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Trade association disclosure rules, incentives to share information, and welfare

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In this article I propose a monopolistic competition framework to analyze the effects of different disclosure rules used by trade associations on the incentives to share information and on the welfare of consumers, firms, and society. This framework is appropriate whenever a single firm cannot influence aggregate market magnitudes, and serves as a benchmark for the analysis of information-pooling agreements abstracting from strategic considerations. I report two main results. First, a policy of nonexclusionary disclosure destroys the incentives to share information, while exclusionary disclosure preserves them. Second, information sharing increases expected total surplus with Cournot competition but decreases it with Bertrand competition in the context of a Quadratic-Normal model with demand uncertainty.

1. Introduction

■ In this article I examine the effects of different disclosure rules used by trade associations on the incentives for firms to share information and on the overall level of welfare in a large industry.

The trade association (hereafter abbreviated TA) is one of the institutions in which information is collected, organized, and transmitted among firms. The statistical program of a TA typically has three steps: (1) collect individual company data, usually on production or demand; (2) compile the industrywide totals; and (3) distribute aggregate reports to member firms and others. Many industries in OECD countries have TAs that fulfill an information-sharing role. Examples of such industries in the United States are semiconductors, trucking, and cement.

Antitrust authorities have not taken a clear-cut position on agreements to exchange information. In the words of Scherer (1980): "The law on trade association price and cost reporting activities is one of the most subtle (and some add the most confused) branches of antitrust doctrine."

In general, U.S. courts have adopted a rule-of-reason approach in trying to assess the potential efficiency gains and losses brought about by information-pooling agreements. A

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series of cases (American Column, 1921; Linseed Oil, 1923; Maple Flooring, 1928; and First Cement, 1925) have established that the exchange of information is not illegal per se; the practice should be challenged only if it acts to restrict competition or to help reach agreements on prices. In Europe and Japan the approach has been similar (see OECD, (1978)). Antitrust authorities have been concerned mainly with the *collusive potential* and the *uniformity effect* on the market of information sharing.

In the United States the courts have looked with suspicion on the sharing of firm-specific data, which may be used to police cartel agreements and identify deviators (American Column and Linseed Oil). On the other hand, the sharing of aggregate, anonymous, and historical data did not raise objections, even though it may bring about a certain uniformity of action in the industry (Maple Flooring and First Cement). In the words of Justice Stone on the Maple Flooring case:

> Persons who unite in gathering and disseminating information . . . are not engaged in unlawful conspiracies in restraint of trade merely because the ultimate result of their efforts may be to stabilize prices or limit production through a better understanding of economic laws. . . . (Areeda, 1981).

If firms in an industry do not attempt to collude through the TA, information pooling has been viewed as beneficial. Attempts during the 1920s and 1930s to cartelize and use TAs to police the agreements ended up in the late 1930s and early 1940s with consent decrees accepted by the defendants, which established the rules that guide TA statistical programs. One such rule I have referred to already: the TA should not disclose individual firm data.

The issue of whether a TA should disclose its aggregate statistics to everyone in the industry (nonexclusionary disclosure) or only to participants (exclusionary disclosure) has not been as clearly defined. Some consent decrees have required aggregate information to be made available to everyone interested; but it also has been found not objectionable per se to withhold such reports from nonparticipants (see Lamb and Shields (1971)). In fact, some TAs only give reports to participants. In the hardwood manufacturers case (American Column) a firm's failure to report data would imply a denial of access to the TA statistics. In the Maple Flooring case, data on average cost was circulated to association members while data on sales and prices was published in trade journals (see Areeda (1981)).

Analysis of many issues raised by the operation of TAs is still lacking. Leaving aside the potential of information-pooling agreements for aiding collusion, several questions are open:

(1) How does information sharing affect the degree of competitiveness within the market?
(2) What types of "uniformity" does information sharing bring to the market? In particular, does it decrease the variability of market aggregates? Does it increase the covariance between firms' actions?
(3) Is it true that information sharing (given that firms do not collude) improves efficiency?
(4) Disclosure rules of TAs are a tool for regulators to control the effects of information-sharing agreements among firms. How does a particular disclosure rule affect the incentives to pool information?

In the literature on information sharing in oligopoly, these questions have no answer or, what may be worse from an applied perspective, have too many answers. This literature had an early start with Ponssard (1979) and was continued by Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984), and Gal-Or (1985), among others. The problem is that oligopolistic interaction seems to lead to case-by-case analysis. The answers to the above questions thus depend on such variables as the number of firms in the market, the type of uncertainty (common value or private value, demand or costs) faced by the firms, and the mode of competition (prices or quantities).

Examples of welfare analysis of information sharing in an oligopoly context are found in Vives (1984), Shapiro (1986), and Sakai and Yamato (1989). The results obtained by these authors, with some relevant exceptions, point to the desirability of information sharing under Cournot competition but not under Bertrand competition. Nevertheless, the essential policy issue implicit in question (4) is left unanswered: how to encourage or discourage information sharing to promote social welfare. The current literature, then, provides virtually no guidance[1] to the antitrust community.

The complex strategic interactions that characterize oligopoly seem to be responsible for this state of affairs. The key fact is that an individual firm's decision to join or not join an information-sharing agreement affects the market outcome, since in an oligopoly context firms are not insignificant and the actions of a single firm have an impact on the market outcome. Nevertheless, a small-numbers market is by no means the only situation in which an information-sharing issue arises. In many instances a reasonably large number of firms, which retain some market power, are involved in the pooling agreements. Some of the mentioned antitrust cases did involve relatively large numbers of firms.[2] Other typical large-market examples are associations of retailers or professionals like doctors or architects.

In this article I propose the *monopolistic competition paradigm*[3] as an appropriate framework to analyze these issues when the number of firms in the industry is large and get some, reasonably general, answers. I shall consider an industry with a large number of firms where there is no scope for collusion but in which firms nevertheless retain some market power: the Chamberlinian "large group."

The large-market framework to analyze the transmission of information among agents in an economy has been set forth in Vives (1989). Information agencies (TAs, for example) have been viewed as optimal mechanisms for sharing information, and the incentive compatibility of information-sharing agreements has been established under certain conditions. In this article I shall address a particular aspect of information-sharing agreements: the effect of the different disclosure rules used by TAs on the individual rationality of participation in the TA and on the resulting level of welfare. In this way I hope to show which disclosure rules are optimal from a social point of view, depending on the characteristics of the market.

Consider the large group Chamberlinian competition: many firms that are negligible (in the sense that the actions of any individual firm do not affect the payoffs of the others), but produce a differentiated commodity, still face a demand curve with finite elasticity. In this situation there is no strategic interaction, since firms are negligible, but information sharing matters nevertheless if firms have private information.

I envision the process of competition in the following way: first, firms decide whether to enter the market; second, they decide whether to share information or not; and third, they compete in the marketplace. For the most part I concentrate on the last two stages with a given mass of firms in the market. I formulate a general monopolistically competitive model with incomplete information, in which firms are anonymous and symmetric. The

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[1] Nevertheless, some economists do venture into giving tentative advice. For example, Scherer (1980) concludes his discussion of TA activities by pointing out that competition would be enhanced if "the courts were to take a uniformly dim view of price reporting schemes that identify the buyers and or sellers in individual transactions, have elaborate auditing provisions or impose penalties for failure to report transactions."

[2] For example, the American Hardwood Manufacturers Association (American Column case) had 400 members, 365 of which adhered to the Open Competition Plan. These firms represented only 5% of total producers and one-third of the U.S. output. The Maple Flooring case involved 22 firms located in the northern part of the Midwest and represented 70% of the market. The Tag Manufacturers Institute case (1947) involved 31 firms that represented 95% of the market. The Container Corporation case (1969) had a more oligopolistic structure; the 18 firms involved in the TA had 90% of the market.

[3] This paradigm, with a continuum of firms, can be seen both as a reasonable approximation in industries with many firms and as a benchmark of analysis that abstracts from strategic interactions.

payoff to a firm depends on its own action, the distribution of the other firms' actions, and a random firm-specific parameter. Actions could be, for example, prices, quantities, or levels of advertising. The information structure is quite general and allows for common-value or private-value type uncertainty. Firm i receives a private noisy signal about its uncertain parameter and there may be constant correlation across firms' parameters. *Ex ante,* though, all firms are identical. With this information, a firm is negligible both strategically and informationally.

As I have said, information-sharing agreements usually take the institutional form of a TA. These associations conduct statistical programs in which individual firm data are collected, aggregated, and disseminated, either to just the members of the TA (exclusionary disclosure) or to all the firms in the industry and other interested parties (nonexclusionary disclosure). I examine the incentives that firms have to share information when the TA follows either a nonexclusionary or an exclusionary disclosure rule, and obtain robust results that do not depend on particular specifications of the payoff or information structure.

