The Regulation of Interdependent Markets

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Abstract

We examine the problem of how to design the jurisdiction of a regulatory authority, when there are two interdependent monopolistic markets for substitutable goods and the regulator can be (in part) captured by the industry. Our analysis shows that under complete information two different agencies - each regulating a single market - charge lower prices than a unique regulator, making consumers better off. However, this leads to excessively high costs for taxpayers who finance subsidies to firms, and thus regulatory centralization turns out to be social welfare improving. Under asymmetric cost information we show that when the efficiency of lobbying activity carried out by firms is sufficiently high a trade-off emerges in equilibrium between substitutability and lobbying effects, and decentralizing the regulatory structure can increase social welfare.

Keywords: asymmetric information, centralization, decentralization, lobbying, substitutability.

JEL classification: D82, L51.

1. Introduction

Several theoretical contributions to regulation literature have focused on the pattern of government intervention in a single-product market, whose features hinder unfettered competition between firms. Those studies which have actually considered the regulation of multiproduct industries have been mostly concerned with the problem of determining which firms will supply which products.[1]

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[1] Armstrong and Sappington [**1**] provide an overview of the most important recent contributions to the theory of regulation.

In this paper we shift our attention from the industry structure to the *regulatory structure* and deal with the problem of how to design the jurisdiction of a regulatory authority when there are two different but related markets. Our focus is *not* on the number of firms, but on the *number of regulators*.

Indeed, the issue of the separation of powers in regulation has been examined in the theory of government organization. Among others, Laffont and Martimort [**5**] argue that splitting regulatory rights between different agencies may act as a device against the threat of regulatory capture. On the other hand, integration could improve efficiency by allowing coordination of regulators.

The aim of this paper is to investigate how the choice between a unique regulator - regime we define as *centralization* - and two different agencies - regime labelled as *decentralization* - may affect the regulatory outcome and thus the welfare of the agents envolved when there are two firms monopolist in two *interdependent* markets which can engage in regulatory capture activities.

We believe that this is an important issue to explore. Regulation is a widespread phenomenon, concerning several sectors which are very often closely related. The interdependence between markets typically occurs when products are *substitutable*, such as, for instance, railroad and motorway services or, to some extent, natural gas and electricity.

We assume that a benevolent political principal (Congress), which maximizes the sum of consumer surplus and taxpayer welfare,[2] can delegate the regulation of two interdependent markets either to a unique regulator or two different agencies. The two regulatory structures differ both in the number of regulated markets (or firms) and in the weight they may attach to the profits of the firm(s) they regulate. This distortion with respect to Congress's mandate reflects possibly different degrees of regulatory capture by the industry which depend on the lobbying activity carried out by firms. Influence typically takes place through indirect means which can show different levels of efficiency, like expensive lunches or the promise of lucrative

[2] Baron [**2**] shows that if there is a strong electoral connection between the benefits delivered to constituents and their electoral support, the legislature will choose a regulatory mandate that favors consumer over producer interests and results in regulation that does *not* maximize expected total surplus. In our model, we assume that Congress does not internalize firms' profits and thus only cares about consumer and taxpayer welfare. Indeed, Neven and Röller [**7**] suggest that when competition authority officials are exposed to the lobbying of firms that can offer them personal rewards a consumer welfare standard might counterbalance the bias resulting from such lobbying.

jobs in the private sector (the *revolving door* phenomenon).

Our model predicts that under complete information - i.e. when the regulator is omniscient - decentralizing the regulation for substitutable goods yields higher quantities than under centralization, making consumers better off. We show that *positive price externalities* occur under regulatory decentralization. However, this leads to excessively high costs for taxpayers who finance subsidies to firms and thus regulatory centralization is social welfare improving.

As firms have priviledged information of their costs, we show that if they can coordinate their influence activities over a unique regulator in an efficient way a trade-off emerges in equilibrium between *substitutability* and the *lobbying effects*, and decentralizing the regulatory structure may increase social welfare.

The plan of the paper is as follows. Section 2 presents the basic structures of the model. In Section 3 we compute the complete-information pricing policies under regulatory decentralization and centralization, respectively. Moreover, we study the impact of the regulatory outcome on the welfare of the agents envolved. In Section 4 we derive the regulatory outcome under both regimes in the case of asymmetric cost information and make welfare comparisons in order to derive policy suggestions. Finally, Section 6 is devoted to some final remarks.

2. The basic model

We consider two symmetric markets for substitutable goods. Following Singh and Vives [**8**], the consumer gross utility from the marketplace is represented by a quadratic utility function of the form

$$U(q_1, q_2) = \alpha q_1 + \alpha q_2 - \frac{1}{2}\left(\beta q_1^2 + 2\gamma q_1 q_2 + \beta q_2^2\right), \tag{1}$$

where q_i denotes the quantity for good $i = 1, 2$ and α, β are positive parameters; $\gamma \in [0, \beta)$ expresses the degree of substitutability between goods.[3]

The consumer surplus net of expenditures on goods is given by

$$CS(q_1, q_2) = U(q_1, q_2) - p_1 q_1 - p_2 q_2. \tag{2}$$

[3] All these assumptions ensure that $U(.)$ is strictly concave and guarantee the positivity of direct demand functions $q_1(.)$ and $q_2(.)$ not derived here.

The inverse demand function $p_i(q_i, q_j)$ for good i is thus[4]

$$p_i(q_i, q_j) = \alpha - \beta q_i - \gamma q_j. \tag{3}$$

The markets are run by monopolies. The profit of firm i is

$$\pi_i(q_i, q_j) = p_i(q_i, q_j) \cdot q_i + S_i - C_i(q_i), \tag{4}$$

where S_i is the subsidy which may accrue to firm i via the regulatory process (see below). The total cost of firm i is assumed to be

$$C_i(q_i) = cq_i + k_i, \tag{5}$$

where $c \in (0, \alpha)$ is the marginal cost (equal for both firms) and $k_i > 0$ is firm i's fixed cost of production.

The regulatory mandate is the sum of the surplus that consumers get from the marketplace and the welfare of taxpayers who finance subsidies to firms. Moreover, we assume that the two regulatory structures may give different weights to profits, according to the distortion to firms' interests.

