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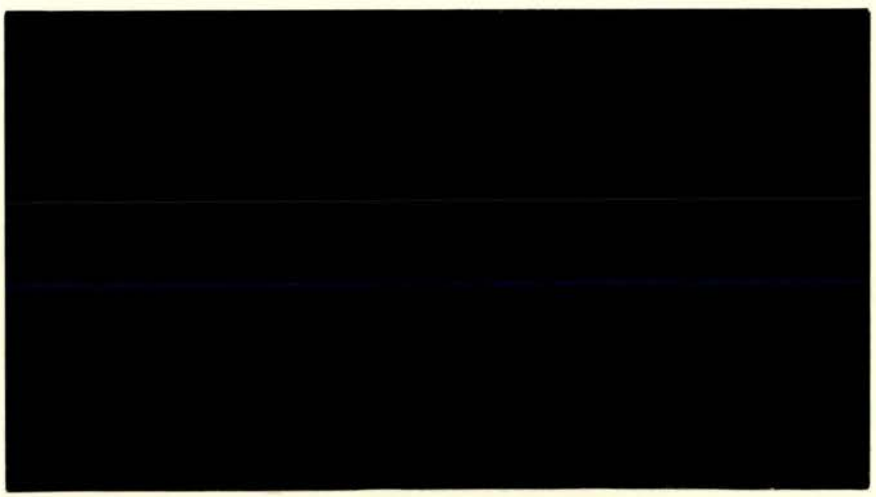

WORKING PAPER SERIES

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THE REPRESENTATIVE FIRM, ENDOGENOUS OUTPUT DECISIONS AND CONSISTENT CONJECTURAL VARIATIONS IN OLIGOPOLY

by
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Working Paper No. 92-11

The Representative Firm, Endogenous Output Decisions and Consistent Conjectural Variations in Oligopoly

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Abstract

This article examines consistent conjectural variations in a homogeneous-product, quantity-setting model in which firms are identical. Previous work by Perry considers this topic. Perry's findings continue to be important in light of the recurrent use of his framework in both theoretical and empirical studies of market power. His results, however, depend crucially on the assumption that firm output is exogenous. Relaxing this restriction, I examine consistency in an equilibrium setting in which firm output is determined endogenously. With simultaneous adjustment in price and aggregate output, the following results are derived: When the number of firms is fixed, the unique consistent conjecture is the monopolistic conjecture. When the number of firms is variable, consistency requires firm output to expand with exit of firms and contract with new entry, but there exists no conjecture that is consistent with equilibrium.

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The Representative Firm, Endogenous Output Decisions and Consistent Conjectural Variations in Oligopoly

This article examines consistent conjectural variations in a homogeneous-product, quantity-setting model in which firms are identical. Previous work by Perry considers this topic. Perry's findings continue to be important in light of the recurrent use of his framework in both theoretical and empirical studies of market power. His results, however, depend crucially on the assumption that firm output is exogenous. Relaxing this restriction, I examine consistency in an equilibrium setting in which firm output is determined endogenously. With simultaneous adjustment in price and aggregate output, the following results are derived: When the number of firms is fixed, the unique consistent conjecture is the monopolistic conjecture. When the number of firms is variable, consistency requires firm output to expand with exit of firms and contract with new entry, but there exists no conjecture that is consistent with equilibrium.

1. Introduction

■ The conjectural-variations model promulgated by Bowley (1924) has been much maligned. Its main criticism stems from the observation that, in general, the *ex ante* conjectures of firms are not realized *ex post* (Fellner). Consequently, the model implies a degree of irrationality about firm behavior that one believes would not persist in long-run equilibrium.[1] Several authors (Laitner (1980), Bresnahan (1981), Boyer and Moreaux (1983), Kamien and Schwartz (1983), Daughety (1985) and Makowski (1987)) consider "consistent" conjectural variations. A consistent conjectural variation is a conjectured response that is realized through a comparative-static adjustment in the encompassing equilibrium. In examining consistency, Perry (1982) provides a key contribution to the literature. At its time of publication it was the first to consider the issue in an oligopoly setting, others before it focusing almost exclusively on the duopoly model. Perhaps because of the greater likelihood of generating insights from symmetric equilibria, Perry limits attention to an industry setting in which firms are identical. Although subsequent work by Dixit (1986) relaxes this restriction, Perry's results remain extremely significant. There are two reasons. First, the identical-firms model is the one most frequently applied in empirical applications of conjectural-variations.[2] Second, several authors (e.g., Seade (1980), Katz and Rosen (1985), Quirmbach (1988)) apply this framework to investigate

