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COST REDUCING STRATEGIES

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We consider an industry where one of the manufacturers and its supplier (S) have engaged in some specific investment in the past. We assume that this has three consequences: S has lower expected production costs than other suppliers, supplier-switching costs exist, and the manufacturer may limit its rivals' access to S. In the case when only S knows its true production costs, we compare alternative mechanisms to induce S to reveal its private information, namely, paying informational rents, using threats of switching suppliers, and most importantly, permitting S to serve other firms. We prove that the presence of asymmetric information mitigates the manufacturer's incentives to engage in vertical restraints. We derive several policy implications from this result.

Keywords: Adapting to more efficient suppliers, supplier switching costs, sharing suppliers, vertical restraints, asymmetric information.

(*JEL* L13, L42, D82)

1. Introducción

In recent years, an extensive literature dealing with customer-specific investments and the consequent existence of supplier-switching costs has emerged. For instance, MacLeod and Malcomson (1993) study which types of (incomplete) contracts induce the buyer and/or the supplier to engage in such investments (either jointly or unilaterally). Monteverde and Teece (1982) analyze the incentives for the buyer to integrate its supplier. Krouse (1995) studies the consequences of such a backward integration in terms of the buyer's competitiveness. Hardt

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(1995) shows that the existence of further trade, switching costs, and reputation issues are sufficient conditions for buyer and supplier to take anti-competitive actions, so that vertical integration is not a necessary condition for market foreclosure to appear. Scheffman and Spiller (1992) study how the presence of specific investments and sunk costs affects the extent of limit pricing that is necessary to deter entry.

We analyze the incentives that a manufacturer has to foreclose its rivals from access to a supercompetitive supplier. Our analysis starts once the customer-specific investments have already been made and are sunk. We also assume that manufacturer and supplier are not integrated. As a consequence of the specific investments, this supplier has lower costs than alternative sources. It is clear, therefore, that the manufacturer has a powerful incentive to foreclose its rivals from access to this supplier. In most of the existing literature studying this problem, it is assumed that buyer's and supplier's information is symmetric. Our main contribution is to show that the incentives to foreclose are mitigated if the supplier has private information.[1]

The situation that we focus on can be described as follows. A downstream firm F_1 and/or its supplier S_1 have made some sunk and specific investment in the past. Consider the following examples. Nippondenso (S_1) serves Toyota (F_1) several parts for its automobiles. Kamath and Liker (1994, p. 158), in their conclusions to a study of supplier-management relations in Japan, report that "to use alternators as an example, Nippondenso's basic research for this product took years an began with intensive discussion between Nippondenso engineers and their customers -primarily Toyota." Similarly, the same authors explain that Eaton corporation makes large-volume valves and lifters for Ford and that Ford asked Eaton to design and manufacture the entire valve-train system.

The existence of this specific investment has three main consequences for the relationship between F_1 and S_1. First, due to the specificity of the investment, it is costly for F_1 to switch from supplier S_1 to any alternative supplier. We refer to these (fixed) costs as *switching costs.* Symmetrically, if another firm other than F_1 is to use S_1's produc-

[1] One might ask whether it is plausible that one of the two firms that have been partners in the development of a specific technology may still posses private information. However, precisely this assumption is exploited in the joint-R&D literature. See, for instance,Veugelers and Kesteloot (1996), Pastor and Sandonís (2000), or Pérez-Castrillo and Sandonís (1997).

tion, this requires some adjustments that are costly. We refer to these (also fixed) costs as *adaptation costs.* For instance, in the Nippondenso example, these adaptation costs would correspond to the costs of designing a procedure that allowed Nippondenso to produce a whole family of alternators in the same production line.

Second, F_1 may prevent other firms' access to S_1 either because S_1 depends on F_1's know how, as in the Nippondenso example, or because F_1 holds a patent on some indispensable part of the intermediate good (or on the whole intermediate good).

Finally, it is likely that supplier S_1 may have lower unit production costs than the other suppliers. This is a natural outcome, since the main objective of such specific investments is that of lowering production costs. We focus on a situation where these three consequences are present.

Suppose now, as it is the case in the above real-world examples, that F_1 competes with other downstream firms in the final good market. Then F_1 has a strong incentive to impede its rivals' access to S_1, in order to attain a competitive advantage. However, Eaton Corporation serves both Ford and Caterpillar – among other firms – and Nippondenso serves alternators – and other parts – to several rivals of Toyota. That is, we observe sharing in the two cases analyzed by Kamath and Liker (1994). This apparent puzzle is the main motivation for our analysis.

Our explanation is based on the existence of an asymmetric information problem. Suppose that only S_1 knows its own true production costs and consider the following policy on the part of F_1. In the contract with S_1, firm F_1 stipulates that it will only allow S_1 to serve its rivals if S_1 declares to have low costs. We refer to this policy as the "No-Share-Threat Arrangement." We show that this may be beneficial to F_1, as we explain next.

In general adverse selection problems, in order to induce the better-informed party to reveal its information, the less-informed party must pay the latter some informational rents. It turns out that F_1 is able to reduce these informational rents by means of the no-share threat. We call this reduction of rents *informational benefits.*[2] The inconvenient

[2]Our model focuses on an adverse-selection problem between buyer and supplier. Yun (1999), on the other hand, focuses on a moral hazard problem. He predicts which type of subcontracting relations emerge as a function of the degree of risk sharing.

of this mechanism is that, if S_1's costs are truly low, then F_1 ends up sharing its supplier with its rivals, thereby losing its competitive edge in the final good market.

Notice, however, that there exists a way for F_1 to avoid paying informational rents altogether. Consider the following alternative policy. The contract between F_1 and S_1 stipulates that F_1 will switch to another supplier if S_1 declares that its costs are high. The inconvenience of this policy is that firm F_1 will have to bear the switching costs if S_1's costs are in fact high. For the sake of comparison, we also study this contract policy and refer to it as the "Switch-Threat Arrangement."

Also for the sake of comparison, we study the contract in which F_1 commits to neither switch suppliers nor share supplier S_1. We refer to this last policy as the "No-Threat Arrangement." Its advantage is that neither switching nor adaptation costs are ever paid. The disadvantage is that large informational rents must be paid in order to induce S_1 to reveal its true costs.

We determine the set of parameter values (say Region I) that ensure that the No-Share-Threat Arrangement is superior to both the Switch-Threat and the No-Threat arrangements. For the sake of completeness, we fully characterize the regions where each of the arrangements is optimal. However, the most important result is the existence of a non-empty Region I. Quite intuitively, this result is reinforced if (a) the probability that the specific investment really lowered costs is not too large, (b) adaptation costs are sufficiently low, and (c) switching costs are sufficiently high. Conditions (a) and (c) ensure that the Switch-Threat Arrangement does not dominate. Condition (b) ensures that sharing is not too costly. Most importantly, we prove that under *symmetric* information, Region I is always empty. Hence, our main result is that, under some conditions, sharing is observed if and only if there exists asymmetric information.

We assume that firm F_1 bears the adaptation costs. This implies that we carry out the complete characterization for the least favorable scenario for our main result (Region I is non-empty) to hold. To formalize this statement, we prove that Region I does not shrink if, instead of F_1, either S_1 or F_2 pay for the adaptation costs.

That the no-share threat is in place implies that the sharing of S_1 will sometimes be observed. This result explains the title of the paper. Whenever F_1 allows S_1 to serve F_1's rivals, this implies a cost reduction for the latter. This is in contrast to results obtained in other settings, where increasing the rival's costs constitutes the optimal strategy, as in Salop and Scheffman (1987).

It is clear that sharing a more competitive supplier has a positive impact on welfare. Several policy implications follow this observation and are further discussed in the final section. First, since sharing cannot occur under symmetric information, the regulator may find it beneficial to protect S_1's private information. If vertical integration diminishes the information asymmetry, then vertical integration should be avoided.

Another reason to avoid vertical integration is the following. The beneficial effects of sharing vanish if F_1 conducts price discrimination in the intermediate good market. Therefore, antidiscrimination laws (like the Robinson-Patman Act) are also beneficial.[3] However, it becomes almost impossible to enact such laws if buyer and supplier are integrated.

Finally, in order to internalize the beneficial effects of sharing on consumer surplus and industry profits, the regulator may want to subsidize the adaptation investments.

In Section 2 we present the model. In Section 3 we analyze the symmetric information case. In Section 4 we analyze the asymmetric information case and characterize Region I. In Section 5 we extend our results in two directions: (a) we prove that Region I expands if either S_1 or F_2 (instead of F_1) bears the adaptation costs and (b) we report the results obtained when price discrimination exists in the intermediate good market. In Section 6 we discuss several policy implications. The proofs are in the Appendix.

2. The model

The players in the game are two manufacturing firms, F_1 and F_2, and n suppliers $\{S_f\}_{f=1}^{n}$ of an intermediate good. The production technology of all firms (manufacturers and suppliers) presents constant returns to scale. The unit of measurement for the final good is chosen so that one unit of the final good is produced for each unit of the intermediate

[3] See Mezines (1969). In Olivella and Pastor (1997), we extend and generalize most of our results for the case in which F_1 captures rents by inducing price discrimination. This extension is discussed in the concluding section.

good. The intermediate good is the only input into production of the final good.