The basic ideas are very simple. With a nonexclusionary disclosure rule, information sharing is not a self-enforcing agreement because of the free rider problem: if a firm defects from the agreement it will not affect the market outcome because the firm is negligible and will keep receiving the aggregate market information, saving the fee of the TA. With an exclusionary disclosure rule, information sharing will always be a self-enforcing agreement, provided the TA fee is not too high. Given that all firms share information, if a firm defects it will not affect the market aggregates but will not get the distribution of signals reported by the TA; it will have to estimate the distribution of actions in the market with only its private information. Consequently, the defector firm will make less in expected-profits terms, provided the saved TA fee is not very high.

To analyze the effects of information sharing on the level of welfare of consumers and firms, I specify a model with quadratic payoffs and a Normal information structure. This way I can explicitly compute the equilibria and answer the welfare questions posed above in a demand-uncertainty context. The basic result is that in terms of expected total surplus, it is good to share information under Cournot competition but bad under Bertrand competition.

The article is organized as follows. Section 2 reviews briefly the literature on information sharing in oligopoly. Section 3 puts forth a general monopolistic competition model with private information. Section 4 deals with the effects of disclosure rules on the incentives to share information. Section 5 develops the welfare analysis. Section 6 contains concluding remarks.

2. Information sharing in oligopoly: what have we learned?

■ What are the general principles that explain the incentives to share information among oligopolists? Very few, if any, according to the by-now long literature on information transmission in oligopoly.

Typically, the following two-stage game between the firms is considered. In the first stage, and before receiving any private information, a firm commits to share/reveal information or to keep it private. After the firms have received their private signals and reports have been sent (truthfully, it is assumed), the information agency makes public the information to the participants in the agreement (exclusionary disclosure) or to everyone in the industry (nonexclusionary disclosure). Competition in the marketplace follows. Several variations on this basic structure have been studied, depending on whether individual data is disclosed by the outside agency and whether this agency collects information on behalf of the firms. In any case, at the second stage a Bayesian game of incomplete information is played.

The literature has used almost exclusively a Quadratic-Normal specification to be able to obtain closed-form solutions for expected profits and make the appropriate comparisons to elicit the firms' incentives to pool information. The results obtained have been shown to be very sensitive to the particular specifications of the model. A change of strategic variables (prices instead of quantities), or of the source of uncertainty (demand instead of cost), or of the type of uncertainty (common value versus private value), yields completely different outcomes.

An example of the first case is provided by comparing Cournot and Bertrand competition with substitute goods in a common-value model of demand uncertainty (Vives, 1984). It can be shown that with nonexclusionary disclosure, sharing information is the unique equilibrium with Bertrand competition and not sharing is the unique equilibrium with Cournot competition. But if we consider a private-value model of cost uncertainty, the results are reversed (Gal-Or, 1986).

An illustration of the second case is given by comparing demand and cost uncertainties in a Bertrand model of substitute goods with a private-value information structure. With demand uncertainty, the tendency is to share information (Sakai, 1986); with cost uncertainty, the tendency is not to share (Gal-Or, 1986).

With respect to the third case, consider the classical Cournot competition homogeneous product model with uncertainty about the constant marginal costs. If the information structure is of the common-value type, the results of Clarke (1983), Vives (1984), Gal-Or (1985), and Li (1985) suggest that no information sharing is the unique equilibrium. But if the information structure is of the private-value type, the results of Fried (1984), Shapiro (1986), and Li (1985) suggest exactly the opposite conclusion. Even in one of the simplest possible worlds, Cournot competition in a homogeneous product market with constant marginal costs and common-value demand uncertainty, seemingly minor modifications of the information structure may provide different incentives to share information, as shown by Nalebuff and Zeckhauser (1986).

In summary, with nonexclusionary disclosure, information sharing arises as an equilibrium with private-value uncertainty, except under Bertrand competition with random costs (Sakai, 1986; Gal-Or, 1986; Li, 1985; and Shapiro, 1986), and with common-value demand uncertainty under Bertrand competition (Vives, 1984; Clarke, 1983 and 1985; Gal-Or, 1985; and Li, 1985). Some of the equilibria are in dominant strategies. With exclusionary disclosure there may be multiple equilibria. This is easily illustrated in a duopoly context: to share information is then an equilibrium if and only if the profits from sharing are larger than those of not sharing. Not sharing is always trivially an equilibrium since if one firm does want to share the rival firm can do nothing about it (Kirby, 1988).

The basic forces that drive the incentives for a firm to share information are the increased precision of information, decomposed in the effect on the firm and on its rivals, and the correlation induced in the strategies of firms. In general, the increased precision of the information for a firm has a positive effect on its expected profits, while the increased precision of the rivals and the increased strategy correlation have a different impact, depending on the nature of competition and uncertainty. With common-value uncertainty, the crucial aspect of the nature of competition is whether the actions of the firms are strategic substitutes or complements, that is, whether reaction curves slope down or up. In the latter case, all effects of information sharing go in the positive direction with demand uncertainty (Vives, 1984). With private-value uncertainty, the slope of reaction curves is not necessarily crucial; with independent values and cost uncertainty, sharing information emerges as an equilibrium with Cournot competition and not sharing with Bertrand competition—whatever the slope of reaction curves. (With complementary products those slopes are reversed from the case, under consideration up to now, of substitute products.) (Gal-Or, 1986)

Apart from the Quadratic-Normal specification, a second aspect of the literature also restricts its applicability: it is assumed that firms will truthfully reveal their private information, even though it is clear that there are many situations in which they have an incentive to lie—for example, pretending that demand is low in a Cournot competition context so as to induce rivals to produce a low level of output. Obviously the incentive to lie exists because the firm is not insignificant and its action will change the performance of the market. Progress on this front has been made assuming that information is verifiable. Research started by Grossman (1981) and Milgrom (1981), and continued in Milgrom and Roberts (1986), assumes that agents may withhold information but they may not lie (because information is verifiable). A player reports a subset of the possible types that must include its true type. Okuno, Postlewaite, and Suzumura (1986) use this approach to provide sufficient conditions for complete revelation of private information to obtain. Crawford and Sobel (1982) provide a careful analysis of information transmission in a strategic context without imposing truth-telling.

Welfare results developed in the literature will be dealt with in Section 5.

3. Monopolistic competition with private information

■ We consider a monopolistic competition model à la Chamberlin with a large (fixed) number of firms: each firm produces a differentiated commodity, is negligible in the sense that its actions alone do not influence the profits of any other firm, and still has some monopoly power, facing a demand curve with finite elasticity.[4]

In this article I shall restrict attention to a class of such models in which there is a continuum of symmetric anonymous firms indexed by $i \in (0, 1)$ and where the profit function of firm i depends only on its own action y_i and on the distribution of the firms' actions, $Y \equiv \{y_j : j \in [0, 1]\}$. The action of an individual firm does not affect the payoff of the other firms, since with a continuum of firms it does not affect the distribution of firms' actions. In many situations the distribution of actions affects payoffs only through some aggregate statistic $\tilde{y}$ that typically will be an average, weighted average or other moment of the action distribution of firms. For example, $\tilde{y}$ may have an additive form: $\tilde{y} = \int g(y_j) d_j$ with $g(\cdot)$ being a real-valued (measurable) function defined on the strategy space of a firm. In a monopolistically competitive industry, only aggregate statistics of firms' actions should be relevant for strategic purposes when consumers use search strategies based only on a few moments of the distribution of actions of firms.

With no uncertainty, the market equilibrium of our monopolistically competitive industry does not depend on whether firms use quantities or prices as strategies. This is so since no firm can influence market aggregates, and thus the perceived elasticity of demand for any firm is the same in both situations. A firm takes the action distribution of firms as given and behaves as a monopoly on the residual demand, then the firm is indifferent between using price or quantity as strategy.[5]

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[4] The literature contains several models with the above features (usually considering free entry). Among them: Spence (1976), Dixit and Stiglitz (1977), Kumar and Satterthwaite (1985), Hart (1986), and Pascoa (1986).

[5] More formally, suppose that inverse demand for firm i is given by

$$p_i = F(x_i, X)$$

where X is the distribution of firms' quantities, x_i the individual output, and p_i the price set by the firm.

The direct demand of the firm is given by

$$x_i = D(p_i, P)$$

where P is the distribution of prices. Costs for a firm are given by the function $C(\cdot)$. Now, it is immediate that the price elasticity of demand for a firm, $\eta_i \equiv \dfrac{p_i}{x_i}\dfrac{\partial D}{\partial p_i}$, equals the inverse of the quantity elasticity of inverse demand, Up to now I have described a standard monopolistic competition model. To that model I want to introduce uncertainty and incomplete information. Let us denote the profit function of firm i by

$$\pi(y_i, Y; \theta_i)$$

where y_i is the action of the firm, Y the distribution of the firms' actions, and θ_i a parameter drawn from a prior distribution with finite variance.