3. Optimally regulated prices under complete information

In each market the regulatory agency has two instruments, i.e. quantity and subsidy to the firm.

Under complete information the timing of the regulatory game is the following.

(I) A benevolent Congress decides to delegate regulation of two interdependent markets either to a unique agency or two different authorities.

(II) Firms engage in a lobbying activity to induce the regulator(s) to internalize (at least in part) their profits in the objective function.

(III) Firm i receives a take-it-or-leave-it offer of a regulatory policy $M_i = \{q_i, S_i\}$.

(IV) Each firm can either accept or reject the offer. If it refuses the proposed policy, the firm does not produce and earns zero profits.

(V) Contracts are executed and regulatory policies are implemented.

[4] Vives [**9**, Ch. 6] shows analytically that, under some basic conditions, if two goods are gross substitutes, which means $\frac{\partial D_i(p)}{\partial p_j} \geq 0$, $i \neq j$, where $D_i(p) = q_i$ is the direct demand for good i and p is the price vector, then we have $\frac{\partial P_i(q)}{\partial q_j} \leq 0$, $i \neq j$, where $P_i(q) = p_i$ is the inverse demand for good i and q is the quantity vector.

The two alternatives we consider differ in the number of markets (or firms) the regulator is responsible for and the value assigned to profits. Let us analyze them in sequence.

3.1. Pricing policy under decentralization

Let us now consider the first regulatory setting, namely one where two different agencies coexist and each of them only cares about regulating one firm. We label this environment as *decentralization*.

This regulatory model can be interpreted as a two-stage game. At the first stage, a lobbying activity occurs which determines the degree of regulatory internalization of profits. At the second stage, the regulator chooses the policy which maximizes its objective function. Let us solve this game by backward induction.

At the second stage, a decentralized regulator for firm i sets the quantity q_i and the subsidy S_i, in order to maximize the sum of consumer surplus, taxpayer welfare, and the profits of the regulated firm weighted by a given parameter $\varphi_i^D \in [0,1]$ determined at the previous stage, which represents the value the regulator assigns to each dollar of firm i's rent. Using (1), the regulator's objective is the following

$$\max_{q_i, S_i} \alpha q_i + \alpha q_j - \frac{1}{2}\left(\beta q_i^2 + 2\gamma q_i q_j + \beta q_j^2\right) - p_i\left(q_i, q_j\right) \cdot q_i +$$

$$-p_j\left(q_i, q_j\right) \cdot q_j - S_i - S_j + \varphi_i^D \pi_i, \tag{6}$$

$$s.t.$$

$$\pi_i \geq 0, \tag{PC$_i$}$$

where the participation constraint (PC$_i$) states that firm i is willing to produce only if it receives from the regulatory mechanism at least its reservation profit (normalized to zero). In Appendix A we show the solution to the problem in (6).

The regulated quantity for each good under regulatory decentralization with complete information is given by

$$q^D = \frac{\alpha - c}{\beta}. \tag{7}$$

It appears from (7) that substitutability between goods does *not* affect the quantities set by two different regulators in equilibrium.

Replacing (7) into (3) yields the complete-information pricing policy. This result is emphasized in the following Lemma.

Lemma 1 *Under complete information, decentralizing the regulation for substitutable goods yields a price equal to*

$$p^D = c - z\left(\alpha - c\right), \tag{8}$$

where $z \equiv \frac{\gamma}{\beta} \in [0, 1)$.

Notice from (8) that as markets are independent ($z = 0$) we find the standard marginal cost pricing.

Taking the derivative of (8) with respect to z yields

$$\frac{\partial p^D}{\partial z} = -\left(\alpha - c\right) < 0,$$

as $c \in (0, \alpha)$. Higher substitutability between goods reduces prices in equilibrium even below costs. We will examine this result when we compare consumer surplus under the two regulatory regimes (Subsection 3.3.1).

At the first stage, each firm engages in a lobbying activity, which determines the weight the regulator is willing to attach to profits. We assume that this weight depends the amount of expenditure incurred to influence the agency, which is financed through profits that the firm anticipates to receive. In other words, the regulatory concern φ_i^D with rents of firm i is the outcome of the following maximization problem

$$\max_{\varphi_i^D} \pi_i^D\left(\varphi_i^D\right) - v\left(\varphi_i^D\right), \tag{9}$$

where $v(.) \geq 0$ (with $v(0) = 0$) is the cost of the lobbying activity incurred by the firm, which is assumed to be (weakly) incresing and convex in φ_i^D ($v' \geq 0$, $v'' > 0$). Since from Appendix A we know that $\pi_i^D = 0$, it is immediate to see that $\varphi_1^{D^*} = \varphi_2^{D^*} = 0$ in equilibrium. In other words, no firm has incentive to lobby the regulator, since it anticipates that it will get zero profits anyway.

3.2. Pricing policy under centralization

The alternative regulatory environment we consider is one where a single agency is given the responsibility for both markets. We label this environment as *centralization.*

At the second stage, quantities q_1 and q_2 and subsidies S_1 and S_2 are determined in order to maximize the sum of consumer surplus, taxpayer welfare, and the profits of the two regulated firms weighted by a given parameter $\varphi^C \in [0,1]$ determined at the previous stage, which captures the value the regulator gives to each dollar of rent. Using (1), the regulator's program is the following

$$\max_{q_1,q_2,S_1,S_2} \alpha q_1 + \alpha q_2 - \frac{1}{2}\left(\beta q_1^2 + 2\gamma q_1 \cdot q_2 + \beta q_2^2\right) +$$

$$-p_1\left(q_1,q_2\right)\cdot q_1 - p_2\left(q_1,q_2\right)\cdot q_2 - S_1 - S_2 + \varphi^C\left(\pi_1+\pi_2\right) \tag{10}$$

$$s.t. \quad (PC_1),\ (PC_2).$$

Appendix B shows the solution to the problem in (10).

The regulated quantity for each good determined by a centralized agency under complete information is given by

$$q^C = \frac{\alpha - c}{\beta\left(1+z\right)}. \tag{11}$$

We can see from (11) that substitutability reduces the equilibrium output. A unique regulator finds it optimal to curb production of substitutes, since consumers can easily "move" from one market to the other.

