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CONSISTENT COMPARATIVE STATICS FOR THE FOOD INDUSTRIES

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Abstract

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> "Paradoxical" results are pervasive in oligopoly; exceptions to "normal" behavior are commonplace, but their interest is only commensurate with their robustness, which needs to be studied. Surprises can be important, aberrations much less so: it all depends on whether the latter are seen to occur for a large and central set of circumstances or not. Unfortunately, a complete characterization of outcomes is usually hard to ascertain in oligopoly, on account of the algebraic barrier these problems can present. But then relying on special examples can be misleading: the generality of their behavior remains open to question.
>
> —Jesus Seade (1985, p. 6)

This paper derives restrictions on a model that is used extensively as an industrial organization paradigm for the food industries. This is the conjectural-variations model of oligopoly. Although it has been the subject of strong criticism (e.g., Dixit),[1] the conjectural-variations model has provided impetus for a large number of empirical investigations of market power. In agriculture the model has been applied repeatedly to assess departures from competitive pricing in both the product and the factor markets of the food industries. Examples of applications can be found in Gollop and Roberts, Sumner, Lopez, Roberts, Sullivan, Schroeter, Holloway, Schroeter and Azzam, Azzam and Pagoulatos, Azzam, Durham and Sexton, Wann and Sexton, and Chen and Lent.[2]

As well as these mostly empirical contributions, the model is employed frequently in comparative static exercises. Important conclusions are derived, usually in the following manner: A standard framework is chosen—typically one with homogeneous products and quantity-setting firms. Exogenous parameters of costs or demand are perturbed and the ensuing adjustments in the endogenous variables are computed. The magnitudes of these adjustments are, of course, conditional on the structural parameters of the model. One of these is the conjectural-variations parameter. Policy conclusions are then derived by assigning to this parameter particular numerical values. These are used to synthesize possible oligopolistic solutions across the entire spectrum between perfect competition and pure monopoly. Policy conclusions are made dependent on the setting assumed.

This approach, though conceptually appealing, suffers from a number of weaknesses. Perhaps the most significant of these is that counter-intuitive findings have emerged that are inexplicable. For example, tax policy in oligopoly has been investigated by de Meza, Seade, Katz and Rosen, and by Besley. Among the results is that ad valorem taxation in an oligopoly can lead to expansions in output and welfare. In another example Quirmbach demonstrates the possibility of a perverse-profits effect—a situation in which profits decline as a result of a favorable shift in demand. Could we conceive of such a situation in a real economy ? A lack of empirical evidence suggests not. For example, the perverse-profits effect predicts that firms will conduct advertising campaigns that are unfavorable toward their own product. Such examples are scant indeed, which draws into question this and other conclusions derived by these authors.

Another issue arising from these investigations concerns the feasibility of various equilibria on the entire spectrum between competition and pure monopoly. Consider a situation in which firms form perceptions about adjustments that result from some exogenous change. Could an equilibrium be sustained if the *ex ante* predictions of firms are inconsistent with the adjustments they observe *ex post* ? A complete response to this question would require a detailed model of learning. However, if we restrict attention to a credible steady state, a simpler alternative exists.

In this paper, I investigate comparative statics for oligopoly when firms form consistent conjectures. Consistency equates perceptions about movements in outputs with the ones that actually occurs as a result of some exogenous change. In general, adjustments in aggregate output differ from those of particular firms, except in one specific case—when symmetry is imposed. In this case, the aggregation condition relating firm and industry output assumes a very simple form. When firm numbers are fixed, the proportional adjustments in firm and industry output are identical. Consequently, the ratio of these adjustments is one. In the language of conjectural variations, the consistent conjecture is the monopolistic conjecture. This simple, but important result appears to be grossly overlooked in the literature. Its implication within a conventional oligopoly model is to restrict attention to an endpoint of the conjectural-variations spectrum. As Quirmbach notes (p. 451): "... a demand shift can produce a perverse profit effect only in the middle ground between competition and complete collusion." Hence, consistency rules out potentially counterintuitive situations. This, of course, is advantageous. A disadvantage, however, is that consistency undermines the framework itself, whose principal attraction is its ability to synthesize outcomes across a broad spectrum of oligopolistic equilibria. This problem of specificity is potentially overcome when we allow firm numbers to adjust. In this case, an additional degree of freedom is imparted to the aggregation condition in the symmetric equilibrium. Retaining symmetry, I investigate consistent conjectures in a conventional oligopoly model with free entry and exit. The results are once again negative: There exists no conjecture that is capable of reconciling perceptions and actual adjustments. I conclude that the frequently invoked symmetric equilibrium, while convenient for comparative statics, is much too restrictive to provide meaningful insights about real oligopolies.

