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BEYOND THE NEED TO BOAST: COST CONCEALMENT INCENTIVES AND EXIT IN COURNOT OLIGOPOLY

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Beyond the Need to Boast: Cost Concealment Incentives and Exit in Cournot Oligopoly*

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Abstract

This paper studies the incentives for production cost disclosure in an asymmetric Cournot oligopoly. Whereas the efficient firm (consumers) prefers information sharing (concealment) when the firms choose accommodating strategies in the product market, the firm (consumers) may prefer information concealment (sharing) when it can exclude its competitors from the market. Hence, the rankings of expected profit and consumer surplus can be reversed if exit of the inefficient firms is possible. Although the efficient firm has stronger incentives to share information when it shares strategically, there remain cases in which the firm conceals information in equilibrium to induce exit.

Keywords: Cournot oligopoly, information disclosure, exit, cost asymmetry, precommitment
JEL Codes: D82, L13

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1 Introduction

Non-colluding Cournot competitors have an incentive to share information about independent production costs, if they use accommodating output strategies in the product market (Fried, 1984, Gal-Or, 1986, and Shapiro, 1986). In this case, information sharing decreases the expected consumer surplus (Shapiro, 1986). Recently, Amir *et al.* (2010) show that these results are driven by the assumption that information is firm-specific.

Whereas the effects of information sharing between accommodating firms are extensively analyzed, the effects of information sharing by a dominant firm are less clear. In this regard, the OECD sees a potential benefit from information sharing: "Increased market transparency may also facilitate entry into the market for new competitors in that it allows potential entrants to better evaluate business opportunities in a given sector." (OECD, 2011, p. 11). Also the Office of Fare Trading in the United Kingdom considers that information sharing by insurance companies may have the pro-competitive effect of facilitating entry (OFT, 2011).[1]

This paper confirms that information sharing by a dominant firm can have pro-competitive effects. Thereby, I show that the aforementioned theoretical results depend on the presumption that firms use accommodating strategies in the product market. The previous results may be reversed when firms do not always use accommodating strategies. If a firm's average technology is sufficiently productive to exclude competitors from the market, then the firm no longer has an incentive to share cost information. In such a case a firm with below-average costs will be indifferent between information sharing and information concealment, since in any case the firm excludes its competitors from the market. A firm with high costs may strictly prefer to conceal its cost, since it avoids sharing the market with the competitors by doing so.

If cost concealment yields market exclusion, then it may be harmful for consumers, since it raises the average price, and eliminates product variety. In this case information sharing would make consumers better off on average.

In short, the profit and surplus rankings may be reversed if exclusionary outputs are feasible for a firm. As a consequence, the antitrust policy towards information sharing by firms in industries with a dominant firm could differ from the policy for

[1] On the other hand, there is a concern that information sharing can create a barrier to entry. Armatier and Richard (2003) give examples of these policy concerns in the tractor trade association in the UK, and in business-to-business market places in the US. However, these concerns typically relate to the exclusion of potential entrants from an information-sharing agreement.

industries without a dominant firm.

Armantier and Richard (2003) analyze a related problem. Armantier and Richard often rely on numerical simulations to study the effects of precommitment to information sharing, whereas I focus on analytical results. In addition, I also consider the incentives to strategically disclose information. This enhances the paper's relevance.

The paper is organized as follows. In the next section I describe the model. The third section presents the equilibrium output levels. In section 4, I compare the expected profit and the expected consumer surplus under information sharing and concealment. Section 5 analyzes the incentives of a firm that discloses information strategically. Finally, section 6 concludes the paper. The proofs of the propositions are relegated to the Appendix.

2 The Model

Consider $N+1$ risk-neutral firms playing a three-stage game (for $N \geq 1$). Firm 0 is the dominant firm, and firms $1, ..., N$ form a fringe of small symmetric firms. In the first stage, before firm 0 privately learns its cost, the firm chooses whether to share the cost information, i.e., $d(\theta_0) = \theta_0$ for all $\theta_0 \in [\underline{\theta}, \overline{\theta}]$, or to keep it secret and send an uninformative message, i.e., $d(\theta_0) = \varnothing$ for all $\theta_0 \in [\underline{\theta}, \overline{\theta}]$.[2]

Subsequently, in the second stage, firm 0 privately draws a cost $\theta_0 \in [\underline{\theta}, \overline{\theta}]$ from p.d.f. $f : [\underline{\theta}, \overline{\theta}] \to \mathbb{R}_+$ (and corresponding c.d.f. $F : [\underline{\theta}, \overline{\theta}] \to [0, 1]$) with full support (i.e., $f(\theta_0) > 0$ for all $\theta_0 \in [\underline{\theta}, \overline{\theta}]$), and discloses or conceals the cost parameter in accordance with the first-stage choice. The unit cost of the fringe firms, θ_1, is common knowledge.

Finally, in the third stage, the firms simultaneously choose their output levels, $x_i \geq 0$ for firm i with $i = 0, 1, .., N$ (Cournot competition).