Let us now derive the complete-information pricing policy under regulatory centralization. This is done in the following Lemma.

Lemma 2 *Under complete information, centralizing the regulation of markets for substitutable goods yields a price equal to*

$$p^C = c. \tag{12}$$

Observe from (12) that price charged by a single regulator equals marginal costs, independently of substitutability between goods.

As under decentralization, at the first stage lobbying occurs which yields the weight given to profits in the regulatory objective function. Unlike the other regime, we assume that the two firms can coordinate their influence activities, since they are subject to the same regulator. Hence, the regulatory concern φ^C with profits of both firms is the outcome of the following maximization problem

$$\max_{\varphi^C} 2\pi_i^C\left(\varphi^C\right) - \left(1+\mu\right)v\left(\varphi^C\right), \tag{13}$$

where $\mu \in [0, 1]$ is a parameter which captures the degree of efficiency of the lobbying activity. The idea is that the expendure incurred by two firms which make pressure on the regulator to jointly represent their interests may less than double with respect to the cost incurred if they acted separately (assumed to be equal to that under decentralization). At the limit, when $\mu = 0$ lobbying activity is so efficient that the two firms spend an amount of money as if they were a single firm. On the other hand, if $\mu = 1$ jointly influencing a unique regulator costs twice as much as separately, and there is no gain in the coordination of lobbying activities.

Since we know from Appendix B that $\pi_i^C = 0$, even under centralization lobbying activity is not profitable in case of complete information and $\varphi^{C^*} = 0$.

3.3. Welfare comparisons

We now compare the welfare of each agent affected by the regulatory outcome under the two regimes and derive some policy suggestions.

3.3.1. Consumer surplus

Substituting (11) and (7) into (1) we find after some manipulations the difference in consumer surplus between decentralization and centralization. This is given by

$$\Delta CS \equiv CS^D - CS^C = z\frac{2+z}{\beta(1+z)}(\alpha - c)^2. \tag{14}$$

Substitutability between goods ($z > 0$) implies that expression (14) is strictly positive. Indeed, taking the difference between prices in (8) and (12) immediately yields

$$\Delta p \equiv p^D - p^C = -z(\alpha - c) \leq 0. \tag{15}$$

We know from (12) that prices under centralization are not affected by substitution. On the contrary, (8) shows that an increase in "competition" between markets - as consumers can easier switch from one good to the other - leads two separate agencies to charge prices even lower than marginal costs. Therefore, under regulatory decentralization substitutability between goods yields *positive price externalities* which are consumer welfare improving.

We summarize this result in the following Lemma.

Lemma 3 *Under complete information, decentralizing the regulation of markets for substitutable goods ($z > 0$) makes consumers strictly better off.*

3.3.2. Taxpayer welfare

We now compute the amount of subsidies the firms receive. Substituting (7) and (11) into (4), we obtain after some manipulations the difference in subsidies given to each firm between the two regulatory regimes

$$\Delta S \equiv S^D - S^C = z\frac{1+z}{\beta\left(1+z\right)}\left(\alpha - c\right)^2. \tag{16}$$

Notice from (16) that the higher production under decentralization requires a greater subsidization which reduces taxpayer welfare.

This result is emphasized in the following Lemma.

Lemma 4 *Under complete information, centralized regulation for substitutable goods ($z > 0$) curbs the amount of subsidies and makes taxpayers strictly better off.*

3.3.4. Social welfare

As Congress maximizes the sum of consumer surplus and taxpayer welfare, the difference in social welfare between the two regimes can be defined as

$$\Delta W \equiv \Delta CS - 2\Delta S. \tag{17}$$

Substituting (14) and (16) into (17) we get after some manipulations

$$\Delta W = -\frac{z^2}{\beta\left(1+z\right)}\left(\alpha - c\right)^2. \tag{18}$$

Notice from (18) that substitutability between goods leads to higher social welfare under centralization. This means that the excess subsidy given under decentralization entails a welfare loss which more than compensates the higher consumer surplus.

In a sense, this is the result one would have expected. Under complete information, centralizing decisions when markets are interdependent yields a better outcome from a social welfare point of view. However, what we consider striking is that the aggregate result conceals a relevant distributional issue: consumers would be better off with decentralization, but this would happen at an excessively large cost for taxpayers.

We summarize this result in the following Lemma.

Lemma 5 *Under complete information, substitutability between goods ($z > 0$) implies that regulatory centralization improves social welfare.*

4. Optimally regulated prices under asymmetric information

Let us now assume that each firm has private information about its marginal cost c. The regulator has only imperfect prior knowledge about c, represented by a density function $f(c)$, which is assumed to be continuous and positive on the domain $[c^-, c^+]$. The corresponding cumulative distribution function is given by $F(c) = \int_{c^-}^{c} f(\widetilde{c})\, d\widetilde{c} \in [0,1]$.

Under asymmetric information the timing of the regulatory game is the following.

(I) Nature draws a (unique) type c for the two firms, according to the density function $f(c)$.

(II) Firms learn their type.

(III) Firms engage in a lobbying activity to induce the regulator(s) to internalize (at least in part) their profits in the objective function.

(IV) Each firm receives a take-it-or-leave-it offer of a direct incentive compatible mechanism $M_i = \{q_i(\widehat{c}_i), S_i(\widehat{c}_i)\}$ where the output $q_i(.)$ and the subsidy $S_i(.)$ targeted to firm i are contingent on its own report $\widehat{c}_i \in [c^-, c^+]$.[5] Each firm is induced to reveal honestly its private information, so that in equilibrium we have $\widehat{c}_i = c$.[6]

(V) Each firm can either accept or reject the offer. If it refuses the proposed policy, the firm does not produce and earns zero profits.

(VI) Contracts are executed and regulatory policies are implemented.

As shown in Appendix C, a local necessary condition for incentive compatibility, which is also globally sufficient if $q_i(.)$ is non-increasing in c, is given by the following expression

$$\pi_i(c) = \pi_i\left(c^+\right) + \int_{c}^{c^+} \frac{\partial C_i(\widetilde{c}, .)}{\partial \widetilde{c}} d\widetilde{c}. \tag{ICC$_i$}$$

[5] This assumption seems to be natural under decentralization, since we expect that a regulator is not allowed to ask the type of the firm outside its jurisdiction. In principle, a unique regulator could exploit the reports of both firms and implement a mechanism of punishments when declarations are inconsistent. However, we suppose that there are administrative requirements that prevent to divulge the information commanded from each firm.

