REGULATION BY DUOPOLY

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This paper analyzes, within the framework of the new regulatory economics that emphasizes asymmetries of information, the optimal structure of an industry. The duplication of fixed costs incurred in a duopoly structure may be socially justified in a static model by three effects: the sampling effect, the yardstick competition effect, and the increasing marginal cost effect.

We show that in general, asymmetric information favors duopoly when the market structure is decided before firms discover their cost characteristics (a common situation in dual sourcing for procurement), and favors monopoly when the market structure is decided after firms discover their cost characteristics (the case of split-award auctions).

1. INTRODUCTION

The organization of sectors, once claimed to be natural monopolies, in the form of duopolistic structures is becoming frequent: MCI and ATT in long-distance telecommunications in the United States; British Telecom and Mercury, until recently, for fixed-linked public telecommunications; Telecom Securitor and Racal-Vodaphone for cellular networks in England; France Telecom and SFR for mobile phone in France. A trade-off appears to exist between the economies of scale that would arise from a monopoly structure and various costs of such a structure. As the director general of Telecommunications in England puts it: "If efficiency of operation were surely guaranteed, the existence of economies of scale would mean that it would be cheaper to provide a given increase of service by expanding an existing network rather than establishing a new one; . . . However, in the world as we find it, some competition between networks is likely to be desirable because monopoly suppliers do not normally operate at the greatest level of efficiency."

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Likewise in U.S. military procurement, dual sourcing, particularly in the development stage of important systems and even in production, is becoming widespread: "Since 1980 dual-sourcing has increased dramatically, especially for important expensive systems such as the Advanced Medium Range Air-to-Air Missile, the Tomahawk cruise missile, and fighter aircraft engines. Currently, the Navy is committed to dual sourcing the Osprey, and the Army will dual-source the LHX and all major LHX subsystems. The Air Force is considering dual-sourcing the ATF . . ." (Burnett and Kovacic, 1989).

The purpose of the paper is to analyze, within the framework of the new regulatory economics that emphasizes asymmetries of information, the benefits and costs of duopolistic structures. It provides a step toward a much needed theory of regulation for oligopolistic markets. The analysis is carried out within a static model and leaves aside many of the interesting issues arising in dynamic relationships (post-contractual opportunism, learning-by-doing effects, relevance of a large industrial basis for future programs) as well as political economy issues (With more firms involved, it is easier to build political support for a program.).

In our model the cost of duopolistic structures is the duplication of fixed costs that can occur either before or after firms learn the private information about their technologies. The benefits are (1) an increased sample that reduces expected marginal cost, (2) the possibility of yardstick competition because of the correlation of firms' private information, and (3) the ability to avoid decreasing returns to scale once the major fixed costs have been incurred.[1]

It would be too lengthy to consider all possible cases. We will focus on two models that address two quite different situations. The first model, *the ex ante case,* is meant to represent dual sourcing in procurement. Then, the market structure must often be decided before firms discover their private information. It is notably the case for the production of new weapon systems that require the development of prototypes. The development costs associated with the prototype are sunk, and the production of a new weapon system appears as a natural monopoly. Despite this fact, "The Department of Defense (DOD) Appropriations Act of 1987 directs the Secretary of Defense to "use a competitive prototype program strategy" in developing major weapon systems. The measure anticipated the fact that by building

1. In Auriol and Laffont (1992), we also consider the positive effect caused by a larger product space associated with the imperfect substitutability of the commodities produced.

competitive prototypes, DOD and its suppliers would refine manufacturing cost estimates and reduce technical uncertainty because DOD could evaluate contrasting design approaches before starting production (Burnett and Kovacic, 1989)." We leave aside the incentive problems raised by the prototype development stage, and we make the extreme assumption that this stage reduces to the payment of a fixed fee. In this framework we focus on two positive effects of a duopolistic structure, *the sampling effect,* that is, the higher probability of drawing a given marginal cost for the industry, and *the yardstick effect,* that is, the better control of firms' informational rents provided by the correlation of firms' efficiency parameters. The analysis delineates the circumstances under which these two effects dominate the duplication of fixed costs. In general, asymmetric information favors the duopoly structure.

The second model, *the ex post case,* is meant to represent split-award auctions.[2] Then, the market structure is often decided after firms discover their private information, and, therefore, it can be made dependent on the particular cost characteristics of the firms. Here, the regulator benefits from the competition of firms without having to incur the duplication of fixed costs. The correlation of firms' private information would only strengthen the competition effect, and for simplicity it is dropped in this second model. The duplication of fixed costs under complete information can be justified by the existence of increasing marginal costs at least beyond some level of production. They may be due to transportation costs or to organizational diseconomies of scale. The paper studies how asymmetric information affects the optimal choice of the market structure when this *increasing marginal cost effect* is present. Contrary to the ex ante case, the monopoly structure is then favored by asymmetric information.

Section 2 sets up the general model of duopolistic regulation that we maintain in the paper. Section 3 specializes the model to constant marginal costs to study how, in the ex ante case, yardstick competition may justify regulation by duopoly. Section 4 specializes the model to independent private informations to study how in the ex post case, the increasing marginal cost effect influences the optimal split-award auction. Our main findings are summarized in Section 5.

2. Work on split award auctions under complete information (Anton and Yao, 1989; Bernheim and Whinston, 1986; Wilson, 1979) and incomplete information (Anton and Yao, 1992; Riordan and Sappington, 1987, 1989) focuses on the equilibria of particular auctions and does not characterize optimal auctions. McGuire and Riordan (1991) is an exception to which we will return in Section 4.

2. THE GENERAL MODEL

We consider a regulated industry with two perfectly substitutable commodities that can be produced by two firms (the market can be served either by firm 1, by firm 2, or by both). The consumers' gross surplus function is $S(q^1 + q^2)$ for $q^i \geq 0$, $i = 1,2$.

We denote by $q = q^1 + q^2$ the total production and by $P(q) = S'(q)$ the inverse demand function. We assume that $S(q)$ is strictly increasing and strictly concave in q:

$$P(q) = S'(q) > 0 \text{ and } P'(q) = S''(q) < 0 \text{ for } q > 0.$$

"Good i" is produced by firm i ($i = 1,2$) with a two-part cost function $C^i(\beta^i,q^i) + K$ for $q^i \geq 0$, $K \geq 0$, $\beta^i \in [\underline{\beta},\bar{\beta}]$.

We suppose that the fixed cost, K, (identical for both firms) and the variable cost function, $C^i(.,.)$, are common knowledge and that the quantity produced by firm i, q^i, is verifiable. On the contrary, β^i, the efficiency parameter identifying firm $i(i = 1,2)$, is assumed to be a private information of its manager (a high β^i corresponds to a high cost, i.e., an inefficient producer).

The stochastic structure of the β^i's, which is common knowledge, is as follows:

a. $\beta^i = \alpha b + (1 - \alpha)\epsilon^i \quad \alpha \in [0,1] \; i = 1,2$
b. $b \in \{\underline{b},\bar{b}\}$ and $\nu = \text{Prob}\,(b = \underline{b})$
c. ϵ^1 and ϵ^2 are stochastically independent with the same distribution $G(.)$ on $[\underline{\epsilon},\bar{\epsilon}]$ with density function $g(.)$; b and ϵ^i are stochastically independent, $i = 1,2$.

Accordingly, the range of β^i, $i = 1,2$, can be rewritten,

$$[\underline{\beta},\bar{\beta}] = [\alpha\underline{b} + (1 - \alpha)\underline{\epsilon}, \alpha\bar{b} + (1 - \alpha)\bar{\epsilon}].$$

We denote by $\hat{F}(\beta^1,\beta^2)$ the joint cumulative distribution function and $\hat{f}(\beta^1,\beta^2)$ the joint density of $(\beta^1,\beta^2) \in [\underline{\beta},\bar{\beta}] \times [\underline{\beta},\bar{\beta}]; F(\beta^i)$ is the marginal cumulative distribution of β^i, $f(\beta^i)$ the marginal density ($\hat{F}(.,.)$, $\hat{f}(.,.)$, $F(.)$, $f(.)$ are common knowledge).

The random variables β^i's share a common part αb and each β^i has also an idiosyncratic part $(1 - \alpha)\epsilon^i$. This particular structure enables us to discuss the regulation of firms with correlated private informations without extracting all the informational rents as the Crémer-McLean theorem would suggest (see more on this point in the next section).

It is easy to check that the β^i's correlation increases with α. That means intuitively that the privacy of the information held by the firms decreases with this parameter. Thus, for $\alpha = 1$, the β^i's are perfectly correlated ($\beta^1 = \beta^2 = b$), and each firm knows the efficiency parameter of the other firm. For $\alpha = 0$, the β^i's are on the contrary independent ($\beta^i = \epsilon^i, i = 1,2$); the firms and the regulator share the same information about the competitor's cost.

The regulator maximizes a utilitarian social welfare function taking into account that the social cost of public funds is $1 + \lambda$. λ is positive because of the need to use distortive taxation to raise money. Finally, we assume that all the agents are risk neutral.

3. Yardstick Competition and Regulation by Duopoly

In this section the timing of the model is as follows. The regulator decides the market structure on the basis of his expectations about the cost characteristics. The firms sink their fixed costs and discover their efficiency parameters. The regulator proposes a set of contracts in which firms choose.[3] Finally, transfers and production levels occur as defined by the contracts agreed upon.