As explained in the introduction, Firms F_1 and S_1 have made some sunk and specific investment in the past. In virtue of this investment, supplier S_1 may bear lower production costs than S_f for all $f \neq 1$. Namely, with probability $0 < \gamma < 1$, firm S_1's unit cost of production are $\theta_1 = \theta_\ell > 0$ and with probability $1 - \gamma$, S_1's unit costs are $\theta_1 = \theta_h > \theta_\ell$, whereas the rest of the suppliers $f \neq 1$ bear unit costs $\theta_f = \theta_h$ with probability one. The probability γ is of public knowledge.

Due to the specificity of the investment, it is costly for F_1 to switch from supplier S_1 to supplier S_f, for all $f \neq 1$. That is, the specific investment is not freely irreversible. We denote these positive and fixed *switching costs* by k'. Similarly, some *adaptation costs* must be paid in order for F_2 to use S_1's production. We denote these fixed costs by $k > 0$. In order to study the least-favorable scenario for F_1 to be willing to share S_1, we assume that adaptation costs are fully paid by F_1.[4] On the other hand, firm F_2 may choose any supplier S_f, $f \neq 1$, without having to pay any adaptation or switching costs. Hence, θ_h is the unit cost associated to the standard technology, which requires no adaptation costs if buyer and supplier have not made any investments to improve it. On the other hand, and since both F_1 and S_1 have departed from the standard technology, F_1 will bear the switching costs if F_1 resorts to an alternative supplier. This is true even if the specific investments fails to reduce costs, which occurs with probability $1 - \gamma$.

We study two alternative frameworks. On the one hand, if the value of θ_1 is public knowledge, we say that we are in a context of symmetric information. On the other hand, if only S_1 knows the true value of θ_1, we then say that we are in a context of asymmetric information.

[4] Perhaps because F_1's bargaining power vis-a-vis F_2 is very dim. In Section 5 we study the cases when S_1 or F_2, instead of F_1, bear the adaptation costs. We show there that our main result is reinforced.

The timing of moves is the following. In the first stage of the game, F_1 designs its contract with S_1.[5] A contract between F_1 and S_1 may stipulate

a) under which conditions will F_1 switch from S_1 to some other supplier S_f, $f \neq 1$;

b) the price that F_1 pays to S_1 per unit of the intermediate good if F_1 has not switched suppliers,

c) under which conditions will F_1 allow S_1 to serve F_2's demand.

Of course, all of these stipulations may be made contingent on any observable and verifiable signal.

We assume that, if F_1 does not switch suppliers and allows S_1 to serve F_2, then F_1 and F_2 pay the same unit price for the intermediate good. We also rule out the possibility of 2nd degree price discrimination. In particular, we do not consider contracts that include a (fixed) royalty for the usage of S_1's production.[6]

In the second stage of the game, S_1 decides whether to accept or to reject F_1's offer. If S_1 rejects F_1's offer, F_1 is forced to resort to an alternative supplier S_f, $f \neq 1$, and to bear the switching costs k'.

In the third stage of the game, F_1 and F_2 compete in the final good market by simultaneously choosing their respective output levels, which we denote by q_i, $i = 1, 2$. Letting r be the price of the final good, demand is given by a linear inverse demand function $r = a - q_1 - q_2$. Hence, a describes the size of the market. An important assumption is that all contracts are publicly observable. This is justified in the

[5] The assumption that F_1 offers take-it or leave-it contracts to S_1 is not crucial for our results. We assume that S_1 accepts the contract if it guarantees a non-negative payoff to S_1. This means that the opportunity utility of S_1 is zero. We could represent some higher bargaining power on S_1's side by raising S_1's opportunity utility. In this respect, Scheffman and Spiller (1992) show that sunk, customer-specific investments made by sellers in a market where buyers are able to commit to switch suppliers limit the seller's ability to exert market power.

[6] Once second-degree price discrimination is allowed, one should also let F_2 establish non-uniform price contracts with its supplier S_f, $f \neq 1$. In the spirit of the delegation literature (see, for instance, Fershtman and Judd, 1987), in equilibrium both firms would commit to a specific output through a forcing contract. Since quantities are strategic substitutes, this would be harmful to both firms. Notice also that the usage of non-uniform prices would not eliminate informational rents in our model (although it could reduce them).

context of our model, since F_i and S_f are independent firms for all $i = 1, 2$ and $f = 1, ..., n$.

3. The game under symmetric information

Since the true unit costs of S_1 are publicly observable under symmetric information, the optimal contracts when $\theta_1 = \theta_\ell$ and when $\theta_1 = \theta_h$ can be found separately. We therefore fix $j \in \{\ell, h\}$ in the remainder of this section, and denote by p_j the price paid by firm F_1 to S_1 when S_1's unit cost is $\theta_1 = \theta_j$.

Obviously, it is optimal for F_1 to offer S_1 the price $p_j = \theta_j$. Similarly, since it is public knowledge that the true cost of any supplier S_f, $f \neq 1$ is $\theta_f = \theta_h$, any firm F_i, $i = 1, 2$, that resorts to one of these suppliers is able to set the unit price for the intermediate good at its acceptable minimum θ_h. This is true also in the next section, where only the costs of S_1 are unknown. Moreover, since information is symmetric, it is useless for F_1 to threaten S_1 with switching suppliers (which costs k' to F_1). Also, by allowing S_1 to serve F_2, firm F_1 would be forced to bear the adaptation costs and F_1 would suffer a loss of competitiveness. (This loss would be strictly positive in the case that $\theta_1 = \theta_\ell$.) Hence, neither switching threats nor the sharing of suppliers can be optimal under symmetric information, even if $k = 0$.

To close the model, we solve now for the last-stage Cournot game.

The payoff functions for F_1 and for F_2 are

$$\Pi_1 = (a - q_1 - q_2 - \theta_j)q_1, \qquad [1]$$

$$\Pi_2 = (a - q_1 - q_2 - \theta_h)q_2. \qquad [2]$$

Denote by q_{ij}^{SI} the equilibrium production level of firm F_i when S_1's costs are θ_j under symmetric information. The equilibrium production levels are

$$q_{1j}^{SI} = \frac{1}{3}(a - 2\theta_j + \theta_h), \qquad [3]$$

$$q_{2j}^{SI} = \frac{1}{3}(a + \theta_j - 2\theta_h). \qquad [4]$$

Denote by Π_{ij}^{SI} the equilibrium profits of firm F_i when S_1's costs are θ_j under symmetric information. The equilibrium profits are

$$\Pi_{1j}^{SI} = [q_{1j}^{SI}]^2,$$

$$\Pi_{2j}^{SI} = [q_{2j}^{SI}]^2.$$

Notice that F_2's equilibrium production reaches its minimum value when F_1 pays θ_ℓ for the intermediate good while F_2 pays θ_h. Next assumption ensures that q_2 is positive even in this case, in order to obtain an interior solution.

ASSUMPTION 1. $a \geq 3\theta_h - 2\theta_\ell$.

Notice that a weaker assumption, namely $a \geq 2\theta_h - \theta_\ell$, would suffice for $q_2 > 0$. However, our main result requires this more stringent assumption.

4. The game under asymmetric information

Under asymmetric information, one cannot find the optimal contract for the high-cost and the low-cost cases separately. In particular, the price cannot be made to depend on S_1's true unit costs. Instead, F_1 requires S_1 to announce its unit costs, and assigns a different contract depending on S_1's announcement, which is publicly observable. Hence, S_1's announcement becomes the verifiable signal upon which contracts are signed.

Firm F_1 may choose among three contract arrangements.

- *Switch-threat arrangement*

The contract stipulates that, if S_1 announces θ_h, then (i) F_1 will switch (at a cost k') to an alternative supplier (thus paying θ_h per unit) and (ii) F_1 will not permit that S_1 serve F_2. This ensures that S_1 does not have an incentive to lie when its true unit costs are θ_ℓ. This implies that firm F_1 can offer a payment of $p_\ell = \theta_\ell$ when S_1 announces θ_ℓ.[7] Obviously, there is no point for F_1 to share S_1 with F_2 in this case.

- *No-share-threat arrangement*

The contract stipulates (i) that F_1 will pay S_1 some unit price p_h, probably equal to θ_h,[8] if S_1 announces θ_h, (ii) that F_1 will pay S_1

[7] One could say that informational rents are zero in this case. However, note that such a contract, although eliminating the asymmetric information problem, it does so at a cost. If S_1 turns out to have high costs, then F_1 is committed to switch suppliers, which costs $k' > 0$.

[8] It is not true in general that p_h will be set equal to θ_h, since a sufficiently high price can be used to indirectly punish the overstatement of costs, i.e., through a

some unit price p_ℓ, probably below θ_h, if S_1 announces θ_ℓ, but that in this case if will allow S_1 to offer its production to F_2 at *the same* price p_ℓ and (iii) that F_1 will never switch suppliers. (The prices p_ℓ and p_h will be calculated in Subsection 4.2.)