Industry Equilibrium and Consistent Conjectures

Consider a collection of m identical firms, each producing output x_j. Entry is free but production incurs variable cost $c(\cdot)$. Firms face an inverse demand schedule $p(\cdot)$, which is defined over the industry aggregate $x = \sum x_j$. When maximizing profits, each firm forms a conjecture about adjustments in output levels. Alternative versions of these conjectures appear in the literature. One type depicts firm-specific responses: $\partial x_i(x_j)/\partial x_j \equiv \hat{\delta}_{ij}$, $\{i,j\} \in \{1,2...m\}$, $i \neq j$. A second type depicts an aggregate response, excluding that of the firm in question: $\partial x_o(x_j)/\partial x_j \equiv \hat{\delta}_{oj}$, $j \in \{1,2...m\}$, $j \notin o$. Finally, a third type depicts the response of the entire industry: $\partial x(x_j)/\partial x_j \equiv \hat{\delta}_j$, $j \in \{1,2...m\}$. Suppose some exogenous shock causes output to change. Consider the actual movements in the output levels of individual firms, dx_j, $j \in \{1,2...m\}$; in the output levels of the rest of the industry, dx_o, $j \notin o$, $j \in \{1,2...m\}$; and in the output level of the entire industry, dx. Accordingly, define the ratios of these respective adjustments as follows: $dx_i/dx_j \equiv \delta_{ij}$, $\{i,j\} \in \{1,2...m\}$, $i \neq j$; $dx_o/dx_j \equiv \delta_{oj}$, $j \in \{1,2...m\}$, $j \notin o$; *and* $dx/dx_j \equiv \delta_j$, $j \in \{1,2...m\}$. The objective in the remainder of this paper is to characterize equilibria in which the former adjustments, perceived by each of the firms, are equivalent to the latter ones, which are implied by the initial equilibrium. That is, situations in which: $\hat{\delta}_{ij} = \delta_{ij}$, $\{i,j\} \in \{1,2...m\}$, $i \neq j$; $\hat{\delta}_{oj} = \delta_{oj}$, $j \in \{1,2...m\}$, $j \notin o$; *and* $\hat{\delta}_j = \delta_j$, $j \in \{1,2...m\}$. The first result follows from examining the aggregation condition defining the symmetric equilibrium:

PROPOSITION 1. *In the symmetric equilibrium in which firm numbers are held constant, the set of consistent conjectures are the collusive conjectures:* $\hat{\delta}_{ij} = 1 = \delta_{ij}$, $\{i,j\} \in \{1,2...m\}$, $i \neq j$; $\hat{\delta}_{oj} = m-1 = \delta_{oj}$, $j \in \{1,2...m\}$, $j \notin o$; *and* $\hat{\delta}_j = m = \delta_j$, $j \in \{1,2...m\}$.

PROOF: The definitions of firm and aggregate output in the symmetric equilibrium are: $x_i = x_j$, $\{i,j\} \in \{1,2...m\}$, $i \neq j$; $x_o = (m-1)\,x_j$, $j \in \{1,2...m\}$, $j \notin o$; and $x = m\,x_j$, $j \in \{1,2...m\}$. Totally differentiating, holding firm numbers constant, yields: $dx_i = dx_j$, $\{i,j\} \in \{1,2...m\}$, $i \neq j$; $dx_o = (m-1)\,dx_j$, $j \in \{1,2...m\}$, $j \notin o$; and $dx = m\,dx_j$, $j \in \{1,2...m\}$. Expressing these as ratios, one obtains: $dx_i/dx_j \equiv \delta_{ij} = 1$, $\{i,j\} \in \{1,2...m\}$, $i \neq j$; dx_o/dx_j

$\equiv \delta_{oj} = m\text{-}1,\ j \in \{1,2...m\},\ j \notin o$; and $dx/dx_j \equiv \delta_j = m,\ j \in \{1,2...m\}$. In order for perceptions to be consistent with equilibrium they must equal these observed ratios. Q.E.D.