3.1 The Model

We consider here the case where the firms have constant marginal costs as in Baron and Myerson (1982): $C^i(q^i,\beta^i) + K = \beta^i q^i + K$. As explained in Section 2, we consider in this section the case where the β^i's are correlated ($\alpha > 0$). For simplicity we set:

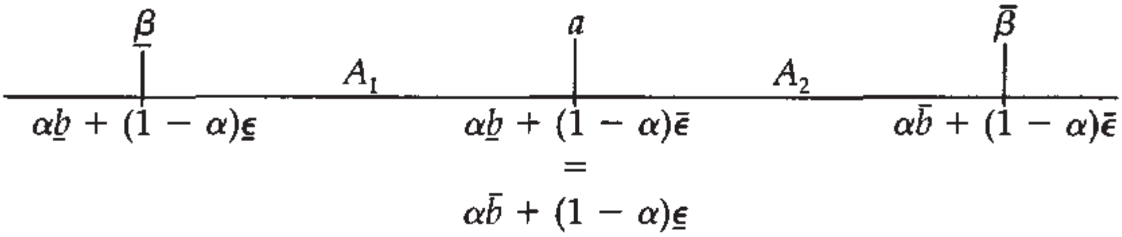
d. $$\alpha = \frac{\bar{\epsilon} - \underline{\epsilon}}{\bar{b} - \underline{b} + \bar{\epsilon} - \underline{\epsilon}}.$$

From Crémer and McLean (1985), we know that, under appropriate rank conditions on conditional distributions, any level of correlation of types between firms enables the regulator to extract all the informational rents. This is an artifact of the convenient assumptions made in this literature of risk neutrality and no ex post bankruptcy constraint. Our assumptions on the stochastic structure do not satisfy the Crémer-McLean rank conditions and enable us to evade their result while still maintaining these convenient assumptions (see Appendix 1).

b is a common factor affecting cost characteristics and the ϵ^i's are

3. Contracts are not offered ex ante because firms have no idea about the nature of the technology. An alternative justification of our timing is that the contract is signed when the duopoly structure is chosen and before agents know their characteristics but firms are infinitely risk averse or their ex post individual rationality constraints must be respected.

idiosyncratic effects. With (b) and (d), when the firms discover their β^i's, they can infer the value of their common factor b (we have $\alpha\underline{b} + (1 - \alpha)\bar{\epsilon} = \alpha\bar{b} + (1 - \alpha)\underline{\epsilon} = a$, the two intervals for β^i's values, A_1 and A_2 are disjoint). It is then intuitive that firms cannot enjoy rents from their knowledge of b. But, simultaneously there is no way the regulator can use the correlation between the β^i's to extract the rents on the ϵ^i's.



Assumption (d) simplifies the analysis and could be, to some extent, relaxed (see Appendix 1). When $\alpha = 1$, we have a special case of Crémer and McLean (1985). The firms share exactly the same information and yardstick competition enables the regulator to reap all the informational rents. When $\alpha = 0$, characteristics are independent and yardstick competition is of no use.

The next subsection provides the benchmark case of a monopoly structure.

3.2 THE MONOPOLY STRUCTURE

The monopoly case, say with firm 1, is a slight variant of the Baron-Myerson model. We drop the index of the firm in this subsection.

Consumers' welfare is $V = S(q) - P(q)q - (1 + \lambda)t$. The firm's utility level is $U = t + P(q)q - \beta q - K$.

Optimal regulation maximizes utilitarian ex post social welfare $U + V = S(q) + \lambda P(q)q - (1 + \lambda)(\beta q + K) - \lambda U$ under the individual rationality constraint $U \geq 0$.

ASSUMPTION A1: *$(1 + 2\lambda)P'(q) + \lambda P''(q)q \leq 0$.*

Under A1 (which follows from the concavity of $S(.)$ if λ is small enough) the regulator's optimization program is concave and yields the solution:[4]

$$U(\beta) = 0 \qquad \forall \beta \in [\underline{\beta}, \bar{\beta}] \tag{1}$$

$$\frac{P(q_M^*) - \beta}{P(q_M^*)} = \frac{\lambda}{1 + \lambda} \frac{1}{\eta(q_M^*)} \tag{2}$$

4. Here and later we assume for simplicity that it is always optimal to have a positive production level.

where $\eta(q)$ is the price elasticity and q^*_M the regulated monopoly full information production level.

Note that, contrary to Baron and Myerson (1982), our benchmark case [eq. (2)] is a form of Ramsey pricing instead of marginal cost pricing. Under complete information the costly rent is set to zero [eq. (1)].

Under asymmetric information, incentive constraints must be added in the regulator's program. From Baron and Myerson (1982) we know that these constraints can be written, using the revelation principle

$$\dot{U}(\beta) = -q(\beta) \qquad \text{a.e.} \tag{3}$$

$$\dot{q}(\beta) \le 0 \qquad \text{a.e.} \tag{4}$$

where $U(\beta)$, the informational rent of the monopoly when he faces the revelation mechanism $(t(\beta), q(\beta))$, is defined by: $U(\beta) = t(\beta) + P(q(\beta))q(\beta) - \beta q(\beta) - K$.

Because the rent is decreasing [from eq. (3)], the individual rationality constraint, $U(\beta) \ge 0$ for any β, reduces to

$$U(\bar{\beta}) \ge 0. \tag{5}$$

To avoid bunching in the monopoly problem, we make the classic monotone hazard rate assumption:

ASSUMPTION A2: *$F(\beta)/f(\beta)$ is nondecreasing for all β.*[5]

As F/f is discontinuous at a (see Appendix 1), we must add the constraint $q(a^-) \ge q(a^+)$ in order to have global incentive compatibility, where a^- (respectively a^+) is the upper (resp. lower) limit of $[\underline{\beta}, a)$ (resp. $(a, \bar{\beta}]$).

Under asymmetric information, the utilitarian regulator solves:

$$\max_{q(\cdot)} \int_{\underline{\beta}}^{\bar{\beta}} \Big[S(q(\beta)) + \lambda P(q(\beta))q(\beta) - (1+\lambda)(\beta q(\beta) + K) - \lambda U(\beta)\Big] dF(\beta)$$

s.t.

$$\dot{U}(\beta) = -q(\beta)$$

$$\dot{q}(\beta) \le 0, \qquad q(a^-) \ge q(a^+)$$

$$U(\bar{\beta}) \ge 0.$$

5. See Appendix 1 for conditions on $G(.)$ and ν ensuring this hypothesis.

The solution of this (by now) classical problem is:

$$\frac{P(q_M) - \beta}{P(q_M)} = \frac{\lambda}{1 + \lambda}\frac{1}{\eta(q_M)} + \frac{\lambda}{1 + \lambda}\frac{F(\beta)}{f(\beta)}\frac{1}{P(q_M)} \tag{6}$$

$$U(\beta) = \int_{\beta}^{\bar{\beta}} q_M(\tilde{\beta})d\tilde{\beta}, \tag{7}$$

where $q_M(\beta)$ [defined by eq. (6)] is the regulated monopoly incomplete information production level.

A rent is now given up to good types and a price distortion that depresses production, and, therefore, the rent [see eq. (7)] is introduced as a regulatory response to asymmetric information. From eq. (6) it is easy to check that, with A2, $q_M(.)$ is decreasing and that $q_M(a^-) > q_M(a^+)$ because $F(a^-)/f(a^-) < F(a^+)/f(a^+)$.

In the next section we study the optimal regulation when two firms are available and compare it with the monopoly case.

3.3 The duopoly structure

With two firms, social welfare becomes: $S(q^1 + q^2) - P(q^1 + q^2)(q^1 + q^2) - (1 + \lambda)(t^1 + t^2) + U^1 + U^2$, and firm i's utility level is: $U^i = t^i + P(q^1 + q^2)q^i - \beta^i q^i - K$.

3.3.1 Under complete information, it is easy to check, because variable costs are linear, that only the most efficient firm produces at the optimum, both rents are equated to zero and the pricing formula is, for the appropriate efficiency parameter, the same as for the monopoly, that is:

$$\frac{P(q_D^*) - \min(\beta^1,\beta^2)}{P(q_D^*)} = \frac{\lambda}{1 + \lambda}\frac{1}{\eta(q_D^*)}. \tag{8}$$

Indeed from eqs. (2) and (8), we get $q_D^*(\beta^1,\beta^2) = q_M^*(\min(\beta^1,\beta^2))$, where $q_D^*(\beta^1,\beta^2)$ is the duopoly full information production level defined by eq. (8).

Under complete information, the choice between the two industry structures reduces to the following trade-off. Duopoly duplicates fixed costs but gives a higher probability of a small marginal cost, *the sampling effect*.

Let $F_{\min}(\beta)$ denote the cumulative distribution of $\min(\beta^1,\beta^2)$. We determine when the fixed cost effect dominates the sampling effect.