[6] The *revelation principle* ensures that, without any loss of generality, the regulator may be restricted to direct incentive compatible policies, which require the firm to report its cost parameter and which give the firm no incentive to lie. For an application of the revelation principle to regulation, see the seminal paper of Baron and Myerson [**4**].

This condition states that the profit $\pi_i(c)$ of firm i must be equal to the expected profit $\pi_i(c^+)$ of the most inefficient firm plus an informational rent (captured by the integral) which represents the reward to the firm for revealing truthfully its private information.

4.1. Pricing policy under decentralization

As under complete information, the regulatory model is interpreted as a two-stage game, which can be solved backwards.

Using (1), at the second stage the maximization problem of a decentralized regulator under asymmetric information is the following

$$\max_{q_i(c),S_i(c)} \int_{c^-}^{c^+} \Big[\alpha q_i(c) + \alpha q_j(c) - \frac{1}{2}\left(\beta q_i^2(c) + 2\gamma q_i(c) q_j(c) + \beta q_j^2(c)\right) +$$

$$-p_i(q_i(c), q_j(c)) \cdot q_i(c) - p_j(q_i(c), q_j(c)) \cdot q_j(c) +$$

$$-S_i(c) - S_j(c) + \varphi_i^D \pi_i\Big] f(c)\, dc, \tag{19}$$

$$s.t.$$

$$\pi_i(c) \geq 0 \tag{PC$_i$}$$

$$\pi_i(c) = \pi_i\left(c^+\right) + \int_c^{c^+} q_i(\widetilde{c})\, d\widetilde{c}, \tag{ICC$_i$}$$

where the incentive compatibility constraint (ICC$_i$) of firm i is derived for the cost specification in (5). Appendix D shows the solution to the problem in (19).

The quantity for each good under regulatory decentralization with asymmetric information is given by

$$\overline{q}^D\left(\varphi_i^D\right) = \frac{1}{\beta}\left[\alpha - c - \left(1 - \varphi_i^D\right) H\right], \tag{20}$$

where $H \equiv \frac{F(c)}{f(c)} \geq 0$ is the hazard rate.[7] As under complete information substitutability between goods does not affect the quantities set by two different regulators.

Replacing (20) into (3) yields the asymmetric-information pricing policy. This result is emphasized in the following Lemma.

Lemma 6 *Under asymmetric cost information, decentralizing the regulation for substitutable goods yields a price equal to*

$$\overline{p}^D\left(\varphi_i^D\right) = c - z\left(\alpha - c\right) + \left(1 + z\right)\left(1 - \varphi_i^D\right)H. \tag{21}$$

If markets are independent ($z = 0$) we find the standard price distortion above marginal costs due to asymmetric information.

Moreover, observe from (21) that

$$\frac{\partial \overline{p}^D}{\partial z} = -\left[\alpha - c - \left(1 - \varphi_i^D\right)H\right] < 0,$$

as $\overline{q}^D > 0$. As under complete information, a higher substitutability between goods reduces prices in equilibrium.

At the first stage, after substituting the equilibrium profit from (ICC_i), as determined by (20), into (9) we can derive the weight given by each agency to profits of the regulated firm. This arises from the following maximization

$$\max_{\varphi_i^D} \int_{c}^{c^+} \frac{1}{\beta}\left[\alpha - \widetilde{c} - \left(1 - \varphi_i^D\right)H\left(\widetilde{c}\right)\right] d\widetilde{c} - v\left(\varphi_i^C\right). \tag{22}$$

The equilibrium value for φ_i^D must satisfy the following first-order condition

$$v'\left(\overline{\varphi}^D\right) = \frac{1}{\beta}\int_{c}^{c^+} H\left(\widetilde{c}\right) d\widetilde{c}, \tag{23}$$

where $\overline{\varphi}^D \equiv \overline{\varphi}_i^D$, $i = 1, 2$. As $v'' > 0$, the weight attached to profits is decreasing in the marginal costs of production. A high-cost firm can incur less expenditure to lobby the regulator, as it anticipates lower profits.

[7] The hazard rate H is supposed to be increasing in c. This monotonicity property, which is met by the most usual distributions, may be interpreted as a decrease in the conditional probability that there are further cost reductions, given that there has already been a cost marginal reduction, as the firm becomes more efficient. Laffont and Tirole [**6**, Ch. 1] offer a decsription of this "decreasing return" assumption.

4.2. Pricing policy under centralization

The maximization program of a unique regulator under asymmetric information is the following

$$\max_{q_1(c),q_2(c),S_1(c),S_2(c)} \int_{c^-}^{c^+} [\alpha q_1(c) + \alpha q_2(c) +$$

$$-\frac{1}{2}\left(\beta q_1^2(c) + 2\gamma q_1(c) \cdot q_2(c) + \beta q_2^2(c)\right) +$$

$$-p_1(q_1(c), q_2(c)) \cdot q_1(c) - p_2(q_1(c), q_2(c)) \cdot q_2(c)] +$$

$$-S_1(c) - S_2(c) + \varphi^C(\pi_1 + \pi_2)\big] f(c)\, dc \tag{24}$$

$$s.t. \quad (PC_1),\ (PC_2),\ (ICC_1),\ (ICC_2).$$

Appendix E shows the solution to the problem in (24).

The quantity for each good determined by a centralized agency under asymmetric information is given by

$$\overline{q}^C\left(\varphi^C\right) = \frac{1}{\beta(1+z)}\left[\alpha - c - \left(1-\varphi^C\right)H\right]. \tag{25}$$

We can see from (25) that as under complete information substitutability between goods reduces the equilibrium output.

Let us now derive the asymmetric-information pricing policy under regulatory centralization. This is done in the following Lemma.

Lemma 7 *Under asymmetric information, centralizing the regulation for substitutable goods yields a price equal to*

$$\overline{p}^C\left(\varphi^C\right) = c + \left(1-\varphi^C\right)H. \tag{26}$$

Notice from (26) that price charged by a single regulator is distorted above marginal costs due to asymmetric information, independently of substitutability between goods.

