The Regulation of Interdependent Markets*

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Abstract

We examine the issue of whether two monopolists which produce substitutable goods should be regulated by one (centralization) or two (decentralization) regulatory authorities, when the regulator(s) can be partially captured by industry. Under full information, where lobbying is inactive, centralized regulation clearly improves social welfare since it internalizes all relevant effects. This (predictable) result conceals a distributional issue of some interest: consumers are better off under decentralization but at the cost of excessively high subsidies to firms. Under asymmetric information about the firms' costs, centralization spurs competition between firms in regulatory capture, which yields an overinvestment in lobbying. Hence, a unique regulator is more distorted to industry's interests, and this reduces social welfare. A sufficiently high substitutability between goods aggravates capture problem so that decentralized regulation is (socially) preferred since it removes competition between firms in the lobbying market.

Keywords: asymmetric information, energy markets, lobbying, regulation, substitutability.

JEL classification: D82, L51.

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1. Introduction

Should a country set up a single energy regulator or rather have separate agencies for gas and electricity? And should we have a unique transport authority, or rather a railway regulator separate from those regulating motorways or airports? Our paper provides an attempt to explore these issues, focusing on how to devise the jurisdiction of a regulatory authority, that is, the *regulatory design*, when there are two markets which provide substitutable goods.

Several theoretical contributions to the literature on regulation have investigated 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] Our focus is thus not on the number of firms, but on the *number of regulators*.

We assume that a benevolent political principal (the Congress) can delegate the regulation of two interdependent markets either to a unique regulator (*centralization*) or to two different authorities (*decentralization*). Regulation may be non-benevolent since it can be captured by the firms' lobbying activities. Our model predicts that under full information, where lobbying is *not* profitable, regulatory centralization is the best option for the Congress. As long as regulation is benevolent, the cooperative (centralized) regime allows to internalize all the relevant effects and thus improves social welfare. This intuitive result covers a distributional issue of some interest: the *market interdependence effect* driven by substitutability between goods implies that the noncooperative behaviour of two different regulators yields lower prices than under centralization, making consumers better off. However, this leads to excessive costs for taxpayers who subsidize firms, and then reduces social welfare.

If firms have private information about their costs, there is scope for lobbying and we find that a unique regulator is more distorted to the industry's interests because the competition between firms in the lobbying market induces an *overinvestment* in capture. A trade-off emerges in equilibrium between the (expected) *market interdependence effect* and the *lobbying effect*. When the substitutability between goods is high enough, the latter effect may outweigh the former, so that decentralizing the regulatory structure can increase social welfare. The noncooperative (decentralized) regime turns out

[1] See Gilbert and Riordan [1995] for an analysis of the relative advantages of bundled supply in multiproduct industries.

to be a good structural response to non-benevolent regulation since it alleviates the capture problem by preventing lobbies from competing to acquire more influence.

Even though they are derived in a regulatory setting, we believe that our results can shed some light on the relevant issue of power separation in government and organizations.

2. Related literature

The design of the regulatory jurisdiction in interdependent markets is an issue which, despite its theoretical and empirical importance, has been only touched by the literature on optimal regulation, so that several gaps remain.[2]

The issue of the separation of powers has indeed been addressed in the theory of regulation. Laffont and Martimort [1999] consider the problem of monitoring a regulated firm which has private information about some pieces of its activity. The authors argue that when regulation makes collusive offers that are accepted by the firm whatever its characteristics, splitting regulatory rights on some aspects of the firm's performance between different agencies may act as a device against the threat of regulatory capture. Separation turns out to be desirable since it reduces regulatory discretion in engaging in socially wasteful activities.[3] In our paper we show that decentralized regulation can mitigate the adverse effect of lobbying in a context of interdependent markets since the noncooperative regulatory behavior removes the competition between firms at the lobbying stage.[4]

Another strand of literature which is relevant for our contribution is the

[2]For a survey on optimal regulation see Armstrong and Sappington [2007].

[3]Martimort [1999] shows that in a dynamic setting with endogenous transaction costs there may exist diseconomies of scale in information acquisition which justify a split in the monitoring technology between two different regulators.

[4]A relevant stream of literature analyzes the trade-off between centralization and decentralization in economic organizations (see Poitevin [2000] for a review on this topic). Laffont and Martimort [1998] show that under certain conditions a decentralized structure can alleviate the problem of collusion if there are limits on communication between the principal and the agents. With this approach we share the assumption that the delegation process is imperfect, so that regulators may have private agendas. However, the Laffont and Martimort results are driven by very different forces from those operating in our setting: decentralization (that they call "delegation") implies an extention of the organizational hierarchy, which can be profitable when the principal cannot communicate with the bottom-level agent. In our model decentralization means separation of the regulatory jurisdiction between two noncooperative agencies and its superiority in terms of social welfare is a consequence of the way the interdependence between markets affects the lobbying stage.

multiprincipal incentive theory. Baron [1985] examines the regulation of a non-localized externality by two different agencies and compares the noncooperative equilibrium with the case in which two regulators are allowed to coordinate their activities. Contrary to our paper, regulatory agencies represent conflicting interests and lobbying by industry is not an issue. In a reduced-form model with two agencies which exhibit different objectives in presence of regulatory capture, Martimort [1996] shows that the duplication of non-benevolent regulators may improve social welfare. This shares some relevant similarities with our analysis, even though our results are driven by market interdependence by endogenizing the lobbying stage.

Our work is finally related to the well-known capture theory of economic regulation, whose seminal contribution traces back to Stigler [1971]. Following his paradigm, we assume that the industry is able to mobilize regulatory powers to obtain favours, since it has greater incentives than dispersed consumers and taxpayers with a low per-capita stake to get organized in order to exercise political influence.[5] Following Martimort [1996], we assume that capture can only be partial, and that it materializes in a higher weight which the regulator puts on profits in her objective function.[6] In line with Grossman and Helpman's [1994] contribution we suppose that regulated firms are involved in a lobbying activity and then the regulator sets a policy. That paper models the interaction between the various lobbies and the government as a "menu-auction" problem à la Bernheim and Whinston [1986] where bidders (lobbies) announce a menu of offers (contributions) for various possible actions open to an auctioneer (the government) and then they pay the bids associated with the action selected. Each organized group confronts the government with a contribution schedule which maps every policy vector the goverment may choose into a contribution level. The government then sets a policy vector and collects from each lobby the contribution associated with its policy choice in order to maximize a weighted sum of total political contributions and aggregate social welfare.[7]

In our paper the contribution schedule of each firm maps every regulatory weight on profits in a contribution level. The costs incurred to lobby the

[5] It is anyway worth quoting the contribution of Miller III *et al.* [1984] which informally argues that centralization should alter the relative rates of return to lobbying for various coalitions, generally in favour of groups having diffuse interests which can focus their lobbying against rent-creating regulation on one location rather than splitting those efforts among a variety of regulatory agencies.

[6] Calzolari and Scarpa [2009] also suggest that the regulator can be captured by the firm and induced to put a larger stake on profits.

[7] Boylan [2000] shows that if contributions from the government to lobbies are feasible, then the best possible auction for the goverment leads to the same policy as in Bernheim and Whinston [1986], although contributions are higher.

agency[8] yield a pro-firm distortion in the regulatory objective function. This is in line with rent-seeking literature starting from Tullock [1980] where effort of each contestant (firm) affects the share of "prize" (profits) it receives.[9] This approach allows us to endogenize Martimort's [1996] black-box formulation of lobbying through the explicit derivation of profit weights.

The rest of the paper is organized as follows. Section 3 presents the basic structures of the model. In Section 4 we compute the full information outcomes and study their impact on welfare of the agents involved. Section 5 derives the regulatory policy under both regimes in the case of asymmetric cost information and makes welfare comparisons. Finally, Section 6 is devoted to some concluding remarks. All relevant proofs are relegated to the Appendix.

