Information sharing in oligopoly: the truth-telling problem

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While under some circumstances information sharing in oligopoly may be beneficial, the literature ignores the possibility of strategic information sharing by assuming verifiability of data. I endogenize the incentives for truthful information sharing and prove that if firms have the ability to send misleading information, they will always do so. To overcome this problem I introduce a (costly) mechanism through which the firm will, in its own best interest, reveal the true value of its private information, even though outside verification is impossible. I show that in some cases benefits from information sharing exceed the signalling costs, while in other cases the reverse is true. The fact that I model a two-sided signalling enables me to mitigate the signalling-cost problem. Rather than burning money, oligopolistic rivals may exchange transfer payments, thereby significantly reducing signalling costs.

1. Introduction

■ Several articles published in recent years have studied the motivation of oligopolists to share their private information with rivals. Articles by Gal-Or (1985, 1986), Novshek and Sonnenschein (1982), Shapiro (1986), Vives (1984), and others show that the relevant parameters for information sharing are the nature of the competition (prices (Bertrand) or quantities (Cournot)), the type of private information ("common value" or "private value" parameters), and the relationship between the products (substitutes or complements).

A theme common to all these articles is that in some cases firms benefit from sharing information. The articles, however, ignore the problem of revealing truthful information to competitors by assuming the existence of some exogenous player who transfers the correct information or by assuming that data is verifiable. Novshek and Sonnenschein assume that the firms employ an "independent testing agency" to generate their signals. Gal-Or says: "If there is an *outside* institution, such as a trade association, that collects and publicizes information, firms may have to commit themselves to a revelation strategy." In this article I attempt to endogenize the incentives for truthful information sharing in oligopolistic relationships.

Two restrictive assumptions appear in information-sharing models. The first is precommitment to disclose information. After firms decide on information-transfer structure,

they need another institution to implement this commitment, such that no firm can deviate, given its realization of the private information. This restriction implies that firms are forced to stay as members in trade associations without the possibility of withdrawing. Such a condition prevails in a regulated environment but not in a competitive market. Clinch (1986) studies this problem in a model where a firm can choose either not to disclose or to truthfully disclose its private information. He shows that without precommitment, the decision to disclose is based on the realization of the private information. In particular, in a nontrivial subset of the realizations, firms will choose not to disclose as their optimal strategy.

The second restrictive assumption is truth telling. Do firms have incentives to disclose the true value of their private information, rather than disclosing misleading information? This question had not been addressed in the context of information sharing in oligopoly.

The problem of hidden information (adverse selection) has been extensively studied in the literature (Akerlof (1970), Rothschild and Stiglitz (1976), and many more). A major contribution in this area is the revelation principle (Myerson, 1982), which shows that without loss of generality we can confine attention to direct mechanisms involving truth telling. But truth telling is a consequence of incentive-compatible constraints where it is in the best interests of the party who sends the information to tell the truth rather than an ad hoc assumption.[1] This article studies whether firms still find it in their interest to share information when communication is subject to strategic manipulations. By solving this problem and introducing *ex post* incentives to disclose truthful information, I also solve the precommitment problem, since if the firm has an incentive to tell the truth for all realizations, it does not need to precommit.[2]

A common assumption used to avoid dealing with strategic disclosure by firms involves introducing the ability to verify the firm's report either through accounting data or market results. It is less clear whether this verification can take place in the real world. Accounting data lack sufficient details and are often not available at decision-making time. Take, for example, the cost per unit of a specific product. This kind of information is part of an internal accounting system that is not subject to external audit and not disclosed in the firm's financial statements. Other kinds of private information are even harder to verify, e.g., "common values" (like demand intercept) parameters are not part of any accounting system. Further, even if one could generate this information as audited accounting data, its reliability depends on the auditor's incentives to look for the information and to disclose his findings correctly (see Antle (1982) and Baiman, Evans, and Noel (1987)). Note that in a nonrepeated game, once production takes place, which is before accounting reports are published, verification is of limited use since it is unreasonable to assume that firms can punish their rivals for untruthful disclosure of information. In particular, courts might regard contracts along those lines as violating antitrust laws. So knowing that someone had cheated at this stage may have no value. If the relationship between the firms is repeated for more than one period, incentives for truthful information sharing may increase, since both firms can benefit from information sharing and have credible threats against each other. This analysis is beyond the scope of this article.