Notice that Firm F_1 must now pay some informational rents to S_1, that is, p_ℓ must exceed θ_ℓ. (To see this, suppose, by contradiction, that p_ℓ is set equal to θ_ℓ. Suppose also that the true unit costs are θ_ℓ. If S_1 declares θ_ℓ then S_1 obtains zero, whereas if S_1 declares θ_h, then S_1 obtains a positive profit.) Moreover, F_1 loses some competitiveness in the final good market (recall that also F_2 pays $p_\ell < \theta_h$). To make things even worse, recall that we assume that the adaptation costs k must be borne by F_1.

- *No-threat arrangement*

The contract stipulates (i) that F_1 will neither switch suppliers nor share S_1 under any circumstances and (ii) that some p_h, probably equal to θ_h, per unit will be paid if S_1 announces θ_h while some $\theta_\ell < p_\ell \leq \theta_h$ per unit will be paid otherwise.

The advantages of this arrangement are that (a), if $\theta_1 = \theta_\ell$, F_1 neither loses competitiveness in the final good market nor pays adaptation costs; and (b), if $\theta_1 = \theta_h$, F_1 does not pay switching costs k'. The disadvantage, as we show later on, is that the informational rents are larger than in the other two arrangements. Notice that the possibility of a typical pooling contract is a particular case of this arrangement, namely, the case where $p_\ell = p_h = \theta_h$.

For each of these arrangements, we first analyze the ensuing Cournot game, we then derive the expected payoff for F_1, and we finally derive the optimal price contract $\{p_\ell, p_h\}$. This is done in subsections 4.1, 4.2, and 4.3, respectively. In subsection 4.4 we find the optimal arrangement.

4.1. Switch-threat arrangement

As explained in the previous section, the optimal contract is given by paying $p_\ell = \theta_\ell$ when S_1 announces θ_ℓ while switching suppliers if S_1 announces θ_h. Notice that the unit price paid by F_1 ends up being

sufficiently important reduction in S_1's demand. This is further discussed after Lemma 1 below. This also applies for the No-Threat Arrangement.

the same as under symmetric information. Therefore, we can write the expected payoff for firm F_1 as

$$E(\Pi_1^A) = \gamma\Pi_{1\ell}^{SI} + (1-\gamma)(\Pi_{1h}^{SI} - k').$$

4.2. No-share-threat arrangement

In order to determine the optimal price contract $\{p_\ell, p_h\}$, we must first solve the Cournot game for each possible price contract $\{p_\ell, p_h\}$ and for each possible announcement by S_1.

If S_1 declares $\theta_1 = \theta_\ell$, then F_1 allows S_1 to serve F_2 and both firms pay p_ℓ per unit. Moreover, F_1 must pay adaptation costs k. The payoff functions for F_1 and F_2 are the following:

$$\Pi_1 = (a - q_1 - q_2 - p_\ell)q_1 - k, \qquad [5]$$

$$\Pi_2 = (a - q_1 - q_2 - p_\ell)q_2. \qquad [6]$$

The equilibrium production levels are

$$q_{1\ell}^B = q_{2\ell}^B = \frac{1}{3}(a - p_\ell), \qquad [7]$$

where the superscript B denotes the No-Share-Threat Arrangement.

The equilibrium profits are

$$\Pi_{1\ell}^B = [q_{1\ell}^B]^2 - k,$$
$$\Pi_{2\ell}^B = [q_{2\ell}^B]^2.$$

If S_1 declares $\theta_1 = \theta_h$, the threat is implemented. That is, F_1 does not allow S_1 to serve F_2. The payoff functions for F_1 and F_2 are

$$\Pi_1 = (a - q_1 - q_2 - p_h)q_1, \qquad [8]$$

$$\Pi_2 = (a - q_1 - q_2 - \theta_h)q_2. \qquad [9]$$

The equilibrium production levels are

$$q_{1h}^B = \frac{1}{3}(a - 2p_h + \theta_h), \qquad [10]$$

$$q_{2h}^B = \frac{1}{3}(a - 2\theta_h + p_h). \qquad [11]$$

The equilibrium profits are

$$\Pi_{1h}^{B} = [q_{1h}^{B}]^2, \quad [12]$$

$$\Pi_{2h}^{B} = [q_{2h}^{B}]^2. \quad [13]$$

We can now define F_1's problem of choosing the optimal price contract $\{p_\ell, p_h\}$. After the appropriate substitutions,[9] the problem is to

$$\underset{\substack{\theta_\ell \le p_\ell \le \theta_h \\ \theta_h \le p_h \le \frac{a+\theta_h}{2}}}{\mathit{Maximize}} \quad \gamma\left[\left(\tfrac{1}{3}(a-p_\ell)\right)^2 - k\right] + (1-\gamma)\left(\tfrac{1}{3}(a-2p_h+\theta_h)\right)^2$$

subject to

$$(p_\ell - \theta_\ell)\,\frac{2}{3}(a-p_\ell) \ge 0, \quad [14]$$

$$(p_h - \theta_h)\,\frac{1}{3}(a-2p_h+\theta_h) \ge 0, \quad [15]$$

$$(p_\ell - \theta_\ell)\,\frac{2}{3}(a-p_\ell) \ge (p_h - \theta_\ell)\frac{1}{3}(a-2p_h+\theta_h), \quad [16]$$

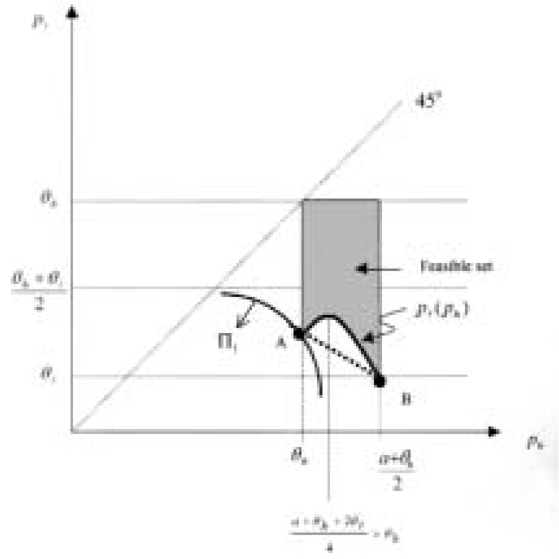
$$(p_h - \theta_h)\,\frac{1}{3}(a-2p_h+\theta_h) \ge (p_\ell - \theta_h)\,\frac{2}{3}(a-p_\ell). \quad [17]$$

The first and second constraint are the voluntary participation constraints when true unit costs are low and high, respectively. The third and fourth constraints are the incentive compatibility constraints when true unit costs are low and high, respectively. (Notice that imposing $p_\ell \le \theta_h$ is both necessary and sufficient to ensure that F_2 accept the contract.) It is also important to recall that S_1 serves both firms whenever θ_ℓ is announced. Hence the presence of 2/3 instead of 1/3 in some of the above expressions.

The next lemma gives the solution to the previous maximization problem. (Figure 1 depicts the feasible set and is derived in the Appendix.)

[9] In particular, we set $p_h \le \frac{a+\theta_h}{2}$ in order to ensure $\frac{1}{3}(a-2p_h+\theta_h) \ge 0$ so that setting q_{1h}^{B} equal to $\frac{1}{3}(a-2p_h+\theta_h)$ is correct. This is an inoquous restriction, since q_{1h}^{B} is zero for all $p_h \ge \frac{a+\theta_h}{2}$ Therefore, the original objective function $\gamma\left[(q_{1\ell}^{B})^2 - k\right] + (1-\gamma)(q_{1h}^{B})^2$ is constant on p_h for $p_h \ge \frac{a+\theta_h}{2}$.

FIGURE 1
The no-share-threat arrangement



LEMMA 1. *Suppose that* $\gamma \leq \overline{\gamma}_1(a)$, *where*

$$\gamma_1(a) = \frac{1}{\frac{(2a-\theta_h-\theta_\ell)(\theta_h-\theta_\ell)}{4(a-\theta_h)^2}+1}$$

is increasing in a. *Then, the optimal price contract under the No-share-threat arrangement is given by* $p_h = \theta_h$ *and* $p_\ell = \widehat{p_\ell} \in (\theta_\ell, \frac{\theta_\ell+\theta_h}{2})$, *where*

$$p_\ell = \frac{1}{2}\left(a+\theta_\ell-\sqrt{(a-\theta_h)^2+(\theta_h-\theta_\ell)^2}\right).$$

Since the upper bound on γ (that is, $\overline{\gamma}_1(a)$) is increasing in a, the set of admissible values of γ expands as market size increases. By Assumption 1, this also implies that $\gamma \leq \overline{\gamma}_1(3\theta_h-2\theta_\ell) = \frac{16}{21}$ (approximately 0,761 9). Notice also that $\overline{\gamma}_1(a)$ tends to 1 as a tends to infinity. In other words, any value for the probability that unit costs are low is admissible provided that the market is large enough.