Firm i receives a private signal s_i about θ_i of the type $s_i = \theta_i + u_i$ where u_i is a noise term, with zero mean and variance v, that is uncorrelated with θ_i and with the noise terms of other firms u_j, $j \neq i$. Furthermore, the parameters of different firms may be correlated with a correlation coefficient ρ for any pair (θ_i, θ_j), $j \neq i$. We thus have a symmetric information structure. *Ex ante,* before uncertainty is realized, all firms face the same prospects. Firm i is also informationally negligible: a signal of an individual firm cannot affect the distribution of the firms' signals, $S \equiv \{s_i : i \in [0, 1]\}$.

Our information structure is general enough to have as particular cases the "common-value" model (where all the firms receive a common shock)—that is, when $\rho = 1$—and the "private-value" model (where shocks are firm-specific but firm i makes no measurement error when estimating θ_i)—that is, when v, the variance of the error term of the signal, is zero. In the latter case, if $\rho = 0$ we are in the "independent-values" model. Let us make the convention[6] that the Strong Law of Large Numbers (SLLN) holds in our continuum context. That is, the average of a continuum of uncorrelated random variables ϵ_i with a common finite mean equals, almost surely, $E\epsilon_i$.

A strategy for firm i in this context is a measurable function $y_i(\cdot)$ from the signal space to the action space of the firm, and the appropriate equilibrium concept is the Bayesian monopolistically competitive equilibrium. A set of strategies $\{y_i(\cdot) : j \in [0, 1]\}$ form a Bayesian equilibrium if for any firm

$$y_i(s_i) \in \underset{z_i}{\operatorname{argmax}}\ E(\pi(z_i, Y; \theta_i) | s_i)$$

for almost all signals s_i where Y is the (random) action distribution induced by the equilibrium strategies. Similarly, when firms share information, the strategy for firm i is contingent on its private signal, s_i, and the distribution of signals in the market, S. A set of strategies $\{y_j(\cdot, \cdot) : j \in [0, 1]\}$ form a Bayesian equilibrium if for any firm

$$y_i(s_i, S) \in \underset{z_i}{\operatorname{argmax}}\ E(\pi(z_i, Y; \theta_i) | s_i, S)$$

for almost all (s_i, S) and where $Y(S)$ is the equilibrium action distribution induced by the equilibrium strategies (which is predictable, knowing the distribution of signals in the market S).

We will assume that in either the private-information or shared-information cases, for any set of strategies of the firms there is a unique solution to the above maximization programs. That is, there is a unique best response for firm i. It is clear then that all equilibria

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$\epsilon_i \equiv \dfrac{x_j}{p_j} \dfrac{\partial F}{\partial x_j}$ since $\dfrac{\partial F}{\partial x_j} \dfrac{\partial D}{\partial p_j} = 1$ (from the fact that the individual action of a firm cannot affect market aggregates and differentiating the identity $p_i = F(D(p_i, P), X)$). As usual, the first-order condition for a symmetric Nash (in prices or quantities) equilibrium will yield

$$\frac{p_i - MC_i}{p_i} = \frac{1}{\eta_i} (= -\epsilon_i)$$

where MC_i is the marginal cost of the firm.

[6] See Vives (1988) for a justification of the continuum approach in terms of replica economies.

must be symmetric since all firms face the same optimization problem at all candidate equilibria.[7]

It is worth noting that in the presence of uncertainty it *does* matter whether firms use prices or quantities as strategies. This should be clear since under uncertainty, even though firms still act as monopolists on their residual demand, a firm is not indifferent, in general, between setting prices or quantities.[8]

Our specification encompasses both demand and cost uncertainty. With demand uncertainty we could have inverse demands given by $p_i = F(x_i, X; \alpha_i)$ or direct demands given by $x_i = D(p_i, P; \beta_i)$. With cost uncertainty the cost function could be given by $C(x_i; m_i)$. α_i, β_i and m_i would be, in each case, the random parameter. Payoffs would be given as usual by revenues, $p_i x_i$, minus costs, C. To illustrate the model let us consider a Quadratic-Normal example.

□ **Quadratic-Normal model.** Suppose payoffs are quadratic and the joint distribution of signals and random parameters is Normal.[9] The profit function of firm i will be given by

$$\pi(y_i, \tilde{y}; \theta_i) = \theta_i y_i - \omega_1 y_i^2 - \omega_2 \tilde{y} y_i$$

where ω_1 is a positive parameter to insure concavity of π with respect to y_i, $\omega_1 + \omega_2 = 1$ and $\tilde{y} = \int y_j d_j$.

The information structure satisfies the assumptions of the general model plus joint Normality. Firm i receives a signal $s_i = \theta_i + u_i$ where

$$\text{cov}\,(\theta_i, u_j) = \text{cov}\,(u_i, u_j) = \text{cov}\,(\theta_i, u_i) = 0$$

for all i and $j, j \neq i$. The parameter θ_i is (Normally) distributed with mean μ and variance σ^2 and $\text{cov}\,(\theta_i, \theta_j) = \rho\sigma^2, j \neq i$, with $\rho \in [0, 1]$. The parameter u_i is (Normally) distributed with mean 0 and variance v. With these distributional assumptions, conditional expectations are affine and easily computed:

$$E(\theta_i | s_i) = \mu + t(s_i - \mu) \qquad \text{and} \qquad E(s_j | s_i) = E(\theta_j | s_i) = \mu + \rho t(s_i - \mu)$$

where $t = \sigma^2/(\sigma^2 + v)$. When signals are perfect, $v = 0$, $t = 1$ and $E(\theta_i | s_i) = s_i$ and $E(\theta_j | s_i) = \mu + \rho(s_i - \mu)$. When they are not informative, $v = \infty$, $t = 0$ and $E(\theta_i | s_i) = E(\theta_j | s_i) = \mu$. We can also derive the relationship of θ_i, s_i and the average parameter $\tilde{\theta} = \int \theta_j d_j$. The vector $(\theta_i, \tilde{\theta}, s_i)$ will be Normally distributed with means $E\theta_i = E\tilde{\theta} = Es_i = \mu$ and variance-convariance matrix

$$\sigma^2 \begin{pmatrix} l & \rho & l \\ \rho & \rho & \rho \\ l & \rho & t^{-1} \end{pmatrix}.$$

It is obvious then that $E(\theta_i | \tilde{\theta}) = \tilde{\theta}$, $E(\tilde{\theta} | \theta_i) = E(\theta_j | \theta_i)$, $E(\tilde{\theta} | s_i) = E(\theta_j | s_i)$ and $E(\theta_i | \tilde{\theta}, s_i) = (1 - d)\tilde{\theta} + ds_i$ where $d = [\sigma^2(1 - \rho)]/[\sigma^2(1 - \rho) + v]$. If signals are perfect, $v = 0$, then $d = 1$ and $E(\theta_i | \tilde{\theta}, s_i) = s_i$. If signals are useless, $v = \infty$, or correlation perfect, $\rho = 1$, then $d = 0$ and $E(\theta_i | \tilde{\theta}, s_i) = \tilde{\theta}$. If both $v = 0$ and $\rho = 1$ then $E(\theta_i | \tilde{\theta}, s_i) = \tilde{\theta} = s_i$ a.s.

If firms share information then the TA needs only to announce the average signal $\tilde{s}$, since given our information structure $(s_i, \tilde{s})$ is sufficient in the estimation of θ_i by firm i

[7] We do not investigate existence issues here; we will just assume the existence of Bayesian equilibria for any information structure that satisfies our conditions. (See Mas-Colell (1984) for existence results in this context.)

[8] See Leland (1972) and Klemperer and Meyer (1986).

[9] Other distributional assumptions fit the model too, since for our purposes the key property of the Normal distribution is the linearity of conditional expectations. There is a class of pairs of priors and likelihoods that satisfy this property (Beta-Bernoulli and Gamma-Poisson, among others).

and with $\tilde{s}$ the firm can predict with certainty the aggregate action $\tilde{y}$. Observe that $\tilde{s} = \tilde{\theta}$ a.s. since $\tilde{s} = \int \theta_i di + \int u_i di$ and $\int u_i di = Eu_i = 0$ according to our convention about the SLLN, since the error terms u_i are uncorrelated and have mean zero.[10]

In the Quadratic-Normal model it is very easy to characterize the unique Bayesian equilibrium with affine strategies in either the private- or shared-information cases. Lemma 1 summarizes the results.

Lemma 1. In the Quadratic-Normal model there is a unique Bayesian equilibrium in affine strategies in both the private- and shared-information cases. The equilibrium strategy of firm i in the private-information case is given by $y(s_i) = a(s_i - \mu) + b\mu$ where $a = t/(2\omega_1 + \omega_2 \rho t)$ and $b = 1/(2\omega_1 + \omega_2)$ and in the shared information case by $z(s_i, \tilde{\theta}) = \hat{a}(s_i - \tilde{\theta}) + b\tilde{\theta}$ where $\hat{a} = d/2\omega_1$.

Proof. See Appendix.