3. The basic model

We consider two symmetric markets for substitutable goods. Following Singh and Vives [1984], the consumers' 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.[10]

The consumer surplus net of expenditures on goods is given by

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

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

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

[8] These costs include side transfers (contributions) in monetary terms or in the form of lucrative employment opportunities of the regulatory staff (Laffont and Tirole [1991]).

[9] In his original formulation, Tullock [1980] assumes that effort increases the probability of winning, which can be easily interpreted as the share of prize. More relevantly, differently from Tullock's, we endogenize the "prize", since profits are the outcome of a lobbying activity.

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

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

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

$$C_i\left(q_i, c_i\right) = c_i q_i + f, \tag{5}$$

where $c_i \in (0, \alpha)$ is the marginal cost of firm i and $f > 0$ is the (common) fixed cost of production. The fixed cost of production does not play any role in our welfare analysis and then without loss of generality it is supposed to be equal for the two firms.

Regulation In line with the main literature the Congress is a benevolent maximizer of a social welfare function,[11] which is given by

$$W\left(q_1, S_1; q_2, S_2\right) = CS\left(q_1, q_2\right) - S_1 - S_2. \tag{6}$$

The Congress cares about consumer surplus net of the subsidization of firms financed by taxpayers via the regulatory process.[12]

The mandate of a decentralized regulator for market i is to maximize the consumer surplus in (2) net of the subsidy S_i she gives to firm i through the regulatory process.[13] Regulation can be partially captured by industries. Following Martimort [1996], the result of such a partial capture is the distortion

[11] Among others, Laffont and Tirole [1990] assume that regulatory institutions result from a constitution drafted by some benevolent "founding fathers" or "social planners", which may be identified with the Congress.

[12] Notice that (6) is a social welfare function à la Baron and Myerson [1982] with zero weights on profits. Without any loss of generality (see Armstrong and Sappington [2007]) we neglect the shadow cost of public funds à la Laffont and Tirole [1986] arising from distortionary taxation. This cost increases even more the weight of taxpayer welfare in the social welfare function, which does not affect qualitatively the results but makes the analysis less transparent.

[13] Baron [1988] 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. Such a regulatory mandate can be also thought as a response to the regulatory capture. In our setting of imperfect delegation, the Congress does not have time, resources and expertise to discover the lobbying activity exerted by the firms and cannot give the regulator the right monetary incentives to completely internalize its objectives. Neven and Röller [2005] suggest that when competition authority's 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.

of regulatory activity to industry's interests. This means that the regulator for market i also cares about profits of firm i, to which she assigns a weight $\varphi_i^D \in [0,1]$.[14] Formally, a decentralized regulator for market i maximizes

$$V_i^D(q_i, S_i; .) = CS(q_i, q_j) - S_i + \varphi_i^D \pi_i. \tag{7}$$

The objective of a unique regulator is

$$V^C(q_1, S_1; q_2, S_2) = CS(q_1, q_2) - S_1 - S_2 + \varphi_1^C \pi_1 + \varphi_2^C \pi_2, \tag{8}$$

where $\varphi_i^C \in [0,1]$ is the weight put on firm i's profits by centralized regulation.

It is worth stressing that the choice of the objective function is not central to our analysis and the results we obtain. Nothing substantial would change if we assumed that the Congress' objective would exhibit a positive weight on profits, and firms lobby to increase that weight in the regulatory objective function(s).

The regulatory instruments are the quantity and the subsidy to the firm in each market. In line with the optimal regulation literature from Baron and Myerson [1982] and Laffont and Tirole [1986] we assume that regulatory agencies are granted appropriations to be used to subsidize the firm. Notice from (7) that a decentralized regulator clearly cares only about the amount of transfers given to the firm she is responsible for.

Although in some sectors price regulation seems to be more natural, in relevant industries like electricity, gas and transport, which are characterized by network assets with limited capacity, the choice of scale plays a crucial role as it yields transmission constraints. A common way in the literature to model this feature is to consider the quantity as a choice variable since the entire capacity is dumped on the market.[15] Notice that this formulation implies a sort of quantity competition between regulators under decentralization. This is in line with empirical works of some relevance to our sectors, which corroborates the idea that binding infrastructure capacity restrictions induce Cournot behavior.[16]

[14] It seems sensible to assume that each firm is able to capture only the regulator established in its market, since they have a direct relationship. More relevantly, notice from Appendix A that the profits of a firm are entirely determined by its own regulator, and then there is no incentive to bribe the regulator for the other market.

[15] See on this topic Tirole [1988, ch. 5].

[16] See Egging and Gabriel [2006] and Holz *et al.* [2008] for empirical evidence about the European natural gas market. Bushnell *et al.* [2008] focus on the U.S. electicity sector.

Lobbying Following Grossman and Helpman [1994] our regulatory model is a two-stage game where first firms lobby the regulator(s) and then the policy is implemented. Non-benevolence of regulatory agencies may take several forms and in line with Martimort [1996] we choose to model it as a pro-firm bias. The weights φ_i^D and φ_i^C are then driven by firms' lobbying activities. As discussed in Section 2, each firm faces a contribution schedule $\varphi \in [0,1] \rightarrow \nu(\varphi) \in R_+$ which maps every profit weight φ into the amount of expenditure $\nu(.)$ incurred to get that weight. The contribution function $\nu(.)$ (with $\nu(0) = 0$) is increasing and convex in φ ($\nu' > 0$, $\nu'' > 0$).[17] This represents the intuitive idea that the higher the profit weight, the higher the cost incurred to capture the regulator. The shape of the contribution function reflects the regulator's preferences for lobbying, that is, her level of corruptability,[18] which depends on a number of variables like personal interests of the regulatory staff.[19] The cost of lobbying is financed through profits the firm anticipates to receive. Hence, each firm picks up the weight which maximizes its (net) profits. In other terms, the regulatory weight φ_i^k in regime k ($k = C, D$) on the rent of firm i is the outcome of the following problem

$$\max_{\varphi_i^k \in [0,1]} \left[\pi_i^k\left(\varphi_i^k, \varphi_j^k\right) - \nu\left(\varphi_i^k\right)\right]. \tag{9}$$

Condition (9) models Stigler's [1971] suggestion that each interest group chooses to influence the government at a level where marginal benefit equals marginal cost.[20]

4. The full information benchmark

In each market the regulatory agency has two instruments, i.e. quantity q_i and subsidy S_i to firm i. Under full information the timing of the regulatory game is the following.

[17] For computational convenience, we also assume $\nu''' = 0$.

[18] A contribution function with a higher slope (larger ν'') denotes a regulator harder to capture, since weights on profits are more costly to firms.

[19] We assume that this shape is the same under the two regulatory regimes. This allows us to derive results without imposing any arbitrary asymmetric bias to capture.

[20] Following Laffont and Tirole [1991] one could imagine that (a fraction of) the firm's total expenditure to bribe the regulator increases the regulatory income. Without loss of generality we neglect such a term in the regulatory objective functions in (7) and (8) since this is the result of the lobbying stage and then it does not affect the policy setting at the following stage.

(I) The 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) Under decentralization the regulator for market i independently and simultaneously makes a take-it-or-leave-it offer of a regulatory mechanism $M_i^D = \left\{q_i^D, S_i^D\right\}$ to firm i. Under centralization a unique agency offers a regulatory policy $M_i^C = \left\{q_i^C, S_i^C\right\}$ to each firm.

(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) If the firm accepts, the contract is executed and the regulatory policy is implemented.

For the sake of convenience, we consider the case where firms exhibit the same costs, i.e. $c_i = c$. We clearly drop this assumption when deriving the results under asymmetric information. Our regulatory model is a two-stage game. At the first stage, the firms' lobbying activity determines the weight on profits in the regulatory objective function(s). At the second stage, each regulator chooses the policy which maximizes her objective function. We solve this game by backward induction. The two alternatives we consider differ in the number of markets (or firms) the regulator is responsible for and (possibly) the value assigned to profits. Let us analyze them in sequence.