At the first stage, after substituting equilibrium profits from (ICC_1) and (ICC_2), as determined by (25), into (13) we can derive the the weight given to profits of both firms by a unique regulator. This arises from the following maximization

$$\max_{\varphi^C} 2\int_{c}^{c^+} \frac{1}{\beta(1+z)}\left[\alpha-\widetilde{c}-\left(1-\varphi^C\right)H\left(\widetilde{c}\right)\right]d\widetilde{c}-(1-\mu)\,v\left(\varphi^C\right). \tag{27}$$

The equilibrium value for φ^C must satisfy the following first-order condition

$$v^{'}\left(\overline{\varphi}^C\right)=\frac{2}{\beta(1+z)(1+\mu)}\int_{c}^{c^+} H\left(\widetilde{c}\right)d\widetilde{c}. \tag{28}$$

As $v^{''}>0$, as under decentralization the weight attached to profits is decreasing in the marginal costs of production. A high-cost firm can incur less expenditure to lobby the regulator, as it anticipates lower profits.

4.3. Welfare comparisons

Following the same procedure as in the case of complete information, we compare the welfare of each agent under the two regimes and derive some policy suggestions.

4.3.1. Consumer surplus

For the sake of convenience, we rewrite the equilibrium value for $\overline{q}^C$ in (25) as

$$\overline{q}^C=\frac{1}{\beta(1+z)}\left[\alpha-c-\left(1-\overline{\varphi}^D\right)H\right]+\frac{1}{\beta(1+z)}\Delta\overline{\varphi}H, \tag{29}$$

where $\Delta\overline{\varphi}\equiv\overline{\varphi}^C-\overline{\varphi}^D$ captures the difference in the equilibrium values attached to profits under decentralization and centralization. When $\Delta\overline{\varphi}>0$ we say that a single regulator is more distorted to firms' interests than two different regulators. Using (23) and (28) this is the case if and only if

$$(1+z)(1+\mu)<2. \tag{30}$$

Notice from (30) that substitutability between goods and the efficiency of lobbying activity have countervailing effects on $\Delta\overline{\varphi}$. The more substitutes are the goods (z goes up), the harder condition (30) is met, and we may find $\overline{\varphi}^D>\overline{\varphi}^C$ in equilibrium. The rationale is that profits under centralization become lower (see Subsection 4.3.2) and then firms are less willing to influence a unique regulator.

On the contrary, an increase in the efficiency of lobbying activity (μ goes down) relaxes condition (30) and $\overline{\varphi}^C > \overline{\varphi}^D$ is more likely to occur in equilibrium. At the limit, when $\mu = 0$, condition (30) is always satisfied. The two firms which lobby together the unique regulator benefit by gains from coordination and can obtain a higher representation of their interests.

Substituting (29) and (20) into (1) we find after some manipulations the difference (in expected terms) in consumer surplus between decentralization and centralization. This is given by

$$\Delta E\left[\overline{CS}\right] \equiv E\left[\overline{CS}^D - \overline{CS}^C\right] = \int_{c^-}^{c^+} \left\{ z \frac{2+z}{\beta(1+z)} \Phi^2 + \right.$$

$$\left. - \frac{\Delta\overline{\varphi}(z,\mu)}{\beta(1+z)} H\left[2(\alpha - c) - H\left(2 - \overline{\varphi}^C - \overline{\varphi}^D\right)\right] \right\} f(c)\,dc, \qquad (31)$$

where $\Phi \equiv \alpha - c - \left(1 - \overline{\varphi}^D\right) H > 0$ as $\overline{q}^D > 0$. The sign of (31) is now driven by two major components, the *substitutability* between goods (captured by z), which operates even under complete information, and the *lobbying efficiency* (represented by μ), which plays a role only in case of asymmetric information. Let us analyze them in sequence.

First of all, notice from (31) and (14) that if the two regulatory structures give the same weight to profits in equilibrium ($\Delta\overline{\varphi} = 0$), we find the same (expected) difference in consumer surplus, and then substitutability between goods yields higher (expected) consumer welfare under decentralization, as in the case of complete information.

For a given level of substitutability an inefficient lobbying activity (μ high) reduces the firms' engagement in the regulatory capture under centralization, and so condition (30) may not hold ($\Delta\overline{\varphi} < 0$). In this case, consumers are even better off under decentralization as in the complete-information setting.[8] Two different agencies are induced to raise production in order to distribute higher informational rents - which increase in output from (ICC_i) - and thus improve also consumer welfare. This result is even more pronounced with a high level of substitutability between goods since, as we will have seen above, firms are worse off under centralization and then they are less willing to lobby.

However, when firms benefit from coordinating their influence activities - i.e. lobbying is efficient - we can see from (30) that a centralized regulatory

[8] The last term in square brackets is positive as long as there is production under both regimes.

structure can be more profit-oriented than two different agencies ($\Delta\overline{\varphi} > 0$). The substitutability and lobbying effects push in opposite directions and consumer preference for either regime depend on the weight of the two forces at issue.

We summarize this result in the following Proposition.

Proposition 8 *Under asymmetric information, when lobbying is inefficient (μ high) two different regulators attach at least the same weight to profits as a single agency ($\Delta\overline{\varphi} \leq 0$) and decentralized regulation for substitutable goods makes consumers better off. When lobbying is efficient (μ low), a single agency can be more concerned with firms' interests ($\Delta\overline{\varphi} > 0$) and a trade-off emerges in equilibrium between substitutability and lobbying effects, so centralizing the regulatory structure may increase consumer surplus.*