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[1] Another common criticism of the static model is that the subsumed notions of conjectures and responses are inherently dynamic ones and, thus, should be depicted as such. A number of authors have responded to this criticism in an obvious manner, with encouraging results. See, for example, Riordan, Karp and Perloff, and the literature cited therein.

[2] Empirical studies that have applied this framework include Sumner (1981), Appelbaum (1982), Lopez (1984), Sullivan (1985), Schroeter (1988), Hall (1988), Shroeter and Azzam (1990), Azzam and Pagoulatos (1990), and Azzam (1992). Studies that circumvent the representative-firm assumption by applying firm-level data include Iwata (1974), Gollop and Roberts (1979), Roberts (1984). For a review of related empirical work see Bresnahan (1989).

qualitative issues in static oligopoly. Unfortunately, the representative-firm model contains some significant limitations that undermine the findings of each of these studies. Since Perry fails to derive these explicitly, the objective of this paper is to illustrate them in the context of his model and discuss their implications for both conceptual and empirical analyses.[3]

Perry summarizes his main findings as follows:

> *When the number of firms is fixed, we find that competitive behavior is consistent when marginal costs are constant, but that when marginal costs are rising, the consistent conjectural variation will be between competitive and Cournot behavior. Finally, if we allow free entry and redefine consistency to account for such, then only competitive behavior will be consistent.*

The major limitation in these results is that they are derived from a model in which firm output is exogenous. This counters traditional analyses wherein an agent's choice variable is determined endogenously and conditioned by the given values of particular parameters. In ensuing comparative statics, we assess this variable's endogenous adjustment in response to changes in the values of these parameters. This prompts an obvious question about the worth of Perry's contribution. As this paper shows, there is much to be gained from revisiting his model and procedures, assuming firm output to be endogenous, and adjusting the definition of consistency accordingly. Among others, we derive the following key results: When the number of firms is fixed, the unique consistent conjecture is the monopolistic conjecture. When the number of firms is variable, consistency requires firm output to expand with exit of firms and contract with new entry, but there exists no conjecture that is consistent with equilibrium.

In what follows, we revisit Perry's setting and provide an explicit articulation of industry equilibrium. For comparative purposes, we employ his notation. We consider the local stability of equilibrium and then embark on comparative statics. Employing proportional-change derivatives, we redefine consistency accordingly and illustrate its correspondence with Perry's definition. The main results are then derived and their implications are discussed.

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[3] Except for a few comments, I leave unanswered the criticism that conjectures and responses should be depicted in a dynamic setting. However, to completely disregard the static analysis of oligopoly is as much a condemnation of the technique of comparative statics as it is a condemnation of conjectural variations itself. Second, one may consider the transition to dynamic analysis one in which the static model is given a potentially more complicated dimension. Hence, it is imperative that we understand the basic model as completely as possible before committing ourselves fully to potentially more complex cases. Currently, as this paper shows, we do not appear to have a full understanding of the basic model.

2. Industry equilibrium

■ Recalling Perry's equilibrium setting, 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 $X_o = X_o(X_j)$ about how the remaining $m-1$ firms adjust their combined output X_o in response to the firm's own adjustment in quantity. We define the differential $dX_o(\cdot)/dX_j \equiv \delta$ to represent the ratio of the respective adjustments as perceived by the firm. The domain of this parameter $\delta \in [-1, m-1]$ circumscribes a full spectrum of conduct including the cases of pure competition $\delta = -1$, monopoly $\delta = m-1$, and Cournot $\delta = 0$.[4] Using these definitions, equilibrium is defined by the following five equations:

$$P = P(X), \tag{1}$$

$$X = X_j + X_o, \tag{2}$$

$$X_o = (m-1)X_j, \tag{3}$$

$$P(X_j+X_O(X_j)) + (1 + \delta)\, P'(X_j+X_o(X_j))\, X_j - C'(X_j) = 0, \tag{4}$$

$$PX_j - C(X_j) = 0. \tag{5}$$

Within this context, Perry considers particular values for the parameter δ that are "consistent" with the equilibrium configuration. As he notes (p. 197): "A conjectural variation is consistent if it is equivalent to the optimal response of the other firms at the equilibrium point defined by that conjecture." However, as acknowledged through his definition (equation (7), p. 199), he defines consistency assuming the output level of the representative firm to be exogenous:

Definition 1. Consistency: Consistent conjectural variations are the fixed points: $\dfrac{dX_o(X/m; m, \delta)}{dX_j} = \delta.$

While void of any technical impropriety, this approach has the unappealing consequence of leaving unexplained movements in X_j. As argued above, this is rather unsatisfactory from both an optimization viewpoint and a comparative-static one. Hence, the remainder of the paper analyzes consistent conjectures assuming X_j to be

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[4] Strictly speaking, the distinction between these alternative modes of conduct and that of conjectural variations is an important one. While different values for the parameter δ can be used to synthesize alternative behavioral modes in the first-order condition of the representative firm, the comparative-static properties of the resulting equilibrium will be different in each case. In particular, the structural models depicting price movements will differ among each of the behavioral modes. The empirical implications of this observation are examined in detail by Holloway and Hertel (1992).

endogenous. Through the familiar technique of counting equations and unknowns, the above equilibrium admits five endogenous variables: P, X, X_o, m and X_j. In order to conduct comparative statics, we now require specification of parameters that can displace these variables from their original levels. We consider two, namely σ and τ; the first emanating from the demand schedule $P(X|\sigma)$ and the second from the variable cost function $C(X_j|\tau)$. Reformulating (1)-(5) accordingly, a convenient reduction of the system is obtained by substituting (3) into (2), (2) into (1), and subsequently (1) into (5).

In performing these substitutions one must resist the temptation to substitute the terms on the right-hand side of equation (3) for the argument $X_o(X_j)$, which appears in the firm's first-order condition. As discussed above, $X_o(X_j)$ represents the firm's perception about how the remainder of the industry adjusts output in response to its own quantity adjustment. The question being posed is whether the conjecture derived therein coincides with the actual response which is revealed through subsequent comparative statics. Making this substitution would necessarily defeat the purpose of the exercise. Unfortunately, this important point has been overlooked by several previous authors. In committing this error their comparisons of postulated conjectures with observed responses are not true ones. Rather, their comparisons are conducted between two hybrid versions of the model. When the correct substitutions are performed, we obtain the two-equation system:

$$\Phi(X_j|\sigma,\tau) \equiv P(X_j+X_O(X_j)|\sigma) + (1+\delta)\, P'(X_j+X_o(X_j)|\sigma)\, X_j - C'(X_j|\sigma) = 0, \tag{6}$$

$$\Psi(X_j,m|\sigma,\tau) \equiv P(mX_j|\sigma)\, X_j - C(X_j|\tau) = 0. \tag{7}$$

Before embarking on comparative statics, we consider the conditions under which this equilibrium is locally stable. The usual adjustment processes that are typically invoked are that incumbent output expands if firms perceive positive marginal profits (Dixit) and that entry adjusts positively to profit incentives (Seade). Hence, we define $\alpha > 0$ and $\beta > 0$ as the adjustment speeds, and define $\dot{X}_j = \alpha\Phi(X_j|\sigma,\tau)$ and $\dot{m} = \beta\Psi(X_j,m|\sigma,\tau)$ as the adjustment processes. Given the assumed strict concavity of the firm's objective function, the above system will be locally stable whenever demand slopes downward.