Remark 1. Our quadratic model has a *certainty-equivalence property:* the expected value of output, with either pooling or not-pooling of information, equals $b\mu$, which is the output that firms would choose if they did not have any information. Otherwise the equilibria are different except if $a = \hat{a}$ and $\tilde{\theta} = \mu$ a.s. or if $b = a = \hat{a}$. The first case obtains if there is no correlation between signals, $\rho = 0$. The second obtains if $2\omega_1(1 - t) = \omega_2 t(1 - \rho)$. This latter equality obviously holds in the perfect information case, $\rho = t = 1$. It cannot hold if $\omega_2 < 0$, or, for ω_1 and ω_2 different from zero, in the common-value case ($\rho = 1, t \in (0, 1)$) or in the private-value case ($t = 1, \rho \in (0, 1)$).

Remark 2. Lemma 1 already gives us the possibility of checking the effect of information sharing on *market uniformity.* A natural index of aggregate variability in our model is the variance of the average action $\tilde{y} = a(\tilde{\theta} - \mu) + b\mu$ in the private-information case and $\tilde{z} = b\tilde{\theta}$ in the shared-information case. We have to compare var $\tilde{y} = a^2$ var $\tilde{\theta}$ with var $\tilde{z} = b^2$ var $\tilde{\theta}$. var $\tilde{y} >$ var $\tilde{z}$ if and only if $a > b$, that is, if $\omega_2 t(1 - \rho) > 2(1 - t)\omega_1$. Since by assumption $\omega_1 > 0$, this can never hold if $\rho = 1$ (common-value case) or if $\omega_2 < 0$. The inequality holds, for example, if $t = 1$ (private-value case) and $\omega_2 > 0$. Thus we see that information sharing may or may not increase market uniformity when interpreted in terms of aggregate variability. It certainly will not in the common-value case or if $\omega_2 < 0$. In those two cases, information pooling makes firms respond to the signals received so much that their actions increase the average variability of the market. If we take as a criterion for increases in market uniformity increases in covariance between individual and market actions, cov $(y_i, \tilde{y})$, or between individual agents' actions, cov (y_i, y_j), the conclusions are reversed. In our model, cov (y_i, y_j) = cov $(y_i, \tilde{y})$ = var $(\tilde{y})$ and cov (z_i, z_j) = cov $(z_i, \tilde{z})$ = var $(\tilde{z})$. When uniformity increases according to the variability criterion, it decreases according to the covariance criterion.

☐ **Bertrand and Cournot competition.** The quadratic model fits a situation with linear demands and constant unit costs. Consider the following system of (random) demands:

$$p_i = \alpha_i - (1 - \delta)x_i - \delta\tilde{x} \qquad \text{with} \qquad \delta \in [0, 1] \qquad \text{and}$$
$$x_i = \beta_i - (1 + \gamma)p_i + \gamma\tilde{p} \qquad \text{with} \qquad \gamma \geqq 0, \tag{1}$$

where (p_i, x_i) is the price-output pair of firms, and tildes denote averages. We can obtain the second equation by inverting the first and letting $\beta_i = (\alpha_i - \delta\tilde{\alpha})/(1 - \delta)$ and

[10] $\int u_i di = 0$ even if the error terms have infinite variance ($v = \infty$) using the continuum analog of Kolgomorov's SLLN.

$\gamma = \delta/(1-\delta)$. Notice that when $\delta = 0$ the firms are isolated monopolies and that when $\delta = 1$ they are perfect competitors since the product is homogeneous. Thus the parameter δ represents the degree of product differentiation.

Assuming that marginal costs are constant, and equal to zero without loss of generality, Lemma 1 immediately gives us the Cournot and Bertrand monopolistically competitive equilibria of our game. In the quantity-competition (Cournot) case $\theta_i = \alpha_i$, $\omega_1 = 1 - \delta$ and $\omega_2 = \delta$, and in the price-competition (Bertrand) case $\theta_i = \beta_i$, $\omega_1 = 1 + \gamma$ and $\omega_2 = -\gamma$.

4. Disclosure rules and the incentives to share information

■ What incentives will the firm have to enter an information-sharing agreement? Institutionally, information-sharing agreements usually take the form of trade associations. At a first stage a firm has to decide whether or not to join the TA, that is, whether or not to reveal its private signal. Then the TA discloses the distribution or an aggregate statistic of the private signals. If the TA follows a nonexclusionary disclosure rule, the information is made available to everyone in the market, not just the participant firms; if the TA follows an exclusionary disclosure rule, it discloses the information only to its members.

In our monopolistic competition context, a firm does not need individual, nonanonymous data about its rivals (that is, firm i does not need to know that firm j has received signal s_j) to determine the action distribution in the market, provided it knows its rivals' strategies. The firm only needs the anonymous distribution of signals S. Individual data is not relevant in a situation where only the distribution of actions is payoff-relevant and firms have the same strategy spaces, that is, in a situation where firms are anonymous. When the distribution of actions affects the payoff of a firm only through an aggregate statistic $\tilde{y}$, then it is typically the case that disclosure of a statistic of firms' signals, say $\tilde{s}$, is sufficient to predict the aggregate action $\tilde{y}$ of the market. Once the TA has disclosed the distribution of the signals S or the statistic $\tilde{s}$, firms compete in the marketplace and a Bayesian-Nash equilibrium results. As I said at the beginning, in this article I do not deal with the problem of truthful revelation. The incentive compatibility of information agreements in large markets has been established in Vives (1989).

The incentives to share information will depend on which disclosure rule the TA uses. With the nonexclusionary disclosure rule, the information-sharing agreement is not stable if joining the TA is costly. This should come as no surprise, since by not joining the TA a firm can get the market information at no cost; and this does not affect any market aggregate, since the firm is negligible. I make here the natural assumption, in our context with a continuum of firms, that if one firm deviates, the others stick to the agreement. With anonymous firms it should be clear that no information sharing is possible if nonparticipants in a costly sharing agreement cannot be excluded from the pooled information. Everyone wants a free ride.

The oligopoly case is different. Leaving aside the problem of truthful revelation (maybe because information is verifiable and firms caught lying are assessed large penalties), there are circumstances under which a firm would join a costly information-sharing agreement with the nonexclusionary disclosure rule. This is so because a firm, by revealing its private information, affects the market outcome in a small-numbers situation, which could be to its advantage. For example, as we have seen before, in a common-value demand-uncertainty context with Bertrand competition in a substitutes product (differentiated) market, firms have a strong incentive to reveal their private information since this correlates their strategies and enhances expected profitability.

Suppose there are three firms in the market and one of them is thinking about deviating from the information-sharing agreement. If it deviates it will save the membership cost of the TA and will still get information about the other firms' signals. But by not revealing its information to the other firms (let us assume for simplicity that the transmission of information can only be done through the TA), it will affect the market outcome and reduce its profits. If the profit reduction is larger than the saved membership fee the firm will stick to the information-sharing agreement. Proposition 1 states the result obtained in the monopolistic competition case, followed by a more formal proof.

Proposition 1. When the trade association follows a nonexclusionary disclosure rule, no costly information-sharing agreement is stable (self-enforcing).

Proof. Suppose firms were to agree to share information; then the TA would disclose the distribution S of the private signals of the firms. In equilibrium, S is sufficient to predict with certainty the action distribution Y of the market. Firm i would solve

$$\max_{z_i} E\{\pi(z_i, Y, \theta_i)|s_i, S\}$$

where Y is known in equilibrium since it depends only on S. The strategy of a firm now depends on (s_i, S). At a symmetric equilibrium $y(s_i, S)$, the action distribution $Y(S) = \{y(s_i, S) : i \in [0, 1]\}$ is completely determined by S. Now, if firm i were to deviate from the agreement it would still observe the distribution S, the action distribution Y would be the same as before since any firm is negligible, and the firm would not have to pay the fee of the TA. Consequently, it pays to deviate since it increases expected profits. *Q.E.D.*

Remark 3. A possible way out of the "free rider" problem is for the TA to charge a fee to nonparticipants in exchange for the information. The fee should equate the costs of participating with those of staying out but receiving the information. This method cannot be used, however, when information has to be made public, in a trade journal for example.

With the exclusionary disclosure rule, information sharing can be a stable arrangement. If everyone shares information it does not pay to deviate, as long as the membership fee is not too high—since by deviating, nothing in the market changes except that the deviator does not receive the distribution S and therefore is less able to predict the action distribution Y of the market. The firm has to predict Y and θ_i with only its private signal s_i, and therefore makes less profit than when it receives (s_i, S) (recall that S predicts Y perfectly).

Again, the situation is very different in an oligopolistic context where the strategic interactions of firms are important. Suppose, for concreteness, that we have an oligopoly with common-value uncertainty. A firm, when considering whether to deviate from an information-sharing agreement, has to take into account that its deviation will change the actions of the other firms in the marketplace, and therefore it must evaluate its profitability at the new equilibrium. Certainly the deviator will be less able to predict the actions of the other firms and the payoff-relevant parameter, but the strategy of the firm will be less correlated with the strategies of the rivals and this may be to its benefit. In fact, this is likely to be the case with Cournot competition if the products are good substitutes (see Vives (1984)). Proposition 2 states the result with monopolistic competition.

