimation of a Model of Entry in the Airline Industry." Econometrica 60 (4), pp. 889-917.

Berry, Steven; Levinsohn, J.; and Pakes, Ariel (1995). "Automobile Prices in Market Equilibrium." Econometrica, 63 (4), pp 841-90.

Berry, Steven; Briggs, Hugh (1988). "A Non-Parametric Test of a First-Order Markov Process for Regimes in a Non-Cooperatively Collusive Industry." Economics Letters 27 (1), pp. 73-77.

Bresnahan, Timothy (1981). "Departures from Marginal Cost Pricing in the American Automobile Industry: Estimates for 1977-1978." Journal of Econometrics, 17 (2), pp 201-27.

Bresnahan, Timoth ; Reiss, Peter (1987). "Do Entry Conditions Vary Across Markets?" Brooking Papers on Economic Activity: Microeconomics, 3 (0), pp. 833-71.

Bresnahan, Timothy; Reiss, Peter (1990). "Entry in Monopoly Markets." Review of Economic Studies 57 (4), pp. 531- 53.

Bresnahan, Timothy; Reiss, Peter (1991). "Entry and Competition in Concentrated Markets." Journal of Political Economy 99 (5), pp. 977-1009.

Bresnhan, Timothy; Stern, Scott; Trajtenberg, Manuel (1995). "Market Segmentation and the Sources of Rents from Innovation: Personal Computers in the late 1980's." Stanford Center for Economic Research Research.

Bresnahan, Timothy (1995). "Competition and Collusion in the American Automobile Industry." Journal of Industrial Economics, 35 (4), pp 457-82.

Burns, M. (1986). "Predatory Pricing and the Acquisition Costs of Competitors." Journal of Political Economy 94, pp. 266-96.

Cosslett, Stephen R. and Lee, Lung-Fei (1985). "Serial Correlation in Latent Discrete Variable Models." Journal of Econometrics 27 (1), pp. 79-97.

Ellison, Glenn (1994). "Theories of Cartel Stability and the Joint Executive Committee." RAND Journal of Economics 25 (1), pp. 37-57.

Fisher, Franklin (1991). "Organizing Industrial Organization: Reflections on the Handbook of Industrial Organization." Brooking Papers on Economic Activity: Microeconomics, pp 210-25.

Gasmi, F, J.J. Laffont and Vuong, Quang (1992). "Econometric Analysis of Collusive Behavior in a Soft Drink Market." Journal of Economics and Management Strategy, 1 (2), pp 277-311.

Goldberg, Pinelope (1995). "Product Differentiation and Oligopoly in International Markets: The Case of the U.S. Automobile Industry." Econometrica, 63 (4), pp 891-951.

Green, Edward J.; Porter, Robert (1984). "Noncooperative Collusion Under Imperfect Price Information." Econometrica 52 (1), pp. 87-100.

Hajivassiliou, Vassilis A. (1989). "Testing Game-Theoretic Models of Price Fixing Behavior." Yale Cowles Foundation Discussion Paper: 935, pp. 36.

Hausman, Jerry A. (1994). "Valuation of New Goods Under Perfect and Imperfect Competition." MIT Mimeo.

Hendricks, Kenneth; Porter, Robert (1988). "An Empirical Study of an Auction with Aymmetric Information." american Economic Review, 78 (5), pp 865-83.

Hendricks, Kenneth; Porter, Robert; Boudreau, Bryan (1987)."Information, Returns, and Bidding Behavior in OCS Auctions: 1954-1969." Journal of Industrial Economics, 35 (4), pp 517-42.

Laffont, Jean-Jacques; Ossard, Herve; Vuong, Quang (1995). "Econometrics of First-Price Auctions." Econometrica, 63 (4), pp. 953-980.

Lee, Lung-Fei; Porter, Robert (1984). "Switching Regression Models with Imperfect Sample Separation Information-With an Application on Cartel Stability." Econometrica, 52 (2), pp 391-418.

McAfee, Preston; McMilan, John (1987). "Auctions and Bidding." Journal of Economic Literature, 25 (2), pp 699-738.

Milgrom, Paul (1989). "Auctions and Bidding: A Primer." Journal-of-Economic-Perspectives; 3(3), pp 3-22.

Paarsch, Harry J (1992). "Deciding Between the Common and Private Value Paradigms in

Empircal Models of Auctions." Journal of Economietrics, 51 (1-2), pp 191-215.

Porter, Robert (1983). "A Study of Cartel Stability: The Joint Executive Committee, 1880-1886." Journal of Economics, 14 (2), pp 301-14.

Porter, Robert (1985). "On the Incidence and Duration of Price Wars." Journal of Industrial Economics, 33 (4), pp 415-26.

Porter, Robert; Zona, J. Douglas (1993). "Detection of Bid Rigging in Procurement Auctions." Journal of Political Economy, 101(3), pp. 518-38.

Reiss, Peter; Spiller, Pablo (1989). "Competition and Entry in Small Airline Markets." Journal of Law and Economics 32 , pp. 179-202.

Roberts, M.; Samuelson, L. (1988). " An Empirical Analysis of Dynamic, Nonprice Competition in an Oligopolistic Industry." RAND Journal of Economics 19, pp 200-20.

Sutton, John (1991). Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration. Cambridge, Mass: MIT Press.

Trajtenber, Manuel (1989). "The Welfare Analysisof Product Innovations, with an Application to Computed Tomography Scanners." Journal of Political Economy, 97 (2), pp 444-79.

Wilson, Robert (1992). "Strategic Analysis of Auctions," Handbook of Game Theory with Economic Applications.1, Auman, Robert J; Hart, Sergiu, eds.

Wolak, Frank A (1994). "An Econometric Analysis of the Asymmetric Information, Regulator-Utility Interaction." Annales-d'Economie-et-de-Statistique, 0(34), pp. 13-69.