3. Comparative statics

■ It is instructive to employ Takayama's "hat calculus" (pp. 35-39), thereby expressing derivatives in proportional-change terms. Using the symbol "~" to denote these changes (i.e., $\tilde{z} \equiv dz/z$), we derive:

$$\begin{pmatrix} \phi_x & 0 \\ \psi_x & \psi_m \end{pmatrix} \begin{pmatrix} \tilde{X}_j \\ \tilde{m} \end{pmatrix} = \begin{pmatrix} \phi_\sigma & \phi_\tau \\ \psi_\sigma & \psi_\tau \end{pmatrix} \begin{pmatrix} \tilde{\sigma} \\ \tilde{\tau} \end{pmatrix}, \tag{8}$$

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 $\psi_\tau \equiv -(\partial\Psi(\cdot)/\partial\tau)\tau$. This representation redirects attention toward elasticity effects. Accordingly, we redefine the notion of a consistent conjectural variation.

We assume that the firm has complete information about the level of adjustment in its own output. Hence, forming a conjecture over the rest of the industry is tantamount to forming a conjecture over the industry aggregate. It is legitimate, therefore, to define the corresponding relationship $X(X_j) \equiv X_j + X_o(X_j)$. This admits the conjectural-variation elasticity $\theta \equiv (\partial X(X_j)/\partial X_j)(X_j/X)$, which, following Appelbaum (1982), has been the focus of attention in most empirical applications. We acknowledge the explicit relationship between this elasticity, price, and marginal costs, by defining the price flexibility $\varepsilon \equiv (\partial P(\cdot)/\partial X)(X/P)$ and manipulating the firm's first-order condition to obtain $P(1+\theta\varepsilon) = C'(\cdot)$.[5] Intuitively, $\theta \in [0,1]$, with limits corresponding respectively to competition $\theta = 0$ and pure monopoly $\theta = 1$. It follows, therefore, that the relationship between this elasticity and Perry's conjectural-variation parameter is: $\delta + 1 = \theta m$. Since firm numbers are strictly positive, these parameters are monotonically related. Consequently, nothing is lost by redefining consistency in the following manner:[6]

Definition 2. Consistency: Consistent conjectural variations are the fixed points: $\dfrac{\tilde{X}(\theta)}{\tilde{X}_j(\theta)} = \theta.$

The first issue we wish to consider are the types of conduct that are consistent with equilibrium when firm numbers are held constant. Perry derives results that depend, among other things, on the forms of the demand and

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[5] Another insightful interpretation of the conjectural elasticity is offered by Quirmbach (1988). He shows that θ may be interpreted as the "perceived weight" in a convex combination of the average and marginal revenues facing the firm (p. 452).

[6] There is an additional advantage of employing an elasticity interpretation of the conjectural variation. This follows from examining the equilibrium conditions in the case where firms incur a sunk cost κ upon entering the industry and thereafter incur constant marginal costs. This scenario is often invoked in the literature on entry. Respecifying variable costs $C(X_j|\tau) \equiv C(\tau)X_j$ and defining $\omega_\kappa \equiv \kappa/PX_j$ as the share of fixed costs in firms' revenues, the corresponding reformulations of equations (4) and (5) imply: $\kappa - \theta\varepsilon = 0$. This specifies the simultaneous relationship between market structure—as depicted by values of ε and κ—and endogenously determined conduct, which is defined by the value θ.

cost functions, the shape of the marginal revenue curve, and the number of incumbent firms in the industry. We replace his results with the following:

Proposition 1. Monopoly: In the symmetric equilibrium with firm numbers held fixed, the unique consistent conjecture is the monopolistic conjecture: $\theta = 1$.

Proof: Equations (2) and (3) together imply $X(\theta) = mX_j(\theta)$. Differentiating this relation, holding firm numbers fixed, we obtain $\tilde{X}(\theta) = \tilde{X}_j(\theta)$. Hence: $\tilde{X}(\theta) / \tilde{X}_j(\theta) = \theta = 1$. *Q.E.D.*

Simply stated, when firms are identical and entry is restricted, the internally consistent outcome is for the industry to operate as a perfect cartel. This result is not surprising. In this case, profits are maximized by exploiting monopoly power and cartel defection is inadmissible since firms are identical.

