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Trade associations as information exchange mechanisms

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This article examines the incentives of firms competing in an oligopolistic industry to share information about an unknown demand parameter when such sharing takes place on a quid pro quo *basis. The model predicts that if total cost functions are sufficiently convex, information sharing (such as through a trade association) is Pareto-preferred to a setting of private information and forms a Nash equilibrium. Expected consumer surplus also always increases when information is shared.*

1. Introduction

■ Trade associations often operate as mechanisms for exchanging or sharing information within a particular industry. Examples include the Semiconductor Industry Association, the Adhesives Manufacturers Association, the American Electronics Association, and the Forging Industry Association. The trade association periodically gathers and aggregates sales information from participating firms in the industry. The aggregate information is then disseminated. Some trade associations provide the aggregate to any firm willing to pay. Others limit distribution to those firms that actually participate in providing the information on which the aggregate is based. I shall refer to the latter arrangement as a *quid pro quo* form of information sharing.[1]

For several decades the motive for this exchange of information has been debated. The disagreement has focussed on whether the exchange of information makes the market more or less competitive. Much of this discussion occurred in the 1920s when the Justice Department filed antitrust suits against several trade associations.[2] In contrast to much of the theoretical work on the incentives of Cournot oligopolists to share information about market demand, this article shows that firms may be better off sharing information than keeping it private. Furthermore, I show that sharing information may constitute a Nash equilibrium and always improves expected consumer surplus. In so doing this article allows for a theo-

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[1] In a survey of 64 trade associations, 24 indicated that they operated an information-exchange program, of which eight provided the aggregate information to participants only. Kirby (1985) provides further results of this survey.

[2] *American Column and Lumber Co.* v. *United States,* 257, U.S. 377 (1921); *Maple Flooring Manufacturers' Association* v. *United States,* 268, U.S. 563 (1925); *United States* v. *Container Corp. of America,* 393, U.S. 333 (1969).

retical interpretation of trade associations as *bona fide* information-exchange mechanisms, and not necessarily as collusion-facilitation mechanisms. I demonstrate these results in a model that assumes a quadratic cost structure for all firms in the industry and a *quid pro quo* information-sharing arrangement.

Previous research into the incentives of oligopolists to share information may also be classified in terms of the type of information-sharing arrangement modelled. Novshek and Sonnenschein (1982), Vives (1984), Gal-Or (1985), and Li (1985) all examine a situation where firms independently select the amount of their private information to be shared, and yet all receive the resulting aggregate. By contrast, Clarke (1983) examines *quid pro quo* information-sharing arrangements. Nevertheless, when only the extreme cases of no-information and full-information sharing are compared, the results for the two types of sharing arrangement are identical. In particular, Novshek and Sonnenschein (1982), Clarke (1983), Gal-Or (1985), and Li (1985) have all shown that under Cournot competition, firms are never strictly better off sharing information. These articles also show that no-information sharing is the unique Nash equilibrium.

In examining the case of a symmetric duopoly Vives (1984), however, shows that the incentives to share information depend on the type of competition (Bertrand or Cournot), the nature of the goods (substitutes or complements), and the degree of product differentiation.[3] In particular, he shows that if the goods produced by the two firms are substitutes, pooling of information may increase expected profits under Cournot competition although it is not self-enforcing.

Section 2 presents the *quid pro quo* model of the trade association and the optimal output strategies pursued by firms in different information settings. Analytic results are derived in Section 3, and final comments appear in Section 4.

2. The model

■ Consider an oligopolistic industry of n firms with identical cost functions,

$$C(x_i) = cx_i + dx_i^2,$$

where both c and d are nonnegative and known and x_i is firm i's level of output.[4] We assume without loss of generality that c is zero. The cost function reflects decreasing returns to scale when $d > 0$ and constant returns to scale when $d = 0$.[5] The firms operate in a market in which price is assumed to be a linear function of quantity demanded:

$$P = a - b \sum_{i=1}^{n} x_i,\ b \geq 0,$$

where b is known by all firms and a is an unknown parameter. All firms have identical prior distributions on a, which are normal with mean μ and variance m.