The above result indicates the stringency of assuming symmetry among firms. It has significant implications for a large and growing literature on empirical investigations of conduct using conjectural variations. In most of these studies symmetry among firms is implied by the estimated model and attention is directed toward testing the null hypothesis that pure competition prevails. It now appears that this practice is somewhat misguided.

The result focuses attention in Quirmbach's experiments toward a specific restriction on his conjectural-variations elasticity, namely $\beta = 1$. The parameter β describes a specific belief on the positive unit interval. Accordingly, let us redefine it as follows: $\beta \equiv (\partial x(x_j)/\partial x_j)(x_j/x) \equiv \hat{\theta} \in [0,1]$. Using this notation, consistency is attained whenever the parameter $\hat{\theta}$ equals the true response, which we denote $\theta \equiv (dx/dx_j)(x_j/x)$. As a result of symmetry, however, $\theta = 1$ and, as noted by Quirmbach, symmetry is guaranteed whenever identical marginal costs are increasing. In the symmetric equilibrium with consistency imposed the results of Quirmbach's experiments are predictable and intuitive: A favorable shift in demand causes firm and aggregate output to expand, raises price and profits, and causes industry welfare to increase. But these effects are the same as those predicted from the purely competitive model.

Can a consistent conjecture exist when we allow firm numbers to adjust ? The answer to this question is somewhat more complicated, though nonetheless relevant than the previous one. Symmetry itself, however, predisposes us to investigate this question in a natural and convenient way. Specifically, let us assume that the number of incumbent firms, m, is an endogenous variable that adjusts in response to profit incentives. These incentives, of course, are affected by a variety of exogenous variables. We restrict attention to two of these, namely one affecting demand, σ, and another affecting costs, τ. Using these definitions, a symmetric equilibrium for the industry is defined by the following four equations:

(1) $p = p(x|\sigma)$,

(2) $x = m\, x_j$,

(3) $p(x(x_j))\,(1 + \hat{\theta}\eta) - c'(x_j|\tau) = 0$,

(4) $px_j - c(x_j|\tau) = 0$,

where $x(x_j)$ denotes firm j's conjectural-variation function, $\eta \equiv (\partial p(\cdot)/\partial x)(x/p(\cdot))$ denotes the price flexibility of demand, and the conjectural elasticity, $\hat{\theta}$, is previously defined.

Through the familiar technique of counting equations and unknowns, the above equilibrium admits four endogenous variables: p, x, m and x_j. In order to conduct comparative statics, a convenient reduction of the system is obtained by substituting (2) into (1), and subsequently (1) into (4). This yields a two-equation system in the two endogenous variables m and x_j. In performing the latter substitutions one must resist the temptation to substitute the terms on the right-hand side of equation (2) for the argument $x(x_j)$, which appears in the firm's first-order condition everywhere in place of x. The expression $x(x_j)$ represents the firm's perception about how the remainder of the industry adjusts output in response to its own quantity adjustment. The question that we wish to pose is whether this conjecture coincides with the actual response observed through subsequent comparative statics. If the aggregation condition mx_j were substituted for the expression $x(x_j)$ one imposes, implicitly, a form of consistency on the model—an aspect of consistency that appears to have been overlooked by previous authors. In making this substitution these authors' comparisons of postulated conjectures with observed responses are not true comparisons. When the correct substitutions are performed and the specific dependencies $\eta(x_j)$ and $\hat{\theta}(x_j)$ are acknowledged, we obtain the system:

(5) $$\Phi(x_j|\sigma,\tau) \equiv p(x(x_j)|\sigma)(1+\hat{\theta}\eta) - c'(x_j|\sigma) = 0,$$