Proposition 2. When the trade association follows an exclusionary disclosure rule, an information-sharing agreement is stable (self-enforcing) provided the cost of participating is not too high.

Proof. Suppose all firms participate in the TA and that firm i is contemplating deviation from the agreement. If the firm stays in the TA it solves the program

$$\max_{z_i} E\{\pi(z_i, Y(S); \theta_i)|s_i, S\}$$

where $Y(S)$ is the equilibrium action distribution of the market given that the TA has announced S. If the firm defects it solves

$$\max_{z_i} E\{\pi(z_i, Y(S); \theta_i) | s_i\}.$$

The first program cannot yield lower expected profits than the second since the signal (s_i, S) is more informative than s_i. That is, s_i can be obtained from (s_i, S) by adding noise (in fact, adding an infinite amount of noise) to S. The result follows then from the Blackwell principle of informativeness (see Kihlstrom (1984)). Furthermore, and in general, the first program will yield strictly higher profits since knowing S, Y can be predicted with certainty, and S will provide relevant information for the optimization. Therefore, provided that the membership fee in the TA is not too high, it will pay to become a member and not to be excluded from the information-sharing agreement. *Q.E.D.*

We illustrate Proposition 2 with the Quadratic-Normal model. If all firms participate in the TA and firm i is contemplating deviation, the firm faces an average market action $\tilde{y} = b\tilde{\theta}$, $(b = (1 + \omega_1)^{-1})$. By participating in the TA the firm obtains the statistic $\tilde{\theta}$ (the distribution S is summarized in the average signal $\tilde{s} = \tilde{\theta}$) and therefore predicts $\tilde{y}$ with certainty. Firm i solves $\max_{z_i} E\{\pi_i | s_i, \tilde{\theta}\}$, where $\pi_i = \theta_i z_i - \omega_i z_i^2 - (1 - \omega_i)\tilde{y}z_i$. The solution, according to Lemma 1, is $y(s_i, \tilde{\theta}) = \hat{a}(s_i - \tilde{\theta}) + b\tilde{\theta}$. Now, if the firm does not participate, it does not get the TA statistic and solves $\max_{z_i} E(\pi_i | s_i)$, where π_i is as before. The solution is easily checked to be $y(s_i) = \bar{a}(s_i - \mu) + b\mu$ where

$$\bar{a} = (1 + \omega_i - (1 - \omega_1)\rho)t/(2\omega_1(1 + \omega_1)).$$

In solving the second program the firm had to estimate both θ_i and $\tilde{\theta}$ with only s_i, while in solving the first it could estimate θ_i with s_i and $\tilde{\theta}$, and $\tilde{\theta}$ was known.

It is possible to check that the first program yields strictly higher expected profits, except for two cases in which the aggregate information $\tilde{\theta}$ is irrelevant and therefore both yield the same solution. First, when there is no correlation between the signals $(\rho = 0)$, then $\tilde{\theta} = \mu$ a.s. (i.e., $\tilde{\theta}$ is a degenerate random variable) and $\hat{a} = \bar{a} = t/2\omega_i$. Second, when $2\omega_1(1 - t) = (1 - \omega_1)t(1 - \rho)$, then $b = a = \bar{a}$. That is, only when information sharing is irrelevant $(\rho = 0)$ or in the exceptional case in which parameters are such that $b = a = \bar{a}$, and therefore both strategies boil down to $y_i = bs_i$, the extra information provided by $\tilde{\theta}$ is not used and expected profits from participating and not participating are equated. Otherwise it pays to participate.

Remark 4. Not to share information is always a stable configuration (Nash equilibrium) also, since if no firm shares information firm i is indifferent between sharing or not sharing since it makes no difference if membership is free, (*a fortiori,* if membership in the TA is costly).

Remark 5. I have not said anything about the relative levels of profit in the no-sharing and sharing cases. Both are self-enforcing configurations under the restricted disclosure rule. In some cases no sharing and in others sharing yields the greatest level of profits; to discuss the factors that influence the profit ranking we need to add more structure to the model, as, for example, in the Quadratic-Normal example.

Remark 6. Proposition 2 asserts that it will pay to join a TA formed by all firms in the industry. Will this still be the case for a "small" TA? To fix ideas let us think in terms of the Quadratic-Normal model. If a small positive measure of firms forms a TA, then it will pay to join. The argument is exactly the same as in Proposition 2. By pooling their signals, the members of the TA will obtain $\tilde{\theta}$, the average parameter. A firm, by joining, obtains its private signal plus $\tilde{\theta}$; if it does not join it does not get $\tilde{\theta}$. Furthermore, the firm's decision to join or not to join does not affect the average market action $\tilde{y}$, which is determined by

$\tilde{\theta}$. Consequently, the firm always faces the *same* optimization problem, but by joining it has more relevant information ($\tilde{\theta}$) to choose its action. Thus we see that there exists a tendency for TAs to expand, since it never pays to defect individually. Nevertheless, this does not mean that the TA is stable against defections of coalitions. To analyze this problem, a potentially appropriate tool is the *strong Nash* concept, in which an equilibrium is by definition stable with respect to defections by coalitions. If expected profits sharing information with the whole industry dominates payoffs for any firm with other configurations (which, in the context of the Quadratic-Normal model, is likely to be the case when the actions of the firms are strategic complements—that is, when $\omega_2 < 0$), then the grand coalition pooling information will be a strong Nash equilibrium. Otherwise, a strong Nash equilibrium may not exist. The costs involved in the formation of a TA should be added to the analysis I have presented here. The stability of information-sharing arrangements will then depend also on the technology of information collection and dissemination. If it presents economies of scale, this will obviously tend to favor large TAs.

Remark 7. Up to now we have dealt with a monopolistic competition model with no free entry. We could think, however, of our model as comprising the last two stages—information-sharing decision and market competition—of a three-stage model, which has as its first stage an entry decision. At this stage a firm decides whether or not to enter, anticipating the equilibrium that will follow if it does. The firm then compares the estimate of the profitability of the market with the entry cost. The only modification we should introduce into the model is that at the second stage, instead of a unit mass of firms in the market, $i \in [0, 1]$, there would be a proportion m of operating firms, $i \in [0, m]$, that have decided to enter at the first stage. Expected profits would then typically be decreasing in m. The equilibrium mass of firms would be determined by the entry cost and would imply zero profits. It is worth noting that this three-stage game could have multiple equilibria, since we have seen that there are circumstances in which both sharing and no-sharing are possible equilibria. Depending on which equilibrium yields higher expected profits, the proportion of operating firms will be higher in the sharing or the no-sharing case.

As a closing remark for this section I would like to emphasize that the results I have obtained in Propositions 1 and 2 reflect general principles of information transmission in monopolistic competition and are robust to different types of competition (Bertrand or Cournot), different types of uncertainty (demand or cost), and different information structures (common value or private value with different degrees of correlation). This contrasts sharply with the literature on information transmission in oligopoly.

5. Welfare analysis

■ We have seen that in a monopolistically competitive world the disclosure rule used by the TA crucially affects the incentives to share information. With exclusionary disclosure, information sharing has a chance, since it is a self-enforcing agreement. Without it, sharing is not possible if it involves some cost, due to the free rider problem: if a firm can get the aggregate information for free it will not join the TA. Thus we see that in the monopolistic competition context the antitrust authority can effectively prevent firms from sharing information by requiring TAs to practice nonexclusionary disclosure of reports. The issue I would like to examine here is in what situations it will be efficient, from the social welfare point of view, to require nonexclusionary disclosure. I will perform this welfare analysis in the Quadratic-Normal model with demand uncertainty. I shall consider two extreme cases: the common-value case ($\rho = 1$) and the private-value case ($v = 0$).