PROPOSITION 1: *With A1, the level of fixed cost beyond which, under complete information, the monopoly structure is favored, is:*

$$K^{CI} = \int_{\underline{\beta}}^{\bar{\beta}} q_M^*(\beta)\Big[F_{\min}(\beta) - F(\beta)\Big]d\beta. \tag{9}$$

Proof. Because $q_M^*(\min(\beta^1,\beta^2)) = q_D^*(\beta_1,\beta_2)$, $K^{CI} = \int_{\underline{\beta}}^{\bar{\beta}} \frac{W(q_M^*(\beta))}{1+\lambda} d[F_{\min}(\beta) - F(\beta)]$ where $W(q(\beta)) = S(q) + \lambda P(q)q - (1 + \lambda)\beta q$. Integrating by parts and using first order conditions, we obtain immediately K^{CI}. □

It is intuitive that the sampling effect has more value when the projects to be realized are large. An exogenous increase of demand (e.g., $\theta S(.)$ instead of $S(.)$ with $\theta > 1$) increases $q_M^*(.)$ and consequently the sampling effect [see eq. (9)]. This remark illustrates Burnett and Kovacic's observation quoted in the introduction that dual sourcing has increased "especially for important, expensive systems."

Note also that the sampling effect has no value when the correlation of technologies is perfect. For $\alpha = 1$, $F_{\min}(.) \equiv F(.)$.

3.3.2 Under incomplete information, the firms' incentive constraints must be added in the regulator's program. We consider implementation in truthful Bayesian Nash equilibria.

A revelation mechanism is now composed of production decisions $q^1(\beta^1,\beta^2), q^2(\beta^1,\beta^2)$ and transfers $t^1(\beta^1,\beta^2), t^2(\beta^1,\beta^2)$.

Let $F(\beta^2/\beta^1)$ be firm 1's conditional expectation about firm 2's characteristic. Under our assumptions $F(\beta^2/\beta^1) = G(\frac{\beta^2 - \alpha b}{1 - \alpha})$ with $b = \underline{b}$ if $\beta^1 \in A_1$ and $b = \bar{b}$ if $\beta^1 \in A_2$, so $\frac{\partial F(\beta^2/\beta^1)}{\partial \beta^1}$ is zero almost everywhere.

Let $U^1(\tilde{\beta}^1,\beta^2/\beta^1)$ be firm 1's utility level when it is of type β^1 and claims it is of type $\tilde{\beta}^1$, when firm 2 is of type β^2 and reveals truthfully its type:

$$U^1(\tilde{\beta}^1,\beta^2/\beta^1) = P(q^1(\tilde{\beta}^1,\beta^2) + q^2(\tilde{\beta}^1,\beta^2))q^1(\tilde{\beta}^1,\beta^2) + t^1(\tilde{\beta}^1,\beta^2) - \beta^1 q^1(\tilde{\beta}^1,\beta^2) - K.$$

Let us denote $U^1(\beta^1) = E_{\beta^2/\beta^1} U^1(\beta^1,\beta^2/\beta^1)$ firm 1's expected rent when it reports truthfully. From the envelope theorem local incentive compatibility is equivalent to

$$\dot{U}^1(\beta^1) = - \underset{\beta^2/\beta^1}{E} q^1(\beta^1,\beta^2).$$

A sufficient local second-order condition of incentive compatibility is:

$$\frac{\partial q^1(\beta^1,\beta^2)}{\partial \beta^2} \leq \forall(\beta^1,\beta^2) \in A_k \times A_k \qquad k = 1,2.$$

And similary for firm 2.

To impose global incentive compatibility, we distinguish two cases.

If $\beta^1 \in A_2 = (a,\bar{\beta}], U^1(\beta^1) = \int_{\beta^1}^{\bar{\beta}} E_{\beta^2/x} q^1(x,\beta^2)dx$ as the firm can lie up to $\bar{\beta}$ and rents are decreasing and costly to the regulator.

If $\beta^1 \in A_1 = [\underline{\beta},a]$, the firm cannot lie above a because it would take the risk of being discovered lying with probability 1. If the regulator associates infinite penalties with incompatible reports, the firm will restrict itself to $\beta^1 \in A_1$ because in a truthful Bayesian Nash equilibrium, it assumes that the other firm is truthtelling. Then

$$U^1(\beta^1) = \int_{\beta^1}^{a} E_{\beta^2/x} q^1(x,\beta^2)dx.$$

We can summarize these conditions as:

$$U^1(\beta^1) = \int_{\beta^1}^{\bar{\beta}(\beta^1)} E_{\beta^2/x} q^1(x,\beta^2)dx \qquad \text{with } \bar{\beta}(\beta^1) = \begin{cases} a & \text{if } \beta^1 \in A_1 \\ \bar{\beta} & \text{if } \beta^1 \in A_2 \end{cases} \tag{10}$$

and similary for firm 2.

The correlation of the information parameters is used to cut down the informational rents. Because a given firm assumes that its competitor reports truthfully, it chooses an announcement compatible with the other firm's report. This reduces the range of possible announcements from $A_1 \cup A_2$ to A_1 or A_2. For identical production levels the informational rents are reduced if the firm's parameter β^i is in A_1 because of the de facto truncation of the asymmetry of information from $[\beta^i,\bar{\beta}]$ to $[\beta^i,a]$. They are unchanged for β^i in A_2 because the asymmetry of information remains $[\beta^i,\bar{\beta}]$.

The regulator wishes to maximize expected social welfare under incentive and individual rationality constraints. We relax the regulator's program by ignoring sufficient second-order conditions of incentive compatibility, and we will check later that they are indeed met at the optimum of the relaxed program. We integrate the first-order conditions of incentive compatibility [eq. (10)] over $A_1 \cup A_2$.

We obtain immediately:

$$\int_{\underline{\beta}}^{\bar{\beta}} U^1(\beta^1)dF(\beta^1) = \int_{\underline{\beta}}^{\bar{\beta}} \int_{\underline{\beta}}^{\bar{\beta}} q^1(\beta^1,\beta^2) \frac{[F(\beta^1) - I_{A_2}(\beta^1)F(a)]}{f(\beta_1)} d\hat{F}(\beta^1,\beta^2)$$

where

$$I_{A_2}(\beta^1) = 1 \quad \text{if } \beta^1 \in A^2$$
$$= 0 \quad \text{otherwise}$$

and similarly for firm 2.

Substituting the rents into the objective function, and maximizing expected social welfare with respect to $q^1(.,.), q^2(.,.)$, we obtain:

PROPOSITION 2: *With A1, A2 under incomplete information, optimal regulation in the duopoly structure entails a single firm, the most efficient one, producing at the level $q_D(min(\beta^1,\beta^2))$ defined by*

$$\frac{P(q_D) - \min(\beta^1,\beta^2)}{P(q_D)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta(q_D)} + \frac{\lambda}{1+\lambda}\frac{F(\min(\beta^1,\beta^2)) - I_{A_2}(\min(\beta^1,\beta^2))F(a)}{f(\min(\beta^1,\beta^2))P(q_D)}. \quad (11)$$

Proof. Straightforward.

Let $q_D(\beta)$ be the optimal production level in the duopoly structure when the most efficient firm has efficiency β, that is, when $\min(\beta^1,\beta^2) = \beta$. From eqs. (6) and (11), it is clear that

$$q_D(\beta) = q_M(\beta) \text{ if } \beta \in A_1 = [\underline{\beta},a]$$
$$> \qquad \text{if } \beta \in A_2 = (a,\bar{\beta}].$$

Figure 1 compares the optimal production levels in the monopoly and duopoly structure under asymmetric information to the first best solution $q^*(\beta)(=q^*_M(\beta) = q^*_D(\beta))$.

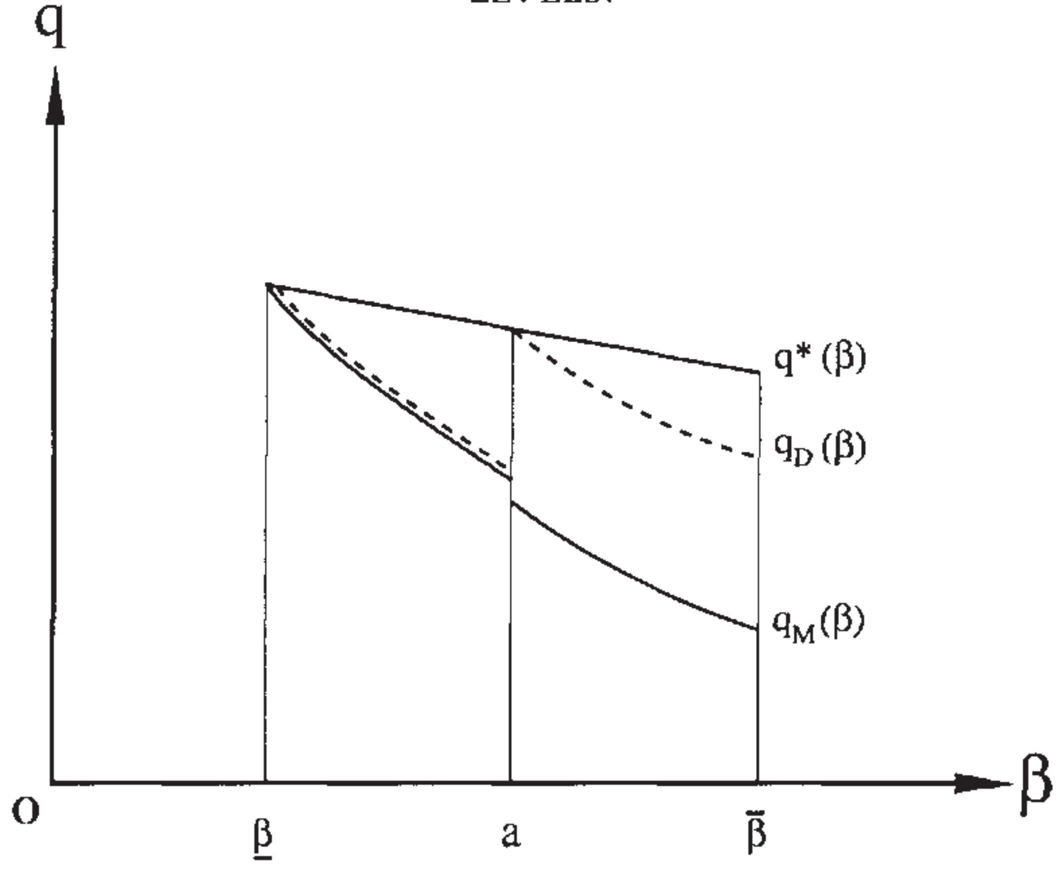
Because informational rents are lowered by yardstick competition, the optimal regulation can afford higher production levels. As shown by eq. (6), the optimal price distortions depend on the "hazard rate" $F(\beta)/f(\beta)$ because for each β they trade off between an allocative inefficiency for firm β (in number $f(\beta)$) and an increase of rent given to all firms more efficient than firm β (in number $F(\beta)$.)