Each firm has its own private information system, which provides an imperfect signal of the true value of the demand intercept. The observed signal, z_i, is assumed to be normally

[3] Gal-Or (1984) shows that incentives to share information are also a function of the source of uncertainty in the market (i.e., demand or technology-based).

[4] The cost function $C(x_i) = cx_i + dx_i^2$, with c and d nonnegative, has an upward sloping average cost curve, which (in a world of certainty) would produce an industry comprising infinitely many firms. Introducing a component of fixed cost creates a U-shaped average cost curve and consequently also an equilibrium in which a finite number of firms each has an incentive to produce. In the current model, with exogenous n, fixed costs would simply reduce the expected profit levels under the private- and shared-information scenarios without affecting the qualitative results.

[5] A negative value of d reflects a technology with increasing returns to scale. In equilibrium such an industry would be a monopoly. Since a monopoly can be viewed as the ultimate form of information sharing, in which all the exchange occurs within a single firm, negative values of d are not considered further.

distributed with expected value equal to the true value a and variance R_1 identical for all firms.[6] The measurement errors in the signals, V_i, $i = 1, \ldots, n$, are assumed to be independent across firms. The accuracy of each firm's information is exogenous to the model and is also common knowledge.

Given this description of an oligopolistic industry, consider the following model of a trade association. The association gathers the private signals of individual firms, aggregates the signals, and then disseminates the aggregate signal, denoted z, to each of the firms that participated by providing its private signal.[7] Hence, z is also distributed with mean a and has variance R_1/k, where k is the number of participating firms. Following Clarke (1983) and Shapiro (1984), I assume that firms reveal the true value of their private signals to the trade association.[8]

Events and actions are assumed to take place in the same sequence as described in Clarke (1983). First, firms decide whether they will join a trade association to share information. This decision is assumed to be binding. Next, nature selects a level of the demand intercept. Each firm then receives a noisy private signal, z_i, related to the true parameter. If firms have previously agreed to do so, they send their private information to the trade association in return for the aggregated signal, z. The aggregate is assumed to be sufficient for the whole vector of signals with respect to both the unknown intercept, a, and the other firms' private signals, z_j for all j.[9] On the basis of the signal it has received (either the private z_i or the shared z), each firm chooses a level of output, $x_i^p(z_i)$ or $x_i^s(z)$, to maximize its expected profit, under the assumption that all other firms are also optimizing their output choices and choosing optimal strategies $\hat{x}_j^p(z_j)$ or $\hat{x}_j^s(z)$. The superscripts p and s indicate private-information and shared-information scenarios, respectively. In other words, at this stage the firms play either the private- (incomplete-) information game or the shared-information game. Both are Cournot games in which firms choose the quantity of output to be produced.[10] An equilibrium price results, and finally each firm receives it payoff, π_i^s or π_i^p.

In the private-information game I assume that the firms already have agreed not to share their information. Each firm chooses output to maximize its expected profits conditional on a particular level of the private signal:

$$\max_{x_i} E_a^p[[a - b(x_i^p(z_i) + \sum_{j \neq i} \hat{x}_j^p(z_j))]x_i^p(z_i) - d[x_i^p(z_i)]^2 \,|\, z_i]. \tag{1}$$

Assuming symmetry among the strategies of the other firms in the industry, I derive the optimal output strategy for firm i, $\hat{x}_i^p(z_i)$, by solving the following first-order condition for all values of z_i:

$$E_a[a \,|\, z_i] - 2bx_i^p(z_i) - b(n-1)E(\hat{x}_j^p(z_j) \,|\, z_i) - 2dx_i^p(z_i) = 0. \tag{2}$$

[6] The normality assumption, although convenient for analytical purposes, results in the possibility of negative quantities and prices in equilibrium. Normality, however, is not necessary for the following results to hold. All that is necessary is an affine information structure in which the expectation of the posterior distribution is a linear function of the observed signal. Other pairs of distributions for the prior and sample information that also result in affine information structures are beta-negative binomial and gamma-Poisson.

[7] This model of a trade association's statistical program does not allow the trade association to hire a consultant or to undertake additional market research. Such behavior would further decrease the error variance in the aggregate signal and make the result of this model more robust. (See Kirby (1987).)