I start with a Cournot game where firms have private information about their production costs. Proposition 1 demonstrates what is shown in Gal-Or (1986): that firms have *ex ante* incentives to share their private information. Once a firm realizes its production costs, incentives to share information disappear for some realizations. This is shown in Proposition 2. Further, in Proposition 3 I prove that if firms have the ability to send misleading

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[1] Further, the revelation principle does not apply in the oligopoly setting, since firms cannot sign contracts or precommit to the use of the information.

[2] The other possibility is to send no message, but this will be interpreted as the worst possible case and hence is dominated by the true signal.

information, they will always do so. This result introduces the question of whether one can achieve information sharing without an exogenous mechanism.

I examine here truth telling as the firm's optimal strategy and require it to be a dominant strategy in a sequentially rational equilibrium, namely that the incentives to disclose information will not disappear once the firm realizes the private value. In addition, I provide a mechanism through which the firm will find it in its own best interests to give the true value of its private information even though outside verification is impossible. Such an equilibrium is derived in Section 4 by introducing costs involved in sending a message about the firm's private information. These costs are constructed such that firms choose truthful messages as their best response.

I show that in some cases benefits from information sharing exceed the signalling costs (Proposition 4) while in other cases the reverse is true (Proposition 5). However, the fact that I model a two-sided signalling enables me to mitigate the cost-of-signalling problem. Rather than burning money (as in one-sided signalling games), the oligopolistic rivals may exchange transfer payments, thereby significantly reducing the signalling costs (or even eliminating them in some cases).

An interesting normative implication of the last result is that when a regulator cannot prevent information sharing, he might consider allowing transfer payments between oligopolists. This would involve higher welfare, as consumers are unaffected and the firms save the deadweight loss associated with the costly signalling.

The organization of the article is as follows. Section 2 motivates the discussion by illustrating cases where firms are *ex ante* willing to share information. Section 3 introduces the model and proves that firms will never report truthfully without a mechanism that implements truth telling. Section 4 derives an equilibrium that involves information sharing, where truth telling is a decision variable. The last section contains concluding remarks and possible extensions.

2. The framework

■ This section motivates the discussion by briefly reviewing results in the literature on information sharing and introduces the intuition behind these results. One should remember that all of these models assume the information is transferred exactly according to some agreement and therefore cannot have bias for any reason.

Novshek and Sonnenschein (1982) deal with a Cournot game where firms collect noisy observations about the demand intercept.[3] Before knowing the realizations, each firm can agree to transfer some of its observations to its competitor. The authors show that when the two firms have the same number of observations, they are indifferent between full revelation of private information (i.e., disclosing all their observations) and no sharing at all. If one firm has more observations than the other, it prefers not to share any of its observations.

Gal-Or (1985, 1986) extends this result. Gal-Or (1985) takes uncertain demand in the Cournot setting where each firm gets its noisy signal and can add additional noise, independent of realization, to the signal it sends to its competitor. The only equilibrium in this setting is to add as much noise as possible, which is equivalent to no transfer of information. Gal-Or (1986) uses the same model but extends the results to Bertrand competition and to the case of uncertainty about production cost. She shows that when private information pertains to "common values" (like the demand intercept), firms will share information in a Bertrand game but not in a Cournot game. In contrast, when they have private information

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[3] Unless otherwise mentioned, models in this section assume linear demand functions and constant cost per unit.

about "private value" (like production cost), we have the opposite result: sharing in a Cournot game and no sharing in a Bertrand game. The rationale behind these results is as follows: revealing information about "private value" parameters leads to more uncorrelated output (since each firm plays against the real value and not the expected value of the parameter). In contrast, acting on "common" parameters increases the correlation between the firms' behavior (both see the same demand instead of different noisy versions of this demand). In Cournot competition, competitive firms have downward-sloping reaction curves and hence prefer uncorrelated output, while in Bertrand the reaction curves are upward sloping and more correlation is desired. (The preceding statements are a direct result of the convexity of the profit function with respect to prices.)

Vives (1984) shows that the implicit assumption that products are substitutes drives Gal-Or's results. With complementary goods, the result is reversed.[4] Shapiro (1986) deals with correlated stochastic costs in an oligopoly and shows that in a Cournot setting, higher correlation between costs reduces the benefits from information sharing.[5] Kirby (1988) uses increasing cost per unit to show incentives to share private information even in the case of the Cournot game with a stochastic demand intercept. This expands even more the class of market situations benefiting from information sharing.