Because the hazard rate is unaffected by upward truncations of the β's domain (from $A_1 \cup A_2$ to A_1), the distortion for $\beta \in A_1$ is identical in the monopoly and duopoly case. On the contrary because the hazard rate is affected by downward truncation of the β's domain (from $A_1 \cup A_2$ to A_2), $\left(\frac{F(\beta)-I_{A2}(\beta)F(a)}{f(\beta)} < \frac{F(\beta)}{f(\beta)}\right)$, the distortion for $\beta \in A_2$ is lower in the duopoly case than in the monopoly case (for $\beta = a^+$ the first best production level is achieved with the duopoly).

Let us denote $W_D(\beta)$ and $W_M(\beta)$ social welfare exclusive of fixed costs in the case of a duopoly for a level $\beta = \min(\beta^1,\beta^2)$ of efficiency, and in the monopoly case for a level β of efficiency, respectively.

Under asymmetric information, the choice between the duopoly and monopoly structures is characterized by the following proposition.

FIGURE 1. OPTIMAL MONOPOLY AND DUOPOLY PRODUCTION LEVELS.



PROPOSITION 3: *With A1, A2, the level of fixed cost below which duopoly is favored under asymetric information is*

$$K^{II} = \int_{a}^{\bar{\beta}} \frac{W_D(\beta) - W_M(\beta)}{1 + \lambda}\, dF_{\min}(\beta)$$

$$+ \int_{\underline{\beta}}^{\bar{\beta}} \left[q_M(\beta) + \frac{\lambda}{\lambda + 1} q_M(\beta) \frac{d}{d\beta} \left(\frac{F(\beta)}{f(\beta)} \right) \right] (F_{\min}(\beta) - F(\beta))d\beta. \quad (12)$$

Proof. The same as Proposition 1.

Let us compare the critical fixed cost below which duopoly is favored under complete and incomplete information [eqs. (9) and (12), respectively]. The first term in eq. (12) is the *yardstick competition effect* under incomplete information. It is positive and can be decomposed in two parts. First of all, there is a direct effect, the decrease of rents given up to firms because of the cross-reports comparison [see eq. (10)]. As a consequence there is an indirect positive effect on production, which is less distorted because informational costs are lower [see eq. (11)], hence the total gain of yardstick competition captured by the first term.

The second term in eq. (12) is the sampling effect under incomplete information. On the one hand its first part ($q_M(\beta)$) is lower than under complete information, because production levels are lower to reduce rents ($q_M(\beta) \leq q_M^*(\beta)$), that is, the quantity effect. On the other hand, there is now a second term ($\frac{\lambda}{1+\lambda} q_M(\beta) \frac{d}{d\beta} \frac{F(\beta)}{f(\beta)}$), which is positive under the monotone hazard rate assumption. This is due to an additional term in total cost, the informational cost, which reinforces the usefulness of the sampling effect, that is, the rent effect. As a consequence the sampling effect may be higher or lower under incomplete information than under complete information. The next proposition gives sufficient conditions to obtain nonambiguous results.

PROPOSITION 4: *Assume that the social cost of public funds is low. If the price elasticity is small enough, then the sampling effect is higher under incomplete information than under complete information. It is the contrary if the price elasticity is big enough.*

Proof. See Appendix 2.

The intuition for Proposition 4 is quite obvious. When the price elasticity is small, the quantities under complete and incomplete information are almost the same ($q_M^* \simeq q_M$). They are equal when the price elasticity is zero, that is, when the quantity to produce is fixed exogenously. In these cases the quantity effect is of little value, and the rent effect dominates. On the other hand, when the price elasticity is big, the optimal quantities under complete and incomplete information are very different ($q_M^*(\beta) >> q_M(\beta)$). The quantity effect is strong and dominates the rent effect.

The duopoly structure is favored if the yardstick effect is higher than the (possible) weakening of the sampling effect. The next proposition gives a sufficient condition for this to happen.

PROPOSITION 5: *Under A1, A2 and if $f(\beta)$ is nondecreasing, asymmetric information distorts the optimal market structure toward duopoly if:*

$$\int_{\underline{\beta}}^{\bar{\beta}} [q_M^*(\beta) - q_M(\beta)][F_{\min}(\beta) - F(\beta)]d\beta \leq \int_{a}^{\bar{\beta}} [q_D(\beta) - q_M(\beta)] \frac{F_{\min}(\beta)}{f_{\min}(\beta)} dF_{\min}(\beta). \quad (13)$$

Proof. Straightforward.

Condition (13) can be read as follows: The weakening of the sampling effect on the production part caused by incomplete information (left term) must be less than the expectation of increases in production (weighted by the hazard rate) caused by yardstick competition (right term).

Remarks. When the firms are identical ($\alpha = 1$), we have a degenerate structure that verifies condition (13). The sampling effect has no value and $K^{CI} = 0$. Under incomplete information, the statistical structure under duopoly satisfies the Crémer-McLean condition, and the regulator is capable of capturing all the informational rents, as in Shleifer (1985). Production levels in the duopoly correspond to first best production levels instead of incomplete information production levels in the monopoly case. For $\alpha = 1$, asymmetric information always favors duopoly.

When the firms' characteristics are stochastically independent ($\alpha = 0$), yardstick competition is of no use, and condition (13) is not verified. The only effect that remains in this case is the sampling one. Thus, from Proposition 4 we know that either the monopoly or duopoly structure may be favored by incomplete information. For example, if the quantity to produce is fixed exogenously at Q, the duopoly is favored by asymmetric information (whatever the value of $\lambda \geq 0$):[6]

$$K^{CI} - K^{II} = -Q \int_{\underline{\beta}}^{\bar{\beta}} \frac{\lambda}{1+\lambda} \frac{d}{d\beta} \left[\frac{F(\beta)}{f(\beta)} \right] [F_{\min}(\beta) - F(\beta)] d\beta \leq 0.$$

On the contrary, if the demand is such that $P(q) = 1 - q^{\frac{1}{2}}$, if ϵ^i is uniformly distributed in [0,1] and λ is not too big, asymmetric information favors the monopoly structure:

$$K^{CI} - K^{II} = \frac{\lambda}{(3\lambda + 2)^2} \frac{1 + 3\lambda - \lambda^2}{15(1 + \lambda)} > 0 \text{ when } \lambda \leq 3.3.$$

To sum up, we have characterized a wide range of circumstances under which asymmetric information favors the duopolistic market structure. The yardstick effect is always favorable to duopoly. The sampling effect also favors the duopoly when the price elasticity and the cost of public funds are not too high. If the sampling effect is weakened by incomplete information, a sufficient condition for the yardstick effect to dominate the sampling effect is given by Proposition 5. In particular in the extreme case of perfect correlation, the duopolistic structure is always favored.

In all cases the duopolistic structure is more valuable when the fixed costs are low and the quantities to produce, high. If the asymmetric information distorts the production levels a lot (because the

6. See Riordan (1992) for another example.

yardstick effect is low or the price elasticity large), it may happen that the monopoly structure is favored by incomplete information. However, we can safely conclude that in general asymmetric information favors the duopolistic structure when the market structure is chosen ex ante.

In the next section we show that this result is reversed when the market structure is chosen ex post.

4. Increasing Marginal Costs and Split-Award Auctions

In this section we consider the case where the market structure can be decided once firms know their cost characteristics. Because of increasing marginal costs both firms may be selected and production split between them. The timing is as follows. The regulator proposes an auction mechanism. The firms make their announcements. The regulator chooses the market structure; production and transfers are set according to the mechanism.

4.1 The Model

Cost functions are chosen strictly convex for positive production levels, $C^i(q^i,\beta^i) + K = \beta^i q^i + \frac{1}{2}(q^i)^2 + K$. The cost characteristics β^i are assumed to be independently distributed: (d)′ $\alpha = 0$.

The cumulative distribution function $G(\beta^i)$ and the density function $g(\beta^i)$ satisfy the monotone hazard rate property: A2′: $G(\beta)/g(\beta)$ is nondecreasing.

The next section characterizes the benchmark case of optimal regulation under complete information.