[8] As Shapiro (1986) points out, an alternative assumption, identical in its effect, is that firms can verify their competitors' reports at some finite cost. Alternatively, since we generally observe only aggregate information being made available for use by other firms, which is difficult to distort by any single firm, the incentives to misrepresent one's own signal might be mitigated sufficiently that truthful revelation is a reasonable assumption.

[9] For example, the aggregate could be the average of all the private signals.

[10] Although observations of reality suggest that firms choose capacity and prices, Kreps and Scheinkman (1983) show that at least for the case of full information the equilibrium resulting from such assumptions is identical to the one resulting from assuming a Cournot quantity-setting game.

Defining the accuracy of the private signal, G_1, as $m/(m + R_1)$ implies that the accuracy takes a value in the interval [0, 1] and is identical for all firms. Assumiung Bayesian updating, we can express the expected value of the posterior distribution of a as a function of the accuracy of the signal: $E_a[a \mid z_i] = G_1 z_i + (1 - G_1)\mu$.[11] In solving for optimal output strategies, I restrict attention to linear strategies. This is based on Lemma 1 of Vives (1986), in which he proves that strategies linear in the signal constitute the unique Nash equilibrium when objective functions are quadratic in the decision variable. Since the firms also are assumed identical, the linear strategies will form a symmetric equilibrium. One can easily show that the optimal output strategy for firm i under the private-information scenario is

$$x_i^p(z_i) = (A - BG_1)\mu + BG_1 z_i,$$

where $A = 1/[2(b + d) + b(n - 1)]$ and $B = 1/[2(b + d) + b(n - 1)G_1]$. The resulting expected profit is

$$E(\pi_i^p) = (b + d)[A^2\mu^2 + B^2 G_1 m]. \tag{3}$$

In the shared-information game each firm chooses its output strategy after having observed a signal, z, of accuracy G_n. By definition, $G_n = m/(m + R_1/n)$, which equals $nG_1/(1 + (n - 1)G_1)$. The identical signal z is observed and used by all the other firms in the industry when they make their output decisions. Each firm chooses output to maximize its expected profit conditional on the observed signal while assuming that all the other firms do the same. The objective of each firm is

$$\max_{x_i} E_a^s[[a - b(x_i^s(z) + \sum_{j \neq i} x_j^s(z))]x_i^s(z) - d[x_i^s(z)]^2 \mid z]. \tag{4}$$

The optimal output strategy is $x_i^s(z) = A(1 - G_n)\mu + AG_n z$, and the resulting expected profit for each firm is

$$E(\pi_i^s) = (b + d)[A^2\mu^2 + A^2 G_n m]. \tag{5}$$

3. Results

■ **Value of information sharing.** Each firm considers information sharing beneficial in the classical Pareto-dominance sense when $E(\pi_i^s) \geq E(\pi_i^p)$ for all i. This is equivalent to requiring that

$$(b + d)[A^2\mu^2 + A^2 G_n m] \geq (b + d)[A^2\mu^2 + B^2 G_1 m]. \tag{6}$$

One can show that this condition is equivalent to a condition on the variances of the two optimal output strategies. This is stated and proved in Proposition 1.

Proposition 1. The expected profit of an individual firm in the sharing regime exceeds the expected profit in the nonsharing regime if and only if the variance of the optimal output level based on shared information exceeds the variance of the optimal output level based on private information, var $(x_i^s(z)) \geq$ var $(x_i^p(z_i))$.

Proof. By assumption we have $z_i = a + v_i$, $E(av_i) = 0$, var $a = m$, and var $(v_i) = R_1$ for all $i = 1, \ldots, n$. Substituting these values into var $(x_i^p(z_i)) = (BG_1)^2$ var (z_i) yields var $(x_i^p(z_i)) = B^2 G_1 m$. Similarly, under information sharing the variance in the output strategy is given by var $(x_i^s(z)) = A^2 G_n m$. Hence, the inequality in (6) is equivalent to var $(x_i^s(z)) \geqq$ var $(x_i^p(z_i))$. *Q.E.D.*

One can also show that there exist parameter values for which this variance relation holds. Thus, contrary to Clarke's (1983) result, information sharing may be of value to all firms in an industry.