Let us explain the role of the assumption on γ. Notice first that, when true costs are low and S_1 overeports θ_1, then S_1's profits are decreasing in p_h if p_h is large enough.[10] Therefore, by setting a large p_h firm F_1 is in fact punishing S_1 when it overstates its costs. Hence, it might be optimal for F_1 to raise p_h above θ_h since this relaxes the incentive compatibility constraint. However, such a strategy is quite costly to F_1 if true costs are high sufficiently often (i.e., if γ is not too large). To see why the threshold on γ increases with a, notice that the cost of setting $p_h > \theta_h$ increases if the market is large: a negative mark-up is multiplied by a larger number of units. In sum, the assumption on γ is made in order to guarantee that $p_h = \theta_h$ at the optimum contract. This facilitates the comparisons among the three arrangements.

Notice that F_1 is able to induce S_1 to report its true costs without setting $p_\ell = \theta_h$. Intuitively, by exaggerating its unit costs, S_1 drastically reduces the demand for its product, since S_1 is not allowed to serve F_2 when it claims that its costs are high. Finally, the formula for $\hat{p}_\ell$ is obtained by using [16] with equality, letting $p_h = \theta_h$, and solving for p_ℓ.

The comparative statics of $\hat{p}_\ell$ with respect θ_ℓ, θ_h, and a are worth some comments. It easy to check that the derivatives of $\hat{p}_\ell$ with respect to θ_h and a are both positive. Intuitively, the value of S_1's private information increases as θ_h and a increase. Therefore, informational rents (proportional to $\hat{p}_\ell - \theta_\ell$) must increase. More interestingly, it is also easy to check that the derivative of $\hat{p}_\ell$ with respect to θ_ℓ is smaller than one. Intuitively, as θ_ℓ increases, the unit price must also increase to preserve acceptability. However, as θ_ℓ approaches θ_h from below, the private information loses its value and informational rents are reduced.

4.3. No-threat arrangement

The procedure is very similar to that in the previous subsection. If S_1 announces θ_ℓ, the payoff functions for F_1 and F_2 are the following (compare to [5] and to [6]):

$$\Pi_1 = (a - q_1 - q_2 - p_\ell)q_1, \tag{18}$$

$$\Pi_2 = (a - q_1 - q_2 - \theta_h)q_2. \tag{19}$$

The equilibrium production levels are

$$q_{1\ell}^C = \frac{1}{3}(a - 2p_\ell + \theta_h), \tag{20}$$

[10] Specifically, if $p_h > \frac{a+\theta_h+2\theta_\ell}{4}$. See the right hand side of [16].

$$q_{2\ell}^C = \frac{1}{3}(a - 2\theta_h + p_\ell). \qquad [21]$$

The equilibrium profits are

$$\Pi_{1\ell}^C = [q_{1\ell}^C]^2,$$

$$\Pi_{2\ell}^C = [q_{2\ell}^C]^2.$$

If S_1 declares $\theta_1 = \theta_h$, the payoff functions for F_1 and F_2 are the same functions of p_h as in the previous subsection. Therefore, the equilibrium quantities and profits are also the same functions of p_h. See expressions [8] through [13].

The optimal menu $\{p_\ell, p_h\}$ solves, after the appropriate substitutions,

$$\underset{\substack{\theta_\ell \le p_\ell \le \theta_h \\ \theta_h \le p_h \le \frac{a+\theta_h}{2}}}{\textit{Maximize}} \quad \gamma(\tfrac{1}{3}(a - 2p_\ell + \theta_h))^2 + (1-\gamma)(\tfrac{1}{3}(a - 2p_h + \theta_h))^2$$

subject to

$$(p_\ell - \theta_\ell)\,\frac{1}{3}(a - 2p_\ell + \theta_h) \ge 0, \qquad [22]$$

$$(p_h - \theta_h)\,\frac{1}{3}(a - 2p_h + \theta_h) \ge 0, \qquad [23]$$

$$(p_\ell - \theta_\ell)\,\frac{1}{3}(a - 2p_\ell + \theta_h) \ge (p_h - \theta_\ell)\frac{1}{3}(a - 2p_h + \theta_h), \qquad [24]$$

$$(p_h - \theta_h)\,\frac{1}{3}(a - 2p_h + \theta_h) \ge (p_\ell - \theta_h)\,\frac{1}{3}(a - 2p_\ell + \theta_h). \qquad [25]$$

The interpretation of the constraints is the same as in the previous subsection. (Figure 2 depicts the feasible set and is derived in the Appendix.) The next lemma gives the optimal price contract under the No-Threat Arrangement.

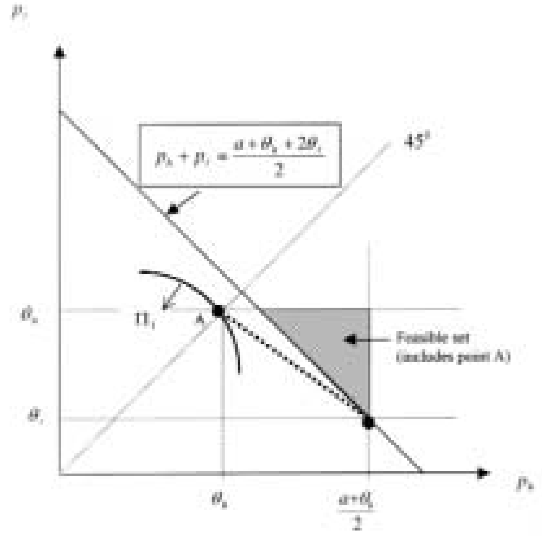
LEMMA 2. *(i) Suppose that* $\gamma \le \overline{\gamma}_2(a)$, *where*

$$\overline{\gamma}_2(a) = \frac{a - \theta_h}{a + \theta_h - 2\theta_\ell}$$

is increasing in a. *Then, the optimal price contract under the No-threat arrangement is given by* $p_h = p_\ell = \theta_h$.

(ii) $\gamma_2(a) < \gamma_1(a)$ *for all a satisfying Assumption 1.*

FIGURE 2
The no-threat arrangement



By part (i), and similarly to Lemma 1, the larger the market size is, the larger is the set of values for γ that are admissible. Also as in Lemma 1, $\overline{\gamma}_2(a)$ tends to one as a tends to infinity, so any γ is admissible provided that the market is large enough. Finally, by Assumption 1, $\overline{\gamma}_2(a) \geq \overline{\gamma}_2(3\theta_h - 2\theta_\ell) = 1/2$. This indicates that $\overline{\gamma}_2(a) < \overline{\gamma}_1(a)$ for some values of a. Part (ii) tells us that this is the case *for all* $a \geq 3\theta_h - 2\theta_\ell$. In other words, for a fixed γ, conditions in Lemma 2 require higher values of market size than those in Lemma 1. Let us explain why this is so next.

In order to simplify the comparisons between the No-Share-Threat Arrangement and the No-Threat Arrangement, we impose conditions on γ ensuring that the optimal contract under the latter arrangement be pooling, i.e., $p_\ell = p_h = \theta_h$. This is so if the only way to induce S_1 to be truthful is that informational rents be set at their highest possible level (i.e., $p_\ell = \theta_h$). By assuming that a is sufficiently large, we ensure that overeporting θ is always a dominant strategy, since any increase in the mark-up due to lying (an increase given by $(p_h - \theta_\ell) - (p_\ell - \theta_\ell) = p_h - p_\ell$) is multiplied by a large number of units. In sum, if a is sufficiently large, S_1's incentives to lie are so strong that the only incentive-compatible contract is a pooling contract.

To sum up, the disadvantage of the No-Threat Arrangement is that unit informational rents are always larger than in the other two arrangements.[11] The advantage is that F_1 is never forced by the contract to either switching or sharing suppliers.

4.4. Comparisons

We have now concluded the study of the different contract arrangements. To close the model, we need to compare F_1's expected payoff under each arrangement. Obviously, we limit our analysis to the case where Lemma 1 and Lemma 2 simultaneously apply. Since $\overline{\gamma}_2(a) < \overline{\gamma}_1(a)$ for all a satisfying Assumption 1, the following assumption suffices.

Assumption 2: $\gamma \leq \overline{\gamma}_2(a)$.