All of these articles agree on some cases where firms benefit from sharing information by assuming truth telling. In the next section, I relax the truth-telling assumption and examine the validity of the information sharing.

3. The model

■ This section focuses on the simplest case described in Section 2 with benefits to information sharing, namely two firms in a Cournot game where the private information is about the uncorrelated production cost. Consider a world with two firms that produce the same product. The inverse demand function is given by

$$p = a - Q, \quad \text{where} \quad Q = q_1 + q_2.[6]$$

Each firm has constant cost per unit of production that is randomly distributed, $c_i \sim [\underline{c}_i, \bar{c}_i]$, where $h_i(c_i)$ is the density function and $H_i(c_i)$ is the cumulative distribution (independent of the other firm). I assume that $h_i(c_i) > 0 \ \forall c_i \in [\underline{c}_i, \bar{c}_i]$.

In the first stage, each firm receives its own signal and hence knows its production cost. The second stage is the information transfer. In contrast to the models described in Section 2, I assume here that firms cannot precommit to participate or to follow any agreement on the nature of the information transfer. Each firm either sends a message $m_i \in [\underline{c}_i, \bar{c}_i]$ about the signal it received (which can be different from the true one) or sends no message.[7] In Section 4, I will introduce the costs involved with sending a message.

After each firm gets the other firm's message, they simultaneously produce Cournot quantities in the third stage of the game. To avoid algebraic difficulties I assume that $q_i > 0 \ \forall c_1, c_2.[8]$ The payoffs are the profits in the third stage net of message cost (when applicable).

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[4] Recall that complementary goods imply that the slope of the reaction curve changes sign; hence, one can use the same intuition.

[5] In the extreme case, perfect correlation yields the same result as no sharing, since each firm knows exactly the other firm's cost and hence does not need the signal.

[6] Recall that the unity slope is without loss of generality, since we can choose unit size.

[7] There is no loss of generality in restricting the message space to be a direct one (see Myerson (1982)).

[8] This assumption implies that $a > \max [2\bar{c}_i - \underline{c}_j, 2\bar{c}_j - \underline{c}_i]$.

As benchmarks, I shall show the results of the game in two extreme cases: no information sharing ($m_i = \varnothing \ \forall i$) and perfect truthful information sharing ($m_i = c_i \ \forall i$).

□ **No information sharing.** This case is a traditional Cournot game with private stochastic production costs, where firms cannot share information. The profit function of firm i is

$$\Pi_i = (p - c_i)q_i = (a - q_i - q_j - c_i)q_i. \tag{1}$$

Solving for both firms, we can calculate the profits of the firms:[9]

$$\Pi_{i(p)} = \left(\frac{2a + 2E(c_j) - E(c_i) - 3c_i}{6}\right)\left(\frac{2a - E(c_j) - E(c_i) + 3c_j - 3c_i}{6}\right). \tag{2}$$

The expected profits before the firm knows its production cost are

$$E(\Pi_i)_{(p)} = \int_{\underline{c_i}}^{\bar{c}_i} \int_{\underline{c_j}}^{\bar{c}_j} \Pi_{i(p)} h_i(c_i) h_j(c_j) dc_j dc_i$$

$$= \frac{1}{36} [4a^2 + 4(E(c_j))^2 + 7(E(c_i))^2 + 9E(c_i^2)$$

$$+ 8aE(c_j) - 16aE(c_i) - 16E(c_i)E(c_j)], \tag{3}$$

and the expected profits given the private information are

$$E(\Pi_i \mid c_i)_{(p)} = \int_{\underline{c_j}}^{\bar{c}_j} \Pi_{i(p)} h_j(c_j) dc_j$$

$$= \left(\frac{2a + 2E(c_j) - E(c_i) - 3c_i}{6}\right)^2. \tag{4}$$

□ **Truthful information sharing.** In this case, while production costs are stochastic, realizations are common knowledge. Each firm knows the other firm's cost and hence

$$\Pi_{i(ts)} = \left(\frac{a + c_j - 2c_i}{3}\right)^2, \tag{5}$$

so

$$E(\Pi_i)_{(ts)} = \int_{\underline{c_i}}^{\bar{c}_i} \int_{\underline{c_j}}^{\bar{c}_j} \Pi_{i(ts)} h_i(c_i) h_j(c_j) dc_j dc_i$$

$$= \frac{[a^2 + E(c_j^2) + 2aE(c_j) + 4E(c_i^2) - 4aE(c_i) - 4E(c_i)E(c_j)]}{9} \tag{6}$$

and

$$E(\Pi_i \mid c_i)_{(ts)} = \int_{\underline{c_j}}^{\bar{c}_j} \Pi_{i(ts)} h_j(c_j) dc_j$$

$$= \frac{[(a - 2c_i)^2 + E(c_j^2) + 2aE(c_j) - 4c_i E(c_j)]}{9}. \tag{7}$$

It is easy to calculate the difference between $E(\Pi_i)_{(ts)}$ and $E(\Pi_i)_{(p)}$, which is described in Proposition 1.