The representative consumer's utility from consuming bundle $(x_0, ..., x_N)$ is:

$$U(x_0, ..., x_N) \equiv \alpha \sum_{\ell=0}^{N} x_\ell - \frac{1}{2}\left(\sum_{\ell=0}^{N} x_\ell\right)^2 + \frac{1}{2}(1-\beta) \sum_{\ell=0}^{N} x_\ell \sum_{k \neq \ell} x_k. \qquad (1)$$

Hence, the inverse demand for the good of firm i is linear, i.e. $P_i(x_0, ..., x_N) = \alpha - x_i - \beta \sum_{j \neq i} x_j$, where $i, j = 0, 1, ..., N$. Parameter β represents the degree of

[2] The assumptions that firms precommit to an information sharing rule, and that information is verifiable, are common in the literature on oligopolistic information sharing (e.g., see Vives, 1999). Adopting the same assumptions facilitates the comparison with existing results. Section 5 analyzes the extension where firm 0 makes the information sharing choice *after* it learns the cost realization.

product substitutability, with $0 < \beta \leq 1$. The profit of firm i with cost θ_i is (for $i, j = 0, 1, ..., N$):

$$\pi_i(x_0, ..., x_N; \theta_i) = \left(\alpha - x_i - \beta \sum_{j \neq i} x_j - \theta_i \right) x_i. \tag{2}$$

The consumer surplus from consumption of $(x_0, ..., x_N)$ equals:

$$S(x_0, ..., x_N) = \frac{1}{2} \left(\sum_{\ell=0}^{N} x_\ell \right)^2 - \frac{1}{2}(1 - \beta) \sum_{\ell=0}^{N} x_\ell \sum_{k \neq \ell} x_k \tag{3}$$

The parameter values should satisfy the following conditions:

$$3\alpha > 4\overline{\theta} - \underline{\theta} \tag{4}$$

and

$$\widetilde{\theta}(\underline{\theta}) < \theta_1 < \widetilde{\theta}(\overline{\theta}) \tag{5}$$

where (for $\theta_0 \in [\underline{\theta}, \overline{\theta}]$) $\widetilde{\theta}$ is defined as

$$\widetilde{\theta}(\theta_0) \equiv \frac{1}{2}\Big((2 - \beta)\alpha + \beta\theta_0 \Big) \tag{6}$$

Conditions (4)-(5) guarantee that firm 1 is always active in the market. Condition (5) guarantees that exclusion of fringe firms happens in some but not all of the cases.[3]

I solve the game backwards, and restrict the analysis to perfect Bayesian equilibria.

3 Output Strategies

Distinguish two cases. First, suppose that firm 0 shares information. Profit-maximization by firm i gives the following first-order condition (for $i, j = 0, 1, ..., N$):

$$x_i(x_{-i}; \theta_i) = \begin{cases} \frac{1}{2}\left(\alpha - \theta_i - \beta \sum_{j \neq i} x_j \right), & \text{if } 0 \leq \sum_{j \neq i} x_j \leq \frac{1}{\beta}(\alpha - \theta_i) \\ 0, & \text{otherwise} \end{cases} \tag{7}$$

Firms 0 and $1, ..., N$ choose the following output levels in equilibrium (for $\theta_0 \in [\underline{\theta}, \overline{\theta}]$):

$$x_0^*(\theta_0, \theta_1) = \begin{cases} x_0^c(\theta_0, \theta_1), & \text{if } \theta_1 \leq \widetilde{\theta}(\theta_0) \\ x^m(\theta_0), & \text{if } \theta_1 > \widetilde{\theta}(\theta_0) \end{cases} \tag{8}$$

[3] By contrast, if $\theta_1 \leq \widetilde{\theta}(\underline{\theta})$, then all firms choose accomodating output strategies, and firm 0 shares all information in the unique equilibrium (Shapiro, 1986). Further, if $\theta_1 \geq \widetilde{\theta}(\overline{\theta})$, then firm 0 is indifferent between information sharing and concealment, since firms $1, ..., N$ always exit.

and

$$x_1^*(\theta_1,\theta_0) = ... = x_N^*(\theta_1,\theta_0) = \begin{cases} x_1^c(\theta_1,\theta_0), & \text{if } \theta_1 \leq \widetilde{\theta}(\theta_0) \\ 0, & \text{if } \theta_1 > \widetilde{\theta}(\theta_0) \end{cases} \tag{9}$$

where the oligopoly and monopoly outputs are defined as

$$x_0^c(\theta_0,\theta_1) \equiv \frac{1}{(2-\beta)(2+\beta N)}\Big((2-\beta)(\alpha-\theta_0)+\beta N(\theta_1-\theta_0)\Big) \tag{10}$$

$$x_1^c(\theta_1,\theta_0) \equiv \frac{1}{(2-\beta)(2+\beta N)}\Big((2-\beta)(\alpha-\theta_1)+\beta(\theta_0-\theta_1)\Big) \tag{11}$$

$$x^m(\theta_0) \equiv \frac{1}{2}(\alpha-\theta_0) \tag{12}$$

Second, if firm 0 conceals information, then firms $1,...,N$ expect the cost $E\{\theta_0\}$ of firm 0. Profit-maximization by firm 0 gives the best-response function (7) for $i=0$. The best-responses of firms $1,...,N$ are as in (7) with x_0 replaced by $E\{x_0(\theta_0)\}$. After concealment the equilibrium output levels of firms 0 and $1,...,N$ are, respectively:

$$x_0^o(\theta_0,\theta_1;E\{\theta_0\}) = \begin{cases} x_0^c(\theta_0,\theta_1) + \frac{\beta^2 N(\theta_0 - E\{\theta_0\})}{2(2-\beta)(2+\beta N)}, & \text{if } \theta_1 \leq \widetilde{\theta}(E\{\theta_0\}) \\ x^m(\theta_0), & \text{if } \theta_1 > \widetilde{\theta}(E\{\theta_0\}) \end{cases} \tag{13}$$

and $x_j^o(\theta_1;E\{\theta_0\}) \equiv x_j^*(\theta_1,E\{\theta_0\})$ with x_1^* as in (9) for $j=1,...,N$.[4]

In any situation the expected equilibrium product market profit is: $\pi_i^k(\cdot) = x_i^k(\cdot)^2$.

4 Information Sharing

In this section I analyze how information sharing affects the profit of firm 0, and the consumer surplus.