(6) $$\Psi(x_j,m|\sigma,\tau) \equiv p(mx_j|\sigma)\,x_j - c(x_j|\tau) = 0.$$

Before embarking on comparative statics, let us consider the conditions under which this equilibrium is locally stable. The usual adjustment processes that are invoked are that output expands if firms perceive positive marginal profits and that firm numbers adjust positively to profit incentives. Allowing $\alpha > 0$ and $\gamma > 0$ denote adjustment speeds, the rates of change in firm output and firm numbers are, respectively: $\dot{x}_j = \alpha\Phi(x_j|\sigma,\tau)$ and $\dot{m} = \gamma\Psi(x_j,m|\sigma,\tau)$. Assuming strict concavity of the firm's objective function, a sufficient condition for local stability of this system is that demand slopes downward.

Comparative Statics

The finding that the unique consistent conjecture is the monopolistic conjecture depends crucially on the assumption that firm numbers are fixed. We now examine consistent conjectures while permitting firm numbers to adjust simultaneously with movements in firm and industry output. For this purpose, it is instructive to express derivatives in (5)-(6) in proportional-change terms, using tildes to denote these changes (i.e., $\tilde{z} \equiv dz/z$). We obtain:

$$(7) \qquad \begin{pmatrix} \phi_x & 0 \\ \psi_x & \psi_m \end{pmatrix} \begin{pmatrix} \tilde{x}_j \\ \tilde{m} \end{pmatrix} = \begin{pmatrix} \phi_\sigma & \phi_\tau \\ \psi_\sigma & \psi_\tau \end{pmatrix} \begin{pmatrix} \tilde{\sigma} \\ \tilde{\tau} \end{pmatrix},$$

where $\phi_x \equiv (\partial\Phi(\cdot)/\partial x_j)x_j$, $\phi_\sigma \equiv -(\partial\Phi(\cdot)/\partial\sigma)\sigma$, $\phi_\tau \equiv -(\partial\Phi(\cdot)/\partial\tau)\tau$, $\psi_x \equiv (\partial\Psi(\cdot)/\partial x_j)x_j$, $\psi_m \equiv (\partial\Psi(\cdot)/\partial m)m$, $\psi_\sigma \equiv -(\partial\Psi(\cdot)/\partial\sigma)\sigma$, and $\psi_\tau \equiv -(\partial\Psi(\cdot)/\partial\tau)\tau$.

Equations (7) direct attention toward elasticity effects. We seek a value for the perceived elasticity, $\hat{\theta}$, that is equivalent to the one predicted by equations (7), namely: $\theta \equiv \tilde{x} / \tilde{x}_j \in [0,1]$. Note, of course, that the latter ratio is itself a function of the perceived response, $\hat{\theta}$, because this parameter is implicit in the initial equilibrium. Thus, if they exist, consistent conjectures are the fixed points that satisfy:

$$(8) \qquad \hat{\theta} = \frac{\tilde{x}(\hat{\theta})}{\tilde{x}_j(\hat{\theta})} .$$

Previously, authors have sought solutions to this problem by deriving restrictions across demand and cost functions. This procedure, of course, presupposes that a consistent conjecture exists. That one may not exist, remains hitherto undetermined. Accordingly, we now investigate this issue. Observe from the definition of aggregate output in the symmetric equilibrium—equation (2)—that the proportional changes in x, m, and x_j must satisfy: $\tilde{x} = \tilde{m} + \tilde{x}_j$. This, in turn, implies that the ratio of actual adjustments on the right-hand side of equation (8) must satisfy: $\theta = 1 + \tilde{m} / \tilde{x}_j$. From the fact that the perception $\hat{\theta}$ is defined on the positive unit interval, the equality $\hat{\theta} = \theta$ implies that the ratio of movements in firm numbers and output must be contained over the negative unit interval. That is: $\tilde{m} / \tilde{x}_j \in [-1,0]$. Therefore, in order for a consistent conjecture to exist, output must expand with exit and contract with entry. But such a situation can never arise in a symmetric equilibrium:

PROPOSITION 2: *In the symmetric equilibrium with endogenous entry, no consistent conjecture exists.*

PROOF: Using the definition of the price flexibility $\eta \equiv (\partial p(\cdot)/\partial x)(x/p)$, expand the terms ψ_x and ψ_m by evaluating them at the equilibrium points $x = mx_j$ and $p(1+\hat{\theta}\varepsilon) = c'(\cdot)$. Observe: $\psi_x = (1-\hat{\theta})\psi_m \equiv (1-\hat{\theta})p\varepsilon x_j$.