4.3.2. Firms' profits

Replacing (20) and (29) into (ICC), we find the difference in (expected) profits for each firm between the two regulatory regimes, which is given by

$$\Delta E\left[\overline{\pi}\right] \equiv E\left[\overline{\pi}^{D} - \overline{\pi}^{C}\right] = \int_{c^-}^{c^+}\int_{c}^{c^+} \left[\frac{z}{\beta\left(1+z\right)}\Phi - \frac{\Delta\overline{\varphi}\left(z,\mu\right)}{\beta\left(1+z\right)}H\right] d\widetilde{c} f\left(c\right) dc =$$

$$= \int_{c^-}^{c^+} H \left[\frac{z}{\beta\left(1+z\right)}\Phi - \frac{\Delta\overline{\varphi}\left(z,\mu\right)}{\beta\left(1+z\right)}H\right] f\left(c\right) dc, \tag{32}$$

where the second equality is derived through the integration by parts. Notice from (32) that the two effects analyzed before play the same role as for consumer surplus. When the two regulatory structures give the same weight to profits in equilibrium ($\Delta\overline{\varphi} = 0$), substitutability between goods implies higher quantities under decentralization, which benefit not only consumers but also firms which receive greater informational rents. This result is stronger if lobbying is inefficient as two different regulators are more profit-oriented ($\Delta\overline{\varphi} < 0$). However, as firms can efficiently coordinate their pressure on a single agency the latter can be more distorted to firm's interests ($\Delta\overline{\varphi} > 0$), and a trade-off emerges in equilibrium.

We write this result as a Lemma of Proposition 8.

Lemma 9 *Under asymmetric information, when lobbying is inefficient (μ high) two different regulators attach at least the same weight to profits as* *a unique agency ($\Delta\overline{\varphi} \leq 0$) and decentralizing the regulation of markets for substitutable goods increases firms' profits. When lobbying is efficient (μ low) a unique agency is more concerned with firms' interests ($\Delta\overline{\varphi} > 0$), and a trade-off emerges in equilibrium between substitutability and lobbying effects, so centralization may raise firms' profits.*

4.3.3. Taxpayer welfare

We compute now the amount of subsidies the firms receive. Substituting (20) and (29) into (4), as specified by (ICC), we obtain after some manipulations the difference in (expected) subsidies between the two regulatory regimes

$$\Delta E\left[\overline{S}\right] \equiv E\left[\overline{S}^D - \overline{S}^C\right] = \int_{c^-}^{c^+} \left\{ \frac{z}{\beta(1+z)} \left[\Phi(\alpha - c)(1+z) + \right.\right.$$

$$\left.\left. -H\left(1 + z - \overline{\varphi}^D(2+z)\right)\right] - \frac{\Delta\overline{\varphi}(z,\mu)}{\beta(1+z)} H\left[\alpha - c - \left(1 - \overline{\varphi}^C - \overline{\varphi}^D\right) H\right] \right\} f(c)\, dc. \tag{33}$$

When the two regulatory structures have the same concern with firms' profits ($\Delta\overline{\varphi} = 0$), the substitutability effect prevails and the higher production under decentralization requires a greater subsidization which harms taxpayers.

This effect is exacerbated if two different agencies are more profit-oriented ($\Delta\overline{\varphi} < 0$), as they are induced to increase the amount of subsidies given to firms.[9]

On the contrary, substitutability effect is counterbalanced by lobbying effect when a unique regulator is more distorted to firms' interests ($\Delta\overline{\varphi} > 0$) and then it is willing to raise transfers.[10]

This result is emphasized in the following Proposition.

Proposition 10 *Under asymmetric information, when lobbying is inefficient (μ high) two different regulators attach at least the same weight to profits as a unique agency ($\Delta\overline{\varphi} \leq 0$) and centralized regulation for substitutable goods curbs the amount of subsidies, making taxpayers better off. When lobbying is efficient (μ low) a unique agency is more concerned with*

[9] Notice that the first expression in square brackets in (33) is positive as long as there is production under decentralization.

[10] Notice that the second expression in square brackets in (33) is positive as long as there is production under both regimes.

firms' interests ($\Delta\overline{\varphi} > 0$) and a trade-off emerges in equilibrium between substitutability and lobbying effects, so decentralization may improve taxpayer welfare.

4.3.4. Social welfare

As Congress maximizes the sum of consumer surplus and taxpayer welfare, the expected difference in social welfare between the two regimes can be defined as

$$\Delta E\left[\overline{W}\right] = \Delta E\left[\overline{CS}\right] - 2\Delta E\left[\overline{S}\right]. \tag{34}$$

Substituting (31) and (33) into (34) we get after some manipulations

$$\Delta E\left[\overline{W}\right] = \int_{c^-}^{c^+} \left[-\frac{z^2}{\beta\left(1+z\right)}\left(\Phi + \frac{2}{z}\overline{\varphi}^D H\right) + \frac{\Delta\overline{\varphi}\left(z,\mu\right)}{\beta\left(1+z\right)}\left(\overline{\varphi}^C + \overline{\varphi}^D\right) H^2\right] f\left(c\right) dc. \tag{35}$$

Notice from (34) that the preference for centralized regulation found under complete information is even more pronounced when lobbying is inefficient and two different regulators are more profit-oriented ($\Delta\overline{\varphi} < 0$). The idea is that they are induced to give higher transfers to firms to increase their informational rents which are wasteful from a social welfare point of view.

However, this clear-cut result no longer holds when a single regulator is more distorted to firms' interests ($\Delta\overline{\varphi} > 0$), as a result of the efficient coordination of lobbying activities by the two firms. If Congress thinks that a centralized structure can be more susceptible to capture by industry, the choice between the two regulatory regimes implies a trade-off whose sign depends on the relative weight of the two forces at work.

We summarize this result in the following Proposition.

Proposition 11 *Under asymmetric information, when lobbying is inefficient (μ high) two different regulators attach at least the same weight to profit as a unique agency ($\Delta\overline{\varphi} \leq 0$) and substitutability between goods implies that regulatory centralization improves expected social welfare. If lobbying is efficient (μ low) a unique agency is more distorted to firm's interests ($\Delta\overline{\varphi} > 0$) and a trade-off emerges in equilibrium between substitutability and lobbying effects, so decentralized regulation may be social welfare enhancing.*

5. Concluding remarks

In this paper, we have tackled the problem of how to design the jurisdiction of a regulatory authority when two markets have interdependent demands and there is the threat of regulatory capture. This is an issue which, despite its theoretical and empirical importance, has been by and large ignored in the literature.

Our analysis has shown that under complete information regulatory centralization is the best solution in terms of social welfare. This very intuitive result covers a distributional aspect of great interest. Indeed, regulatory decentralization favours consumers. Two different agencies, each regulating a single market, set lower prices than a single authority and the higher quantities produced in equilibrium increase consumer welfare. We have argued that positive price externalities arise from the decentralized regulation of markets for substitutable goods.