4.1 Profit

Now I solve the first stage of the game where firm 0 chooses whether to share or conceal information about its cost θ_0 (before it learns the cost).

The expected profit from precommitment to information sharing equals:

$$\Pi_0^*(\theta_1) = \int_{\underline{\theta}}^{\widetilde{\theta}^{-1}(\theta_1)} \pi^m(y)dF(y) + \int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}} \pi_0^c(z,\theta_1)dF(z) \tag{14}$$

where $\widetilde{\theta}^{-1}(\theta_1) \equiv [2\theta_1 - (2-\beta)\alpha]/\beta$ is the inverse of $\widetilde{\theta}(\cdot)$. Fringe firms condition their output choices on information about the cost of firm 0. If firm 0 is relatively efficient

[4] Notice that there exists no equilibrium in which some fringe firms set positive output levels while other fringe firms exit. This result is due to the symmetry among the fringe firms.

(i.e., $\theta_0 \leq \widetilde{\theta}^{-1}(\theta_1)$), then firms $1, ..., N$ exit, and firm 0 earns the monopoly profit π^m. If, on the other hand, firm 0 is less efficient (i.e., $\theta_0 > \widetilde{\theta}^{-1}(\theta_1)$), then the firms choose accommodating output strategies, and firm 0 earns the oligopoly profit π_0^c.

The expected profit from concealment equals:

$$\Pi_0^o(\theta_1) = \begin{cases} E\left\{\left(x_0^c(\theta_0, \theta_1) + \frac{\beta^2 N(\theta_0 - E\{\theta_0\})}{2(2-\beta)(2+\beta N)}\right)^2\right\}, & \text{if } \widetilde{\theta}(\underline{\theta}) \leq \theta_1 < \widetilde{\theta}(E\{\theta_0\}) \\ E\{\pi^m(\theta_0)\}, & \text{if } \widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta}) \end{cases} \quad (15)$$

After information concealment, a fringe firm cannot condition its output on the actual cost of firm 0, but needs to rely on the expected cost. If a fringe firm's cost is sufficiently low in comparison with firm 0's average cost (i.e., $\theta_1 < \widetilde{\theta}(E\{\theta_0\})$), then the firms choose accommodating outputs, and firm 0 earns (distorted) oligopoly profits for all cost parameters $\theta_0 \in [\underline{\theta}, \overline{\theta}]$. If the cost θ_1 is equal to or above $\widetilde{\theta}(E\{\theta_0\})$, then fringe firms exit the market and firm 0 earns the monopoly profit for all cost parameters θ_0.

The comparison of (14) and (15) gives the following result.

Proposition 1 *There exists a critical cost level θ^o, with $\widetilde{\theta}(\underline{\theta}) < \theta^o < \widetilde{\theta}(E\{\theta_0\})$, such that firm 0 conceals information in equilibrium if and only if $\theta^o < \theta_1 < \widetilde{\theta}(\overline{\theta})$.*

This result has a simple intuition. If the cost of fringe firms is sufficiently high (i.e., $\theta_1 \geq \widetilde{\theta}(E\{\theta_0\})$), then firm 0 earns the monopoly profit for any cost parameter θ_0 by choosing cost concealment, since concealment induces exit of firms $1, ..., N$. Firm 0 expects a lower profit from information sharing, since it cannot always exclude fringe firms from the market under information sharing. In particular, the firm earns oligopoly profits after it shares information about relatively high costs, i.e., $\theta_0 > \widetilde{\theta}^{-1}(\theta_1)$. Therefore, the firm prefers cost concealment.

If the fringe firm's cost is lower than $\widetilde{\theta}(E\{\theta_0\})$, then firm 0 faces the following trade-off. On the one hand, information sharing makes fringe firms more "aggressive" competitors (i.e., $x_1^*(\theta_1; \theta_0) > x_1^o(\theta_1; E\{\theta_0\})$), if $\theta_0 > E\{\theta_0\}$. On the other hand, fringe firms become less "aggressive" in the product market after information sharing, i.e., $x_1^*(\theta_1; \theta_0) < x_1^o(\theta_1; E\{\theta_0\})$, if $\theta_0 < E\{\theta_0\}$. The gain from information sharing is truncated, since fringe firms exit the market when firm 0 has the lowest cost parameters (i.e., $\theta_0 \leq \widetilde{\theta}^{-1}(\theta_1)$). Therefore, the former effect outweighs the latter, if θ_1 is sufficiently close to $\widetilde{\theta}(E\{\theta_0\})$.

Proposition 1 contributes in the following way to the literature on information sharing in oligopoly (e.g., Fried, 1984, Gal-Or, 1986, and Shapiro, 1986). The literature finds that a firm has an incentive to share information when the firms choose accommodating strategies. This result also emerges here if the cost of fringe firms is very low (i.e., $\theta_1 \leq \widetilde{\theta}(\underline{\theta})$). Proposition 1 shows that the result extends to settings where fringe firms are slightly less efficient and exit in a few cases (i.e., $\widetilde{\theta}(\underline{\theta}) < \theta_1 \leq \theta^o$). By contrast, firm 0 has an incentive to conceal information when exit matters most, as the proposition shows for $\theta_1 > \theta^o$. In other words, the profit ranking of a firm that induces exit can differ dramatically from the ranking of a firm that uses accommodating output strategies in the product market.

Figure 1 illustrates the effects of information sharing through the equilibrium outputs in a duopoly ($N = 1$). The thin lines are the best response curves of firm 0. The bold lines are the best response curves of firm 1. First, Figure 1(a) illustrates the effects for accommodating firms. Information disclosure enables firm 1 to adjust its output levels to the actual efficiency level of firm 0. The equilibrium outputs lie along the line A-B. For example, if firm 0 discloses the highest (lowest) cost level, then the equilibrium is reached in point A (B). After cost concealment, firm 1 sets output level x_1^o, which is the best response to firm 0's expected output level (point E). Firm 0's best response to output level x_1^o gives equilibrium output levels along the line C-D. Information sharing increases firm 0's expected profit, since it creates a mean-preserving spread, and profits are convex in the firm's output level.