4.1. Pricing policy under decentralization

Let us first consider the regulatory setting in which two different agencies coexist. We label this environment as *decentralization*.

At the second stage the regulator in charge of market i sets the quantity q_i and the subsidy S_i, in order to maximize consumer surplus net of subsidy plus the profits of firm i weighted by a given parameter $\varphi_i^D \in [0, 1]$ determined at the previous stage. Substituting (2) and (4) into (7), the objective of the regulator for market i is the following

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

$$-p_j\left(q_i, q_j\right) q_j - S_i + \varphi_i^D \pi_i \Big] \quad s.t. \tag{10}$$

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

where the participation constraint (PC_i) states that firm i produces only if it receives from the regulatory mechanism at least its reservation profit (normalized to zero). Referring to Appendix A for the details, from the first-order condition for q_i the regulated quantity for good i is given by

$$q_i^D \equiv q^D = \frac{\alpha - c}{\beta}. \tag{11}$$

Replacing (11) into (3) yields the full information pricing policy. This result is emphasized in the following Lemma.

Lemma 1 *Under full information, decentralized regulation yields a price for good i equal to*

$$p_i^D \equiv p^D = c - z\left(\alpha - c\right), \tag{12}$$

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

Notice from (12) that if markets are independent, i.e. $z = 0$, we find the first-best condition of marginal cost pricing. As $c \in (0, \alpha)$, the substitutability between the goods, i.e. $z > 0$, reduces equilibrium prices *below* marginal costs.

At the first stage each firm engages in a lobbying activity, which determines the weight the regulator attaches to profits. As discussed in Section 3, we assume that this weight depends on the amount of expenditure incurred to influence the agency. From (9) the regulatory weight φ_i^D on the rent of firm i is the outcome of the following problem

$$\max_{\varphi_i^D \in [0,1]} \left[\pi_i^D\left(\varphi_i^D, \varphi_j^D\right) - \nu\left(\varphi_i^D\right)\right]. \tag{13}$$

Since $\varphi_i^D \in [0, 1]$ and then with full information there is no reason to leave the firm any rents, i.e. $\pi_i^D = 0$, it is immediate to see that $\varphi_i^D = 0$ in equilibrium. In other words, no firm has incentives to lobby the regulator, since it anticipates zero profits anyway.

4.2. 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 a unique regulator sets the quantities q_1 and q_2 and subsidies S_1 and S_2 in order to maximize her objective function. Replacing (2) and (4) into (8), the regulator's program is the following

$$\max_{\{q_1,S_1;q_2,S_2\}} \Big[\alpha q_1 + \alpha q_2 - \frac{1}{2}\left(\beta q_1^2 + 2\gamma q_1 q_2 + \beta q_2^2\right) - p_1(q_1,q_2)\,q_1$$

$$-p_2(q_1,q_2)\,q_2 - S_1 - S_2 + \varphi_1^C \pi_1 + \varphi_2^C \pi_2\Big] \quad s.t. \quad (PC_1),\,(PC_2). \tag{14}$$

Appendix B shows the solution to the problem in (14). From the first-order condition for q_i the regulated quantity for good i is given by

$$q_i^C \equiv q^C = \frac{\alpha - c}{\beta(1+z)}. \tag{15}$$

We can see from (15) that substitutability reduces the equilibrium output. A unique regulator finds it optimal to curb production of substitutes, since consumers can move from one market to the other.

We derive now the full information pricing policy under regulatory centralization. This is shown in the following Lemma.

Lemma 2 *Under full information centralized regulation yields a price for good i equal to*

$$p_i^C \equiv p^C = c. \tag{16}$$

Observe from (16) that the price set by a single regulator equals marginal costs independently of substitutability between goods, and then allocative efficiency is maximized.

As under decentralization, at the first stage lobbying occurs which yields the weight given to profits in the regulatory objective function. Hence, the regulatory weight φ_i^C on profits of firm i is the outcome of the following problem

$$\max_{\varphi_i^C \in [0,1]} \left[\pi_i^C\left(\varphi_i^C, \varphi_j^C\right) - \nu\left(\varphi_i^C\right)\right]. \tag{17}$$

Since $\pi_i^C = 0$ in equilibrium, even under centralization lobbying activity is not profitable in case of full information, which implies $\varphi_i^C = 0$.

From the analysis above we can conclude that in both regimes lobbying does not emerge in equilibrium. This confirms the well-known idea that in absence of asymmetric information, regulated firms are unable to extract rents and therefore have no incentives to influence regulatory outcomes.

4.3. Welfare comparisons

We compare now the welfare of each agent under the two regulatory structures. We first consider price levels, which turn out to be crucial for the analysis of our main results. Taking the difference between (12) and (16) immediately yields

$$p^D - p^C = -z(\alpha - c) = -I(z), \tag{18}$$

where

$$I(z) \equiv z(\alpha - c) \geq 0 \tag{19}$$

as $c \in (0, \alpha)$. Notice that (18) is negative as long as goods are substitutes. We know from (16) that centralized prices equal marginal costs. Conversely, (12) shows that with connected markets the noncooperative behavior of each regulator, who disregards the amount of subsidies granted by the other, pushes prices below marginal costs. Hence, a "*market interdependence effect*", denoted by $I(z)$, occurs under full information and yields a *downward* distortion in decentralized prices that definitely benefits consumers.

We can now present our first results of some relevance, which will be proved and commented upon in different steps.

Proposition 1 *Assume that $z \in (0, 1)$, i.e. goods are substitutes. Then, under full information regulatory decentralization*
(i) increases consumer surplus, i.e. $CS^D > CS^C$
(ii) increases subsidies, i.e. $S^D > S^C$
(iii) decreases social welfare, i.e. $W^D < W^C$.

To show point (i), plugging (11) and (15) into (2) yields the difference in consumer surplus between the two regulatory regimes, which after some manipulations can be written as

$$CS^D - CS^C \equiv \Delta CS = z\frac{2+z}{\beta(1+z)}(\alpha - c)^2. \tag{20}$$

Substitutability between goods implies that expression (20) is strictly positive, i.e. $CS^D > CS^C$, so decentralization makes consumers better off. This is a straightforward consequence of lower prices under this regime, as is evident from (18).

Coming to subsidies, notice that regulated prices are lower under decentralization, but equilibrium profits are zero in all cases. This can work because of subsidies which are bound to be lower under centralized regulation. To be more precise, we compute the amount of subsidies the firms receive, which proves point (*ii*) of Proposition 1. Substituting (11) and (15) into (4), we obtain after some computations the difference in subsidies granted to each firm between the two regulatory regimes, i.e.

$$S^D - S^C \equiv \Delta S = \frac{z}{\beta} (\alpha - c)^2 . \tag{21}$$

Not surprisingly, (21) reveals that the higher production under decentralization requires a greater subsidization, i.e. $S^D > S^C$, which reduces taxpayer welfare.

As from (6) we know that the Congress cares about the consumer surplus net of subsidies financed by taxpayers, using (20) and (21) the difference in social welfare between the two regimes can be written after some manipulations as

$$W^D - W^C \equiv \Delta W = -\frac{z^2}{\beta (1+z)} (\alpha - c)^2 . \tag{22}$$

Notice from (22) that, as we have emphasized in point (*iii*) of Proposition 1, substitutability between goods yields higher social welfare under centralization, i.e. $W^D < W^C$. 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 full information nothing interferes with the regulator's ability to maximize her objective function which, as long as $\varphi \in [0, 1]$, entails zero profits irrespective of the weight each regulator gives to the private firm's profits (Baron and Myerson [1982]). Therefore, lobbying is not profitable, and having one powerful regulator in charge of both markets which perfectly internalizes taxpayer welfare clearly yields a better outcome. However, what we consider relevant is that the (predictable) aggregate result conceals a distributional issue of some interest: consumers would be better off with two independent regulators, but this would happen at an excessively large cost for taxpayers.