4.2 Complete Information

Let $x^D(\beta^1,\beta^2), x^1(\beta^1,\beta^2)$ and $x^2(\beta^1,\beta^2)$ be the probabilities of being respectively in a duopoly structure, in a monopoly structure with firm 1 and in a monopoly structure with firm 2; $W_D(\beta^1,\beta^2), W^1_M(\beta^1)$ and $W^2_M(\beta^2)$ are the corresponding utilitarian ex post social welfare. $U^i_D(\beta^1,\beta^2)$ and $U^i_M(\beta^i)$ are firm i's profit when the market structure is respectively a duopoly and a monopoly with firm i. With obvious notations:

$$W_D = S(q_D) - P(q_D)q_D - (1+\lambda)(t^1_D + t^2_D) + U^1_D + U^2_D$$

$$W^i_M = S(q^i_M) - P(q^i_M)q^i_M - (1+\lambda)t^i_M + U^i_M \qquad i = 1,2$$

$$U^i_h = t^i_h + P(q_h)q^i_h - C^i(q^i_h,\beta^i) - K \qquad h = D,M;\ i = 1,2$$

$$q_D = q^1 + q^2,\ q_M = q^i_M$$

The utilitarian regulator solves[7]

$$\max_{\substack{x^D,q^1,q^2\\ x^i,q^i_M}} \left\{x^D(\beta^1,\beta^2)W_D(\beta^1,\beta^2) + x^1(\beta^1,\beta^2)W^1_M(\beta^1) + x^2(\beta^1,\beta^2)W^2_M(\beta^2)\right\}$$

s.t.

$$\text{(RI)}\ U^i(\beta^1,\beta^2) = x^D U^i_D(\beta^1,\beta^2) + x^i U^i_M(\beta^i) \geq 0 \quad i = 1,2$$

$$x^D(\beta^1,\beta^2) + x^1(\beta^1,\beta^2) + x^2(\beta^1,\beta^2) \overset{(\leq)}{=} 1$$

$$x^k(\beta^1,\beta^2) \geq 0 \qquad k = 1,2,D.$$

We assume that it is worth realizing the project even with an inefficient firm, that is:

$$x^D(\beta^1,\beta^2) + x^1(\beta^1,\beta^2) + x^2(\beta^1,\beta^2) = 1 \quad \forall(\beta^1,\beta^2) \in [\underline{\beta},\bar{\beta}]^2.$$

Moreover because the objective function is linear in x^D, x^1, and x^2, these probabilities are at the optimum either equal to 0 or 1. Thus, we maximize independently W_D, W^1_M, W^2_M with respect to quantities. The optimal market structure is the one associated with the maximum of these three programs.

Under assumption A1, W_D and W^i_M ($i = 1,2$) are both concave; first-order conditions are sufficient. Under complete information the rents that are costly to the regulator ($\lambda > 0$) are set to zero in each regime.

$$U^i_h = 0 \qquad h = D,M, \quad i = 1,2 \tag{14}$$

and the optimal production levels in the duopoly case are

$$\begin{cases} q^{1^*} = \dfrac{q^*_D}{2} + \dfrac{\beta^2 - \beta^1}{2} \\ \\ q^{2^*} = \dfrac{q^*_D}{2} + \dfrac{\beta^1 - \beta^2}{2} \end{cases} \qquad \text{if } q^*_D > |\beta^2 - \beta^1| \tag{15}$$

with $q^*_D = q^{1^*} + q^{2^*}$ solution of eq. (16)

$$\frac{P(q^*_D) - \frac{1}{2}(q^*_D + \beta^1 + \beta^2)}{P(q^*_D)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta(q^*_D)} \tag{16}$$

and the monopoly solution (17) associated with the minimum of (β^1,β^2) otherwise

7. Because the firms are risk neutral and costs independent, there is no need in the monopoly case for considering contracts that depend on both types.

$$\frac{P(q_M^*) - (q_M^* + \min(\beta^1,\beta^2))}{P(q_M^*)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta(q_M^*)} . \tag{17}$$

Because of the convexity of the variable cost function, the regulator splits the production between the two firms [eq. (15)] when he chooses a duopoly. The most productive firm receives a greater part of the market than its competitor. The gap between their production levels increases (linearly) with the difference of their cost parameters. The pricing formula [eq. (16)] is an extension of Ramsey pricing; the difference between the price and the *average* marginal cost [$\frac{1}{2}(q^{1*} + \beta^1 + q^{2*} + \beta^2)$] is inversely proportional to the price elasticity.

If the cost difference between the two producers is too big, the duopoly structure is no more attractive; the firm with the highest-cost parameter has a zero probability of producing:

$$x_M^i(\beta^1,\beta^2) = 0 \qquad \text{if } \beta^i = \max(\beta^1,\beta^2) \qquad i = 1,2.$$

The monopoly is held by the most efficient producer, the pricing formula follows the Ramsey rule [see eq. (17)].

Comparing the monopoly and the duopoly structures at the optimum of complete information, we define $\Delta^*(\beta)$ as the critical difference between the cost parameters such that:

$$W_D^*(\beta,\beta + \Delta^*(\beta)) = W_M^*(\beta) \qquad \forall\beta \in [\underline{\beta},\bar{\beta}], \tag{18}$$

where $W_D^*(\beta^1,\beta^2)$ and $W_D^*(\beta^i)$ are the ex post social welfare functions at the optimum of complete information when the market structure is, respectively, a duopoly and a monopoly with firm i.

If the difference between the cost parameters $|\beta^2 - \beta^1|$ is greater than $\Delta^*(\min(\beta^1, \beta^2))$, the monopoly structure is optimal under complete information. Otherwise, the duopoly structure is preferred. Accordingly the duopoly structure becomes less attractive when one of the firms is much more efficient than the other ($|\beta^2 - \beta^1|$ large) or when the fixed cost is high (It is easy to check that $\frac{d\Delta^*}{dK} = \frac{-1}{\min(q_1^*,q_2^*)} \leq 0$.).

Note from eq. (15) that if $K = 0$, then $\Delta^*(\beta) = q_D^*(\beta,\beta + \Delta^*(\beta))$, that is, substituting in eq. (16) $\Delta^*(\beta) = q_M^*(\beta)$. Thus, the duopoly is optimal if $|\beta^2 - \beta^1| \leq q_M^*(\min(\beta^1,\beta^2))$.

In the next section we study how asymmetric information distorts the choice of the industrial structure.

4.3 Incomplete Information

Under incomplete information we restrict the analysis to direct revelation mechanisms by the revelation principle. A revelation mechanism is here composed of probabilities $x^D(\tilde{\beta}^1,\tilde{\beta}^2), x^1(\tilde{\beta}^1,\tilde{\beta}^2), x^2(\tilde{\beta}^1,\tilde{\beta}^2)$, of transfer functions $[t^1(\tilde{\beta}^1,\tilde{\beta}^2),t^2(\tilde{\beta}^1,\tilde{\beta}^2)]$ and $t^i_M(\tilde{\beta}^1,\tilde{\beta}^2)$ $(i = 1,2)$ and associated production levels $[q^1(\tilde{\beta}^1,\tilde{\beta}^2),q^2(\tilde{\beta}^1,\tilde{\beta}^2)]$ and $q^i_M(\tilde{\beta}^1,\tilde{\beta}^2)(i = 1,2)$.

The regulator maximizes expected welfare under incentive and individual rationality constraints.

Let $U^i(\beta^i) = E_{\beta_j}U^i(\beta^i,\beta^j/\beta^i)$ be the expected utility of the firm when telling the truth. From the envelope theorem, first-order incentive compatibility constraints are

$$(IC1)\ \dot{U}^i(\beta^i) = -\int_{\underline{\beta}}^{\bar{\beta}} [x^D(\beta^1,\beta^2)q^i(\beta^1,\beta^2) + x^i(\beta^1,\beta^2)q^i_M(\beta^i)]dF(\beta^j)$$

$$\forall \beta^i \in [\underline{\beta},\bar{\beta}]\ i = 1,2 \quad j \neq i$$

and second-order conditions of incentive compatibility are

$$(IC2)\ \frac{\partial}{\partial \beta^i}\int_{\underline{\beta}}^{\bar{\beta}} [x^D(\beta^1,\beta^2)q^i(\beta^1,\beta^2) + x^i(\beta^1,\beta^2)q^i_M(\beta^i)]dF(\beta^j) \leq 0$$

$$\forall \beta^i \in [\underline{\beta},\bar{\beta}]\ i = 1,2 \quad j \neq i.$$

Because the expected rents are socially costly and decreasing, the individual rationality constraints are binding at $\bar{\beta}$: $(IR)\ U^i(\bar{\beta}) = 0$ $i = 1,2$.