The linear-demand system (1) in Section 3 can be obtained from the optimizing behavior of a representative consumer which maximizes $U(x) - px$, where

$$U(x) = \int \alpha_i x_i di - \left(\tilde{x}^2 + (1 - \delta)\left(\int x_i^2 di - \tilde{x}^2\right)\right)\Big/2$$

and $px = \int p_i x_i di$ is average expenditure. Consumer surplus (CS) in terms of prices is given by

$$CS(p) = \left[(1-\delta) \int \beta_i^2 di + \delta \tilde{\beta}^2 + (1+\gamma) \int p_i^2 di - \gamma \tilde{p}^2 - 2 \int \beta_i p_i di \right] \Big/ 2$$

where, as before, $\beta_i = (\alpha_i - \delta\tilde{\alpha})/(1-\delta)$ and $\gamma = \delta/(1-\delta)$. Note that $\tilde{\beta} = \tilde{\alpha}$. Consumer surplus in terms of quantities is given by

$$CS(x) = \left(\delta \tilde{x}^2 + (1-\delta) \int x_i^2 di \right) \Big/ 2.$$

Since costs are assumed to be zero, $U(x)$ represents total surplus (TS). We want to compare the levels of expected total surplus with and without information sharing. We will consider two cases only: common value, where $\rho_\alpha = 1$ and $\alpha_i = \alpha$ (a.s.) for all i, and private value, where $v = 0$ and firm i receives the signal with no error term: $s_i = \alpha_i$ (a.s.) in the Cournot case and $s_i = \beta_i$ (a.s.) in the Bertrand case. Table 1 gives the equilibrium strategies in both cases.[11]

Substituting the equilibrium strategies obtained in the expression for $U(x)$ and $CS(x)$ and taking expected values we get the formulae for ETS and ECS in the Cournot case. In the Bertrand case we substitute the equilibrium strategies in the expression for $CS(p)$, take expected values to get ECS, and add expected profits to obtain ETS. Obviously, in making computations we can take advantage of the fact that $U(x)$ and $CS(p)$ have closely related functional forms. The results obtained are given in Tables 2 and 3 for the common-value and private-value cases respectively.

Lemma 2 provides the results of the effect of information sharing on the levels of expected consumer and total surplus. See Chart 1.

TABLE 1 **Equilibrium Strategies**

	No Sharing	Sharing
	Private Value	
Cournot	$x(\alpha_i) = \frac{1}{2 - \delta(2 - \rho_\alpha)}(\alpha_i - \mu) + \frac{1}{2-\delta}\mu$	$x(\alpha_i, \tilde{\alpha}) = \frac{1}{2(1+\delta)}(\alpha_i - \tilde{\alpha}) + \frac{1}{2+\delta}\tilde{\alpha}$
Bertrand	$p(\beta_i) = \frac{1}{2 + \gamma(2 - \rho_\beta)}(\beta_i - \mu) + \frac{1}{2+\gamma}\mu$	$p(\beta_i, \tilde{\beta}) + \frac{1}{2(1+\gamma)}(\beta_i - \tilde{\beta}) + \frac{1}{2+\gamma}\tilde{\beta}$
	Common Value	
Cournot	$x(s_i) = \frac{t}{2 - \delta(2 - t)}(s_i - \mu) + \frac{1}{2-\delta}\mu$	$x(\alpha) = \frac{1}{2-\delta}\alpha$
Bertrand	$p(s_i) = \frac{t}{2 + \gamma(2 - t)}(s_i - \mu) + \frac{1}{2-\gamma}\mu$	$p(\alpha) = \frac{1}{2+\gamma}\alpha$

[11] It is worth noticing that the distribution assumptions on α_i (i.e., θ_i) impose a similar structure on $\beta_i \equiv (\alpha_i - \delta\tilde{\alpha})/(1-\delta)$. It is easily checked that $E\beta_i = E\alpha_i \equiv \mu$, var $(\beta_i) \equiv \sigma_\beta^2 = (1 - \delta\rho_\alpha(2-\delta))\sigma^2/(1-\delta)^2$ and that the correlation coefficient between β_i and β_j is $\rho_\beta = (1-\delta)^2\rho_\alpha/(1 - \delta\rho_\alpha(2-\delta))$, which is always less than ρ_α, the correlation coefficient between α_i and α_j. The qualitative properties of the β-information structure are the same as those of the α-information structure.

TABLE 2 **Common Value**

	No Sharing	Sharing (t = 1)	
Cournot	$\frac{1-\delta}{(2-\delta)^2}\mu^2 + \frac{(1-\delta)t}{(2-2\delta+\delta t)^2}\sigma^2$	$\frac{1-\delta}{(2-\delta)^2}(\mu^2+\sigma^2)$	$E\pi$
	$\frac{1}{2(2-\delta)^2}\mu^2 + \frac{(1-\delta+\delta t)t}{2(2-2\delta+\delta t)^2}\sigma^2$	$\frac{1}{2(2-\delta)^2}(\mu^2+\sigma^2)$	ECS
	$\frac{3-2\delta}{2(2-\delta)^2}\mu^2 + \frac{(3-3\delta+\delta t)t}{2(2-2\delta+\delta t)^2}\sigma^2$	$\frac{3-2\delta}{2(2-\delta)^2}(\mu^2+\sigma^2)$	ETS
Bertrand	$\frac{1+\gamma}{(2+\gamma)^2}\mu^2 + \frac{(1+\gamma)t}{(2+2\gamma+\gamma t)^2}\sigma^2$	$\frac{1+\gamma}{(2+\gamma)^2}(\mu^2+\sigma^2)$	$E\pi$
	$\frac{1}{2}\left(\frac{1+\gamma}{2+\gamma}\right)^2\mu^2 + \left(1 - \frac{(3+3\gamma-\gamma t)t}{(2+2\gamma-\gamma t)^2}\right)\frac{\sigma^2}{2}$	$\frac{1}{2}\left(\frac{1+\gamma}{2+\gamma}\right)^2(\mu^2+\sigma^2)$	ECS
	$\frac{3+2\gamma+\gamma^2}{2(2+\gamma)^2}\mu^2 + \left(1 - \frac{(1+\gamma(1-t))t}{(2+2\gamma-\gamma t)^2}\right)\frac{\sigma^2}{2}$	$\frac{3+2\gamma+\gamma^2}{2(2+\gamma)^2}(\mu^2+\sigma^2)$	ETS

Lemma 2. Assume that $\delta \in (0, 1)$. With common values, $\rho = 1$ and $v > 0$. With private values, $v = 0$, $\rho \in (0, 1)$. Then, under Bertrand competition, $ECS^{ns} > ECS^s$ and $E\pi^{ns} < E\pi^s$ always. Under Cournot competition, with common values, $ECS^{ns} < ECS^s$ and $E\pi^{ns} \gtrless E\pi^s$ if and only if $\delta \gtrless [2(1-\sqrt{t})]/(2-t-\sqrt{t})$; with private values, $ECS^{ns} \gtrless ECS^s$ if and only if $\delta \gtrless (4-2\sqrt{\rho_\alpha})/(4-\rho_\alpha)$ and $E\pi^{ns} < E\pi^s$.

Proof. By manipulation of Tables 2 and 3. See the Appendix.

The results given in Chart 1 are understood better with the help of Charts 2 and 3. Chart 2 describes the effect of information sharing on the variability of individual, y_i, and average, $\tilde{y}$, actions. Chart 3, the effect of changes on var y_i and var $\tilde{y}$ on $E\pi$, $ECS(x)$ and $ECS(p)$:

$$ECS(x) = (\delta E\tilde{x}^2 + (1-\delta)Ex_i^2)/2$$

$$ECS(p) = [\{(1-\delta(1-\rho))\sigma_\beta^2 + \mu^2\} + (1+\gamma)Ep_i^2 - \gamma E\tilde{p}^2 - 2E\beta_i p_i\}/2$$

$$E\pi_C = (1-\delta)Ex_i^2$$

$$E\pi_B = (1+\gamma)Ep_i^2.$$

Expected profits are subindexed by C or B to denote that to get the expressions I made use of the first-order conditions in the Cournot and Bertrand cases respectively.

Let us think first about the common-value case. When pooling information, the slope of the equilibrium strategy (the responsiveness to signals) of firms increases. This tends to increase expected profits $E\pi$ since it increases the variability of the action and $E\pi$ are a convex function of it. Nevertheless, there is another force working in the opposite direction: pooling of information reduces the variance of the signal received by firms. With no information sharing, firms get s_i with variance $\sigma^2 + v$; with information sharing they get α with variance σ^2. In the Cournot case this second force may dominate; in the Bertrand case the first always dominates. An increase in information precision for *all* firms can be decomposed between the increase in precision for firm i and the increase for the rivals. In the Bertrand case *both* tend to increase the responsiveness firm's price to the signal received. In the