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[9] Hereafter I shall use the subscript (p) to denote the private-information case and the subscript (ts) to denote the truthful-sharing case.

Proposition 1 (Gal-Or, 1986). For any nondegenerate distribution of c_1 and c_2, firms strictly prefer truthful transfer to no information sharing.

Proof. $E(\Pi_i)_{(ts)} - E(\Pi_i)_p = \dfrac{4 \operatorname{Var}(c_j) + 7 \operatorname{Var}(c_i)}{36} > 0.$ *Q.E.D.*

Further, the following corollary is immediate:

Corollary 1. The higher the variance of the cost distribution, the higher the benefits of truthful sharing, compared to no sharing at all.

The benefits from truthful sharing can be partitioned into two parts: (i) $\frac{7}{36} \operatorname{Var}(c_i)$ are the benefits to firm i from the message it sends and the changes in the behavior of firm j that this message creates; (ii) $\frac{4}{36} \operatorname{Var}(c_j)$ are the benefits of firm i from the message it receives and the consequent changes in its behavior. Since both terms are always non-negative, we can conclude that each firm prefers to send a truthful message irrespective of whether the other firm does the same or not. In other words, the information transfer is a dominant strategy for both firms.

The preceding analysis was for the first stage of the game, before each firm knows its cost. Once a firm gets private information, its incentives to share it truthfully with its rival change and depend on the signal it received. This is summarized in Proposition 2:

Proposition 2. (i) *Ex post*, each firm has positive benefits from sending a truthful message if and only if its production costs are below their expected value ($c_i < E(c_i)$). (ii) If the demand intercept a is large enough, the benefits are decreasing in c_i.

Proof.
(i) $E(\Pi_i \mid c_i)_{(ts)} - E(\Pi_i \mid c_i)_{(p)}$

$$= \frac{1}{36}[E(c_i) - c_i][4a + 4E(c_j) - 7c_i - E(c_i)] + \frac{4}{36} \operatorname{Var}(c_j). \quad (8)$$

The last term of the right-hand side represents the benefits from receiving the message. Now, $[4a + 4E(c_j) - 7c_i - E(c_i)] > 0$, since $a > 2\bar{c}_i - \underline{c}_j$; hence, the sign of the first term is the same as that of $[E(c_i) - c_i]$.

(ii) Take the derivative of equation (8) with respect to c_i:

$$\frac{\partial[8]}{\partial c_i} = \frac{-[4a + 4E(c_j) - 7c_i - E(c_i)] - 7(E(c_i) - c_i)}{36}.$$

$E(c_i) > c_i \Rightarrow$ both terms are negative. $E(c_i) < c_i \Rightarrow \dfrac{\partial[8]}{\partial c_i}$ can have either sign, but if the demand intercept a is "large enough" the sum will be negative.   *Q.E.D.*

Let c_i^* be the minimum between $\bar{c}_i$ and c_i that solves the equation

$$E(\Pi_i \mid c_i)_{(ts)} = E(\Pi_i \mid c_i)_{(p)}.$$

The benefits from truthful information sharing are: (1) If $c_i < E(c_i)$, firm i has positive benefits independent of whether firm j sends a message. (2) If $E(c_i) < c_i < c_i^*$, such positive benefits are conditional on receiving firm j's message. (3) If $c_i^* < c_i$, firm i loses by sending a truthful signal.

Given this benchmark, we can return to the information-sharing stage with unrestricted messages, so each firm can send any cost message and is not confined to the truth.

Let $g_i = E(c_i \mid m_i)$ be the conditional expected cost of firm i given the message it sends, calculated by firm j. We do not require that firm j believes the message it gets or makes any change in its beliefs of firm i's cost.