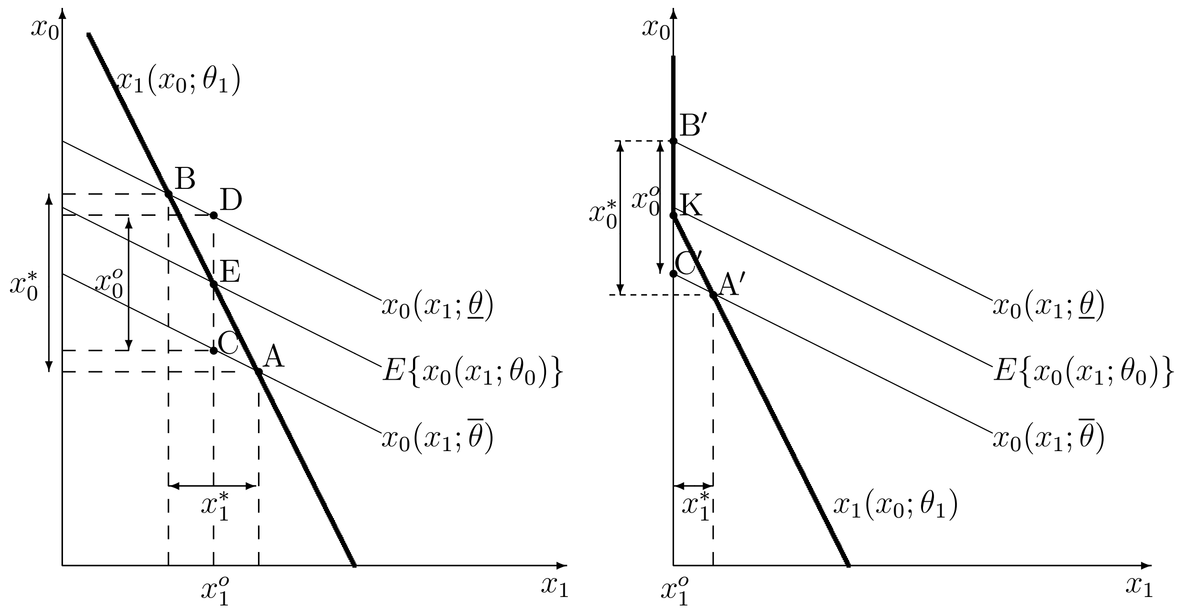

Fig. 1(a): Accommodation Fig. 1(b): Exclusion

Figure 1: Effects of information sharing

Second, Figure 1(b) illustrates the effects of information sharing when firm 0 can exclude its competitor from the market if θ_0 is low. Again, disclosure yields some output adjustments by firm 1, i.e., the firms set equilibrium outputs along the kinked line A′-K-B′. Firm 1's output adjustments create a spread of firm 0's output levels corresponding to the vertical distance between A′ and B′. Information concealment excludes firm 1 from the market (i.e., $x_2^o = 0$), and creates a smaller spread of firm 0's outputs (i.e., outputs along the line B′-C′). Even tough information sharing creates a bigger output spread for firm 0, it does not increase the firm's expected profit. This happens since information disclosure does not preserve the mean of firm 0's output, but reduces it.

4.2 Consumer Surplus

The comparison of consumer surplus under full and no information sharing is similar. The consumer surplus under information sharing equals:[5]

$$S^*(\theta_1) = \int_{\underline{\theta}}^{\widetilde{\theta}^{-1}(\theta_1)} S\left(x^m(y), 0\right) dF(y) + \int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}} S\left(x_0^c(z, \theta_1), N x_1^c(\theta_1, z)\right) dF(z) \quad (16)$$

The consumer surplus under information concealment equals:

$$S^o(\theta_1) = \begin{cases} E\left\{S\left(x_0^c(\theta_0, \theta_1) + \frac{\beta^2 N(\theta_0 - E\{\theta_0\})}{2(2-\beta)(2+\beta N)}, N x_1^c(\theta_1, E\{\theta_0\})\right)\right\}, & \text{if } \widetilde{\theta}(\underline{\theta}) \leq \theta_1 < \widetilde{\theta}(E\{\theta_0\}) \\ E\left\{S\left(x^m(\theta_0), 0\right)\right\}, & \text{if } \widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta}) \end{cases} \quad (17)$$

Comparing these surpluses gives the following result:

Proposition 2 *There exists a critical cost level θ^*, with $\widetilde{\theta}(\underline{\theta}) < \theta^* < \widetilde{\theta}(E\{\theta_0\})$, such that the expected consumer surplus is higher with information sharing if $\theta^* < \theta_1 < \widetilde{\theta}(\overline{\theta})$, and higher without information sharing otherwise.*

The intuition is similar to the intuition for Proposition 1. If $\theta_1 \geq \widetilde{\theta}(E\{\theta_0\})$, then information concealment yields exit of fringe firms for all θ_0. By contrast, information sharing yields accommodation for sufficiently inefficient technologies of firm 0 (i.e., $\theta_0 > \widetilde{\theta}^{-1}(\theta_1)$). This increases the consumer surplus, since outputs expand and product variety increases. If θ_1 is slightly lower than $\widetilde{\theta}(E\{\theta_0\})$, an analogous intuition applies: information sharing expands the average output levels, and thereby increases expected consumer surplus.