By Lemmata 1 and 2, price contracts and profits under each of the arrangements are

(A) Under the Switch-Threat Arrangement, $p_h = \theta_h$, $p_\ell = \theta_\ell$, and

$$E(\Pi_1^A) = \gamma \left(\frac{a - 2\theta_\ell + \theta_h}{3} \right)^2 + (1-\gamma) \left[\left(\frac{a - \theta_h}{3} \right)^2 - k' \right]. \qquad [26]$$

(B) Under the No-Share-Threat Arrangement, $p_h = \theta_h$, $p_\ell = \hat{p}_\ell$ (given in Lemma 1) , and

$$E(\Pi_1^B) = \gamma \left[\left(\frac{a - \hat{p}_\ell}{3} \right)^2 - k \right] + (1-\gamma) \left(\frac{a - \theta_h}{3} \right)^2. \qquad [27]$$

(C) Under the No-Threat Arrangement, $p_h = p_\ell = \theta_h$, and

$$E(\Pi_1^C) = \left(\frac{a - \theta_h}{3} \right)^2. \qquad [28]$$

[11] This is true even if, under the No-Threat Arrangement, $p_\ell < p_h$. If $2\theta_h - \theta_\ell \leq a < 3\theta_h - 2\theta_\ell$, then it can be shown that the optimal price contracts under the No-Threat Arrangement and under the No-Share-Threat Arrangement are given by, respectively, $(p_\ell^{NT}, p_h^{NT}) = (\frac{a-\theta_h+2\theta_\ell}{2}, \theta_h)$ and $(p_\ell^{NST}, p_h^{NST}) = (\widehat{p}_\ell, \theta_h)$. In particular, Lemma 1 still applies so $p_\ell^{NST} < \frac{\theta_h+\theta_\ell}{2}$. On the other hand, notice that $a < 3\theta_h - 2\theta_\ell$ implies that $p_\ell^{NT} < \theta_h$ while $a \geq 2\theta_h - \theta_\ell$ implies that $p_\ell^{NT} \geq \frac{\theta_h+\theta_\ell}{2}$. To sum up, $p_\ell^{NT} > p_\ell^{NST}$, so unit informational rents are larger under the No-Threat Arrangement. (Recall that there are no informational rents in the Switch-Threat Arrangement, where $p_\ell = \theta_\ell$.)

These expected profits can now be compared. First, we set up some notation to facilitate the statement of our results. Let $M = (a - 2\theta_\ell + \theta_h)^2 - (a - \hat{p}_\ell)^2$, $N = (a - \hat{p}_\ell)^2 - (a - \theta_h)^2$, and $L = (a - \theta_\ell)(\theta_h - \theta_\ell)$. Notice that M, N, and L are all independent of k, k', and γ. It is easy to check that M, N, and L are all positive (using Assumption 2). We have the following result.

PROPOSITION 1 *a) Firm F_1 prefers the No-share-threat arrangement to the Switch-threat arrangement (that is, $E\left(\Pi_1^B\right) \geq E\left(\Pi_1^A\right)$) if and only if*

$$k' \geq \frac{\gamma}{1-\gamma}\left(\frac{M}{9} + k\right). \qquad [a]$$

b) Firm F_1 prefers the No-share-threat arrangement to the No-threat arrangement (that is, $E\left(\Pi_1^C\right) \geq E\left(\Pi_1^A\right)$) if and only if

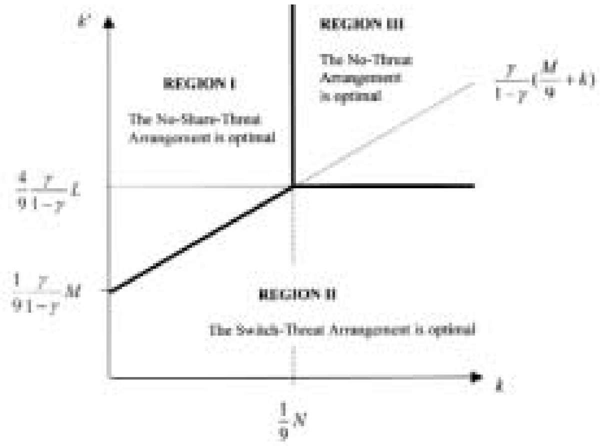
$$k \leq \frac{1}{9}N. \qquad [b]$$

c) Firm F_1 prefers the No-threat arrangement to the Switch-threat arrangement (that is, $E\left(\Pi_1^C\right) \geq E\left(\Pi_1^A\right)$) if and only if

$$k' \geq \frac{4}{9}\frac{\gamma}{1-\gamma}L. \qquad [c]$$

These results can be combined and summarized as indicated in Figure 3. Conditions [a] and [b] are jointly necessary and sufficient for the No-Share-Threat Arrangement be optimal. The set of parameter satisfying [a] and [b] is depicted as Region I in Figure 3.

FIGURE 3
The optimal arrangement



On the other hand, the negation of condition [a] and the negation of condition [c] are jointly necessary and sufficient for the Switch-Threat Arrangement be optimal. This is depicted as Region II.

Finally, condition [c] and the negation of condition [b] are jointly necessary and sufficient for the No-Threat Arrangement be optimal, depicted as Region III.

We are specially interested in Region I, since it is in this region where our most important result holds. Indeed, in this region firm F_1 ends up sharing its super-competitive supplier whenever this supplier declares that its costs are low.

Region I is characterized by low values of the adaptation costs k and high values of the switching costs k'. A low k implies that sharing is not too costly, while a high k' implies that switching suppliers is not beneficial. Notice that Region I expands while Region II contracts as γ tends to zero. Intuitively, as γ tends to zero, the costs of setting the Switch-Threat Arrangement increase, since the threat will have to be carried out with more probability.

Unfortunately, the comparative statics of Region I with respect to the rest of the parameters (θ_ℓ, θ_h, and a) do not yield any interesting results.[12]

5. Extensions

We address several extensions of our model. First, as discussed in Section 4, our assumptions imply the least favorable scenario for a sharing agreement. In particular, we have assumed that F_1 bears the adaptation costs. We formalize this discussion by showing that Region I does not shrink if either S_1 or F_2 bear these adaptation costs (see Subsections 5.1 and 5.2, respectively).

Second, in Subsection 5.3 we report the results in Olivella and Pastor (1997), where firm F_1 is allowed to impose price discrimination in the

[12] When either θ_h or θ_ℓ increase, it is easy to check that both M and N are reduced. However, the reduction in M expands Region I while the reduction in N contracts it. The derivative of N with respect to a can be proven to be positive for a large enough. On the other hand, it is easy to check that M increases with a for all a satisfying Assumption 2. Therefore, for a large enough, an increase in a expands Region I through the increase in M but at the same time contracts Region I through the increase in N.

intermediate good market. Basically, although the size or Region I expands, social welfare is reduced.

Finally, in Subsection 5.4 we address the case of price competition in the final good market. In short, the No-Share-Threat Agreement is never observed.[13] Interestingly, we show that this result holds independently of whether one allows price discrimination in the intermediate good market or not.

5.1. The rival firm pays for the adaptation costs

In the reminder, we denote Region I in Figure 3 by R_I. This is the region where the No-Share-Threat Arrangement dominates when F_1 bears the adaptation costs. When F_2 instead of F_1 pays for k, the fact that $p_\ell < \theta_h$ no longer guarantees that F_2 accept the sharing arrangement. Therefore, a voluntary participation constraint (F_2's VPC henceforth) must be added to the set defined by [14]-[17]. However, this constraint will not be binding if k is small, i.e., if

$$\left(\frac{a-\widehat{p}_\ell}{3}\right)^2 - k \geq \left(\frac{a-2\theta_h+\widehat{p}_\ell}{3}\right)^2, \qquad [29]$$

where the left and right hand side respectively denote F_2's profits if he accepts and if he rejects.[14] Intuitively, the increase in F_2's mark-up (this increase is given by $(a-\widehat{p}_\ell)-(a-\theta_h) = \theta_h - \widehat{p}_\ell$) suffices to compensate the fixed adaptation costs if they are small. Let $\widehat{k}$ be the value of k that solves [29] with equality.

Instead of calculating the optimal price contract for each possible value of k, we take the following short-cut. Let us ignore F_2's VPC. Then Lemma 1 applies. For any $0 < k < \widehat{k}$, the new expected payoff of F_1 must be larger than before, since (p_ℓ, p_h) remain unchanged while F_1 no longer bears the adaptation costs. Therefore, for any point (k, k') in R_I such that $k \leq \widehat{k}$, firm F_1 earns larger profits (strictly if $k > 0$) under the No-Share-Threat Arrangement than in any other arrangement.[15] Finally, we show that *all* (k, k') in R_I satisfy $k < \widehat{k}$.

Formally, solving [29] with equality for k yields

$$\widehat{k} = \frac{4}{9}(a-\theta_h)(\theta_h - \widehat{p}_\ell).$$

[13] We are thankful to a referee that pointed this out to us.

[14] Notice that, if F_2 rejects, firm F_1 still receives the intermediate input at the low price $\widehat{p}_\ell$, since F_2's decision is taken once S_1 has already accepted the price contract.

[15] Notice that, under the other arrangements, S_1 is never shared, so the solution is independent of k.

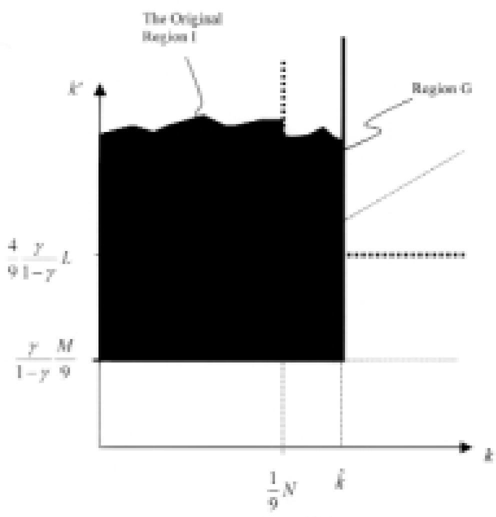
Recall that any (k, k') in R_I satisfies $k \leq \frac{1}{9}N$, where $N = (a - \hat{p}_\ell)^2 - (a - \theta_h)^2$. Hence, it suffices to show that $\widehat{k} \geq \frac{1}{9}N$. This is equivalent, after some algebra, to

$$2a - 3\theta_h + \widehat{p_\ell} \geq 0. \qquad [30]$$

Use now Assumption 1 and $\theta_\ell < \widehat{p_\ell} < \theta_h$ to see that [30] holds.