In this case

$$q_i(c_i) = \frac{a - 2c_i + g_j + q_i(g_i)}{4}, \qquad (9)$$

where $q_i(g_i)$ is the quantity that firm j thinks that firm i will produce given the message it received. Since the profit function is quadratic, we can use Radner's (1962) results and deal with linear strategies: $q_i(c_i) = \delta a + \alpha c_i + \beta g_i + \gamma g_j$. But firm j does not know c_i, so it takes it as g_i and hence $q_i(g_i) = \delta a + (\alpha + \beta)g_i + \gamma g_j$. Equate the coefficients and use equation (9) to conclude

$$q_i = \frac{2a - 3c_i - g_i + 2g_j}{6}, \qquad (10)$$

and

$$\Pi_i = \left(\frac{2a + 3c_j - g_i - g_j - 3c_i}{6}\right)\left(\frac{2a - 3c_i - g_i + 2g_j}{6}\right) \qquad (11)$$

is the payoff of the game.

Given this, we can prove the main result of this section:

Proposition 3. Firms will never voluntarily share their true information.

Proof. It is clear that $g_i \in [\underline{c}_i, \bar{c}_i]$. Now

$$\frac{\partial \Pi_i}{\partial g_i} = \frac{-4a - 3c_j + 6c_i + 2g_i - g_j}{36} < 0 \qquad \forall c_i, c_j, g_i, g_j,$$

which is an immediate consequence of our assumption that $a \geq 2\bar{c}_i - \underline{c}_j$. Hence Π_i is maximized when $g_i = \underline{c}_i$. Q.E.D.

This proposition is significant, and it gives the motivation for this article. We must have some way to convince the other firm that the information is correct, but given Proposition 3 this cannot be done without another mechanism that enforces truth telling. Given the problems I discussed with respect to outside verification mechanisms, I derive in the next section a mechanism that transfers information truthfully, and hence succeeds in convincing the other firm about the true value of c.

4. Truth-telling equilibria

■ In this section I find the unique equilibrium class that induces truth telling from all firms. The solution involves consistent beliefs of each firm about the other firm's behavior. Then I reduce this equilibrium class to a unique solution.

After the first stage of the game, each firm has its private information and is ready to announce it. In sending its message, it has to take into account its implications both in the second stage (information transfer and forming of beliefs) and in the third stage (production). We know from Proposition 3 that the firm has incentives to convince its rival that it has the lowest possible cost realization. This implies that in order to induce the firm to send the (truthful) higher message, it must be compensated in some other place, or it must incur other costs when announcing low production costs. I do this by introducing a cost to send a message, which is a function of the message content.

Define $f_i(m_i)$ as the amount that firm i "pays" when sending message m_i. By introducing the message to the game we are dealing with a signalling game, where the cost to send a message is the signalling cost. Now a firm does not have to send an explicit message. By spending money in the amount of $f_i(m_i)$, its rival will calculate that the cost is c_i. This spending can be observed in uninformative advertising, charity expenses, etc. (see Milgrom and Roberts (1986)).

Including this payment in the profit function, we get

$$\Pi_i(c_i, m_i, c_j, m_j)$$

$$= \left(\frac{2a + 3c_j - g_i(m_i) - g_j - 3c_i}{6}\right) \cdot \left(\frac{2a - 3c_i - g_i(m_i) + 2g_j(m_j)}{6}\right) - f_i(m_i). \quad (12)$$

This term is maximized when

$$\frac{\partial \Pi_i(c_i, m_i, c_j, m_j)}{\partial m_i} = \frac{-36f'_i(m_i) + \frac{\partial g_i}{\partial m_i}[-4a - 3c_j + 6c_i + 2g_i - g_j]}{36} = 0.$$

Now since the information transfer is simultaneous, firm i does not yet know m_j and hence $g_j = E(c_j)$. Integrating the last equation with respect to c_j, we can write

$$-f'_i(m_i) = \frac{\partial g_i}{\partial m_i}\left[\frac{a + E(c_j) - \frac{1}{2}g_i - \frac{3}{2}c_i}{9}\right].$$

In order to induce truthful transfer, we must have $g_i = c_i$. This can be achieved when $m_i = c_i$ and hence $\frac{\partial g_i}{\partial m_i} = 1$,[10] so $-f'_i(m_i) = \frac{a + E(c_j) - 2c_i}{9}$. Integrate it to get

$$f_i(m_i) = \int_{\underline{c}_i}^{c_i} f'_i(m_i)dc_i + f_i(\underline{c}_i) = \frac{-[(a + E(c_j))(c_i - \underline{c}_i) - (c_i - \underline{c}_i)^2]}{9} + f_i(\underline{c}_i). \text{ Use}$$

again $m_i = c_i$ to get $f_i(m_i) = \dfrac{-[(a + E(c_j))(m_i - \underline{c}_i) - (m_i - \underline{c}_i)^2]}{9} + f_i(\underline{c}_i)$.