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[11] This is an application of DeGroot's (1970) theorem on conjugate distributions and would also hold for other pairs of distributions.

Proposition 2. The expected profit from sharing information exceeds the expected profit from not sharing information when the quadratic cost coefficient d is sufficiently large.

Proof. The expected benefit from information sharing is equal to

$$E(\pi_i^S) - E(\pi_i^P) = \frac{m(b + d)(n - 1)G_1(1 - G_1)[4d(b + d) - b^2(n - 1)(nG_1 + 1)]}{[1 + (n - 1)G_1][2(b + d) + b(n - 1)]^2[2(b + d) + b(n - 1)G_1]^2}, \quad (7)$$

which is positive when $4d(b + d) - b^2(n - 1)(nG_1 + 1) \geq 0$.[12] Since this is a nonnegative quadratic, this expression is positive outside its roots:

$$d_{ROOTS} = -\frac{b}{2} \pm \frac{b}{2}\sqrt{n[1 + (n - 1)G_1]}. \quad (8)$$

Since we restrict d to nonnegative values only, there are increases in expected profit from sharing information when $d \geq -.5b[1 - \sqrt{n[1 + (n - 1)G_1]}]$. *Q.E.D.*

The critical value of d will be referred to as d_{PO}: the value of d at which information sharing becomes Pareto optimal.

For the case of $n = 2$ Proposition 2 corroborates results in Vives (1984). Vives considers a model with two firms, each producing a differentiated good. The firm's profit function is of the form $\pi_i = (\alpha - \beta x_i - \gamma x_j)x_i$, where $\alpha > 0$ and net of constant marginal cost and $\beta \geq |\gamma| \geq 0$. When $\gamma \geq 0$ ($\gamma = \beta$), the goods are (perfect) substitutes. This is equivalent to the profit function in this article when $n = 2$, $\pi_i = (a - bx_i - bx_j)x_i - dx_i^2$, if we identify a with α, $b + d$ with β, and b with γ. This substitution makes Proposition 2 consistent with Proposition 5 in Vives (1984), which states that information sharing dominates no-information sharing when $\beta - \gamma$ is sufficiently large (i.e., d is sufficiently large). Similarly, our critical value of d, d_{PO}, can be reconciled with the condition in Vives' Proposition 5.[13] Thus, a firm's expected net profits are greater under information sharing if the products are sufficiently different, since the costs of information sharing in terms of potential losses in market share are less because the firms are no longer such direct competitors.

The intuition for the above results is straightforward. First, the variance result (Proposition 1) can be interpreted as saying that firms prefer information system Ω to information system Ω' if Ω leads the firm to take actions farther from the mean than does Ω'. In other words, information system Ω leads to actions that are more finely tuned to the variation in the environment. This is not counterintuitive. What is counterintuitive is that information system Ω is not necessarily the most informative system, in the Blackwell sense. In my model the shared signal is always more informative, but the setting in which all firms receive the shared signal is not always preferred since it does not always induce an output distribution of greater variance.

Proposition 2 states that the shared signal is preferred by all firms only when cost functions are sufficiently quadratic. Simply, the intuition is that as d increases, marginal cost also increases, and "errors" in production become very costly: hence, the increased value from sharing information.

The effect of information sharing may be divided into three components. These are a gain by firm i of an information advantage from increased signal accuracy, a loss of firm i's information advantage as all other firms attain the same accuracy, and the disappearance of signal variability across firms. By solving intermediate games, one can show

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[12] It is clear that this is negative when d is zero, that is when the industry is characterized by linear cost functions. Such is the situation described by Clarke (1983).