Proposition 1 has some rather negative implications for oligopoly models that conform to the identical-firms, restricted-entry framework. In theoretical applications, *Proposition 1* undermines the potency of several counterintuitive results. For example, Katz and Rosen (1985) suggest that a factor tax in oligopoly may lead to increased profits for the industry, while Quirmbach (1988) suggests that profits may alter unfavorably when demand shifts outward. These results are ruled out by restricting the range of oligopoly outcomes to the single point at which they are consistent with equilibrium, namely $\theta = 1$. In empirical studies our result is equally troublesome. In most of these applications a point estimate of θ is sought from a variant of the first-order condition $P(1+\theta\varepsilon) = C'(\cdot)$. Entry is typically not modeled. Since firm-level data are usually unavailable, inter-firm differences are negated by requiring marginal costs to be constant and identical across firms. This implies that the true value θ is the same for each firm. But if firms behave rationally, the true value of this parameter is known, namely $\theta = 1$—an observation hitherto overlooked in this literature.[7]

The above results depend 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. In this context, we are also able to shed light on an issue that has received considerable attention in the literature—

[7] It is noteworthy that none of the cited empirical studies test the theoretical restriction implied by their model. Instead, they focus attention on refuting the null hypothesis H_O: $\theta = 0$.

the existence of a "business-stealing" effect. As defined by Mankiw and Whinston (1986, p. 49): "The business-stealing effect exists when the equilibrium strategic response of existing firms to new entry results in their having a lower volume of sales—that is when a new entrant 'steals business' from incumbent firms."[8] The presence of this effect has important consequences for the normative implications of entry when there are fixed set-up costs. As Mankiw and Whinston show, when a business-stealing effect is present, entry is more profitable to the entering firm than it is to society and, hence, an "entry bias" exists in which the equilibrium number of firms exceeds that which is socially optimal. Since entry can occur only in response to profit incentives, one would expect that those same incentives would cause incumbents to expand output. Consequently, a business-stealing effect may appear somewhat counter-intuitive. Seade (1980), on the other hand, considers the plausibility of output per firm to rise simultaneously with an increase in firm numbers. Referring to this as a "perverse" effect, he considers business-stealing to be somewhat more plausible.[9] This intuition can be confirmed rigorously by requiring firms conjectures to be consistent:

Proposition 2. Business Stealing: In the symmetric equilibrium with endogenous entry, a necessary and sufficient condition for conjectural variations to be consistent is the existence of a business-stealing effect.

Proof: For business stealing to occur we must observe simultaneous and opposite movements in $\tilde{X}_j(\theta)$ *and* $\tilde{m}(\theta)$. Thus the ratio $\tilde{m}(\theta) / \tilde{X}_j(\theta)$ must be negative. Combining equations (2) and (3) and subsequently differentiating, we observe that $\tilde{X}(\theta) = \tilde{X}_j(\theta) + \tilde{m}(\theta)$. Normalizing on $\tilde{X}_j(\theta)$ and invoking the definition of a consistent conjectural variation, we have $\tilde{X}(\theta) / \tilde{X}_j(\theta) = \theta = 1 + \tilde{m}(\theta) / \tilde{X}_j(\theta)$. The conditions $\theta \in [0,1]$ and $\tilde{m}(\theta) / \tilde{X}_j(\theta) \in [-1,0]$ imply one another. *Q.E.D.*

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[8] Although Mankiw and Whinston refer to the volume of sales, their definition of the business-stealing effect is derived with reference to the volume of firm output. In our model, the issue of adjustment in sales is complicated by the fact that both price and quantity may adjust in equilibrium. Mankiw and Whinston assume price to remain constant.

[9] Mankiw and Whinston also consider the "integer constraint." The integer constraint arises because, strictly speaking, m can take only integer values. This value is determined by an entry process that ensures that the m^{th} firm makes non-negative profits but that the $m+1^{th}$ firm would make a loss if it decided to enter. Both the above analysis and that of Seade suffer this limitation. However, Seade (p. 482) shows that little is lost in assuming m to be continuous.

In light of previous findings, *Proposition 2* contains negative implications about the social desirability of consistent conjectures. Specifically, consistency implies that the conditions necessary for an entry bias will be met. Of course, these conditions may not be met if conjectures are inconsistent. Hence, the final issue that we need consider is whether there exists a conjecture that is capable of rationalizing firms predictions with the *ex post* adjustments that occur in equilibrium.