The next step is to find a value for $f_i(\underline{c}_i)$. It is easy to see that $f_i(\bar{c}_i)$ must be nonpositive. Assuming the contrary, a firm with a cost of $\bar{c}_i$ will be better off by not sending the signal, since the assessment of its cost by the other firm will be no more than $\bar{c}_i$ and it will save the signal cost. If we interpret f_i as a real monetary payment, it is clear that it must be nonnegative. So we are left with a unique value of zero for the message cost of the highest-cost firm. Adding this requirement to the last equation yields a unique solution for the problem:

$$f_i(m_i) = \frac{(a + E(c_j))(\bar{c}_i - m_i) + (m_i - \underline{c}_i)^2 - (\bar{c}_i - \underline{c}_i)^2}{9}, \quad (13)$$

and every firm pays a positive amount as long as it has a better realization than the worst one.

It is important to observe the major difference between this solution and those proposed in the literature. While in essentially all the other articles there is truthful information sharing, only in the current study is truthful information sharing the firm's best response. In all of the articles referred to above, the information sharing results from *ex ante* gains (before firms learn their production costs) and is facilitated by assuming an exogenous mechanism that implements the communication and preserves the equilibrium from strategic behavior of firms (after they observed their private information). Here we get the information-sharing result as part of the equilibrium strategy. Each firm sends its true cost realization because this maximizes its profits. Any misleading report will decrease the firm's profits. Consequently, each firm finds the other firm's report to be credible, and uses it to determine production level.

The mechanism proposed above involves costs to the firms. It is natural at this point to compare the benefits (from information sharing) to the signalling costs. Unfortunately,

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[10] One can generally have $m_i = m_i(c_i)$ for m_i monotone and continuous. In such a case, $\frac{\partial g_i}{\partial m_i}$ and $f'_i(m_i)$ will change but not their ratio, so the actual payment remains the same (see footnote 7).

the answer is ambiguous. One can identify nontrivial cases where the benefits exceed the costs and vice versa.

I first derive necessary and sufficient conditions for the benefits to exceed the costs. After a short discussion of these conditions, I consider the opposite case, where the signalling costs exceed information sharing's benefits. I connect this case to the signalling literature and propose a modification to the mechanism, which significantly reduces signalling costs while leaving the benefits level intact.

Proposition 4. (i) The benefits for firm i from information sharing exceed the signalling costs if and only if

$$3 \text{ Var}(c_i) + 4 \text{ Var}(c_j) + 4(\bar{c}_i - E(c_i))(\bar{c}_i + E(c_i) - a - E(c_j) - 2\underline{c}_i) \geq 0.$$

(ii) Similarly, the sum of the benefits to both firms exceeds the sum of the signalling costs if and only if

$$7 \text{ Var}(c_i) + 7 \text{ Var}(c_j) + 4(\bar{c}_i - E(c_i))(\bar{c}_i + E(c_i) - a - E(c_j) - 2\underline{c}_i)$$
$$+ 4(\bar{c}_j - E(c_j))(\bar{c}_j + E(c_j) - a - E(c_i) - 2\underline{c}_j) \geq 0.$$

Proof. (i) We know from Section 3 that the expected profits to firm i from information sharing are

$$\frac{7 \text{ Var}(c_i) + 4 \text{ Var}(c_j)}{36}.$$

Now

$$E[f_i(m_i)] = \frac{(a + E(c_j) + 2\underline{c}_i)(\bar{c}_i - E(c_i)) + E(c_i^2) - \bar{c}_i^2}{9}.$$

Simple algebraic manipulation yields the expression of the proposition.

(ii) Add the terms for firm i and firm j.   Q.E.D.

The benefits from information sharing depend only on production-cost variances, while the expected payment, $E[f_i(m_i)]$, depends also on the demand intercept a. Consequently, a necessary condition for the benefits to exceed the costs is a relatively low demand intercept. This means that the firms operate on the flexible portion of the demand function.