[13] Vives' variable $\mu = \gamma/\beta$ is inversely related to d. The condition that $d \geq d_{PO}$ can be rewritten in terms of Vives' variables as $\mu \leq 2/[1 + \sqrt{2(2 + VAR)/(1 + VAR)}]$, where $VAR = v/V(\alpha)$ (or R_1/m in our notation). Thus, when $VAR = 0$, $\mu \leq 2/3$, and for infinitely large VAR, $\mu \leq 2(\sqrt{2} - 1)$, which are cases (i) and (iii), respectively, in Vives' Proposition 5.

that the effects of these components on expected profit are positive, negative, and negative in sign for firm i for all values of the parameters b, d, G_1, μ, n.[14]

In the analysis so far, the number of firms has been exogenous and fixed costs nonexistent. Under the assumption, however, that there is free entry into the industry, the number of firms should be determined by the values of the other parameters including a fixed cost of production, F. Suppose that n_s and n_p are the (zero-expected-profit) equilibrium numbers of firms under the shared- and private-information regimes, respectively. Does restricting the number of firms to n_s and n_p and introducing the fixed cost annihilate the parameter region for which there was value to information sharing, or can trade associations acting as information-exchange mechanisms still potentially be explained in terms of competing firms' acting cooperatively with respect to information acquisition? To prove that the former is not the case, I use a counterexample and show that there exist values of the quadratic cost coefficient that support an industry (i.e., n_s, $n_p > 1$) and for which there is value to sharing (i.e., $n_s > n_p$).

Example. Let $b = m = F = 1$, $\mu^2 = 100$, and $G_1 = .7$. The critical value d_{PO} at which sharing becomes valuable is 5.2871. At this value of d, $n_s = n_p = 13.62115$. By contrast, when $d = 7$, n_s falls in the interval (13.42, 13.43) while n_p falls in the interval (13.41, 13.42), so that $n_s > n_p$ and n_p, $n_s > 1$. Similarly, when $d = 19$, n_s and n_p fall in the interval (5.92, 5.93) and (5.88, 5.89), respectively.

This example suffices to show that allowing the number of firms to be determined by free entry does not annihilate the possible value of sharing information. This value is reflected by the entry of additional firms into the industry. In the remainder of the article, I again assume that n is exogenous and there are no fixed costs.

□ **Nash-equilibrium analysis.** The results from the previous subsection show that there are conditions under which firms' sharing information on a *quid pro quo* basis is Pareto superior to their not sharing information. I now investigate whether either of these situations forms a Nash equilibrium in the game of information-system choice. For a set of information-regime choices to be a Nash equilibrium in this game, it is necessary that, given the information-system choices of its competitors, there is no incentive for any firm unilaterally to deviate from that original set of choices.

It is a Nash equilibrium for each firm to use only its private information, since each firm is indifferent between keeping its signal private and contributing its signal to a pool from which it is the only recipient. Sharing is also Nash behavior if firm i's expected profit is greater when it shares its information with all the other firms that are already sharing than when it alone chooses output based on its private signal. This comparison by firm i is made with the knowledge that all $(n - 1)$ other firms are sharing their information and that those $(n - 1)$ other firms know that firm i is acting purely on the basis of its private signal. The expected profit when all firms share their information has been calculated already (see equation (5)). The expected profit to firm i when all the other firms share their information emerges from the following optimization problem:

$$\max_{x_i} E_i^{i,(n-1)}[[a - b(x_i^p(z_i) + \sum_{j\neq i} \hat{x}_j^s(z_{n-1}))]x_i^p(z_i) - d[x_i^p(z_i)]^2 \mid z_i] \tag{9}$$

[14] This analysis into three components has been hinted at by others. In Clarke (1985) and Gal-Or (1984), the main breakdown is into two components, a single-firm information improvement (my first effect) and a multifirm effect (sum of second and third effects), while in Vives (1984) the two effects are the joint decrease in variance (my first two effects) and the increased correlation in strategies (my third effect). This breakdown into three components is described more fully in Kirby (1986), along with an alternative breakdown into the separate effects on expected revenue and cost of a change in information regime.

subject to

$$\hat{x}_j^s(z_{n-1}) = \arg\max_{x_j} E_a[[a - b(x_j^s(z_{n-1}) + \sum_{\substack{k\neq i\\ k\neq j}} \hat{x}_k^s(z) + \hat{x}_i^p(z_i))]x_j^s(z_{n-1}) - d[x_j^s(z_{n-1})]^2 \mid z_{n-1}], \quad (10)$$

where z_{n-1} is the aggregate signal when $(n - 1)$ firms share their private signals.