As the *Proof* of *Proposition 2* illustrates, when firm numbers vary there exists an additional degree of flexibility in relating movements in firm and aggregate output. This additional flexibility is manifested through a term defining the ratio of proportional changes in firm numbers to proportional changes in incumbent firm output. When this ratio is zero, the monopolistic conjecture is the unique consistent conjecture. This is *Proposition 1*. When it is not zero, there may exist a range of admissible conjectures that are consistent with particular values of this ratio. These values, however, must be contained along the negative unit interval. This is *Proposition 2*. Accordingly, we wish now to ascertain the existence of such values. In general, the result may depend upon which of the exogenous variables is being displaced. We therefore consider separately the effects of shifts in σ and τ. Both effects, however, yield the same outcome.

Proposition 3. Nonexistence: In the symmetric equilibrium with endogenous entry and firm output, no consistent conjecture exists.

Proof: Using the definition of the price flexibility $\varepsilon \equiv (\partial P(\cdot)/\partial X)(X/P)$, we expand the terms ψ_x and ψ_m by evaluating them at the equilibrium points $X = mX_j$ and $P(1+\theta\varepsilon) = C'(\cdot)$. We observe $\psi_x = (1-\theta)\psi_m \equiv (1-\theta)P\varepsilon X_j$. Imposing this dependence on the system in (8), we solve for the equilibrium movements $\tilde{X}_j(\theta)$ and $\tilde{m}(\theta)$, setting $\tilde{\sigma} = 0$ and $\tilde{\tau} = 0$, respectively. We compute $\tilde{m}(\theta) / \tilde{X}_j(\theta) = (\theta-1) + (\phi_x/\psi_m)\times(\psi_\sigma/\phi_\sigma)$ when demand shifts and derive that $\tilde{m}(\theta) / \tilde{X}_j(\theta) = (\theta-1) + (\phi_x/\psi_m)\times(\psi_\tau/\phi_\tau)$ when variable costs shift. From the *Proof* of *Proposition 2*, recall that consistent conjectural variations imply the condition: $\theta = 1 + \tilde{m}(\theta)/\tilde{X}_j(\theta)$. This equality is mutually inconsistent with the computed 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-valued. 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. *Q.E.D.*

4. Concluding comments

■ A criticism of conjectural variations is the model's inherent potential for generating inconsistency between predicted phenomena and observed outcomes. In contrast to Perry, this paper derives results under the assumption that firm output is endogenous. We consider the modes of firm conduct that are admissible in an equilibrium setting in which price and aggregate output are determined endogenously, and simultaneously with firm output. When the number of firms is held fixed, consistency imposes a severe restriction on the admissible mode of conduct. In particular, we observe that firms must behave monopolistically. Relaxing the restriction that firm numbers are fixed, we allow for entry and exit in accordance with the maintenance of zero profits. We consider consistent conjectures in this setting and show that these must co-exist with a business-stealing effect in which firm numbers and incumbent firm output move in opposite directions. We then show that this is mutually inconsistent with the equilibrium setting. Hence no conjecture exists that is capable of reconciling predicted responses with the comparative-static adjustments that occur in equilibrium.

These are clearly negative results. They appear to further undermine the concept of conjectural-variations, which has acquired some considerable disfavor in recent years. This is unfortunate. Conjectural variations provide a plausible generalization of the behavioral rule of our most familiar agent—the perfectly competitive firm. For this reason, the concept of conjectural variations has the potential to extend knowledge in a manner that is pedagogically appealing. Although we do not require competitive behavior to meet such stringent requirements, few would argue that it is unreasonable to do so in an oligopoly setting in which firms may have considerable freedom in choosing their behavioral mode. But when firms are identical, no such freedom exists. Relaxing this assumption one derives that there exists a multitude of consistent conjectures, each one defined on the open interval $\theta \in (X_j/X, 1]$.[10] The formal derivation of this result lies outside the scope of this paper. It is noteworthy however, for two reasons.

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[10] This result and some related ones are available from the author upon request.

First, it shows how the negative implications of the identical-firm model are undermined in a more general—albeit more realistic—equilibrium setting. Second, it provides a much needed link between purely qualitative analyses of oligopoly and the objectives of empirical industrial organization. In light of the negative findings presented above, future research should focus on relaxing this decidedly restrictive assumption.

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