A second requirement is that the distribution of production costs is skewed toward the costs' upper bound $(\bar{c}_i)$. This implies that in most cases the signalling costs are very low (as they are zero at $c_i = \bar{c}_i$). High signalling costs appear only in the relatively rare cases where the costs are low.[11]

In other cases where the above conditions are not satisfied, the additional costs involved in eliciting the truth exceed the savings involved in information sharing. This kind of result is not surprising. It is common in the signalling literature for all player types in a signalling equilibrium to be worse off relative to the no-signalling (pooling) equilibrium (see Spence (1973)). But this does not eliminate the signalling equilibrium. The equilibrium can be supported if all firms' beliefs are the following: the amount of money firm i spends is firm j's signal of firm i's cost, and vice versa. Given such beliefs, firm i will spend according to $f_i(m_i)$ even though it may cost more than the benefits, since no spending implies $\bar{c}_i$ and even more cost.[12]

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[11] For example, if both firms have the following identical cost distribution (I use a binary distribution for illustration purposes): $\underline{c} = 0$ with probability $1 - P$, $\bar{c} = 100$ with probability P, and $a = 200$, then for any $P > \frac{4}{7}$ the benefits from information sharing exceed the signalling costs for both firms.

[12] This possibility is in line with the results in Melumad and Reichelstein (1989). They show, in a very different setting, that the truth-telling restriction may be "too expensive" and hence the communication equilibrium cannot dominate the no-communication equilibrium.

The next proposition demonstrates a case where both firms prefer the private-information case to truthful information sharing with the message costs.

Proposition 5. If both firms have symmetric distributions of costs with the same lower and upper bounds, then the expected payment will always be greater than the expected benefits from sharing.

Proof. The expected profits from the combined action are

$$E(\Delta\Pi_i) = \frac{4 \text{ Var } (c_j) + 7 \text{ Var } (c_i)}{36} - E(f_i(m_i)).$$

By the assumptions in the proposition, $E(c_i) = E(c_j) = \frac{\underline{c} + \bar{c}}{2}$ and $E(c_i^2) \leq \frac{1}{2}(\underline{c}^2 + \bar{c}^2)$,

so

$$E(\Delta\Pi_i) \leq \frac{23}{4} \underline{c}^2 + \frac{15}{4} \bar{c}^2 - \frac{38}{4} \underline{c}\bar{c} - 2a(\bar{c} - \underline{c})$$

$$= \left(\frac{15}{4} \bar{c} - \frac{23}{4} \underline{c} - 2a \right) (\bar{c} - \underline{c}) < 0.$$

The last inequality is arrived at by using $\bar{c} > \underline{c}$ and $a \geq 2\bar{c} - \underline{c}$.   *Q.E.D.*

An alternative way to achieve the information transfer without the high signalling cost is by a direct payment from each firm to its competitor when it sends a message. In such a case, we have the same properties of the information transfer, but each firm receives the other firm's payment (which is not related to the signal it sends and hence does not change incentives), which compensates it for some of the cost involved in sending its signal. As a result, one can have the (truthful) information-sharing equilibrium without the signalling costs. The expected cost in the symmetric firms' case is zero.

The legality of such transactions is questionable.[13] The implications of the legality problem are that one cannot observe such transactions directly. An alternative means for the firms to achieve information sharing is to spend the money on activities that may benefit them (but where the marginal cost exceeds the marginal benefit; otherwise they would do it before and not as a signal), like joint advertising. For the mechanism to work, one needs to subtract the value of the benefits the firm receives from its signal, hence the costs of signalling are not altered. However, it is not unusual to see very complicated transactions that may occur in order to hide an illegal transaction between two firms. Simplifying these transactions may show that the firms are just transferring information through such payments. In order to transfer x amount of money from firm i to firm j, firm i buys from firm j worthless assets in the amount of x dollars, and vice versa. If the firms have an agreement (even implicit) about dual purchases and form the corresponding beliefs, then they all have incentives to pay (and receive) the amounts related to the corresponding values of private information. This can be done even without an agreement, since the incentives to share the information are independent of the other firm's participation.

An interesting normative implication is that when a regulator cannot prevent information sharing, he might consider allowing transfer payments between oligopolists. This would involve higher welfare, as consumers are unaffected and the firms save the deadweight loss associated with the costly signalling. I do not recommend here that a regulator should give up antitrust laws, since in such a case the oligopolistic firms may create a monopoly or cartel resulting in consumers' welfare reduction. The cartel problem may explain why the regulator does not allow a contract-based relationship in spite of the potential benefit

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[13] By antitrust laws, oligopolists cannot collude, negotiate, or correlate behavior.

in allowing transfer payments. Such contracts may lead to monopolistic behavior. Further, allowing reciprocal transfer payments may make it more difficult for new firms to enter the industry, and this could reduce consumer welfare.