In models where firms choose accommodating output strategies, information concealment makes consumers on average better off (Shapiro, 1986). The proposition

[5] This slightly abuses notation: using symmetry, $S(x_0, Nx_1)$ is shorthand for $S(x_0, x_1, ..., x_1)$.

shows that the surplus ranking is reversed when fringe firms' incentives to exit are affected by information sharing.

5 Strategic Information Disclosure

In this section I characterize firm 0's *interim* information disclosure incentives. That is, firm 0 chooses a disclosure rule $d(\theta_0) \in \{\theta_0, \varnothing\}$ *after* it privately learns the cost θ_0 for any $\theta_0 \in [\underline{\theta}, \overline{\theta}]$. The equilibrium outputs after disclosure of θ_0 are as in (8)-(9). If firm 0 does not disclose its cost, then each fringe firm expects the cost $E\{\theta_0|\varnothing\}$ of firm 0. The equilibrium outputs are then as in (13) with $E\{\theta_0\}$ replaced by $E\{\theta_0|\varnothing\}$, and $x_1^o(\theta_1; E\{\theta_0|\varnothing\}) \equiv x_1^*(\theta_1, E\{\theta_0|\varnothing\})$.

First, I show that there always exists an equilibrium with full disclosure.

Proposition 3 *There always exists an equilibrium in which firm 0 discloses all information, i.e., $d(\theta_0) = \theta_0$ for any $\theta_0 \in [\underline{\theta}, \overline{\theta}]$.*

A full disclosure equilibrium exists if firms $1, ..., N$ hold skeptical beliefs, i.e. $E\{\theta_0|\varnothing\} = \overline{\theta}$. Given these beliefs, firm 0 has an incentive to disclose its cost θ_0 for all $\theta_0 \in [\underline{\theta}, \overline{\theta}]$, since it discourages output production by the competitors (i.e., $x_1^*(\theta_1, \theta_0) < x_1^o(\theta_1; \overline{\theta})$ for all $\theta_0 < \overline{\theta}$). This is a standard unraveling result (e.g., Okuno-Fujiwara *et al.*, 1990). However, this equilibrium is not always unique.

In spite of the fact that the incentive to disclose information is stronger than in the model with precommitment, there remain cases in which it is optimal for firm 0 to conceal. In particular, I find the following for sufficiently high cost of firms $1, ..., N$.

Proposition 4 *If $\widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta})$, then for any subset $\mathcal{D}$ of the interval $[\underline{\theta}, \widetilde{\theta}^{-1}(\theta_1)]$ such that $E\{\theta_0|\theta_0 \notin \mathcal{D}\} \leq \widetilde{\theta}^{-1}(\theta_1)$ the following disclosure rule is an equilibrium rule:*

$$d(\theta_0) = \begin{cases} \theta_0, & \textit{if } \theta_0 \in \mathcal{D} \\ \varnothing, & \textit{otherwise.} \end{cases} \tag{18}$$

The proposition has the following immediate implication.

Corollary 1 *If $\widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta})$, then an equilibrium exists in which firm 0 keeps any cost secret, i.e. $d(\theta_0) = \varnothing$ for all $\theta_0 \in [\underline{\theta}, \overline{\theta}]$.*

Proof. If $\mathcal{D} = \emptyset$, then $E\{\theta_0|\theta_0 \notin \mathcal{D}\} = E\{\theta_0\} \leq \widetilde{\theta}^{-1}(\theta_1)$, since $\widetilde{\theta}(E\{\theta_0\}) \leq \theta_1$. ■

If $\widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta})$, and fringe firms have beliefs consistent with full concealment (i.e., $E\{\theta_0|\varnothing\} = E\{\theta_0\}$), then firm 0 has an incentive to keep any cost secret. Given these beliefs, firms $1, ..., N$ exit the market if firm 0 conceals its cost. By contrast, disclosure would yield accommodating output strategies (i.e., $x_1^*(\theta_1, \theta_0) > 0 = x_1^o(\theta_1; E\{\theta_0\})$) if firm 0 is less efficient than expected (i.e., $\theta_0 > E\{\theta_0\}$). It yields exclusion of fringe firms if firm 0 is more efficient than expected (i.e., $\theta_0 \leq E\{\theta_0\}$). In other words, cost concealment gives firm 0 profits which are greater than or equal to the profits under disclosure.

A comparison of the profits from the disclosure rules in Propositions 3 and 4 gives the following. The firm's profit from full disclosure is $\pi_0^*(\theta_0, \theta_1)$. Under the conditions of Proposition 4, firm 0's profits from disclosure rule (18) are $\pi_0^o(\theta_0, \theta_1; E\{\theta_0|\theta_0 \notin \mathcal{D}\})$. The profit from disclosure rule (18) is greater than or equal to the profit from full disclosure, i.e., $\pi_0^o(\theta_0, \theta_1; E\{\theta_0|\theta_0 \notin \mathcal{D}\}) \geq \pi_0^*(\theta_0, \theta_1)$ for any θ_0 and $\widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta})$, since fringe firms are excluded more often from the market under disclosure rule (18).

6 Conclusion

I characterized the conditions under which a firm keeps its cost of production secret in a Cournot oligopoly. The firm may prefer to conceal cost information in cases where its competitor can be excluded from the market. This result holds not only in a setting where the firm precommits to share information, but also (though in fewer cases, and not uniquely) in a setting in which the firm makes a strategic disclosure choice. The possibility of exit may make consumers on average be better off under information sharing.

By contrast, when the firms choose accommodating output strategies in the product market, a firm prefers to share information about independent cost parameters, and consumers prefer the equilibrium allocation under information concealment.