TABLE 3 **Private Value**

	No Sharing	Sharing	
Cournot	$\frac{1-\delta}{(2-\delta)^2}\mu^2+\frac{1-\delta}{(2-\delta(2-\rho_\beta))^2}\sigma_\beta^2$	$\frac{1-\delta}{(2-\delta)^2}\mu^2+\frac{(2-\delta)^2(1-\rho_\alpha)+4(1-\delta)^2\rho_\alpha}{4(1-\delta)(2-\delta)^2}\sigma_\beta^2$	$E\pi$
	$\frac{1}{2(2-\delta)^2}\mu^2+\frac{1-\delta(1-\rho_\alpha)}{2(2-\delta(2-\rho_\alpha))^2}\sigma_\alpha^2$	$\frac{1}{2(2-\delta)^2}\mu^2+\frac{(1-\rho_\alpha)(2-\delta)^2+4(1-\delta)\rho_\alpha}{8(1-\delta)(1-\delta)^2}\sigma_\alpha^2$	ECS
	$\frac{3-2\delta}{2(2-\delta)^2}\mu^2+\frac{3-3\delta+\delta\rho_\alpha}{2(2-\delta(2-\rho_\alpha))^2}\sigma_\alpha^2$	$\frac{3-2\delta}{2(2-\delta)^2}\mu^2+\frac{(2-\delta-\delta\rho_\alpha)(6-3\delta-\delta\rho_\alpha)}{8(1-\delta)(2-\delta)^2}\sigma_\alpha^2$	ETS
Bertrand	$\frac{1+\gamma}{(2+\gamma)^2}\mu^2+\frac{1+\gamma}{(2+\gamma(2-\rho_\beta))^2}\sigma_\beta^2$	$\frac{1+\gamma}{(2+\gamma)^2}\mu^2+(1+\gamma)\left(\frac{\rho_\beta}{(2+\gamma)^2}+\frac{1-\rho_\beta}{4(1+\gamma)^2}\right)\sigma_\beta^2$	$E\pi$
	$\frac{1+\gamma^2}{2(2+\gamma)^2}\mu^2+\left(\frac{1+\gamma\rho_\beta}{1+\gamma}-\frac{3+3\gamma-\gamma\rho_\beta}{(2+\gamma(2-\gamma_\beta))^2}\right)\frac{\sigma_\beta^2}{2}$	$\frac{1+\gamma^2}{2(2+\gamma)^2}\mu^2+\left(\frac{1+\gamma\rho_\beta}{1-\gamma}-\frac{(2+\gamma+\rho_\beta\gamma)(6+3\gamma+\rho_\beta\gamma)}{4(1+\gamma)(2+\gamma)^2}\right)\frac{\sigma_\beta^2}{2}$	ECS
	$\frac{(1+\gamma)^2+2}{2(2+\gamma)^2}\mu^2+\left(\frac{1+\gamma\rho_\beta}{1+\gamma}-\frac{1+\gamma-\gamma\rho_\beta}{(2+\gamma(2-\rho_\beta))^2}\right)\frac{\sigma_\beta^2}{2}$	$\frac{(1+\gamma)^2+2}{2(2+\gamma)^2}\mu^2+\left(\frac{1+\gamma\rho_\beta}{1+\gamma}-\frac{\gamma^2(1-\rho_\beta)^2+4(1+\gamma)}{4(1+\gamma)(2+\gamma)^2}\right)\frac{\sigma_\beta^2}{2}$	ETS

CHART 1 **Effects of Information Sharing on**

	$E\pi$	ECS
Bertrand	+	−
Cournot	c.v.[a] ± p.v.[b] +	c.v. + p.v. ±

[a] c.v. = common value.
[b] p.v. = private value.

Cournot case, the increase in the rivals' precision tends to decrease the firm's own responsiveness, mitigating the positive effect of information pooling on expected profits. The impact of the rivals' increase in precision is more important when the products are close substitutes (δ close to 1), then $E\pi^{ns} > E\pi^{s}$.

With respect to expected consumer surplus, ECS, as a function of quantities is a convex combination of the variance of average output and the variance of individual output. The first always increases with information pooling since firms respond more to information, and with Cournot competition the combined effect of both always increases ECS. Under Bertrand competition the opposite happens: $ECS^{ns} > ECS^{s}$. This is so because $ECS(p)$ increases with the variance of individual prices and decreases with the variance of the average price and with the covariance of the random-demand parameter, α, and individual price, p_i. Information sharing increases the first, as we have seen before, but also increases the last two, all through the increase in responsiveness of the price firms charge. The two negative effects always dominate.

Turning now to the private-value case, the variance of the individual action of a firm increases with the sharing of information in both the Cournot and Bertrand cases. When pooling information, a firm responds both to its private type and to the average type in the market, resulting in a higher variability of its action. Consequently, expected profits increase. With respect to consumer surplus there are two conflicting forces in the Cournot case. Individual output variance goes up but average output variance goes down. From Remark 2 (in Section 3) we know that the variance of the average action goes down with information pooling if $\omega_2 t(1-\rho) > 2\omega_1(1-t)$. This certainly holds, since in the case we consider $t = 1$ and $\omega_2 = \delta > 0$. One or the other force dominates, depending on the parameters δ and ρ. In the Bertrand case the variance of the individual price and the variance of the average price follow the same pattern. They both increase with information pooling. Furthermore, there is the effect of the covariance between β_i and p_i, which is larger when sharing information:

$$\operatorname{cov}(\beta_i, p_i^s) = \left(\frac{1-\rho_\beta}{2(1+\gamma)} + \frac{\rho_\beta}{2+\gamma}\right)\sigma_\beta^2 > \frac{\sigma_\beta^2}{2+\gamma(2-\rho_\beta)} = \operatorname{cov}(\beta_i, p_i^{ns}).$$

CHART 2 **Information Sharing Impact on**

	Variable y_i	Variable $\tilde{y}$	$\operatorname{Cov}(\theta_i, y_i)$
Bertrand	+	+	+
Cournot	c.v.[a] ± p.v.[b] +	c.v. + p.v. −	0

[a] c.v. = common value.
[b] p.v. = private value.

CHART 3 **Effect of an Increase in**

	Variable y_i	Variable $\tilde{y}$	$\mathrm{Cov}(\theta_i, y_i)$
$E\pi$	+	0	0
$ECS(x)$	+	+	0
$ECS(p)$	+	−	−

The negative effects (increase in aggregate variability and covariance) dominate the factor that tends to increase *ECS* under information pooling: the increase in individual variance.

It is worth noticing that with private-value uncertainty and Cournot competition, information sharing makes the market more "uniform," as "common wisdom" suggests, by reducing the variability of the market aggregates. This effect is bad for consumers (see Chart 2). Nevertheless, with common-value uncertainty, information sharing increases the variability of the market aggregate since firms respond more to the unique (perfect) signal received. The effect is then good for consumers (but would be bad under Bertrand competition). Furthermore, information pooling always reduces market uniformity under Bertrand competition (since $\omega_2 = -\gamma < 0$ and according to Remark 2 in Section 3). Therefore the only situation that seems to fit common-wisdom ideas about information sharing and market uniformity is Cournot competition with private-value uncertainty. In fact, the general condition for information pooling to reduce the variability of average output is $\delta t(1-\rho) > 2(1-t)(1-\delta)$. It is likely to be satisfied for t and δ close to one and ρ close to zero; that is, markets with good information, a lot of competition (low product differentiation), and weak correlation in the individual demands of the firms.

If our criterion for uniformity is the correlation between the firms' strategies, then the results are reversed according to Remark 2. Common-wisdom ideas are then corroborated under Bertrand competition and under common-value uncertainty.

We are ready now to add up our welfare indicators for consumers and firms to evaluate social welfare.

Proposition 3. Under the assumptions of Lemma 2, with Cournot (Bertrand) competition information sharing always increases (decreases) expected total surplus.

Proof. Again, by manipulation of Tables 2 and 3. See the Appendix.

The result is clear-cut, but according to Lemma 2, different factors produce the outcome. Under Bertrand competition we always find that sharing information is good for firms but bad for consumers, and the second effect dominates when computing total surplus. Sharing information increases the variability of individual prices, which is good for everybody, increases the variability of the average price, which is bad for consumers, and increases the covariance between the random-demand parameters and individual prices, which is also bad for consumers. The net result is that total welfare goes down when firms share information.

Under Cournot competition and common values, pooling information increases the variability of average output, which is good for consumers, and may increase or decrease the variability of individual output. Expected consumer surplus and total surplus always increase with information sharing. With private-value uncertainty, information sharing increases the variance of individual output and reduces the variance of average output. The net effect on total welfare is positive, although consumers may suffer.

We should emphasize that the results obtained apply to the uncertain-demand case. Cost uncertainty can be accommodated easily with Cournot competition (if m_i is the constant marginal cost of firm i—just redefine the intercept α_i net of m_i) but not with Bertrand competition. With the latter, new computations have to be made. Nevertheless, results obtained by Sakai and Yamato (1990) in a private-value differentiated duopoly context suggest that total surplus is also larger under no sharing of information with Bertrand competition. The effects on firms' profits, though, are ambiguous.

The oligopoly literature on information sharing has obtained several welfare results that are in line with Proposition 3. In the context of Cournot competition and private-value uncertainty, Shapiro (1986) in a homogeneous product world, and Sakai and Yamato (1989) with differentiated products, have concluded that total welfare and individual firms' profits are always larger with information pooling. With common-value demand uncertainty and in a differentiated duopoly context Vives (1984) has shown that under Cournot competition expected total surplus is larger with information sharing. Under Bertrand competition it will also be larger if the products are good substitutes; otherwise it is smaller than if there is no pooling of information. In the same context but with private-value demand uncertainty, results by Sakai (1986) indicate a larger total expected surplus with information pooling. The Bertrand result contrasts with that obtained in this article in which, under Bertrand competition, expected total surplus always decreases with information sharing. Li, McKelvey and Page (1987), in a homogeneous oligopoly context (also with common value uncertainty), show that expected total surplus is larger with information sharing.