5. Asymmetric cost information

We assume now that firms have private information about their production technology. Firm i's costs are independently and identically (i.i.d.) distributed according to a density function $f(c_i)$, which is continuous and positive on the domain $[\underline{c}, \overline{c}]$. The corresponding cumulative distribution function is given by $F(c_i) = \int_{\underline{c}}^{c_i} f(\widetilde{c}_i)\, d\widetilde{c}_i \in [0,1]$. Under asymmetric information the timing of the regulatory game is the following.

(I) Nature draws a cost type c_i for firm i, according to the density function $f(c_i)$.

(II) The Congress decides to delegate regulation either to a unique agency or two different authorities.[21]

(III) Firms engage in a lobbying activity to induce the regulator(s) to internalize (at least in part) their profits in the objective function.[22]

(IV) Each firm learns its type.

(V) Invoking the revelation principle (Myerson [1979]), under decentralization each regulator independently and simultaneously offers a direct incentive compatible mechanism $M_i^D = \left\{q_i^D(\widehat{c}_i), S_i^D(\widehat{c}_i)\right\}$ where the output $q_i(.)$ and the subsidy $S_i(.)$ targeted to firm i are contingent on its own report $\widehat{c}_i \in [\underline{c}, \overline{c}]$. Under centralization, a unique regulator offers $M_i^C = \left\{q_i^C(\widehat{c}_i, \widehat{c}_j), S_i^C(\widehat{c}_i, \widehat{c}_j)\right\}$, where $q_i(.)$ and $S_i(.)$ are contingent on the reports of both firms. Each firm is induced to reveal honestly its private information, so that in equilibrium we have $\widehat{c}_i = c_i$.

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

(VII) If the firm accepts, the contract is executed and the regulatory policy is implemented.

All results of the paper are derived under the assumption of i.i.d. costs. To check their robustness, in Appendix F we consider the case of (perfectly) correlated costs, which may have some relevance in connected markets, and we show that our main conclusions still apply.

[21] In line with some relevant literature (see Iossa [1999]) the Congress chooses the regulatory regime before firms learn their costs. One might imagine that this choice could affect the degree of *ex ante* asymmetric information of the regulator(s). For instance, a decentralized (specialized) regulator might be expected to have better information than a unique (generalist) regulator. Conversely, the latter might be better informed because she could have a cheaper access to data if there are economies of scale in information acquisition. This seems to be especially an empirical question, which is outside the scope of this paper. Hence, according to our timing neither cost distribution nor Nature's move is affected by the choice of the regulatory regime.

[22] Notice that lobbying stage takes place before firms know their type. This is clearly the case when lobbying is a long-term activity in which firms are involved before they build up the production technology. This assumption is also meant to avoid signaling issues, which are outside the scope of the paper. In the literature on regulatory capture (Laffont and Tirole [1993, ch. 11]) the opposite timing is often used since collusion deals with concealment of costs from the principal, which is not an issue here.

The incentive compatibility constraint of firm i is

$$\int_{\underline{c}}^{\overline{c}} \pi_i (c_i, .) f (c_j) dc_j = \int_{\underline{c}}^{\overline{c}} \pi_i (\overline{c}, .) f (c_j) dc_j + \int_{\underline{c}}^{\overline{c}} \int_{c_i}^{\overline{c}} q_i (\widetilde{c}_i) d\widetilde{c}_i f (c_j) dc_j. \tag{ICC$_i$}$$

Notice that firm i considers its expected profits according to firm j's cost distribution when it signs the contract and makes its cost declaration. Condition (ICC$_i$) states that the (expected) profit of firm i must be equal to the (expected) profit of the most inefficient firm plus the informational rent (captured by the double integral) which represents the reward to the firm for revealing truthfully its private information.[23]

5.1. Pricing policy under decentralization

A decentralized regulator maximizes (7) in expected terms since she designs the policy mechanism before knowing firms' costs. Using (2) and (4), at the second stage the optimization problem is the following

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

$$\left. + \beta q_j^2 (c_j) \right) - p_i (q_i (c_i), q_j (c_j)) q_i (c_i) - p_j (q_i (c_i), q_j (c_j)) q_j (c_j)$$

$$- S_i (c_i) + \varphi_i^D \pi_i (c_i, .) \Big] f (c_i) f (c_j) dc_i dc_j \quad s.t. \tag{23}$$

$$\int_{\underline{c}}^{\overline{c}} \pi_i (c_i, .) f (c_j) dc_j \geq 0 \tag{PC$_i$}$$

$$\int_{\underline{c}}^{\overline{c}} \pi_i (c_i, .) f (c_j) dc_j = \int_{\underline{c}}^{\overline{c}} \pi_i (\overline{c}, .) f (c_j) dc_j + \int_{\underline{c}}^{\overline{c}} \int_{c_i}^{\overline{c}} q_i (\widetilde{c}_i) d\widetilde{c}_i f (c_j) dc_j, \tag{ICC$'_i$}$$

[23] See for instance Baron [1989, pp. 1363-1369].

where (PC_i) is the participation constraint of firm i and the incentive compatibility constraint ($ICC_i^{'}$) is derived from (ICC_i) for the cost specification in (5). Appendix C shows the solution to the problem in (23).

From the first-order condition for $q_i(.)$ the quantity produced by firm i as a function of φ_i^D is given by

$$\overline{q}_i^D\left(\varphi_i^D\right)=\frac{1}{\beta}\left[\alpha-c_i-\left(1-\varphi_i^D\right)H\left(c_i\right)\right], \tag{24}$$

where $H\left(c_i\right)\equiv\frac{F(c_i)}{f(c_i)}\geq 0$ is the hazard rate.[24]

Replacing (24) into (3) yields the asymmetric information prices as functions of the profit weights, which are shown in the following Lemma.

Lemma 3 *Under asymmetric information decentralized regulation yields a price for good i equal to*

$$\overline{p}_i^D\left(\varphi_i^D,\varphi_j^D\right)=c_i-z\left(\alpha-c_j\right)+\left[\left(1-\varphi_i^D\right)H\left(c_i\right)+z\left(1-\varphi_j^D\right)H\left(c_j\right)\right]. \tag{25}$$

The impact of substitutability on prices is now twofold. On the one hand, as under full information higher substitutability yields a reduction in prices. On the other, the distortion above the full information price, captured by the expression in square brackets, is exacerbated by the substitutability between goods. To see which effect prevails, we compute from (25)

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

as $\overline{q}_j^D>0$ (see (24) inverting i and j). As under full information even though at a lesser extent, we find that a stronger substitutability between goods reduces prices in equilibrium (for a given φ_j^D).

Finally, notice that an increase in the weight φ_j^D put on the profits of the firm j yields a reduction in the equilibrium price $\overline{p}_i^D$. Indeed, a higher quantity produced in market j when the regulator is more profit distorted decreases the price for the substitutable good i (see (3)).