The expected profit to the deviating firm in the solution to this program is

$$E\pi_i^{i,(n-1)} = (b + d)[A^2\mu^2 + B_i^2 G_1 m], \quad (11)$$

where

$$B_i = \frac{2(b + d) - b[(n - 1)G_{n-1} - (n - 2)]}{4(b + d)^2 + 2b(b + d)(n - 2) - b^2(n - 1)G_1G_{n-1}}.$$

This expression is compared with the expected profit to each firm when all n firms share their information to prove the following proposition.

Proposition 3. If information sharing Pareto-dominates keeping information private, then information sharing also constitutes Nash-equilibrium behavior.

Proof. See the Appendix.

This result is in sharp contrast to those in the literature. Despite the similarity of the value of information-sharing results derived here to those of Vives (1984) for $n = 2$, Vives (1984) shows that no-information sharing is the dominant strategy when there are Cournot competition and substitute products. In his model, although information sharing would increase the firms' profits when the goods are not very good substitutes (i.e., d large), it is not self-enforcing. The apparent contradiction between his results and those presented here is resolved when it is recognized that the rules of the information-exchange mechanism differ in the two models.[15] Vives allows the aggregate signal to be available to all firms in the industry regardless of whether they choose to pool, while the current model introduces a cost for receiving aggregate information by assuming a *quid pro quo* information-sharing arrangement.

□ **Welfare analysis.** We now investigate the effect of producers' information sharing on consumers. With consumer surplus defined as the area under the demand curve up to the equilibrium level of industry output, net of the revenue paid by consumers to purchase that level of output, expected consumer surplus in the private-information setting is[16]

$$E_a(CS^p \mid z_1, z_2, \ldots, z_n) = E_a\left[\frac{bQ_p^2}{2}\right]. \quad (12)$$

Since $Q_p = \sum_{i=1}^{n} x_i^p(z_i)$, we have $Q_p^2 = \sum_i [x_i^p(z_i)]^2 + n(n-1) \sum_{\substack{j\neq i\\ j=1}}^{n} x_j^p(z_j)x_i^p(z_i)$. Substituting for the optimal strategies and evaluating the expectations yield

$$E_a(CS^p \mid z_1, z_2, \ldots, z_n) = \frac{b}{2} n^2[A^2\mu^2 + B^2G_1m] - \frac{n(n-1)}{2} bB^2G_1m(1 - G_1). \quad (13)$$

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[15] I am grateful to an anonymous referee for making this point.

[16] Expected consumer surplus is an appropriate welfare measure in a world of uncertainty if each consumer's marginal utility of income is constant with respect to the price in the given market and the source of variation in price lies solely in the supply curve (Rogerson, 1979). In other words, a problem arises when the overall utility function is different in different states of the world. In my setting the variation in price arises from both supply and demand variation, since the uncertainty is in the signal and in the unknown demand intercept. These both generate uncertainty in supply. If the uncertainty in a were due to variation in other prices, then it would be sufficient to assume in addition that the marginal utilities of income of all consumers are constant with respect to those prices.

Similarly, the expected consumer surplus under the setting of shared information is

$$E_a(CS^s \mid z) = \frac{n^2 b}{2}[A^2 G_n m + A^2 \mu^2]. \tag{14}$$

Equations (13) and (14) can be used to prove the following proposition.

Proposition 4. Expected consumer surplus always increases when firms share information.

Proof. The change in expected consumer surplus as the information regime changes from private to shared is

$$\Delta E(CS) = \frac{n^2 bm}{2G_n}[A^2 G_n^2 - B^2 G_1^2].$$

This is always positive since BG_1 (the slope of the private information optimal output strategy) is always less than AG_n (the slope of the shared optimal output strategy). *Q.E.D.*

Clarke's (1983) result that in his model expected consumer surplus increases with information sharing is a special case of Proposition 4. It is also straightforward to relate the latter to Vives' (1984) Proposition 7 in the $d = 0$ (perfect substitutes) case. When d is positive, however, although the profit functions in my model and Vives' are isomorphic, the consumer surplus functions are not because Vives' inverse demand function is affected by the product differentiation measure, d, while the demand function used here is not. Combining Proposition 4 with the results of the previous section makes it clear that both producers and consumers are better off if information is shared by firms through trade associations when d is sufficiently large. When d is small, however, the interests of the two groups conflict: consumers prefer that information be shared, and producers do not.