However, these results are tempered under asymmetric cost information when a unique regulator is more distorted to firms' interests than two separate agencies as a result of lobbying activities carried out by firms. In this case, a trade-off emerges in equilibrium between substitutability and lobbying effects, and decentralizing the regulatory structure can be social welfare enhancing.

We believe that much scope exists for future research in this field and our model can be enriched in a variety of directions. We would like to mention two aspects which are left for future development.

First of all, markets may be also interconnected on the cost side. This occurs when one good enters into the production process of the other. Examples of this kind are given by gas and water, which both affect the final cost of electricity.

The second idea concerns the informational framework examined in the paper. While asymmetric cost information is certainly relevant, limited regulatory knowledge about market demands would be equally interesting to consider, especially when demands are interdependent.

We believe that a greater effort in these directions might shed some light on many other important issues.

Appendix A

After replacing the choice variable S_i with π_i from (4), the regulator's optimization problem in (6) may be written as follows

$$\max_{q_i,\pi_i} \alpha q_i + \alpha q_j - \frac{1}{2}\left(\beta q_i^2 + 2\gamma q_i q_j + \beta q_j^2\right) +$$
$$-p_j\left(q_i, q_j\right) \cdot q_j - C_i\left(q_i\right) - S_j - \left(1 - \varphi^D\right)\pi_i \tag{36}$$

$$s.t. \quad (PC_i).$$

Since (36) is decreasing in π_i, firm i gets zero profits in equilibrium ($\pi_i^D = 0$).

Maximizing (36) with respect to q_i yields the following first-order condition

$$\alpha - \beta q_i - c_i = 0. \tag{37}$$

Appendix B

We replace the choice variables S_1 and S_2 from (4) with π_1 and π_2 respectively. The regulator's optimization program in (10) may be rewritten as follows

$$\max_{q_1,q_2,\pi_1,\pi_2} \alpha q_1 + \alpha q_2 - \frac{1}{2}\left(\beta q_1^2 + 2\gamma q_1 q_2 + \beta q_2^2\right) - C_1\left(q_1\right) +$$
$$-C_2\left(q_2\right) - \left(1 - \varphi^C\right)\left(\pi_1 + \pi_2\right) \tag{38}$$

$$s.t. \quad (PC_1), \, (PC_2).$$

Since (38) is decreasing in π_1 and π_2, the two firms get zero profits in equilibrium ($\pi_1^C = \pi_2^C = 0$).

Maximizing (38) with respect to q_i yields the following first-order condition

$$\alpha - \beta q_i - \gamma q_j - c_i = 0. \tag{39}$$

Appendix C

We derive the local necessary incentive compatibility condition (ICC$_i$) seen in Section 4 and show that this condition is also globally sufficient for the cost specification in (5) if $q_i\left(.\right)$ is non-increasing in c_i.

The set of global incentive compatible mechanisms satisfies for any $c, \widehat{c}_i \in [c^-, c^+]$ the following constraint

$$\pi_i(c) \equiv \pi_i(c, c) \geq \pi_i(\widehat{c}_i, c). \tag{40}$$

Condition (40) requires that firm i does not have any incentive to misrepresent its private information, since the profit $\pi_i(c)$ received by revealing truthfully its marginal costs $c \in [c^-, c^+]$ is at least as great as the profit $\pi_i(\widehat{c}_i, c)$ it could obtain for any report $\widehat{c}_i$.

Following the Baron [**3**] approach and using (4) and (5), the right-hand side of (40) may be rewritten as

$$\pi_i(\widehat{c}_i, c) = \pi_i(\widehat{c}_i) + C_i(q_i(\widehat{c}_i), \widehat{c}_i) - C_i(q_i(\widehat{c}_i), c), \tag{41}$$

where $\pi_i(\widehat{c}_i) \equiv \pi_i(\widehat{c}_i, \widehat{c}_i)$. After substituting (41) into (40), we get

$$\pi_i(c) - \pi_i(\widehat{c}_i) \geq C_i(q_i(\widehat{c}_i), \widehat{c}_i) - C_i(q_i(\widehat{c}_i), c). \tag{42}$$

Reversing the roles of c and $\widehat{c}_i$ in (40) and (41) yields

$$\pi_i(c) - \pi_i(\widehat{c}_i) \leq C_i(q_i(c), \widehat{c}_i) - C_i(q_i(c), c) \tag{43}$$

Combining (42) and (43) implies

$$C_i(q_i(\widehat{c}_i), \widehat{c}_i) - C_i(q_i(\widehat{c}_i), c) \leq \pi_i(c) - \pi_i(\widehat{c}_i) \leq$$

$$\leq C_i(q_i(c), \widehat{c}_i) - C_i(q_i(c), c). \tag{44}$$

Dividing the inequalities in (44) by $\widehat{c}_i - c$ for $\widehat{c}_i > c$ and taking the limit as $\widehat{c}_i \to c$ yields

$$\frac{d\pi_i(c)}{dc} = -\frac{\partial C_i(c, .)}{\partial c}. \tag{45}$$

After integrating both sides of equation (45) and combining terms, we obtain the local necessary incentive compatibility condition (ICC$_i$) seen in Section 4

$$\pi_i(c) = \pi_i\left(c^+\right) + \int_c^{c^+} \frac{\partial C_i(\widetilde{c}, .)}{\partial \widetilde{c}} d\widetilde{c}. \tag{46}$$

Now we show that condition (46) is also globally sufficient for the cost specification in (5) if $q_i(.)$ is non-increasing in c_i. Substituting $\pi_i(\widehat{c}_i)$ from (46) for $\widehat{c}_i = c$ into (41) and using (5) yields

$$\pi_i(\widehat{c}_i, c) = \pi_i\left(c^+\right) + \int_{\widehat{c}_i}^{c^+} q_i(\widetilde{c})\, d\widetilde{c} + (\widehat{c}_i - c)\, q_i(\widehat{c}_i)\,. \tag{47}$$