5.2. Pricing policy under centralization

Substituting (2) and (4) into (8) in expected terms, the program of a unique regulator is

[24]The usual assumption of increasing hazard rate holds, i.e. $\frac{\partial H}{\partial c_i}>0$.

$$\max_{\{q_1(c_1,c_2),S_1(c_1,c_2);q_2(c_1,c_2),S_2(c_1,c_2)\}} \int_{\underline{c}}^{\overline{c}} \int_{\underline{c}}^{\overline{c}} [\alpha q_1 (c_1, c_2) + \alpha q_2 (c_1, c_2)$$

$$-\frac{1}{2} \left(\beta q_1^2 (c_1, c_2) + 2\gamma q_1 (c_1, c_2) q_2 (c_1, c_2) + \beta q_2^2 (c_1, c_2)\right)$$

$$-p_1 (q_1 (c_1, c_2), q_2 (c_1, c_2)) q_1 (c_1, c_2) - p_2 (q_1 (c_1, c_2), q_2 (c_1, c_2)) q_2 (c_1, c_2)$$

$$-S_1 (c_1, c_2) - S_2 (c_1, c_2) + \varphi_1^C \pi_1 (c_1, c_2) + \varphi_2^C \pi_2 (c_1, c_2)\big] f (c_1) f (c_2) dc_1 dc_2 \tag{26}$$

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

Notice that with i.i.d. cost draws the incentive compatibility constraints under centralization are a straightforward extension of those derived for the case of decentralization. The only difference is that now the quantity is contingent on the declaration of both firms.

From the first-order condition for $q_i(.)$ the quantity produced by firm i for given φ_i^C and φ_j^C is

$$\overline{q}_i^C \left(\varphi_i^C, \varphi_j^C\right) = \frac{1}{\beta (1 - z^2)} [(1 - z) \alpha - c_i + z c_j$$

$$- \left(1 - \varphi_i^C\right) H (c_i) + z \left(1 - \varphi_j^C\right) H (c_j)] \,. \tag{27}$$

Notice from (27) that

$$\frac{\partial \overline{q}_i^C}{\partial \varphi_j^C} = -\frac{z}{\beta (1 - z^2)} H (c_j) \leq 0. \tag{28}$$

Centralized regulation entails a sort of rivalry between the firms, which has implications for their lobbying activities. A higher weight obtained by firm j on its profits harms firm i, which is allowed to produce (and earn) less since goods are substitutes.

We are now in a position to derive the asymmetric information prices as a function of profit weights. This is done in the following Lemma.

Lemma 4 *Under asymmetric information centralized regulation yields a price for good i equal to*

$$\overline{p}_i^C\left(\varphi_i^C\right) = c_i + \left(1-\varphi_i^C\right) H\left(c_i\right). \tag{29}$$

Notice from (29) that the price charged by a single regulator is distorted above marginal costs due to asymmetric information, independently of the substitutability between goods.

Hence, in both regulatory structures asymmetric information increases prices. However, under centralization the regulated price is above marginal cost, while this is not necessarily the case under decentralization (see (25)).

5.3. Equilibrium lobbying activities

Now that we have derived the equilibrium prices/quantities in the regulation stage (as functions of the profit weights φ_i^k, with $k = C, D$), we can proceed backwards to determine the equilibrium levels of lobbying activities, by using (9). To this end, we need to calculate the expected profits on the basis of equilibrium quantities, as lobbying takes place before firms learn their private information.

In case of decentralization, after substituting the equilibrium profit from (ICC_i), as determined by (24), into (9) we can derive the weight given by each agency to the profits of firm i as the solution to

$$\max_{\varphi_i^D\in[0,1]}\left\{\int_{\underline{c}}^{\overline{c}}\int_{\underline{c}}^{\overline{c}}\int_{c_i}^{\overline{c}}\frac{1}{\beta}\left[\alpha-\widetilde{c}_i-\left(1-\varphi_i^D\right)H\left(\widetilde{c}_i\right)\right]d\widetilde{c}_i\right.$$

$$\left.\times f\left(c_i\right)f\left(c_j\right)dc_idc_j-\nu\left(\varphi_i^D\right)\right\}.$$

The (interior) equilibrium value[25] for φ_i^D must satisfy the following first-order condition

$$\nu'\left(\overline{\varphi}_i^D\right)=\frac{1}{\beta}\int_{\underline{c}}^{\overline{c}}\int_{\underline{c}}^{\overline{c}}\int_{c_i}^{\overline{c}}H\left(\widetilde{c}_i\right)d\widetilde{c}_if\left(c_i\right)f\left(c_j\right)dc_idc_j,$$

i.e. the equilibrium weight is such that the marginal cost of lobbying equates the (expected) marginal profit. This implies

[25] To get an interior optimum it is sufficient that $\nu'(1)$ is high enough.

$$\overline{\varphi}_i^D \equiv \overline{\varphi}^D = (\nu')^{-1}\left(\frac{E\left[H^2\right]}{\beta}\right), \tag{30}$$

where $E\left[H^2\right] = \int_{\underline{c}}^{\overline{c}}\int_{\underline{c}}^{\overline{c}}\int_{c_i}^{\overline{c}} H\left(\widetilde{c}_i\right) d\widetilde{c}_i f\left(c_i\right) f\left(c_j\right) dc_i dc_j$, $i = 1, 2$ (as costs are i.i.d.) and $E\left[.\right]$ denotes the expectation operator. Since they expect the same profits, the two firms behave identically at the lobbying stage, which implies $\overline{\varphi}_i^D \equiv \overline{\varphi}^D$.

Turning to the case of centralization, we can proceed in an analogous way using (9) and (27). The weight given to profits of firm i by a unique regulator arises from the following program

$$\max_{\varphi_i^C\in[0,1]}\left\{\int_{\underline{c}}^{\overline{c}}\int_{\underline{c}}^{\overline{c}}\int_{c_i}^{\overline{c}}\frac{1}{\beta\left(1-z^2\right)}\left[\left(1-z\right)\alpha-\widetilde{c}_i+zc_j-\left(1-\varphi_i^C\right)H\left(\widetilde{c}_i\right)\right.\right.$$

$$\left.\left.+z\left(1-\varphi_j^C\right)H\left(c_j\right)\right]d\widetilde{c}_i f\left(c_i\right)f\left(c_j\right)dc_i dc_j-\nu\left(\varphi_i^C\right)\right\}.$$

The (interior) equilibrium value for φ_i^C must satisfy the following first-order condition

$$\nu'\left(\overline{\varphi}_i^C\right) = \frac{1}{\beta\left(1-z^2\right)}\int_{\underline{c}}^{\overline{c}}\int_{\underline{c}}^{\overline{c}}\int_{c_i}^{\overline{c}} H\left(\widetilde{c}_i\right) d\widetilde{c}_i f\left(c_i\right) f\left(c_j\right) dc_i dc_j, \tag{31}$$

which implies

$$\overline{\varphi}_i^C \equiv \overline{\varphi}^C = (\nu')^{-1}\left(\frac{E\left[H^2\right]}{\beta\left(1-z^2\right)}\right). \tag{32}$$

The two firms will get the same weight on their profits in equilibrium, i.e. $\overline{\varphi}_i^C \equiv \overline{\varphi}^C$.

An important consequence of this analysis, which can be simply obtained by comparing (30) and (32), is the following.

Proposition 2 *In an interior equilibrium,* $\Delta\overline{\varphi}\left(z\right) \equiv \overline{\varphi}^D - \overline{\varphi}^C\left(z\right) : [0, 1) \rightarrow (-1, 0]$*, i.e. the weight of profits in the regulatory objective function is higher under centralization. Moreover,* $\Delta\overline{\varphi}\left(z\right)$ *is*

(a) (strictly) decreasing, i.e. $\frac{\partial\Delta\overline{\varphi}(z)}{\partial z} < 0$ *for* $z \in (0, 1)$

(b) (strictly) concave, i.e. $\frac{\partial^2\Delta\overline{\varphi}(z)}{\partial z^2} < 0$.

The proof is quite straightforward. Proposition 2 stresses that a single regulator is *more* distorted to firms' interests than two noncooperative agencies. We have already pointed out that centralization introduces an element of rivalry between the firms, which are actually engaged in a sort of *competition* in the lobbying market. Points (a) and (b) of Proposition 2 reveal that the profit weight with centralization rises at an increasing rate with substitutability. We know from (28) that a higher weight on the profits of a firm implies a larger output at the rival's expense and then larger informational rents. Notice that (28) is decreasing (at an increasing rate) in z, which means that the higher the degree of substitutability, the larger the negative impact of an increase in profit weight of a firm on the quantity (and profit) of the other. The interdependence between markets exacerbates the negative externality each firm imposes on the other when they compete at the lobbying stage.