The paper's qualitative results do not depend on the number of fringe firms. It would be interesting to study how an increase in the number of fringe firms affects the dominant firm's incentive to share information at the margin. Unfortunately, the effect of N on critical cost level θ^o in Proposition 1 is not clear, since standard results from monotone comparative statics do not apply to the analysis of this effect.[6]

[6] In particular, it can be shown that the profits Π_0^* as well as Π_0^o are decreasing in N. Moreover, $\partial\Pi_0^*(\widetilde{\theta}(\underline{\theta}))/\partial N > \partial\Pi_0^o(\widetilde{\theta}(\underline{\theta}))/\partial N$ whereas $\partial\Pi_0^*(\widetilde{\theta}(E\{\theta_0\}))/\partial N < \partial\Pi_0^o(\widetilde{\theta}(E\{\theta_0\}))/\partial N$. Therefore, the sign of $\partial[\Pi_0^*(\theta_1) - \Pi_0^o(\theta_1)]/\partial N$ is not constant for $\widetilde{\theta}(\underline{\theta}) \leq \theta_1 \leq \widetilde{\theta}(E\{\theta_0\})$.

A possible extension to the analysis could be to consider a duopoly and introduce incomplete information about the fringe firm's cost. The paper's results would still hold if the fringe firm's cost is randomly drawn from an interval with inefficient technologies (e.g., $\theta_1 \in [\max\{\theta^o, \theta^*\}, \widetilde{\theta}(\overline{\theta})]$).

These observations provide a caveat for antitrust policy towards information sharing in industries with a dominant firm. It may be neither feasible nor practical for an antitrust authority to determine when a dominant firm should be forced to share information. However, the paper's results suggest that an antitrust authority should be suspicious if a dominant firm attempts to precommit to conceal information from potential entrants. The authority could try to avoid such a precommitment, and let the firm make its disclosure decision strategically instead. Strategic disclosure reduces the scope for concealment, and thereby reduces the likelihood of exit from the market.

A Appendix

This Appendix provides proofs to the propositions.

Proof of Proposition 1

First, if $\widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta})$, then $\Pi_0^o(\theta_1) > \Pi_0^*(\theta_1)$, since $\pi^m(\theta_0) > \pi_0^c(\theta_0, \theta_1)$ for all $\theta_0 > \widetilde{\theta}^{-1}(\theta_1)$. Second, take $\widetilde{\theta}(\underline{\theta}) \leq \theta_1 < \widetilde{\theta}(E\{\theta_0\})$. The first derivative of $\Pi_0^*(\theta_1)$ equals:

$$\begin{aligned}
\frac{d\Pi_0^*(\theta_1)}{d\theta_1} &= \frac{d\widetilde{\theta}^{-1}(\theta_1)}{d\theta_1}\left[x^m(\widetilde{\theta}^{-1}(\theta_1))^2 - x_0^c(\widetilde{\theta}^{-1}(\theta_1), \theta_1)^2\right] f(\widetilde{\theta}^{-1}(\theta_1)) \\
&\quad + \int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}} 2\frac{\partial x_0^c(z, \theta_1)}{\partial \theta_1} x_0^c(z, \theta_1) dF(z) \\
&= \frac{2\beta N}{(2-\beta)(2+\beta N)} \int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}} x_0^c(z, \theta_1) dF(z)
\end{aligned}$$

since $x^m(\widetilde{\theta}^{-1}(\theta_1)) = x_0^c(\widetilde{\theta}^{-1}(\theta_1), \theta_1)$. Taking the first derivative of $\Pi_0^o(\theta_1)$ yields:

$$\begin{aligned}
\frac{d\Pi_0^o(\theta_1)}{d\theta_1} &= \int_{\underline{\theta}}^{\overline{\theta}} 2\frac{\partial x_0^c(z, \theta_1)}{\partial \theta_1}\left(x_0^c(z, \theta_1) + \frac{\beta^2 N(z - E\{\theta_0\})}{2(2-\beta)(2+\beta N)}\right) dF(z) \\
&= \frac{2\beta N}{(2-\beta)(2+\beta N)} \int_{\underline{\theta}}^{\overline{\theta}} x_0^c(z, \theta_1) dF(z)
\end{aligned}$$

Comparing the derivatives gives $d\Pi_0^o(\theta_1)/d\theta_1 > d\Pi_0^*(\theta_1)/d\theta_1$. The evaluation of the expected-profit functions for extreme values of θ_1 gives:

$$\begin{aligned}\Pi_0^*(\widetilde{\theta}(E\{\theta_0\})) &= \int_{\underline{\theta}}^{E\{\theta_0\}} \pi^m(\theta)dF(\theta) + \int_{E\{\theta_0\}}^{\overline{\theta}} \pi_0^c(z,\theta_1)dF(z) \\ &< \int_{\underline{\theta}}^{\overline{\theta}} \pi^m(z)dF(z) = \Pi_0^o(\widetilde{\theta}(E\{\theta_0\}))\end{aligned}$$

and

$$\begin{aligned}\Pi_0^*(\widetilde{\theta}(\underline{\theta})) &= \int_{\underline{\theta}}^{\overline{\theta}} \pi_0^c(z,\widetilde{\theta}(\underline{\theta}))dF(z) \\ &> \int_{\underline{\theta}}^{\overline{\theta}} \left(x_0^c(z,\widetilde{\theta}(\underline{\theta})) + \frac{\beta^2 N(z-E\{\theta_0\})}{2(2-\beta)(2+\beta N)}\right)^2 dF(z) = \Pi_0^o(\widetilde{\theta}(\underline{\theta}))\end{aligned}$$

The existence of the critical value θ^o, with $\widetilde{\theta}(\underline{\theta}) < \theta^o < \widetilde{\theta}(E\{\theta_0\})$, follows directly from the monotonicity of the expected profit difference $\Pi_0^o(\theta_1) - \Pi_0^*(\theta_1)$, and the inequality $\Pi_0^o(\widetilde{\theta}(\underline{\theta})) - \Pi_0^*(\widetilde{\theta}(\underline{\theta})) < 0 < \Pi_0^o(\widetilde{\theta}(E\{\theta_0\})) - \Pi_0^*(\widetilde{\theta}(E\{\theta_0\}))$. □

Proof of Proposition 2

The proof is similar to the proof of Proposition 1.