6. Concluding remarks

■ What have we learned about information sharing in an industry with many firms?

Under general conditions we have found that disclosure rules crucially affect the incentives to pool information. In particular, requiring nonexclusionary disclosure in a large market destroys the incentives to share information. Exclusionary disclosure restores the incentives, although it cannot guarantee that firms will enter into an information-sharing agreement.

Under the assumptions of the Quadratic-Normal model:

(1) *Competitiveness.* Information sharing does not affect the competitiveness of the market but the responsiveness of the firms to information and therefore the variability of the aggregate market statistics. This is a consequence of the certainty equivalence property of the model. It suggests that pooling information need not bias the market toward a more or less competitive outcome, provided the firms have no possibility to collude.

(2) *Market uniformity.* Pooling information increases the variability of the average market action under Bertrand competition and under common-value uncertainty. Thus, if the measure of market uniformity is the variability of aggregate statistics, we seem to be left with the Cournot private-value case as support of the common idea that the sharing of information will increase market uniformity. If we take as a measure of market uniformity the correlation of the firms' strategies, then the results are reversed. Under Bertrand competition or under common-value uncertainty, pooling information makes the market more uniform.

(3) *Consumer impact of market uniformity.* A decrease in the variability of the aggregate market action tends to hurt consumers in the Cournot case and benefit them in the Bertrand case. Therefore, there seems to be no basis for always seeking this type of market uniformity in the name of consumer welfare.

(4) *Public policy.* Taking as a social-welfare indicator expected total surplus, the public authority should try to encourage (discourage) information sharing in those large markets characterized by Cournot (Bertrand) competition. In particular, in the second case a nonexclusionary disclosure rule could be imposed. In the first case, exclusionary disclosure would seem appropriate. Nevertheless, with common-value uncertainty this may not suffice, since expected profits may be higher without sharing information.

(5) *More weight to consumers.* If more weight is given to consumer surplus than to profits, then the preceding remarks may have to be modified in the case of Cournot competition with private values. Then, expected consumer surplus may be higher with no sharing of information if the products are differentiated enough.

In summary, the monopolistic competition framework has proved fruitful for characterizing the effects of different disclosure rules of trade associations. To derive the welfare implications of information pooling I had to posit a specific model that served to illuminate the forces at work. Obviously, to check whether the results obtained with the Quadratic-Normal model obey general principles it would be worthwhile, lacking a general welfare theory of information exchange, to try to perform the analysis with other models. In particular, it would be interesting to explore the robustness of the clear-cut result in the Quadratic-Normal model with uncertain demand—that information sharing is good from the social point of view under Cournot competition but bad under Bertrand competition.

Appendix

■ Proofs of Lemmas 1 and 2 and Proposition 3 follow.

Proof of Lemma 1. In the private-information case, given the average $\tilde{y}$, the optimization program of firm i is given by

$$\max_{z_i} E((\pi(z_i, \tilde{y}, \theta_i)|s_i)$$

which for an interior solution yields the first-order condition (FOC)

$$2\omega_1 y(s_i) = E(\theta_i|s_i) - \omega_2 E(\tilde{y}|s_i).$$

Let $y(s_i) = a(s_i - \mu) + b\mu$ be our candidate symmetric equilibrium strategy. Taking expectations on the FOC we immediately get that $b = (2\omega_1 + \omega_2)^{-1}$, noticing that $E\tilde{y} = Ey(s_i) = b\bar{\theta}$. We get $a = t(2\omega_1 + \omega_2\rho t)^{-1}$ by substituting the equilibrium strategy in the FOC and using the fact that $E(\tilde{y}|s_i) = a(E(\tilde{s}|s_i) - \mu) + b\mu$ where $\tilde{s}$ is the average signal and $E(\tilde{s}|s_i) = E(s_j|s_i) = \mu + \rho t(s_i - \mu), j \neq i$.

Substituting the FOC in the payoff of firm i we immediately get an expression for equilibrium expected profits: $E\pi_i = \omega_1 E(y(s_i))^2$.

In the shared-information case, firm i gets $(s_i, \tilde{s})$ and solves

$$\max_{z_i} E\{\pi(z_i, \tilde{y}; \theta_i)|s_i, \tilde{s}\}$$

yielding a FOC

$$2\omega_1 y(s_i, \tilde{s}) = E(\theta_i|s_i, \tilde{s}) - \omega_2 \tilde{y}.$$

By averaging the FOC of the firms we obtain $\tilde{y} = \tilde{\theta}/(2\omega_1 + \omega_2)$. To see this, use the fact that

$$E(\theta_i|s_i, \tilde{s}) = (1 - d)\tilde{\theta} + ds_i$$

and therefore, $\int E(\theta_i|s_i, \tilde{s})di = \tilde{\theta}$ from the observation that $\tilde{s} = \tilde{\theta}$.

Plugging $\tilde{y} = \tilde{\theta}/(2\omega_1 + \omega_2)$ back into the FOC and postulating an affine equilibrium strategy

$$y(s_i, \tilde{\theta}) = \hat{a}(s_i - \tilde{\theta}) + b\tilde{\theta}$$

we obtain the coefficients $\hat{a} = d/2\omega_1$ and $b = 1/(2\omega_1 + \omega_2)^{-1}$. As before, expected profits are given by $E\pi = \omega_1 E(y(s_i, \tilde{s}))^2$. *Q.E.D.*

Proof of Lemma 2. Let $\delta \in (0, 1)$. In the common-value case ($\rho = 1, v > 0$) it is readily checked that

$$\frac{\partial ECS_C^{ns}}{\partial t} = \frac{2 - 4\delta + 2\delta^2 + 3\delta(1-\delta)t}{(2 - 2\delta + \delta t)^3}\frac{\sigma^2}{2} > 0$$

$$\frac{\partial ECS_B^{ns}}{\partial t} = -\frac{(12 - t)\gamma + (6 + t)\gamma^2 + 6}{(2 + 2\gamma - \gamma t)^3}\frac{\sigma^2}{2} < 0.$$

With respect to expected profits, they increase with t in the Bertrand case and may increase or decrease with t in the Cournot case. Therefore, since sharing information is equivalent to $t = 1$, we have $ECS_C^{ns} < ECS_C^s$,

$ECS_B^{ns} > ECS_B^s$ and $E\pi_B^{ns} < E\pi_B^s$. In the Cournot case the inequality in the lemma follows immediately, comparing $E\pi_C^{ns}$ with $E\pi_C^s$.

The private-value case ($v = 0$, $\rho \in (0, 1)$) is more cumbersome. Everything follows by manipulation of the expressions in the tables. This way we obtain (on the relevant domains for δ and ρ):

$$\text{sign}\,\{ECS_B^{ns} - ECS_B^s\} = \text{sign}\,\{8(1-\rho_\beta)(2+3\gamma) + \gamma^2(8 - \rho_\beta(9-\rho^2{}_\beta))\} = \oplus$$

since $\rho_\beta(9-\rho_\beta^2) < 8$ for $\rho_\beta \in (0, 1)$, and

$$\text{sign}\,\{ECS_C^{ns} - ECS_C^s\} = \text{sign}\left\{\frac{4\delta^2 - 8\delta + 4}{\delta^2} - \rho_\alpha\right\} = \text{sign}\left\{\frac{4 - 2\sqrt{\rho_\alpha}}{4-\rho_\alpha} - \delta\right\}. \qquad Q.E.D.$$

Proof of Proposition 3. Let $\delta \in (0, 1)$. In the common-value case ($\rho = 1$, $v > 0$) we have

$$\frac{\partial ETS_C^{ns}}{\partial t} = \frac{6 - 12\delta + 6\delta^2 + \delta(1-\delta)t}{(2-2\delta+\delta t)^3}\frac{\sigma^2}{2} > 0$$

$$\frac{\partial ETS_B^{ns}}{\partial t} = \frac{(4-3t)\gamma + (2-t)\gamma^2 + 2}{(2+2\gamma-\gamma t)^3}\frac{\sigma^2}{2} < 0.$$

Sharing information is equivalent to $t = 1$. Therefore $ETS_C^{ns} < ETS_C^s$ and $ETS_B^{ns} > ETS_B^s$. In the private-value case ($v = 0$, $\rho \in (0, 1)$) we obtain

$$\text{sign}\,\{ETS_B^{ns} - ETS_B^s\} = \text{sign}\,\{8(1+\gamma) + \rho_\beta^2\gamma^2 + (8 + 24\gamma + 13\gamma^2)\rho_\beta - 2\rho_\beta^2\gamma(4+3\gamma)\} = \oplus,$$

and

$$\text{sign}\,\{ETS_C^{ns} - ETS_C^s\} = \text{sign}\left\{\frac{12\delta^2 - 32\delta + 20}{5\delta^2 - 8\delta} - \rho_\alpha\right\} = \theta. \qquad Q.E.D.$$

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