Like in a standard Tullock [1980] contest, the "prize" (the expected profit) that a contestant (firm) receives is increasing in its own effort (cost of lobbying) but decreases in the opponent's effort. Joint profit maximizing weights are solutions to

$$\max_{\left\{\varphi_1^C,\varphi_2^C\right\}\in[0,1]} \left\{ \int_{\underline{c}}^{\overline{c}} \int_{\underline{c}}^{\overline{c}} \frac{1}{\beta\left(1-z^2\right)} \left[\int_{c_1}^{\overline{c}} \left[(1-z)\,\alpha - \widetilde{c}_1 + zc_2 - \left(1-\varphi_1^C\right) H\left(\widetilde{c}_1\right) \right.\right.\right.$$

$$\left. +z\left(1-\varphi_2^C\right) H\left(c_2\right) \right] d\widetilde{c}_1 + \int_{c_2}^{\overline{c}} \left[(1-z)\,\alpha - \widetilde{c}_2 + zc_1 - \left(1-\varphi_2^C\right) H\left(\widetilde{c}_2\right) \right.$$

$$\left.\left. +z\left(1-\varphi_1^C\right) H\left(c_1\right) \right] d\widetilde{c}_2 \right] f\left(c_1\right) f\left(c_2\right) dc_1 dc_2 - \nu\left(\varphi_1^C\right) - \nu\left(\varphi_2^C\right) \Big\},$$

which implies from first-order conditions

$$\overline{\varphi}_1^{C^*} = \overline{\varphi}_2^{C^*} \equiv \overline{\varphi}^{C^*} = \left(\nu'\right)^{-1} \left(\frac{E\left[H^2\right]}{\beta\left(1+z\right)} \right) < \overline{\varphi}^C$$

by (32) as $\nu'' > 0$. Centralization yields an *overinvestment* in lobbying in equilibrium, since each firm does not internalize the loss it imposes on the other.[26] As difference between $\overline{\varphi}^C$ and $\overline{\varphi}^{C^*}$ increases in z, the interdependence between markets increases the upward distortion in lobbying investment. Conversely, decentralization reduces regulatory bias to industry's profits since it removes competition between firms in the lobbying market.

[26] Like in a standard Prisoner's Dialemma problem, joint profit maximization clearly makes both firms better off. Integrating by parts, firm i's ex-

5.4. Welfare comparisons

The above considerations imply that there is a significant trade-off to be considered. In a sense, centralization is "obviously" preferable under full information, in that a benevolent regulator will be better able to achieve the social goals when the actions in the two markets are fully coordinated. However, things may be different under asymmetric information. This is especially true as centralization spurs lobbying activity, which can be self-defeating: the very notion of a benevolent regulator is undermined by firms' pressures.

We start comparing price levels, which will prove to be crucial to the overall results. After defining $\psi(c_i) \equiv \alpha - c_i - \left(1-\overline{\varphi}^D\right) H(c_i)$ (with $\psi(.) > 0$ as $\overline{q}_i^D > 0$), we derive from (25) and (29) of equilibrium the difference in *expected* prices between the two regimes, which it is useful to write as[27]

$$E\left[\overline{p}_i^D\right] - E\left[\overline{p}_i^C\right] = -zE[\psi] - \Delta\overline{\varphi}(z)\, E[H] = -\overline{I}(z) + \overline{L}(z), \qquad (33)$$

with

$$\overline{I}(z) \equiv zE[\psi] \geq 0 \qquad (34)$$

and

$$\overline{L}(z) \equiv -\Delta\overline{\varphi}(z)\, E[H] \geq 0, \qquad (35)$$

where the expression in (35) is non-negative by Proposition 2. Notice from (33) that the impact of substitutability on equilibrium (expected) prices is now twofold. The term $\overline{I}(z)$ captures the "*(direct) market interdependence effect*" under asymmetric information, which yields *ceteris paribus* lower prices under decentralization, as in the case of full information. The "*lobbying effect*", represented by $\overline{L}(z)$, can be seen as a second, indirect effect of substitutability, which plays a role only in case of asymmetric information

tra profit (in expected terms) is after some manipulations $E\left[\overline{\pi}^{C^*}\right] - E\left[\overline{\pi}^C\right] = \frac{\overline{\varphi}^{C^*} - \overline{\varphi}^C}{\beta(1-z^2)} \int_{\underline{c}}^{\overline{c}} \int_{\underline{c}}^{\overline{c}} \left[(H(c_i))^2 - zH(c_i)H(c_j)\right] f(c_i) f(c_j)\, dc_i dc_j - \nu\left(\overline{\varphi}^{C^*}\right) + \nu\left(\overline{\varphi}^C\right)$. By Taylor expansion we can write $\nu\left(\overline{\varphi}^C\right) \approx \nu\left(\overline{\varphi}^{C^*}\right) + \left(\overline{\varphi}^C - \overline{\varphi}^{C^*}\right)\nu'\left(\overline{\varphi}^C\right)$. Substituting (31) implies $E\left[\overline{\pi}^{C^*}\right] - E\left[\overline{\pi}^C\right] = z\frac{\overline{\varphi}^C - \overline{\varphi}^{C^*}}{\beta(1-z^2)} \int_{\underline{c}}^{\overline{c}} \int_{\underline{c}}^{\overline{c}} H(c_i) H(c_j) f(c_i) f(c_j)\, dc_i dc_j > 0$.

[27] Notice that i.i.d. costs imply $E\left[\overline{p}_1^k\right] = E\left[\overline{p}_2^k\right]$ for $k \in \{C, D\}$.

and entails that prices under centralization are lower than under decentralization. A single regulator will be exposed to competition between firms in the lobbying market and will thus be more profit oriented; she will decrease prices in order to increase production and distribute higher informational rents.

Notice from (33) that asymmetric information influences the two effects in the same direction. On the one hand, it mitigates the market interdependence effect, which is now *weaker* ($\overline{I} < I$ from (19) and (34)), since the price distortion from asymmetric information (even in the absence of any difference in lobbying activities) is higher under decentralization (see from (25) and (29) in expected terms with $\overline{L} = 0$ that $(1+z)(1-\varphi)E[H] > (1-\varphi)E[H]$). On the other hand, asymmetric information yields a lobbying effect, which decreases prices under centralization. Therefore, due to asymmetric information, prices increase in both regimes. However, they rise more under decentralization than under centralization. When this distortion due to asymmetric information is large enough, the full information result in (18) may well be reversed.

In order to establish our main results, it is useful to first consider the following intermediate step.

Lemma 5 *Define the function* $\Gamma(z) : [0,1) \to R$ *as* $\Gamma(z) \equiv E\left[\overline{p}_i^D\right] - E\left[\overline{p}_i^C\right] = -\Delta\overline{\varphi}(z)E[H] - zE[\psi] = \overline{L}(z) - \overline{I}(z)$. *Then, the following is true:*

(a) $\Gamma(0) = 0$

(b) $\Gamma(.)$ *is initially (strictly) decreasing, i.e.* $\Gamma'(0) < 0$, *and then (strictly) increasing, i.e.* $\Gamma'(z) > 0$ *for* z *large enough*

(c) $\Gamma(.)$ *is (strictly) convex, i.e.* $\Gamma''(.) > 0$

(d) if $E[H] > -\frac{zE[\psi]}{\Delta\overline{\varphi}(z)}$ *for some* $z \in (0,1)$ *there exists a unique value of* z *(call it* z^**) such that* $\Gamma(z^*) = 0$

(e) $\Gamma(z) > 0$ *if and only if* $z \in (z^*, 1)$.