Integrating the $(IC1)$ constraint taking into account (IR) and substituting it in the regulator's objective function, we get:

$$\int_{\underline{\beta}}^{\bar{\beta}}\int_{\underline{\beta}}^{\bar{\beta}} x^1(\beta^1,\beta^2)\left\{S(q^1_M) + \lambda P(q^1_M)q^1_M - (1+\lambda)[C^1(q^1_M,\beta^1) + K] - \lambda q^1_M \frac{F(\beta^1)}{f(\beta^1)}\right\}$$
$$+ x^2(\beta^1,\beta^2)\left\{S(q^2_M) + \lambda P(q^2_M)q^2_M - (1+\lambda)[C^2(q^2_M,\beta^2) + K] - \lambda q^2_M \frac{F(\beta^2)}{f(\beta^2)}\right\}$$
$$+ x^D(\beta^1,\beta^2)\Big\{S(q_D) + \lambda P(q_D)q_D - (1+\lambda)[C^1(q^1,\beta^1) + C^2(q^2,\beta^2) + 2K]$$
$$- \lambda q^1 \frac{F(\beta^1)}{f(\beta^1)} - \lambda q^2 \frac{F(\beta^2)}{f(\beta^2)}\Big\} dF(\beta^1)dF(\beta^2). \quad (19)$$

We relax the regulator's program by ignoring the $(IC2)$ constraints and we will check later that they are met at the optimum. Maximizing eq. (19) with respect to $q^1(.,\,.)q^2(.,\,.),q^i_M(.)$ we obtain the optimal production levels in the duopoly case

$$\begin{cases} q^1 = \frac{q_D}{2} + \frac{\beta^2-\beta^1}{2} + \frac{\lambda}{1+\lambda}\frac{1}{2}\left[\frac{F(\beta^2)}{f(\beta^2)} - \frac{F(\beta^1)}{f(\beta^1)}\right] \\ q^2 = \frac{q_D}{2} + \frac{\beta^1-\beta^2}{2} + \frac{\lambda}{1+\lambda}\frac{1}{2}\left[\frac{F(\beta^1)}{f(\beta^1)} - \frac{F(\beta^2)}{f(\beta^2)}\right] \end{cases} \tag{20}$$

if $q_D = q_1 + q_2 > |\beta^2 - \beta^1| + \frac{\lambda}{1+\lambda}\left|\frac{F(\beta^2)}{f(\beta^2)} - \frac{F(\beta^1)}{f(\beta^1)}\right|$ with q_D solving of eq. (21)

$$\frac{P(q_D) - \frac{1}{2}(q_D + \beta_1 + \beta_2)}{P(q_D)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta(q_D)} + \frac{\lambda}{1+\lambda}\frac{1}{2}\left[\frac{F(\beta^2)}{f(\beta^2)} + \frac{F(\beta^1)}{f(\beta^1)}\right] \tag{21}$$

and otherwise the monopoly solution (22) associated with the minimum of (β^1,β^2)

$$\frac{P(q_M) - [q_M + \min(\beta^1,\beta^2)]}{P(q_M)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta(q_M)} + \frac{\lambda}{1+\lambda}\frac{F(\min(\beta^1,\beta^2))}{f(\min(\beta^1,\beta^2))} \tag{22}$$

(Appendix 3 shows that (*IC*2) constraints are met by these solutions.).

The optimal market sharing rule is modified under incomplete information because of the additional informational costs [term $\frac{F(\beta^i)}{f(\beta^i)} - \frac{F(\beta^j)}{f(\beta^j)}$ in eq. (20)]. The most efficient producer receives a larger part of the total production. So it is less attractive to mimic a high-cost firm because its market share is decreased. Moreover, the pricing rule is distorted in order to reduce the informational costs [term $\frac{\lambda}{1+\lambda}\frac{1}{2}\left[\frac{F(\beta^2)}{f(\beta^2)} + \frac{F(\beta^1)}{f(\beta^1)}\right]$ in eq. (21)]; the total production is lower $[q_D^*(\beta^1,\beta^2) \geq q_D(\beta^1,\beta^2)$—compare eqs. (16) and (21)]. If the difference between the cost parameters is too large, only the most efficient firm is in charge of the whole production.

Note from eqs. (15) and (20) that other things being equal the monopoly regime occurs more often under incomplete information than under complete information $(|\beta_2 - \beta_1| + \frac{\lambda}{1+\lambda}\left|\frac{F(\beta^2)}{f(\beta^2)} - \frac{F(\beta^1)}{f(\beta^1)}\right| \geq |\beta_2 - \beta_1|$, $\forall(\beta_1,\beta_2))$. As a response to asymmetric information, the monopoly production is also distorted [term $\frac{\lambda}{1+\lambda}\frac{F(\min(\beta^1,\beta^2))}{f(\min(\beta^1,\beta^2))}$ in eq. (22)], $q_M^*(\min(\beta^1,\beta^2)) \geq q_M(\min(\beta^1,\beta^2))$.

Let us now compare the monopoly and duopoly welfares under incomplete information. We define $\Delta(\beta)$ as the critical difference between the cost parameters such that:

$$W_D(\beta,\beta + \Delta(\beta)) = W_M(\beta) \qquad \forall\beta \in [\underline{\beta},\bar{\beta}]. \tag{23}$$

If the cost parameter difference $|\beta^2 - \beta^1|$ is greater than $\Delta(\min(\beta^1,\beta^2))$, the monopoly structure is optimal under incomplete information. Otherwise the duopoly structure is preferred.

Note that when the fixed cost is nul, from eq. (21) $\Delta(\beta)$ is such that:

$$q_M(\beta) = \Delta(\beta) + \frac{\lambda}{1+\lambda}\left(\frac{F(\beta+\Delta(\beta))}{f(\beta+\Delta(\beta))} - \frac{F(\beta)}{f(\beta)}\right).$$

Comparing with the first best case, we get $\Delta(\beta) \leq \Delta^*(\beta) = q_M^*(\beta)$ $\forall\beta \in [\underline{\beta},\overline{\beta}]$, since A2′ is satisfied. So when the fixed costs are nul, the asymmetric information favors the monopoly structure. This result generalizes to all $K \geq 0$. This is our main finding for this section.

PROPOSITION 6: *When the market structure is chosen ex post the asymmetric information favors the monopoly structure.*

Proof. From eq. (18) we obtain: (i)$\frac{d\Delta^*(\beta)}{d\beta} = -\frac{2(q_D^*-q_M^*)}{q_D^*-\Delta^*(\beta)} \leq 0$. Comparing next eqs. (17) and (22), (16) and (21), we get for $\Delta \geq 0$:

$$q_D(\beta,\beta+\Delta) = q_D^*\left(\beta + \frac{\lambda}{1+\lambda}\frac{F(\beta)}{f(\beta)}, \beta+\Delta+\frac{\lambda}{1+\lambda}\frac{F(\beta+\Delta)}{f(\beta+\Delta)}\right)$$

and

$$q_M(\beta) = q_M^*\left(\beta + \frac{\lambda}{1+\lambda}\frac{F(\beta)}{f(\beta)}\right).$$

Substituting in the social welfare functions, we obtain that $\Delta(\beta)$ defined by eq. (23) is also such that:

$$W_D^*\left(\beta + \frac{\lambda}{1+\lambda}\frac{F(\beta)}{f(\beta)}, \beta+\Delta(\beta)+\frac{\lambda}{1+\lambda}\frac{F(\beta+\Delta(\beta))}{f(\beta+\Delta(\beta))}\right) = W_M^*\left(\beta+\frac{\lambda}{1+\lambda}\frac{F(\beta)}{f(\beta)}\right). \quad (24)$$

Because $\beta + \frac{\lambda}{1+\lambda}\frac{F(\beta)}{f(\beta)} \geq \beta$ we derive from (i) that:

$$\Delta^*(\beta) \geq \Delta(\beta) + \frac{\lambda}{1+\lambda}\left(\frac{F(\beta+\Delta(\beta))}{f(\beta+\Delta(\beta))} - \frac{F(\beta)}{f(\beta)}\right),$$

hence, the result from assumption A2′. □

Asymmetric information adds to production cost an extra cost proportional to $F(\beta)/f(\beta)$. This informational cost favors the monopoly structure. In order to lower the informational costs, the regulator distorts the market share in favor of the most efficient firm. This reduces the gain for an efficient firm of mimicking an inefficient producer. The regulator also distorts the industrial structure in favor of the monopoly because by doing so he lowers the incentive for inflating the cost report (A higher-cost producer has a decreased probability of producing under incomplete information.). These distortions add to the usual one of depressing production levels, to lower the interest of a duopolistic structure.

FIGURE 2. OPTIMAL MARKET STRUCTURE UNDER COMPLETE AND INCOMPLETE INFORMATION.