Finally, let us insist that R_I does not exhaust the set of (k, k') pairs where the No-share Threat Arrangement dominates when F_2 bears the adaptation costs. To fully characterize the comparison between the three arrangements would require re-calculating the price contract when F_2's VPC *is* binding.[16]

FIGURE 4
The original Region I and Region G.



5.2. *The supplier pays for the adaptation costs*

When S_1 bears the adaptation costs, the optimal price contract depends on k even if k is small. The reason is that p_ℓ must now not only

[16] By directly comparing F_1's expected payoffs in the three arrangements it is easy to check that, for all $k \leq \widehat{k}$, the region where the No-Share Threat Arrangement dominates is given by set G in Figure 4. That is, Region I expands in strict terms when F_2 instead of F_1 bears the adaptation costs.

include informational rents, but also ensure that S_1 is willing to bear the adaptation costs. Moreover, by having S_1 pay for k makes it more difficult to induce S_1 to be truthful. Hence, informational rents must be larger. Anyhow, we are able to prove the following:

PROPOSITION 2 *Region I does not shrink when S_1 instead of F_1 pays for the adaptation costs.*

Intuitively, instead of calculating the optimal contract under the No-Share-Threat Arrangement for each k and carrying out the necessary comparisons, we propose another shortcut. For each (k, k') in R_I we propose a feasible contract that yields profits for F_1 that are not lower than those obtained in the original model. This can be explained as follows. Increasing p_ℓ does not harm F_1's competitiveness, since F_2 must also pay a higher cost. Moreover, the fact that k is no longer borne by F_1 more than compensates the increase in p_ℓ. Thus, the crucial step is to show that p_ℓ increases with k quite slowly inside Region I.

5.3. Price discrimination in the intermediate good market

If the Robinson-Patman Act is not enforced, then F_1 is allowed to conduct third-degree price discrimination in the intermediate-good market. This is in fact studied formally in Olivella and Pastor (1997). We show there that if F_1's bargaining power *vis-à-vis* F_2 is strong, then F_1 charges a high price for the intermediate good. In sum, allowing price discrimination in the intermediate good market seriously hampers the social advantages of the sharing agreement. We return to this point in the final section.

We also show there that the optimality of the sharing agreement is consistent with larger values of k. This is so because there exists an additional reason for F_1 to allow S_1 to serve its rival. Firm F_1 captures rents from F_2 by lowering the unit mark-up it pays to S_1 while raising that of F_2. In sum, under price discrimination Region I will expand further. Moreover, one would observe sharing agreements even under symmetric information. Again, however, the social advantages of these agreements would tend to vanish if F_1's bargaining power is strong.

5.4. Price competition in the final good market

Our assumption that competition between manufacturers is in quantities is crucial. Suppose that competition was *à la* Bertrand. Then sharing the supplier would lead to symmetric unit costs under uniform pricing in the intermediate good market. Symmetry together with constant returns to scale would lead to zero profits for both manufacturers. Hence, F_1 would never share its supplier.

Perhaps more surprisingly, this is also true if price discrimination is allowed. Clearly, a sharing agreement would never entail F_2 paying a lower price than F_1, since this would imply that F_1 is expelled from the final good market.[17] For the same reason, the only way that firm F_2 produce a positive quantity in equilibrium (otherwise sharing is devoid of meaning) is that F_2 pay at most the same price as F_1.[18] These two arguments imply that a sharing agreement must entail uniform prices. This is again never in the interest of F_1.[19]

6. Policy implications

Our main result is that the presence of asymmetric information between a manufacturing firm and its super-competitive supplier may have beneficial effects on competition. Indeed, in order to decrease informational rents, the manufacturer shares its supplier with its rivals. This is so despite the fact that the manufacturing firm loses competitiveness *vis à vis* its rivals. More surprisingly, we have shown that the manufacturer may find sharing beneficial even if this requires some additional investment (the adaptation costs).

An important consequence is that, as shown in Olivella and Pastor (1997), both the consumer surplus and social welfare may be larger under asymmetric information. This is so if adaptation costs are sufficiently small. Intuitively, in this case F_1 shares S_1 with F_2 under asymmetric information. Recall that sharing is never observed under

[17] Throughout this section we ignore the technical issue of non-existence of a Nash equilibrium under asymmetric costs and constant returns to scale. Moreover, due to Assumption 1, this issue is always present, since $a > \theta_h - 2\theta_\ell$ implies that the monopolistic price in the final good market (given by $\frac{a+\bullet_\ell}{2} > \frac{a+\theta_\ell}{2}$) is always above θ_h.

[18] In this setting, a "price squeeze" (that is, F_1 offers S_1's product at such a high price that F_2 is unwilling to accept the offer, see Joskow, 1985) occurs at any p_ℓ above that payed by F_1.

[19] The comparison between the No-Threat Arrangement and the Switch-Threat Arrangement under Bertrand competition is well beyond the scope of this paper.

symmetric information, even if adaptation costs are zero. When sharing does occur, the total amount produced is larger. Although F_1's production is carried out at a larger cost under asymmetric information (due to informational rents) F_2 bears much lower costs, due to its access to a cheaper supply of the intermediate good.

This suggests several policy implications. First, as mentioned in Subsection 5.3, the government should enforce anti-discrimination laws in the intermediate good market. More so if F_1 has a strong bargaining position *vis à vis* its rivals. Otherwise, F_1 would share S_1 at such a high price that the beneficial effects of sharing would vanish. Second, once uniform pricing is secured, the regulator should foster policies that favor F_1's incentives to share its supplier. Notice that, when considering a sharing agreement, firm F_1 ignores its beneficial effects on both the consumer surplus and on F_2's profits. Therefore, if adaptation and switching costs are outside (but no too far from) Region I, F_1 will not share its supplier despite it being socially beneficial. The regulator should then subsidize adaptation investments in order to promote a sharing agreement. An important lesson of our analysis is that such policy is only useful under asymmetric information, since otherwise sharing agreements are harmful to F_1 even if adaptation costs are zero.

Finally, the regulator should not allow F_1 to vertically integrate its supplier. Integration could both reduce the informational asymmetry between manufacturer and supplier and, more importantly, make it very hard to implement the Robinson-Patman Act. As discussed above, this would seriously hamper the social advantages of the sharing agreement.

Appendix A1

Proof of Lemma 1

We first analyze the feasible set.

Step 1. Redundant constraints.

1) Since $\theta_h > \theta_\ell$, restrictions [15] and [16] imply [14].

2) Since $p_\ell \leq \theta_h$, the right hand side of [17] is non-positive. Since $p_h \geq \theta_h$, the left hand side is non-negative. Hence, [17] is redundant.

3) Since $\theta_h \leq p_h \leq \frac{a+\theta_h}{2}$, constraint [15] is also redundant.

Step 2. Analysis of the remaining constraint [16].

Notice first that the objective function is decreasing in both p_h and p_ℓ. Define

$$G(p_h, p_\ell) = (p_\ell - \theta_\ell)\frac{2}{3}(a - p_\ell) - (p_h - \theta_\ell)\frac{1}{3}(a - 2p_h + \theta_h).$$

Then we can express [16] as $G(p_h, p_\ell) \geq 0$. Clearly, this constraint must be binding since otherwise one could lower either p_h or p_ℓ, thereby increasing the objective function. The following remarks will be useful later on.

Solving for p_ℓ in $G(p_h, p_\ell) = 0$, we obtain two solutions:

$$p_\ell = \frac{1}{2}\left(a + \theta_\ell \pm \sqrt{(a^2 + \theta_\ell^2 - 2p_h a + 4p_h^2 - 2p_h\theta_h - 4\theta_\ell p_h + 2\theta_\ell\theta_h)}\right).$$

1) Let us first show that these two solutions are well-defined, that is, that the radicand, say $R(p_h|a)$, is always positive. Note that the radicand is increasing in a. Then substitute a by $2\theta_h - \theta_\ell < 3\theta_h - 2\theta_\ell < a$ (by Assumption 1). Then $R(p_h|a)$ is larger than $R(p_h|2\theta_h - \theta_\ell)$. Use now $p_h > \theta_h > \theta_\ell$, to show that $R(p_h|2\theta_h - \theta_\ell)$ is increasing in p_h. Hence,

$$R(p_h|2\theta_h - \theta_\ell) \geq R(\theta_h|2\theta_h - \theta_\ell) = 2\left(\theta_\ell - \theta_h\right)^2 > 0,$$

and we are done.

2) The solution with the positive root is unfeasible. The reason is that $p_\ell > (a + \theta_\ell)/2$ implies $p_\ell > \theta_h$, by Assumption 1. Let us analyze the other solution, which we refer to as $p_\ell(p_h)$.