Notice from (33) that the function $\Gamma(.)$ represents the difference between the lobbying effect and the market interdependence effect. If Γ is positive (negative), then the former (latter) force dominates, which yields lower prices under centralization (decentralization).

Points (a) to (c) of Lemma 5 are straightforward consequences of the definitions of $\psi(.)$ and $\Delta\overline{\varphi}(z)$ (see Proposition 2). The remaining points (d) and (e) stress that the lobbying effect prevails over the market interdependence effect, i.e. $\Gamma(.) > 0$, if goods are substitutes enough, i.e $z \in (z^*, 1)$. This can be the case when the cost distribution makes the lobbying effect sufficiently active, i.e. $E[H] > -\frac{zE[\psi]}{\Delta\overline{\varphi}(z)}$.[28] Otherwise, the market interdependence effect always prevails, and centralization yields higher prices (see (33)), as under full information. For this reason, we focus hereafter on the case in which a threshold value $z^* \in (0,1)$ exists. The immediate implication of Lemma 5 is that decentralization increases equilibrium prices as long as substitutability among the goods is high enough, i.e. $z \in (z^*, 1)$.

Expected prices will prove to be crucial for our analysis but clearly they are not exhaustive. The idea is that the expected welfare of each agent is also affected by other statistics (second moments) of the price (quantity) distribution arising from the original cost distribution, like (co)variances between prices.[29] As Appendix E shows, their effect turns out to be of the *second* order, and they do not affect qualitatively the results on welfare comparisons driven by the impact of the lobbying and market interdependence effects on expected prices.

We are now in a position to state our main findings, which we will then discuss in different steps.

Proposition 3 *There exist threshold values for z, one for the welfare of each agent,* above *which decentralized regulation with asymmetric information*

i) decreases expected consumer surplus, i.e. $E\left[\overline{CS}^D\right] < E\left[\overline{CS}^C\right]$

ii) decreases expected profits, i.e. $E\left[\overline{\pi}^D\right] < E\left[\overline{\pi}^C\right]$

iii) decreases expected subsidies, i.e. $E\left[\overline{S}^D\right] < E\left[\overline{S}^C\right]$

iv) increases expected social welfare, i.e. $E\left[\overline{W}^D\right] > E\left[\overline{W}^C\right]$.

There are threshold values for z, one for the welfare of each agent, below *which the opposite holds.*

These results corroborate the implications of our full information analysis, with the additional trade-off driven by the lobbying effect. Because of asymmetric information, lobbying becomes potentially effective, and we know from Proposition 2 that decentralization decreases the incentive to lobby. Notice from (34) and (35) that the lobbying effect increases with z faster than the market interdependence effect. While the impact of substitutability on the latter effect is constant (equal to $E[\psi]$), the weight on profits under centralization increases at an increasing rate (see Proposition 2) because competition in the lobbying market aggravates the negative externality one firm imposes on the other. When goods are substitutes enough, the strength

[28] This occurs with commonly used probability distributions, like the power distribution.

[29] The utility of each agent in (2), (4) and (6) is not linear in prices (quantities), and then (co)variances are also needed for the derivation of expected values.

of the lobbying effect induces the Congress to prefer decentralization, which alleviates capture problem by removing competition for lobbying.

Appendix E shows the relevant threshold values for z, which prove to be crucial in the welfare analysis. We know from Lemma 5 that decentralization yields higher prices for values of substitutability large enough. Points (i) and (ii) of Proposition 3 reveal that this penalizes not only consumers and but also firms, as their rents depend positively on output levels. As rents largely come from taxpayers, this category's interests go in the opposite direction (point (iii)) and prevail in the social welfare analysis (point (iv)). To give the intuition for this result, we derive the (expected) prices which maximize social welfare. Since from (6) and (8) the Congress' objective corresponds to that of a unique regulator with $\varphi^C = 0$, we immediately find from (29) that $E\left[\overline{p}_i^{SW}\right] = E[c] + E[H]$, $i = 1, 2$ (costs are i.i.d.). Then, we compute from (25) and (29)

$$E\left[\overline{p}_i^{SW}\right] - E\left[\overline{p}_i^{D}\right] = zE[\psi] + \overline{\varphi}^D E[H]$$

and

$$E\left[\overline{p}_i^{SW}\right] - E\left[\overline{p}_i^{C}\right] = \overline{\varphi}^C(z)\, E[H].$$

Notice that both regimes yield lower prices than those maximizing social welfare. When the lobbying effect dominates, i.e. $-\Delta\overline{\varphi}E[H] > zE[\psi]$, decentralization ensures less distorted prices, which implies that it is (socially) preferred if substitutability is sufficiently high. Centralization will clearly perform better if goods are weakly substitutes, that is, when the dominant market interdependence effect induces prices which are closer to social welfare maximization.

The contrast of interests between consumers and shareholders, on the one hand, and taxpayers, on the other hand, appears in the whole regulation literature since Baron and Myerson [1982]. Relative to a single market regulation, here we compare two different regimes and this comparison highlights aspects, which in other analyses remain implicit. This allows us to give some predictions when the Congress also can be captured by firms. In this case, it will promote a decision that clearly benefits firms and consumers but can hurt taxpayers and the society as a whole.

The result in Proposition 3 suggests that with interdependent markets decentralization can be a reasonable structural response to non-benevolent regulation since it mitigates the capture problem in the delegation of the regulatory authority. When substitutability between goods is high enough, the trade-off between the market interdependence effect and the lobbying effect implies that the Congress will find it desirable to decentralize market regulation.

6. 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.

Our analysis has shown that under full information, where lobbying is inactive, centralized (cooperative) regulation is the best solution in terms of social welfare. This intuitive result covers a distributional aspect of some interest. Two different agencies, each regulating a single market, set lower prices than a single authority. This market interdependence effect definitely benefits consumers but it increases the amount of subsidies, which is social welfare detrimental.

However, these results may no longer hold under asymmetric cost information as a unique regulator is more distorted to firms' interests as a result of competition at the lobbying stage. In this case, a trade-off emerges in equilibrium between the market interdependence effect and the lobbying effect. When the substitutability between goods is high enough, the latter effect outweighs the former and decentralizing the regulatory structure turns out to be social welfare enhancing. Hence, a decentralized (noncooperative) regime can be a good response to non-benevolent regulation since it alleviates the capture problem.

We believe that much scope exists for future research in this field and our suggestions could be helpful for the design of organizations even outside a regulatory environment.

Appendix A

After replacing the choice variable S_i with π_i from (4), the regulator's optimization problem in (10) may be written as follows

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

$$\left. -p_j\left(q_i, q_j\right) q_j - C\left(q_i\right) - \left(1-\varphi_i^D\right)\pi_i\right] \quad s.t. \quad (PC_i).$$

Since the maximand is decreasing in π_i, we find $\pi_i^D = 0$. Optimizing with respect to q_i yields the following first-order condition

$$\alpha - \beta q_i - c_i = 0.$$

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 (14) may be rewritten as follows

$$\max_{\{q_1,\pi_1;q_2,\pi_2\}} \Big[\alpha q_1 + \alpha q_2 - \frac{1}{2}\left(\beta q_1^2 + 2\gamma q_1 q_2 + \beta q_2^2\right) - C(q_1)$$

$$-C(q_2) - \left(1-\varphi_1^C\right)\pi_1 - \left(1-\varphi_2^C\right)\pi_2\Big] \quad s.t. \;\; (PC_1),\, (PC_2).$$

Since the maximand is decreasing in π_1 and π_2, we find $\pi_1^C = \pi_2^C = 0$. Optimizing with respect to q_i yields the following first-order condition

$$\alpha - \beta q_i - \gamma q_j - c_i = 0.$$

Appendix C

We replace the choice variable $S_i(.)$ with $\pi_i(.)$ from (4) as shown in Appendix A. Then, substituting (ICC$_i'$) into (23) and integrating by parts yields