It is interesting to note that an increase in expected consumer surplus coincides with an increase in the variance of *aggregate* output, while an increase in expected producer surplus coincides with an increase in the variance of *individual* firm output. The latter is a sufficient but not a necessary condition for the former.

The results of this welfare analysis appear consistent with the empirical observation that often government agencies, rather than industry trade associations, produce industry statistics. This may be interpreted as the government's forcing some degree of information sharing for the benefit of consumers when producers are unwilling to do the sharing through a trade association.

4. Conclusion

■ In this article I have shown that trade associations operating as *quid pro quo* information-exchange mechanisms are an equilibrium phenomenon in oligopolistic industries in which individual firms make output choices noncooperatively, provided that the cost function of firms in the industry has a sufficiently large quadratic cost coefficient. Trade associations, therefore, are not *prima facie* evidence of collusion, except possibly when costs reflect only minimally decreasing returns to scale. Even then, although it is not Pareto optimal to share information, such sharing still may form a Nash equilibrium.

Whether these results conform with empirical evidence has not been tested. It is clear, however, that many trade associations do not operate information-exchange programs. Examples include the American Book Producers' Association, the American Concrete Institute, the National Peanut Council, and the Tobacco Institute.[17] These industries are more established and therefore may know their market parameters more exactly than do the more modern industries mentioned in the Introduction. Furthermore, these older industries may

[17] Inferring that companies in these industries do not exchange information is risky since some industries have several trade associations.

be less dependent on expensive high-technology capital investment and, consequently, have different cost structures, as predicted by this model.

Since firms acting collusively always benefit from sharing information about uncertain market demand, there still remains the question of empirically distinguishing between the cooperative and noncooperative scenarios. I have shown here that the existence of an information-exchange mechanism is not sufficient to make this distinction. The mean and variance of the optimal output level do vary, however, according to the scenario, and this difference might be used as the basis for a discriminating test.

Appendix

■ The proof of Proposition 5 follows.

Proof of Proposition 5. We find a critical value of d, d_{NASH}, such that for $d \geq d_{NASH}$, $E(\pi_i^s) \geq E(\pi_i^{i\&(n-1)})$, and show that $d_{NASH} \leq d_{PO}$ for all relevant parameter values. First, using equations (5) and (11), we have $E(\pi_i^s) \geqq E(\pi_i^{i,(n-1)})$ if and only if $A^2G_n \geq B_i^2G_1$. Since A, B_i, G_1, and G_n are all positive, we can take the square root of each side of this inequality and substitute for the parameters to obtain:

$$N[4(b+d)^2 + 2b(b+d)(n-2) - b^2(n-1)G_1G_{n-1}] \\ - [2(b+d) + b(n-1)][2(b+d) - b[(n-1)G_{n-1} - (n-2)]] \geq 0, \quad \text{(A1)}$$

where $N = \sqrt{n/[1+(n-1)G_1]}$. Rewriting equation (A1) as a quadratic in d enables us to solve for d_{NASH}, the value of d above which sharing is self-enforcing. This yields

$$d_{NASH} = -\frac{bK_1}{4(N-1)} + \frac{b}{4(N-1)}\sqrt{(K_1)^2 - K_2},$$

where $K_1 = [(n+2)(N-1) - (n-1)(1-G_{n-1})]$

and $K_2 = 4(N-1)[2n(N-1) - n(n-1) + (n-1)G_{n-1}[n+1-NG_1]]$.

Finally, it remains to be shown that $d_{PO} \geq d_{NASH}$ for all b, n, and G_1. Rewriting d_{PO} as a function of N, we have $d_{PO} \geqq d_{NASH}$ if and only if

$$-\frac{b}{2}\left[\frac{N-n}{N}\right] \geq -\frac{b}{4(N-1)}[K_1 - \sqrt{K_1^2 - K_2}].$$

Simplifying, we require that $nG_{n-1}(n-2)(1 - G_1(N-1) \geq 0$, which is true for all $n \geq 2$. *Q.E.D.*

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