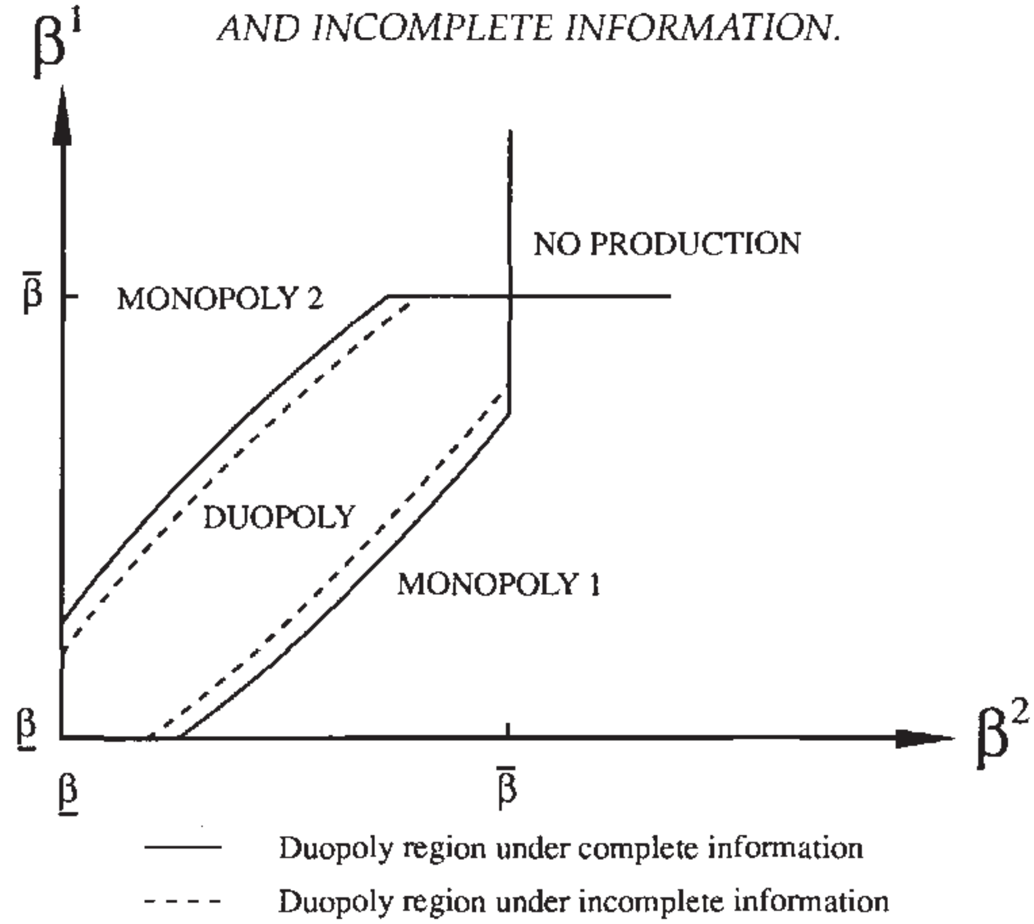


Figure 2 shows in the (β^1, β^2) space when incomplete information favors monopoly.[8]

Remark. We must stress that the distortion toward monopoly is due to the specification of the cost function. The informational rents grow with $\partial C^i/\partial\beta^i$ and, therefore, they grow here linearly with production. For variable costs of the form $\frac{1}{2}\beta^i(q^i)^2$, informational rents grow faster than linearly, and this may favor the duopoly. For example, when the quantity to produce is exogenously fixed and when the firms are not

8. McGuire and Riordan (1991) study a similar problem within the Laffont and Tirole (1986) model with both moral hazard and adverse selection and with cost observability. They obtain the same effect for λ small. For λ large the opposite effect may occur because in that model a large λ implies a high distortion of effort, which decreases the "fixed cost" represented by the disutility of effort. Dana and Spier (1992) in an auctioning production right model where the regulator chooses either a monopoly, a duopoly, or self-production, find similar results. In their model the regulator controls transfers and entry on the market but not the prices or the quantities. Dana (1992) studies the trade-off between the duplication of fixed costs and the informational gains caused by the correlation of firms' private informations. In that paper the Crémer-McLean problem is avoided by introducing ex post limited liability constraints and restricting the analysis to two-state informational parameters.

too different (i.e., $3\frac{G(\min(\beta^1,\beta^2))}{g(\min(\beta^1,\beta^2))} \geq \frac{G(\max(\beta^1,\beta^2))}{g(\max(\beta^1,\beta^2))}$) asymmetric information favors duopoly because separate productions lower informational rents (see Appendix 4).

Finally, it can be easily checked that Proposition 6 may be reversed under the ex ante timing. In particular if the quantity to produce Q is fixed exogenously and not too small ($Q \geq \bar{\beta} - \underline{\beta} + \frac{\lambda}{1+\lambda}\frac{1}{f(\underline{\beta})}$), we find that[9] $K^{II} = K^{CI} + \frac{1}{2}[\text{Var}(\beta + \frac{\lambda}{1+\lambda}\frac{F(\beta)}{f(\beta)}) - \text{Var}\beta]$. Under A2′, the covariance of $F(\beta)/f(\beta)$ and β is positive so that asymmetric information favors the duopoly.

5. Conclusion

This paper has begun a systematic study of the regulation of oligopolies within the methodology of the new regulatory economics. More specifically we have studied the regulation of duopolies in a static Baron-Myerson type of model.

The duplication of fixed costs may be valuable in an industry under a variety of circumstances. The impact of asymmetric information on the optimal market structure depends on the timing of the revelation game.

In an ex ante framework, the *sampling effect* favors a duopoly structure. It is particularly valuable when the technologies are very risky (new). Incomplete information introduces the *yardstick effect,* which is particularly strong when the correlation of firms' types is high (In this case the sampling effect is of lower value.). In general these two effects combine in such a way that incomplete information favors the duopolistic structure.

In an ex post framework, *increasing marginal cost* may justify a duopoly structure. The effect of asymmetric information is to add an additional cost to production costs that can grow slower or faster than production levels according to the particular form of the cost functions. We show that, when the marginal effect of the informational parameter on cost is at most linear in production, asymmetric information always favors the monopoly structure (This is not necessarily true when it grows faster than production.).

A similar analysis could be carried out in the Laffont-Tirole (1990) framework, which allows cost observability (see McGuire and Riordan, 1991, for a start). Also, the analysis should be extended to take into account the dynamic issues raised in the introduction.

9. See Auriol and Laffont (1992).

APPENDIX 1: THE STOCHASTIC STRUCTURE

$$\beta^i = \alpha b + (1-\alpha)\epsilon^i \begin{cases} \alpha \in [0,1], b \text{ and } \epsilon^i \text{ are independent} \\ b \in \{\underline{b}, \bar{b}\}, \nu = \text{Prob}\,(b = \underline{b}) \\ \epsilon^i \in [\underline{\epsilon}, \bar{\epsilon}],\ G(.) \text{ is the distribution function and} \\ \quad g(.) \text{ the density function} \end{cases}$$

This stochastic structure is the continuous version of $\beta^i = \alpha b + (1 - \alpha)\epsilon^i$ with $b \in \{\underline{b}, \bar{b}\}$ and $\epsilon^i \in E$ discrete. It is easy to check that when E has more than one element (i.e., ϵ^i can take more than one value) and $\alpha < 1$, the matrix of conditional distribution M, of generic element $m_{ij} = \text{Prob}(\beta^j/\beta^i)$, does not satisfy the Crémer-McLean condition, that is, it is impossible to write any row as a convex combination of the other rows. So with our structure, it is impossible to obtain the first best solution as a Bayesian Nash equilibrium.

In the continuous case, β^i can take its values in two intervals depending on the realization of b, either in $A_1 = [\alpha\underline{b} + (1 - \alpha)\underline{\epsilon}, \alpha\underline{b} + (1 - \alpha)\bar{\epsilon}]$ or in $A_2 = [\alpha\bar{b} + (1 - \alpha)\underline{\epsilon}, \alpha\bar{b} + (1 - \alpha)\bar{\epsilon}]$. We consider in this paper the case where A_1 and A_2 are disjoint (the observation of β^i reveals the value of b). The case of a nonempty intersection is more difficult to treat because of second-order conditions of incentive compatibility. However, in the uniform case it is tractable, and the general results are similar to those obtained here; but, because of the nonmonotonicity of the hazard rate, there is bunching at the optimum (see Auriol, 1992).

So, for the sake of simplicity, we assume: $\alpha\underline{b} + (1 - \alpha)\bar{\epsilon} = \alpha\bar{b} + (1 - \alpha)\underline{\epsilon}$. This assumption implies

$$F(\beta^j/\beta^i) = \begin{cases} G\left(\dfrac{\beta^j - \alpha\underline{b}}{1-\alpha}\right) & \text{if} \quad \beta^i \in A_1 \\ \\ G\left(\dfrac{\beta^j - \alpha\bar{b}}{1-\alpha}\right) & \text{if} \quad \beta^i \in A_2 \end{cases}$$