If we replace $\pi_i(c^+)$ from (46) into (47), we get after some manipulations

$$\pi_i(\widehat{c}_i, c) = \pi_i(c) - \int_{c}^{\widehat{c}_i} q_i(\widetilde{c})\, d\widetilde{c} + (\widehat{c}_i - c)\, q_i(\widehat{c}_i)\,. \tag{48}$$

Finally, combining terms in (48) yields

$$\pi_i(\widehat{c}_i, c) = \pi_i(c) + \int_{c}^{\widehat{c}_i} [q_i(\widehat{c}_i) - q_i(\widetilde{c})]\, d\widetilde{c}. \tag{49}$$

The global incentive compatibility condition in (49) is satisfied for any $c, \widehat{c}_i \in [c^-, c]$ if the second term on the right-hand side in (49) is non-positive. Our claim is that this occurs if $q_i(.)$ is non-increasing in c_i. To see why such is the case, notice that, if $\widehat{c}_i \geq c$, then the weak monotonicity of $q_i(.)$ implies that the integral in (49) is non-positive. When $\widehat{c}_i < c$, then the term in square brackets in (49) is nonnegative if $q_i(c_i)$ is a non-increasing function but reversing the direction of the integral shows that the second term in (49) is non-positive. Therefore, the local necessary incentive compatibility condition (ICC_i) in (46) is also globally sufficient for the cost specification in (5) provided that $q_i(.)$ is non-increasing in c_i.

Appendix D

We replace the choice variable $S_i(c)$ with $\pi_i(c)$ from (4) as shown in Appendix A. Then, substituting (ICC_i) into (19) and integrating by parts yields

$$\max_{q_i(c), \pi_i(c^+)} \int_{c^-}^{c^+} \Big[\alpha q_i(c) + \alpha q_j(c) - \frac{1}{2}\left(\beta q_i^2(c) + 2\gamma q_i(c)\, q_j(c) + \beta q_j(c)\right) +$$

$$-p_j(q_i(c), q_j(c)) \cdot q_j(c) - C_i(q_i(c)) - S_j(q_j(c)) +$$

$$-\left(1-\varphi_i^D\right)\left(\frac{F\left(c\right)}{f\left(c\right)}q_i\left(c\right)+\pi_i\left(c^+\right)\right)\Bigg]f\left(c_i\right)dc_i \tag{50}$$

$$s.t.$$

$$\pi_i\left(c^+\right)\geq 0. \tag{PC$_i$}$$

Since (50) is decreasing in $\pi_i\left(c^+\right)$, the regulator finds it optimal to give zero profit to the most inefficient firm.

Maximizing pointwise (50) with respect to q_i yields the following first-order condition

$$\alpha-\beta q_i\left(c\right)-c_i-\left(1-\varphi_i^D\right)\frac{F\left(c\right)}{f\left(c\right)}=0. \tag{51}$$

Appendix E

We replace the choice variable $S_i\left(c\right)$ with $\pi_i\left(c\right)$ from (4) as shown in Appendix B. Then, substituting (ICC$_1$) and (ICC$_2$) into (24) and integrating by parts yields

$$\max_{q_1(c),q_2(c),\pi_1(c^+),\pi_2(c^+)}\int\limits_{c^-}^{c^+}\left[\alpha q_1\left(c\right)+\alpha q_2\left(c\right)+\right.$$

$$-\frac{1}{2}\left(\beta q_1^2\left(c\right)+2\gamma q_1\left(c\right)q_2\left(c\right)+\beta q_2^2\left(c\right)\right)-C_1\left(q_1\left(c\right)\right)-C_2\left(q_2\left(c\right)\right)+$$

$$-\left(1-\varphi^C\right)\left(\frac{F\left(c\right)}{f\left(c\right)}q_1\left(c\right)+\pi_1\left(c^+\right)+\frac{F\left(c\right)}{f\left(c\right)}q_2\left(c\right)+\pi_2\left(c^+\right)\right)\Bigg]f\left(c\right)dc \tag{52}$$

$$s.t.$$

$$\pi_1\left(c^+\right)\geq 0$$

$$\pi_2\left(c^+\right)\geq 0.$$

Since (52) is decreasing in $\pi_1(c^+)$ and $\pi_2(c^+)$, the firms with the highest costs obtain zero profits in equilibrium.

Maximizing pointwise (52) with respect to $q_i(c)$ yields the following first-order condition

$$\alpha - \beta q_i(c) - \gamma q_j(c) - c_i - \left(1 - \varphi^C\right) H_i = 0. \tag{53}$$

References

[**1**] Armstrong, M. and D. E. M. Sappington (2007), "Recent Developments in the Theory of Regulation", in *Handbook of Industrial Organization*, Vol. 3, edited by M. Armstrong and R. Porter, Elsevier Science Publisher B. V., 1557-1700.

[**2**] Baron, D. P. (1988), "Regulation and Legislative Choice", in *The RAND Journal of Economics*, Vol. 19, No. 3, 467-477

[**3**] Baron, D. P. (1989), "Design of Regulatory Mechanisms and Institutions", in *Handbook of Industrial Organization*, Vol. II, edited by R. Schmalensee and R. D. Willig, Elsevier Science Publisher B. V., 1347-1447.

[**4**] Baron, D. P. and R. B. Myerson (1982), "Regulating a Monopolist with Unknown Costs", in *Econometrica*, Vol. 50, No. 4, 911-930.

[**5**] Laffont, J.-J. and D. Martimort (1999), "Separation of Regulators against Collusive Behavior", in *The Rand Journal of Economics*, Vol. 30, No. 2, 232-262.

[**6**] Laffont, J.-J. and J. Tirole (1993), *A Theory of Incentives in Procurement and Regulation*, MIT Press, Cambridge, Massachusetts.

[**7**] Neven, D. J. and L.-H. Röller (2005), "Consumer Surplus vs. Welfare Standard in a Political Economy Model of Merger Control", in *International Journal of Industrial Organization*, Vol. 23, 829-848.

[**8**] Singh, N. and X. Vives (1984), "Price and Quantity Competition in a Differentiated Duopoly", in *The Rand Journal of Economics*, Vol. 15, Issue 4, 546-554.

[**9**] Vives, X. (1999), *Oligopoly Pricing*, MIT Press, Cambridge, Massachusetts.