Imposing this dependence on the system in (7), solve for the equilibrium movements $\tilde{x}_j$ and $\tilde{m}$, first setting $\tilde{\sigma} = 0$ and subsequently setting $\tilde{\tau} = 0$. One computes $\tilde{m} / \tilde{x}_j = (\hat{\theta}-1) + (\phi_x/\psi_m)\times(\psi_\sigma/\phi_\sigma)$ when demand shifts and $\tilde{m} / \tilde{x}_j = (\hat{\theta}-1) + (\phi_x/\psi_m)\times(\psi_\tau/\phi_\tau)$ when variable costs shift. Recall, from the aggregation condition, that the true value θ must satisfy: $\theta = 1 + \tilde{m} / \tilde{x}_j$. The equality $\hat{\theta} = \theta$ is therefore mutually inconsistent with the preceding ratios, unless the respective expressions $(\phi_x/\psi_m)\times(\psi_\sigma/\phi_\sigma)$ and $(\phi_x/\psi_m)\times(\psi_\tau/\phi_\tau)$ are zero. The condition $\phi_x = 0$ is inconsistent with local uniqueness of the first-order condition. Similarly, $\psi_m \equiv p\varepsilon x_j = -\infty$ is ruled out by the assumptions that price is endogenous and firms produce finite output levels. It follows, therefore, that the ratio ϕ_x/ψ_m is strictly positive and finite-valued. The conditions $\psi_\sigma = 0$ and $\psi_\tau = 0$ are ruled out by the assumptions that σ shifts demand and τ shifts variable costs, and the conditions $\phi_\sigma = \infty$ and $\phi_\tau = \infty$ are inadmissible in comparative statics. It follows that the ratios ψ_σ/ϕ_σ and ψ_τ/ϕ_τ are also positive and finite-valued. Hence, no consistent conjecture exists in the symmetric equilibrium with endogenous entry. Q.E.D.

Discussion

The results of this paper should be considered building blocks for ongoing research into deriving consistent comparative statics for the food industries.

Internal consistency of qualitative predictions is desirable in comparative statics. Imposing consistency, however, appears to be quite restrictive in a conventional oligopoly setting: In a short run situation in which firm numbers are fixed, consistency restricts attention to a single point in the domain of the conjectural elasticity. This has the desirable consequence of eliminating counterintuitive findings, but it also has a significant disadvantage: It undermines the use of the model itself as a tool for investigating adjustments in oligopoly. In this paper I argue that consistency is important because one suspects that firms in steady-state equilibria should possess this foresight. For this reason, consistent qualitative predictions are potentially of greater significance than those derived from models in which consistency is ignored.

Our knowledge about adjustments occurring in static oligopoly is growing, but still scant. Despite its criticisms, the conjectural-variations model provides an attractive framework for acquiring new knowledge. In the author's opinion, the use of the model is more defensible when consistency is imposed. To some, however, the negative results of this paper may suggest otherwise. In this case, it is important to emphasize that the negative results stem, not from the imposition of consistency, but from the less defensible assumption of symmetry among firms. That real industries depart substantially from this case is cause to consider non-symmetric settings in oligopoly models. Unfortunately, deriving consistent comparative statics under these circumstances seems somewhat intractable, even in the most adept hands. Further work should focus on extending Dixit's framework to derive consistent qualitative predictions from non-symmetric equilibria. Specifically, for the food industries, immediate interest lies in the robustness of these results to assumptions that are relevant in that context. In particular, endogeneity of a single factor—representing an agricultural product—may be sufficient to overturn some of the findings presented above. Further research will pursue this issue.

Footnotes

[1]As Dixit (p. 107) notes, these criticisms pertain to the model's static environment, within which the inherently dynamic concepts of conjectures and reactions are nebulous.

[2]For other empirical examples see the works cited in Bresnahan (1989).

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