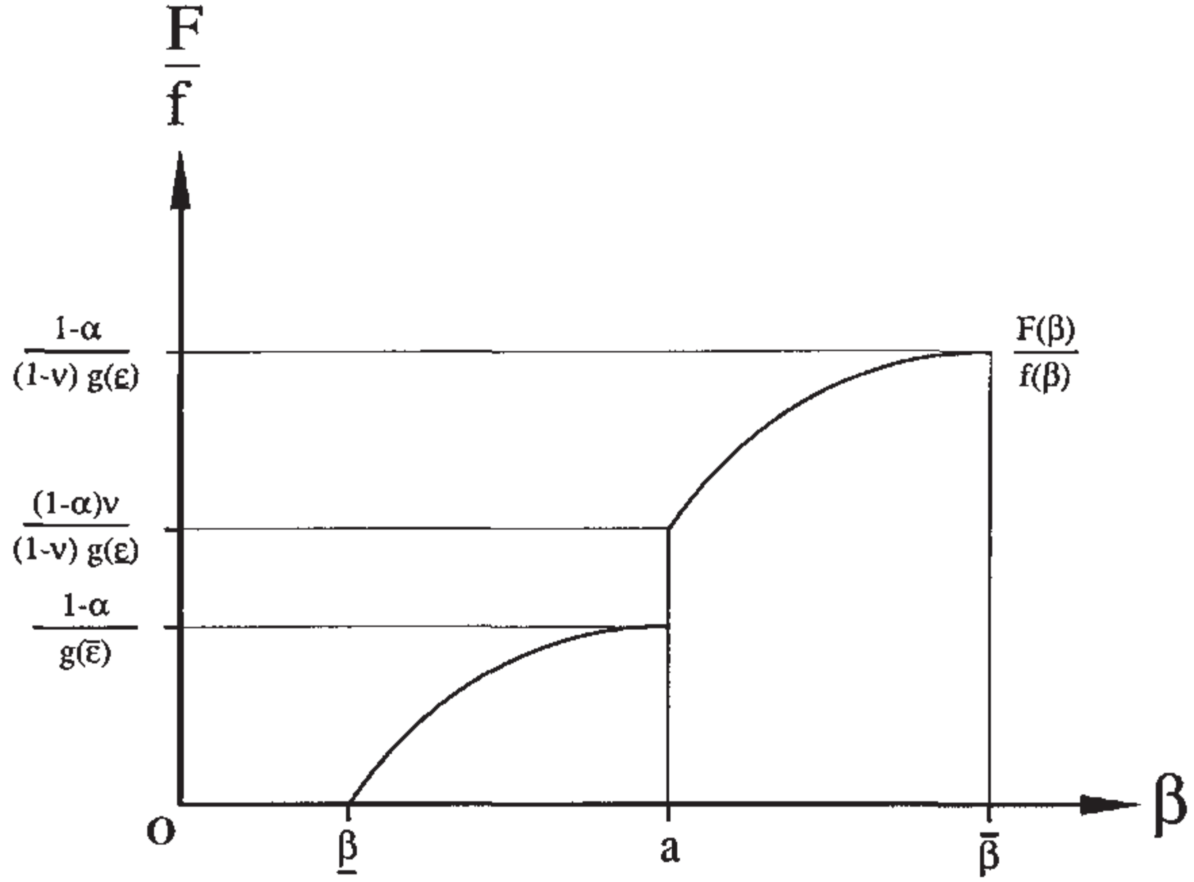
and so $\partial F(\beta^j/\beta^i)/\partial\beta^i = 0$ almost everywhere.

Moreover, in order to have the global monotonicity of $F(\beta)/f(\beta)$ we assume that:

$$\begin{cases} \dfrac{G(\epsilon)}{g(\epsilon)} \text{ and } \dfrac{G(\epsilon) + \frac{\nu}{1-\nu}}{g(\epsilon)} \text{ are nondecreasing (local)} \\ \dfrac{g(\underline{\epsilon})}{g(\bar{\epsilon})} \leq \frac{\nu}{1-\nu} \qquad \text{(global).} \end{cases}$$

See Figure A1.

FIGURE A1. HAZARD RATE FUNCTION.



Appendix 2: Proof of Proposition 4

We focus on the first claim of Proposition 4, that is, the sampling effect increases under incomplete information when the price elasticity is small; the second claim is proved by symmetric arguments.

Let us denote S^{II} the sampling effect under incomplete information [second term in eq. (12)] and K^{CI}, defined by eq. (9), the complete information one. Differentiating $S^{II} - K^{CI}$ with respect to λ, for λ close to zero, we get:

$$\frac{d(S^{II} - K^{CI})}{d\lambda}\Big|_{\lambda=0} = \int_{\underline{\beta}}^{\bar{\beta}} \left[\frac{F(\beta)/f(\beta)}{P'(q_M^*(\beta))q_M^*(\beta)} + \frac{d}{d\beta}\left(\frac{F(\beta)}{f(\beta)}\right)\right] q_M^*(\beta)\Big|_{\lambda=0} [F_{\min}(\beta) - F(\beta)]d\beta.$$

Because $S^{II} = K^{CI}$ at $\lambda = 0$, the first claim is true if

$$\frac{d}{d\lambda}(S^{II} - K^{CI})\Big|_{\lambda=0} > 0.$$

A sufficient condition for this to happen is that for any $q > 0$

$$\eta(q) < \frac{\bar{\beta} \int_{\underline{\beta}}^{\bar{\beta}} \frac{d}{d\beta}\left(\frac{F(\beta)}{f(\beta)}\right)[F_{\min}(\beta) - F(\beta)]d\beta}{\int_{\underline{\beta}}^{\bar{\beta}} \frac{F(\beta)}{f(\beta)}[F_{\min}(\beta) - F(\beta)]d\beta}. \qquad \square$$

APPENDIX 3: (*IC*2) CONSTRAINTS

Let $X(\beta^i) = \Delta(\beta^i) + \beta^i$ be the solution of eq. (23). Differentiating with respect to β^i, we get $\frac{dX(\beta^i)}{d\beta^i} \equiv q^i_M(\beta^i) - q^i(\beta^i, X(\beta^i)) \gtreqless 0$ depending on the particular form of the surplus function.

If $\Delta(\beta^i) \le 0$, then $x^i(\beta^1,\beta^2) = 1 - F(\beta^i)$, $x^D(\beta^1,\beta^2) = 0$; thus, (*IC*2) is true because A2 is satisfied.

If $\Delta(\beta^i) > 0$ then $x^i(\beta^1,\beta^2) = 1 - F(X(\beta^i))$ and

$$x^D(\beta^1,\beta^2) = \begin{cases} F(X(\beta^i)) & \text{if } X'(\beta^i) \le 0 \\ F(X(\beta^i)) - F(X^{-1}(\beta^i)) & \text{otherwise} \end{cases}$$

Thus,

$$X'(\beta^i) \le 0 \Rightarrow \frac{\partial E_{\beta^j}(x^D q^i(\beta^1,\beta^2) + x^i q^i_M(\beta^i)]}{\partial \beta^i} = [1 - F(X(\beta^i))]\dot{q}^i_M(\beta^i)$$

$$-f(X(\beta^i))X'(\beta^i)[q^i_M(\beta^i) - q^i(\beta^i,X(\beta^i))] + \int_{\underline{\beta}}^{X(\beta^i)} \frac{\partial q^i(\beta^1,\beta^2)}{\partial \beta^i}\, dF(\beta^j) \le 0$$

under assumption A2. And

$$X'(\beta^i) \ge 0 \Rightarrow \frac{\partial E_{\beta^j}[x^D q^i(\beta^1,\beta^2) + x^i q^i_M(\beta^i)]}{\partial \beta^i} = -X^{-1'}(\beta^i) f(X^{-1}(\beta^i)) q^i_M(\beta^i)$$

$$-f(X(\beta^i))X'(\beta^i)[q^i_M(\beta^i) - q^i(\beta^i,X(\beta^i))]$$

$$+[1 - F(X(\beta^i))]\dot{q}^i_M(\beta^i) + \int_{X^{-1}(\beta^i)}^{X} \frac{\partial q^i(\beta^1,\beta^2)}{\partial \beta^i}\, dF(\beta^j) \le 0$$

under assumption A2.

APPENDIX 4: CONVEX INFORMATION RENTS

We consider the same model as in Section 4 except that total production is exogenously fixed at Q and that the cost functions are $C^i(q^i,\beta^i) + K = \frac{1}{2}\beta^i(q^i)^2 + K, \qquad i = 1,2.$

The production levels under asymmetric information (for the complete information levels set $\lambda = 0$) are:

$$q^i(\beta^1,\beta^2) = \frac{[(1+\lambda)\beta^j + \lambda G(\beta^j)/g(\beta^j)]Q}{(1+\lambda)(\beta^1+\beta^2) + \lambda[G(\beta^1)/g(\beta^1) + G(\beta^2)/g(\beta^2)]} \text{ for } i = 1,2,\ j \ne i$$

We obtain immediately:

PROPOSITION 6′: *The duopoly is the optimal market structure if the quantity socially desirable Q is larger than*

$$q^{II}(\beta^1,\beta^2,K) = \frac{\sqrt{2(1+\lambda)K[(1+\lambda)(\beta^1+\beta^2)] + \lambda[G(\beta^1)/g(\beta^1) + G(\beta^2)/g(\beta^2)]}}{(1+\lambda)\min(\beta^1,\beta^2) + \lambda G(\min(\beta^1,\beta^2))/g(\min(\beta^1,\beta^2))}.$$

The similar production level under incomplete information $q^{CI}(\beta^1,\beta^2,K)$ *is obtained by setting* $\lambda = 0$.

Let $\beta^{(1)} = \min(\beta^1,\beta^2)$ and $\beta^{(2)} = \max(\beta^1,\beta^2)$. Then

$$q^{CI}(\beta^1,\beta^2,K) - q^{II}(\beta^1,\beta^2,K) =$$

$$\left[\beta^{(1)} + \frac{\lambda}{1+\lambda}\frac{G(\beta^{(1)})}{g(\beta^{(1)})}\right]\sqrt{\beta^{(1)}+\beta^{(2)}} - \beta^{(1)}\sqrt{\beta^{(1)}+\beta^{(2)} + \frac{\lambda}{1+\lambda}\left(\frac{G(\beta^{(1)})}{g(\beta^{(1)})} + \frac{G(\beta^{(2)})}{g(\beta^{(2)})}\right)}$$

In particular if $3\frac{G(\beta^{(1)})}{g(\beta^{(1)})} \geq \frac{G(\beta^{(2)})}{g(\beta^{(2)})}$, $q^{CI} > q^{II}$, that is, asymmetric information distorts the optimal market structure toward duopoly when the firms are not too different.

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