By symmetry of the fringe firms' equilibrium output levels, the consumer surplus (3) simplifies as follows:

$$S(x_0, Nx_1) = \frac{1}{2}(x_0 + Nx_1)^2 - \frac{1}{2}(1-\beta)\left[2x_0 + (N-1)x_1\right]Nx_1$$

First, if $\widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta})$, then:

$$S^*(\theta_1) - S^o(\theta_1) = \int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}} \left[S(x_0^c(z,\theta_1), Nx_1^c(\theta_1,z)) - S(x^m(z),0)\right]dF(z)$$

and

$$\begin{aligned}\frac{d\left[S^o(\theta_1) - S^*(\theta_1)\right]}{d\theta_1} &= \frac{d\widetilde{\theta}^{-1}(\theta_1)}{d\theta_1}\left[S\left(x^m(\theta_0),0\right) - S\left(x_0^c(\theta_0,\theta_1), Nx_1^c(\theta_1,\theta_0)\right)\right]f(\theta_0)\Bigg|_{\theta_0=\widetilde{\theta}^{-1}(\theta_1)} \\ &\quad + \int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}} \frac{dS(x_0^c(z,\theta_1), Nx_1^c(\theta_1,z))}{d\theta_1}dF(z) \\ &= \int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}} \frac{dS(x_0^c(z,\theta_1), Nx_1^c(\theta_1,z))}{d\theta_1}dF(z) < 0\end{aligned}$$

since $S\left(x^m(\theta_0),0\right)=S\left(x_0^c(\theta_0,\theta_1),Nx_1^c(\theta_1,\theta_0)\right)$ for $\theta_0=\widetilde{\theta}^{-1}(\theta_1)$, and

$$\begin{aligned}\frac{dS(x_0^c(\theta_0,\theta_1),Nx_1^c(\theta_1,\theta_0))}{d\theta_1} &= \left[x_0^c(\theta_0,\theta_1)+\beta Nx_1^c(\theta_1,\theta_0)\right]\frac{\partial x_0^c(\theta_0,\theta_1)}{\partial\theta_1}\\ &\quad+\left(\beta x_0^c(\theta_0,\theta_1)+[1+\beta(N-1)]x_1^c(\theta_1,\theta_0)\right)N\frac{\partial x_1^c(\theta_1,\theta_0)}{\partial\theta_1}\\ &= \frac{-N\left(\beta x_0^c(\theta_0,\theta_1)+[2(1-\beta)+\beta(2-\beta)N]x_1^c(\theta_1,\theta_0)\right)}{(2-\beta)(2+\beta N)}<0\end{aligned}$$

for all $\theta_0>\widetilde{\theta}^{-1}(\theta_1)$. Consequently, $S^*(\theta_1)-S^o(\theta_1)>S^*(\widetilde{\theta}(\overline{\theta}))-S^o(\widetilde{\theta}(\overline{\theta}))=0$.

Second, take $\widetilde{\theta}(\underline{\theta})\leq\theta_1<\widetilde{\theta}(E\{\theta_0\})$. For these parameter values the consumer surpluses under information sharing and information concealment are, respectively:

$$\begin{aligned}S^*(\theta_1) &= \int_{\underline{\theta}}^{\widetilde{\theta}^{-1}(\theta_1)}S\left(x^m(y),0\right)dF(y)+\int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}}S\left(x_0^c(z,\theta_1),Nx_1^c(\theta_1,z)\right)dF(z)\\ S^o(\theta_1) &= E\left\{S\left(x_0^c(\theta_0,\theta_1)+\frac{\beta^2N(\theta_0-E\{\theta_0\})}{2(2-\beta)(2+\beta N)},Nx_1^c(\theta_1,E\{\theta_0\})\right)\right\}\end{aligned}$$

The first derivative of $S^*(\theta_1)$ equals:

$$\begin{aligned}\frac{dS^*(\theta_1)}{d\theta_1} &= \frac{d\widetilde{\theta}^{-1}(\theta_1)}{d\theta_1}\Big[S\left(x^m(\widetilde{\theta}^{-1}(\theta_1)),0\right)\\ &\qquad -S\left(x_0^c(\widetilde{\theta}^{-1}(\theta_1),\theta_1),Nx_1^c(\theta_1,\widetilde{\theta}^{-1}(\theta_1))\right)\Big]f(\widetilde{\theta}^{-1}(\theta_1))\\ &\quad+\int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}}\frac{dS(x_0^c(z,\theta_1),Nx_1^c(\theta_1,z))}{d\theta_1}dF(z)\\ &= \int_{\widetilde{\theta}^{-1}(\theta_1)}^{\overline{\theta}}\frac{dS(x_0^c(z,\theta_1),Nx_1^c(\theta_1,z))}{d\theta_1}dF(z)\end{aligned}$$

since $x^m(\widetilde{\theta}^{-1}(\theta_1))=x^d(\widetilde{\theta}^{-1}(\theta_1),\theta_1)$. Taking the first derivative of $S^o(\theta_1)$ yields:

$$\begin{aligned}\frac{dS^o(\theta_1)}{d\theta_1} &= \int_{\underline{\theta}}^{\overline{\theta}}\frac{dS\left(x_0^c(z,\theta_1)+\frac{\beta^2N(z-E\{\theta_0\})}{2(2-\beta)(2+\beta N)},Nx_1^c(\theta_1,E\{\theta_0\})\right)}{d\theta_1}dF(z)\\ &= \int_{\underline{\theta}}^{\overline{\theta}}\frac{dS(x_0^c(z,\theta_1),Nx_1^c(\theta_1,z))}{d\theta_1}dF(z)\end{aligned}$$