3) Eliminate a in the notation for the radicand. We show now that $p_\ell(p_h)$ is concave. This is equivalent to proving that $(R'(p_h))^2 < 2R''(p_h)$ $R(p_h)$. Substitute $R(p_h)$, $R'(p_h)$, and $R''(p_h)$ by their corresponding expressions. The inequality can then be written as $(\theta_h - a)\,(3a + \theta_h - 4\theta_\ell)$ < 0. Assumption 1 and $a > \theta_h$ imply that the inequality holds.

4) Since p_h lies always between $(a + \theta_h)/2$ and θ_h, it is useful to prove that

(i) $p_\ell((a + \theta_h)/2) = \theta_\ell$,

(ii) $p_\ell(\theta_h) > \theta_\ell$, and

(iii) $p_\ell(\theta_h) < (\theta_h + \theta_\ell)/2$.

Assertion (i) is proven by direct substitution. Let us prove (ii) next.

Let $D=\frac{1}{3}(\theta_h - \theta_\ell)(a - \theta_h) > 0$. Then, $G(\theta_h, \theta_\ell)=-D$ and $G(\theta_h, \theta_h) = D$. This proves that the solution $p_\ell(\theta_h)$ to $G(\theta_h, p_\ell) = 0$ belongs to the open interval (θ_ℓ, θ_h).

Finally, we prove assertion (iii). The fact that $G(\theta_h, p_\ell)$ is strictly concave in p_ℓ (since $\dfrac{\partial^2 G}{\partial^2 p_\ell} = -\left(\frac{4}{3}\right)$) allows us to use the fact that the secant joining point $(\theta_\ell, G(\theta_h, \theta_\ell))$ and point $(\theta_h, G(\theta_h, \theta_h))$ is always below the curve $G(\theta_h, p_\ell)$. That is, we can write that, for all $x \in (\theta_\ell, \theta_h)$, it must be true that

$$\begin{aligned} G(\theta_h, x) &> G(\theta_h, \theta_\ell) + \frac{G(\theta_h, \theta_h) - G(\theta_h, \theta_\ell)}{\theta_h - \theta_\ell} \\ (x - \theta_\ell) &= -D + \frac{2D}{\theta_h - \theta_\ell}(x - \theta_\ell). \end{aligned}$$

Suppose, by contradiction, that $p_\ell(\theta_h) \geq (\theta_\ell + \theta_h)/2$. Then, taking $x = p_\ell(\theta_h)$, we can write

$$0 = G(\theta_h, p_\ell(\theta_h)) > -D + \frac{2D}{\theta_h - \theta_\ell}(p_\ell(\theta_h) - \theta_\ell) \geq$$

$$\geq -D + \frac{2D}{\theta_h - \theta_\ell}\left(\frac{(\theta_\ell + \theta_h)}{2} - \theta_\ell\right) = 0,$$

a contradiction.

5) We now study the slope of the function $p_\ell(p_h)$. The slope of $p_\ell(p_h)$ has the opposite sign of the slope of the radicand in the expression of $p_\ell(p_h)$. The slope of the radicand is positive if and only if $p_h > \dfrac{\theta_h + 2\theta_\ell + a}{4}$, which is strictly smaller than $\dfrac{a + \theta_h}{2}$ since $\theta_\ell < \theta_h < a$ (this will be needed later on). Notice that, by Assumption 1, $a \geq 3\theta_h - 2\theta_\ell$, which in turn implies that $\dfrac{\theta_h + 2\theta_\ell + a}{4} \geq \theta_h$. Therefore, the function $p_\ell(\theta_h)$ has a strict maximum at $p_h = \dfrac{\theta_h + 2\theta_\ell + a}{4}$ in the interval $[\theta_h, \dfrac{a + \theta_h}{2}]$ (recall that $\dfrac{\theta_h + 2\theta_\ell + a}{4} < \dfrac{a + \theta_h}{2}$).

The function $p_\ell(p_h)$ is depicted in Figure 1.

This analysis allows us to draw the *feasible set*, defined by $p_\ell \geq p_\ell(p_h)$, $p_\ell \leq \theta_h$, $p_h \geq \theta_h$, and $p_h \leq \dfrac{a+\theta_h}{2}$. (See Figure 1.)

We now give a sufficient condition for the corner $(p_h, p_\ell) = (\theta_h, p_\ell(\theta_h))$ (point A in Figure 1) to be the solution of the maximization problem. The solution $\widehat{p_\ell}$ given in the lemma is therefore obtained by substituting $p_h = \theta_h$ into $p_\ell(p_h)$.

Notice first that F_1's objective function is quasiconcave and decreases with both p_ℓ and p_h. Hence, F_1's indifference curves in the space (p_h, p_ℓ) are concave and decreasing. Therefore, it suffices to prove that, in absolute values, the slope of F_1's indifference curve at the proposed solution be larger than or equal to the slope of segment AB in Figure 1. This can be written (after some algebra) as

$$\frac{1-\gamma}{\gamma} \geq \frac{(a-\widehat{p_\ell})(\widehat{p_\ell}-\theta_\ell)}{(a-\theta_h)^2}. \qquad \text{[A1.1]}$$

Using that $\widehat{p_\ell} < (\theta_h + \theta_\ell)/2$ (see (iii) above), it is easy to check that the right hand side (RHS) of [A1.1] increases with $\widehat{p_\ell}$. Hence, using $\widehat{p_\ell} < \frac{\theta_h+\theta_\ell}{2}$ again, we know that the RHS of [A1.1] is smaller or equal than

$$\frac{(2a-\theta_h-\theta_\ell)(\theta_h-\theta_\ell)}{4(a-\theta_h)^2}.$$

In other words, it suffices to prove that $\frac{1-\gamma}{\gamma} \geq \frac{(2a-\theta_h-\theta_\ell)(\theta_h-\theta_\ell)}{4(a-\theta_h)^2}$. Isolating γ from this inequality yields the condition $\gamma \leq \overline{\gamma}_1(a)$ in the Lemma. By differentiating the denominator of $\overline{\gamma}_1(a)$ with respect to a and using $a > \theta_h > \theta_\ell$ it is easy to check that $\overline{\gamma}_1(a)$ increases with a. ■

Proof of Lemma 2

The proof is quite similar to that of Lemma 1. We first analyze the feasible set.

Step 1. One can show, using the same arguments as in the previous proof, that [22], [25], and [23] are all implied by (i) $\theta_\ell \leq p_\ell \leq \theta_h$ and (ii) $\theta_h \leq p_h \leq \dfrac{a+\theta_h}{2}$. Statements (i) and (ii) also imply that $p_h \geq \theta_h \geq p_\ell$.

Step 2. Analysis of the remaining constraint [24]. Let us analyze the constraint set by means of Figure 2, which we derive next. After rearranging terms, (and using the fact that $x^2 - y^2 = (x+y)(x-y)$ for all x and y), if $p_h > p_\ell$ then [24] can be rewritten as

$$\frac{a + \theta_h + 2\theta_\ell}{2} \leq p_h + p_\ell. \quad \text{[A1.2]}$$

On the other hand, if $p_h = p_\ell = \theta_h$ (the only remaining case), then [24] is also satisfied. It now becomes crucial to check whether the feasible pair $(p_h, p_\ell) = (\theta_h, \theta_h)$ (point A in Figure 2) is already included in the set satisfying [A1.2], or, on the contrary, it constitutes a new feasible pair. The latter will hold if $2\theta_h < \frac{a + \theta_h + 2\theta_\ell}{2}$, which turns out to be true whenever $a > 3\theta_h - 2\theta_\ell$. This is admissible, by Assumption 1. We depict the feasible set under this assumption in Figure 2. If, on the other hand, a is exactly equal to $3\theta_h - 2\theta_\ell$, then point A is included in [A1.2].

This concludes the analysis of the feasible set. We now find a sufficient condition ensuring that the corner $(p_h, p_\ell) = (\theta_h, \theta_h)$ is the solution to the maximization problem.

Again, due to the quasi-concavity of the objective function, it suffices to prove that, in absolute values, the slope of the indifference curve going through point A is larger than or equal to the slope of segment AB in Figure 2. After some algebra, this can be rewritten as

$$\frac{(1-\gamma)}{\gamma} \geq 2\frac{\theta_h - \theta_\ell}{a - \theta_h}. \quad \text{[A1.3]}$$

Isolating γ from the last expression yields the condition $\gamma \leq \overline{\gamma}_2(a)$ in the lemma. Differentiate $\overline{\gamma}_2(a)$ with respect to a and use $\theta_h > \theta_\ell$ to see that $\overline{\gamma}_2(a)$ is increasing in a. This concludes the proof of part (i) of the lemma.