5. Conclusions

■ Communication of private information can increase the profits of all firms in the market, and consequently firms will try to cooperate and share this information. Unfortunately, this transfer cannot be done without a truth-telling mechanism, since firms can earn even higher benefits by claiming to be stronger than they really are. This article has shown, by constructing an equilibrium in a signalling game, that we can get truth telling—and hence the benefits of private information sharing—as part of the firm's chosen strategies and without using third parties, assumed to be nonstrategic, like trade associations. The cost of signalling by "burning money" may be higher or lower than the benefits from the information sharing. This leads me to propose a less costly mechanism to transfer the information, such as transfer payments between firms.

   A possible extension to the model is to restrict firms to behave according to the message they send. In this case the benefits from sending a false message are smaller, since the forced production is not optimal. In some examples, this last requirement is sufficient to induce truth telling. Another possibility is a sequential information transfer. I model simultaneous information transfer, so each firm does not know its rival's cost when sending the cost message. In a two-stage transfer, the sequence of events is as follows: first, firm i sends a message to firm j, and only after that, knowing firm i's cost, does firm j make its optimal decision for the message it sends. In this case we have to make the following adjustments: (1) The second firm knows exactly what the competitor's cost is, and hence its payment function $f_j(m_j)$ should include c_j instead of $E(c_j)$. (2) Since the payments of the second firm depend on the value of the first firm's announcement, we need to add this influence to the first announcer's payment function.

References

AKERLOF, G.A. "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism." *Quarterly Journal of Economics,* Vol. 84 (1970), pp. 488–500.

ANTLE, R. "The Auditor as an Economic Agent." *Journal of Accounting Research,* Vol. 20 (1982), pp. 503–527.

BAIMAN, S., EVANS, J.H., AND NOEL, J. "Optimal Contracts with Utility-Maximizing Auditor." *Journal of Accounting Research,* Vol. 25 (1987), pp. 217–244.

CLINCH, G. "Information Sharing in Oligopoly with No Commitment." Mimeo, Graduate School of Business, Stanford University, 1986.

GAL-OR, E. "Information Sharing in Oligopoly." *Econometrica,* Vol. 53 (1985), pp. 329–343.

———. "Information Transmission—Cournot and Bertrand Equilibria." *Review of Economic Studies,* Vol. 53 (1986), pp. 85–92.

KIRBY, A.J. "Trade Associations as Information Exchange Mechanisms." *RAND Journal of Economics,* Vol. 19 (1988), pp. 138–146.

MELUMAD, N.D. AND REICHELSTEIN, S. "Value of Communication in Agencies." *Journal of Economic Theory,* Vol. 47 (1989), pp. 334–368.

MILGROM, P. AND ROBERTS, J. "Price and Advertising Signals of Product Quality." *Journal of Political Economy,* Vol. 94 (1986), pp. 796–821.

MYERSON, R.B. "Optimal Coordination Mechanisms in Generalized Principal-Agent Problems." *Journal of Mathematical Economics,* Vol. 10 (1982), pp. 67–81.

NOVSHEK, W. AND SONNENSCHEIN, H. "Fulfilled Expectations Cournot Duopoly with Information Acquisition and Release." *Bell Journal of Economics,* Vol. 13 (1982), pp. 214–218.

RADNER, R. "Team Decision Problems." *Annals of Mathematical Statistics,* Vol. 33 (1962), pp. 857–881.

ROTHSCHILD, M. AND STIGLITZ, J.E. "Equilibrium in Competitive Insurance Markets, an Essay on the Economics of Imperfect Information." *Quarterly Journal of Economics,* Vol. 90 (1976), pp. 630–649.

SHAPIRO, C. "Exchange of Cost Information in Oligopoly." *Review of Economic Studies,* Vol. 53 (1986), pp. 433–446.

SPENCE, A.M. "Job Marketing Signaling." *Quarterly Journal of Economics,* Vol. 87 (1973), pp. 355–374.

VIVES, X. "Duopoly Information Equilibrium: Cournot and Bertrand." *Journal of Economic Theory,* Vol. 34 (1984), pp. 71–94.