The comparison of first derivatives gives:

$$\frac{dS^o(\theta_1)}{d\theta_1}-\frac{dS^*(\theta_1)}{d\theta_1}=\int_{\underline{\theta}}^{\widetilde{\theta}^{-1}(\theta_1)}\frac{dS(x_0^c(z,\theta_1),Nx_1^c(\theta_1,z))}{d\theta_1}dF(z)<0$$

since $dS(x_0^c(\theta_0,\theta_1), Nx_1^c(\theta_1,\theta_0))/d\theta_1 < 0$ for all $\theta_0 \leq \widetilde{\theta}^{-1}(\theta_1)$ and $\theta_1 < \widetilde{\theta}(E\{\theta_0\})$. The evaluation of the consumer surpluses for extreme values of firm 2's cost gives the following:

$$\begin{aligned} S^*(\widetilde{\theta}(E\{\theta_0\})) &= \int_{\underline{\theta}}^{E\{\theta_0\}} S(x^m(\theta),0)dF(\theta) + \int_{E\{\theta_0\}}^{\overline{\theta}} S(x_0^c(z,\theta_1), Nx_1^c(\theta_1,z))dF(z) \\ &> \int_{\underline{\theta}}^{\overline{\theta}} S(x^m(z),0)dF(z) = S^o(\widetilde{\theta}(E\{\theta_0\})) \end{aligned}$$

and

$$\begin{aligned} S^*(\widetilde{\theta}(\underline{\theta})) &= \int_{\underline{\theta}}^{\overline{\theta}} S(x_0^c(z,\widetilde{\theta}(\underline{\theta})), Nx_1^c(\widetilde{\theta}(\underline{\theta}),z))dF(z) \\ &< \int_{\underline{\theta}}^{\overline{\theta}} S\left(x_0^c(z,\widetilde{\theta}(\underline{\theta})) + \frac{\beta^2 N(z - E\{\theta_0\})}{2(2-\beta)(2+\beta N)}, Nx_1^c(\widetilde{\theta}(\underline{\theta}), E\{\theta_0\})\right) dF(z) \\ &= S^o(\widetilde{\theta}(\underline{\theta})) \end{aligned}$$

The existence of the critical value θ^o, with $\widetilde{\theta}(\underline{\theta}) < \theta^* < \widetilde{\theta}(E\{\theta_0\})$, follows directly from the monotonicity of the expected profit difference $S^o(\theta_1)-S^*(\theta_1)$, and the observations $S^o(\widetilde{\theta}(E\{\theta_0\})) - S^*(\widetilde{\theta}(E\{\theta_0\})) < 0$ and $S^o(\widetilde{\theta}(\underline{\theta})) - S^o(\widetilde{\theta}(\underline{\theta})) > 0$. □

Proof of Proposition 3

The proof is similar to standard proofs of the unravelling result.

Suppose that each fringe firm holds skeptical beliefs, i.e. $E\{\theta_0|\varnothing\} = \overline{\theta}$. Given these beliefs, firm 0 earns higher profits under information disclosure than under concealment, since $x_0^*(\theta_0,\theta_1) > x_0^o(\theta_0,\theta_1;\overline{\theta})$ for all $\theta_0 \in [\underline{\theta},\overline{\theta})$, and $x_0^*(\theta_0,\theta_1) = x_0^o(\theta_0,\theta_1;\overline{\theta})$ for $\theta_0 = \overline{\theta}$. Notice that the beliefs are consistent with the information disclosure incentives. □

Proof of Proposition 4

Suppose $\widetilde{\theta}(E\{\theta_0\}) \leq \theta_1 < \widetilde{\theta}(\overline{\theta})$, and $\mathcal{D} \subset [\underline{\theta}, \widetilde{\theta}^{-1}(\theta_1)]$ is such that $E\{\theta_0|\theta_0 \notin \mathcal{D}\} \leq \widetilde{\theta}^{-1}(\theta_1)$. Further, suppose that each fringe firm holds beliefs consistent with disclosure rule (18). In that case $\theta_1 = \widetilde{\theta}\left(\widetilde{\theta}^{-1}(\theta_1)\right) \geq \widetilde{\theta}(E\{\theta_0|\theta_0 \notin \mathcal{D}\})$, and therefore firm 0 receives the profit $\pi^m(\theta_0)$ under concealment. For all $\theta_0 \leq \widetilde{\theta}^{-1}(\theta_1)$ the profit from disclosure of θ_0 is $\pi_0^*(\theta_0,\theta_1) = \pi^m(\theta_0)$, and therefore disclosure of $\theta_0 \in \mathcal{D}$ and concealment of $\theta_0 \in [\underline{\theta}, \widetilde{\theta}^{-1}(\theta_1)]\backslash\mathcal{D}$ is optimal. For all $\theta_0 > \widetilde{\theta}^{-1}(\theta_1)$ the profit from disclosure is $\pi_0^*(\theta_0, \theta_1) = x_0^c(\theta_0, \theta_1)^2 < \pi^m(\theta_0)$, and concealment is optimal. Hence, any type $\theta_0 \notin \mathcal{D}$ has an incentive to conceal, and any type $\theta_0 \in \mathcal{D}$ has an incentive to disclose. $\square$

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