Part (ii) is proven as follows. The inequality $\overline{\gamma}_1(a) > \overline{\gamma}_2(a)$ is equivalent to

$$\frac{a - \theta_h}{a + \theta_h - 2\theta_\ell} < \frac{1}{\frac{(2a-\theta_h-\theta_\ell)(\theta_h-\theta_\ell)}{4(a-\theta_h)^2} + 1}.$$

Now multiply and divide the right hand side by $4(a-\theta_h)^2 > 0$, cancel $(a - \theta_h) > 0$ in both sides, and multiply both sides by the product of the resulting denominators, which are both positive since $a > \theta_h > \theta_\ell$, to get

$$(2a - \theta_\ell - \theta_\ell)(\theta_h - \theta_\ell) + 4(a-\theta_h)^2 < 4(a-\theta_h)(a + \theta_h - 2\theta_\ell).$$

After some algebra and letting $D_0(a) \equiv (\theta_h - \theta_\ell)(-7\theta_h + \theta_\ell + 6a)$, the last inequality is equivalent to $D_0(a) > 0$. Now $D_0'(a) = 6(\theta_h - \theta_\ell) > 0$, so it suffices to show that $D_0(3\theta_h - 2\theta_\ell) > 0$, since $a \geq 3\theta_h - 2\theta_\ell$ by Assumption1. By substitution, $D_0(3\theta_h - 2\theta_\ell) = 11(\theta_h - \theta_\ell)^2 > 0$, which concludes the proof of part (ii) of the lemma. ■

Proof of Proposition 1

The proof follows directly from comparing expressions [26], [27], and [28]. ■

Proof of Proposition 2

If S_1 bears k, the feasible set under the No-Share-Threat Arrangement is given by

$$(p_\ell - \theta_\ell)\frac{2}{3}(a - p_\ell) - k \geq 0, \qquad \text{[A1.4]}$$

$$(p_h - \theta_h)\frac{1}{3}(a - 2p_h + \theta_h) \geq 0, \qquad \text{[A1.5]}$$

$$(p_\ell - \theta_\ell)\frac{2}{3}(a - p_\ell) - k \geq (p_h - \theta_\ell)\frac{1}{3}(a - 2p_h + \theta_h), \qquad \text{[A1.6]}$$

$$(p_h - \theta_h)\frac{1}{3}(a - 2p_h + \theta_h) \geq (p_\ell - \theta_h)\frac{2}{3}(a - p_\ell) - k. \qquad \text{[A1.7]}$$

Respectively, these expressions represent S_1's voluntary participation constraints when $\theta_1 = \theta_\ell$ and when $\theta_1 = \theta_h$ and S_1's incentive compatibility constraints when $\theta_1 = \theta_\ell$ and when $\theta_1 = \theta_h$. Notice that we have substracted k from S_1's variable profits whenever S_1 serves F_2 (i.e., whenever S_1 announces θ_ℓ). The rest of the proof follows several steps.

Step 1: Construct a feasible contract for each k.

Set $p_h = \theta_h$ in [A1.6] and move all terms to the left hand side. This yields $(p_\ell - \theta_\ell)\frac{2}{3}(a - p_\ell) - (\theta_h - \theta_\ell)\frac{1}{3}(a - \theta_h) - k \geq 0$. Denote the left hand side by $G(p_\ell, k)$. Now solve $G(p_\ell, k) = 0$ for p_ℓ and denote the smallest solution for each k by $p_\ell(k)$.

The contract that is proposed is $(p_\ell, p_h) = (p_\ell(k), \theta_h)$.

Step 2: Show that there exists $\overline{k}$ such that $\theta_\ell < p_\ell(k) < \theta_h$ for all $0 < k < \overline{k}$ and $p_\ell(\overline{k}) = \theta_h$.

In the proof of Lemma 1 we showed that the smallest solution to the feasible set when $p_h = \theta_h$ and F_1 bears k is given by $\widehat{p}_\ell$. Suppose now that $k = 0$. Then it does not matter who pays k and the same solution must appear when S_1 bears k. Hence, $p_\ell(0) = \widehat{p}_\ell$. By Lemma 1, we have $\theta_\ell < \widehat{p}_\ell = p_\ell(0) < \frac{\theta_h+\theta_\ell}{2} < \theta_h$.

We now construct $\overline{k}$. Set $p_\ell = \theta_h$ in $G(p_\ell, k) = 0$ and isolate k. This is the value of $\overline{k}$. This yields

$$\overline{k} = \frac{1}{3}(\theta_h - \theta_\ell)(a - \theta_h).$$

Notice now that $G(p_\ell, k)$ is quadratic and concave in p_ℓ and that it shifts downwards with k. Therefore, the equation $G(p_\ell, k) = 0$ has at most two solutions and, when it does have two solutions, the smaller solution increases with k. For instance, if $k = \overline{k}$ then it is trivial to check that the two solutions are $p_\ell = \theta_h$ (by construction) and $p_\ell = a + \theta_\ell - \theta_h$. By Assumption 1, the first one is the smaller of the two. In other words, $p_\ell(\overline{k}) = \theta_h$.

To sum up, we have shown that $p_\ell(0) \in (\theta_\ell, \theta_h)$, that $p_\ell(\overline{k}) = \theta_h$, and that $p_\ell(k)$ is increasing in p_ℓ. This concludes Step 2.

Step 3: Prove that the proposed solution in Step 1 is feasible for all $0 \leq k \leq \overline{k}$.

Constraint [A1.4] is implied by [A1.5], [A1.6], and $\theta_h > \theta_\ell$. Constraint [A1.6] is satisfied with equality since $p_h = \theta_h$. Constraint [A1.6] is satisfied with equality by construction. (Recall that $G(p_\ell(k), k) \equiv 0$.) Finally, Constraint [A1.7] is satisfied since the left hand side is zero ($p_h = \theta_h$) while the right hand side is non-positive since $p_\ell(k) \leq \theta_h$ for all $0 \leq k \leq \overline{k}$.

Step 4: Show that, for all (k, k') in R_I, F_1's expected profits at the proposed contract $(p_\ell(k), \theta_h)$ when S_1 bears the adaptation costs not smaller than those obtained at the original contract $(\widehat{p}_\ell, \theta_h)$ when F_1 bears the adaptation costs (denoted by $E(\Pi_1^B)$ and given in Subsection 4.4). That is, we must show that

$$E(\Pi_1(p_\ell(k), \theta_h)) = \frac{1}{9}\left[\gamma(a - p_\ell(k))^2 + (1-\gamma)(a - \theta_h)^2\right] \geq$$

$$\frac{1}{9}\left[\gamma(a - \widehat{p}_\ell)^2 + (1-\gamma)(a - \theta_h)^2\right] - \gamma k = E(\Pi_1^B).$$

This also requires several steps.

Step 4.1. Show that $p_\ell(k) < \theta_h$ for all (k, k') in R_I.

For all (k,k') in R_I, we have $k < \frac{1}{9}N = \frac{1}{9}\left[(a-\widehat{p_\ell})^2-(a-\theta_h)^2\right]$. Hence, by Step 2 it suffices to prove that $\frac{1}{9}N < \underline{\overline{k}}$, or $(a-\widehat{p_\ell})^2 - (a-\theta_h)^2 < 3(\theta_h-\theta_\ell)(a-\theta_h)$. Using $\widehat{p_\ell} > \theta_\ell$, we have this inequality is implied by $(a-\theta_\ell)^2 - (a-\theta_h)^2 < 3(\theta_h-\theta_\ell)(a-\theta_h)$. Use now $x^2-y^2=(x-y)(x+y)$ in the left hand side to rewrite this inequality as $2\theta_h-\theta_\ell < a$, which is true by Assumption 1.

Step 4.2. Define $DIF(k) = E(\Pi_1(p_\ell(k),\theta_h)) - E(\Pi_1(\widehat{p_\ell},\theta_h))$. Obviously, $DIF(0) = 0$. It only remains to prove that $DIF'(k) > 0$ for all (k,k') in R_I.

This is equivalent to

$$(a-p_\ell(k))p_\ell'(k) < 9/2. \qquad [A1.8]$$

Calculate $p_\ell'(k)$ by differentiating the identity $G(p_\ell(k),k) \equiv 0$. This yields

$$p_\ell'(k) = \frac{3/2}{a-2p_\ell(k)+\theta_\ell}.$$

Substitute this expression into [A1.8] to get

$$a > \frac{5}{2}p_\ell(k) - \frac{3}{2}\theta_\ell. \qquad [A1.9]$$

By Step 4.1, $p_\ell(k) < \theta_h$ for all (k,k')in R_I. Hence, it suffices to prove that $a > \frac{5}{2}\theta_h - \frac{3}{2}\theta_\ell$. It is straightforward to see that Assumption 1 and $\theta_h > \theta_\ell$ implies precisely this condition. ■

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Resumen

Estudiamos una industria en que una empresa (F) y su proveedor (S) han realizado previamente una inversión específica. En consecuencia, S tiene costes esperados de producción menores, existen costes de cambiar de proveedor y F puede limitar el acceso de sus rivales a S. Cuando sólo S conoce sus costes de producción, comparamos tres mecanismos para inducir a S a revelar esta información: pagar rentas informacionales, amenazar con cambiar de proveedor, y permitir que S sirva a empresas rivales. La presencia de información asimétrica mitiga el incentivo de F a realizar restricciones verticales. Discutimos varias implicaciones de este resultado.

Palabras clave: Adaptarse a los proveedores, costes de cambio de proveedor, comporter proveedores, restricciones verticales, información asimétrica.

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