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

$$\left.+\beta q_j^2(c_j)\right) - p_j\left(q_i(c_i), q_j(c_j)\right) q_j(c_j) - C\left(q_i(c_i)\right)\Big] - \left(1-\varphi_i^D\right)$$

$$\times\left(\frac{F(c_i)}{f(c_i)} q_i(c_i) + \pi_i(\bar{c},.)\right)\Bigg] f(c_i)\, f(c_j)\, dc_i dc_j \;\; s.t. \;\; \int_{\underline{c}}^{\bar{c}} \pi_i(\bar{c},.)\, f(c_j)\, dc_j \geq 0.$$

Since the maximand is decreasing in $\pi_i(\bar{c},.)$, we find $\int_{\underline{c}}^{\bar{c}}\pi_i(\bar{c},.)\, f(c_j)\, dc_j = 0$. Optimizing pointwise with respect to $q_i(.)$ yields the following first-order condition

$$\alpha - \beta q_i(c_i) - c_i - \left(1-\varphi_i^D\right) = 0.$$

Appendix D

We replace the choice variables $S_1(.)$ and $S_2(.)$ with $\pi_1(.)$ and $\pi_2(.)$ from (4) as shown in Appendix B. Then, substituting (ICC_1) and (ICC_2) into (26) and integrating by parts yields

$$\max_{\{q_1(c_1,c_2),\pi_1(\bar{c},.);q_2(c_1,c_2),\pi_2(\bar{c},.)\}} \int_{\underline{c}}^{\bar{c}}\int_{\underline{c}}^{\bar{c}}\left[\alpha q_1(c_1,c_2)+\alpha q_2(c_1,c_2)-\frac{1}{2}\left(\beta q_1^2(c_1,c_2)\right.\right.$$

$$\left.+2\gamma q_1(c_1,c_2)\,q_2(c_1,c_2)+\beta q_2^2(c_1,c_2)\right)-C\left(q_1(c_1,c_2)\right)-C\left(q_2(c_1,c_2)\right)-\left(1-\varphi_1^C\right)$$

$$\left.\times\left(\frac{F(c_1)}{f(c_1)}q_1(c_1,c_2)+\pi_1(\bar{c},.)\right)-\left(1-\varphi_2^C\right)\left(\frac{F(c_2)}{f(c_2)}q_2(c_1,c_2)+\pi_2(\bar{c},.)\right)\right]$$

$$\times f(c_1)\,f(c_2)\,dc_1dc_2 \quad s.t. \quad \int_{\underline{c}}^{\bar{c}}\pi_i(\bar{c},.)\,f(c_j)\,dc_j\geq 0,\; i=1,2.$$

As the maximand decreases in $\pi_i(\bar{c},.)$, we find $\int_{\underline{c}}^{\bar{c}}\pi_i(\bar{c},.)\,f(c_j)\,dc_j=0$. Optimizing pointwise with respect to $q_i(.)$ yields the following first-order condition

$$\alpha-\beta q_i(c_i,c_j)-\gamma q_j(c_i,c_j)-c_i-\left(1-\varphi_i^C\right)H(c_i)=0.$$

Appendix E

Consumer surplus Expected consumer surplus in (2) can be written after some manipulations as

$$E[CS]=\frac{1}{2}\beta E\left[q_1^2\right]+\frac{1}{2}\beta E\left[q_2^2\right]+\gamma E[q_1q_2]$$

$$=\beta\left((E[q])^2+var[q]\right)+\gamma\left((E[q])^2+cov[q_1,q_2]\right), \tag{36}$$

where $var[.]$ and $cov[.]$ are the variance and covariance operators respectively, and second equality comes from the assumption of i.d.d. costs.[30]

[30] We drop the index i when i.i.d. costs allow us to focus on the value of a variable in one market.

Using (36) expected consumer surplus under decentralization and centralization is equal respectively to

$$E\left[\overline{CS}^D\right] = \frac{1+z}{\beta}\left(E\left[\psi\right]\right)^2 + \frac{var\left[\psi\right]}{\beta} \tag{37}$$

$$E\left[\overline{CS}^C\right] = \frac{\left(\alpha - E\left[c\right] - \left(1-\overline{\varphi}^C\right)E\left[H\right]\right)^2}{\beta\left(1+z\right)} + \frac{var\left[c+\left(1-\overline{\varphi}^C\right)H\right]}{\beta\left(1-z^2\right)}. \tag{38}$$

After substituting (24) and (27) of equilibrium into (37) and (38), the difference in expected consumer surplus $\Delta E\left[\overline{CS}\right] = E\left[\overline{CS}^D\right] - E\left[\overline{CS}^C\right]$ between the two regimes is given by

$$\Delta E\left[\overline{CS}\right] = \frac{zE\left[\psi\right] + \Delta\overline{\varphi}E\left[H\right]}{\beta\left(1+z\right)}\left(\left(2+z\right)E\left[\psi\right] - \Delta\overline{\varphi}E\left[H\right]\right)$$

$$+\left(\frac{var\left[\psi\right]}{\beta} - \frac{var\left[c+\left(1-\overline{\varphi}^C\right)H\right]}{\beta\left(1-z^2\right)}\right) = E^{CS} + V^{CS}, \tag{39}$$

where E^{CS} is the term on the first line of (39) driven by expectations and V^{CS} is the term on the second line arising from variances. Notice that E^{CS} (which equals zero for $z = 0$) is positive if $zE\left[\psi\right] > -\Delta\overline{\varphi}E\left[H\right]$, that is, when the market interdependence effect more than compensates the lobbying effect, which occurs for $z \in (0, z^*)$ (Lemma 5 of the paper). Taking the derivative of V^{CS} yields

$$\frac{\partial V^{CS}}{\partial z} = 2\frac{\frac{\partial\overline{\varphi}^C}{\partial z}\left(1-z^2\right)\left(cov\left[c,H\right] + \left(1-\overline{\varphi}^C\right)var\left[H\right]\right) - zvar\left[c+\left(1-\overline{\varphi}^C\right)H\right]}{\beta\left(1-z^2\right)^2}. \tag{40}$$

Expression (40) shows that V^{CS} (which equals zero for $z = 0$) changes at a lower rate than E^{CS} for z low enough ($\left.\frac{\partial\overline{\varphi}^C}{\partial z}\right|_{z=0} = 0$, see (32)). This implies that there exists a threshold value z^D_{CS} such that for $z \in \left(0, z^D_{CS}\right)$ we have $E^{CS} > V^{CS}$, and then decentralization increases (expected) consumers welfare. Notice that E^{CS} is negative if $-\Delta\overline{\varphi}E\left[H\right] > zE\left[\psi\right]$, that is, when the lobbying effect prevails, which occurs for $z \in (0, z^*)$. For z high enough, V^{CS} will also become negative ($\left(1-z^2\right)var\left[\psi\right] < var\left[c+\left(1-\overline{\varphi}^C\right)H\right]$), and then there exists another threshold value z^C_{CS} such that for $z \in \left(z^C_{CS}, 1\right)$ centralization is consumer welfare improving.

Profits From (ICC_i') of equilibrium, expected profits can be written after integrating by parts as

$$E[\pi] = E[H]\,E[q] + cov[H,q]\,. \tag{41}$$

Substituting (24) and (27) of equilibrium into (41) yields after some manipulations

$$E\left[\overline{\pi}^D\right] = \frac{E[\psi]\,E[H]}{\beta} - \frac{cov[c,H] + \left(1-\overline{\varphi}^D\right) var[H]}{\beta} \tag{42}$$

and

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

$$-\frac{cov[c,H] + \left(1-\overline{\varphi}^C\right) var[H]}{\beta(1-z^2)}. \tag{43}$$

Subtracting (43) from (42) yields after some manipulations

$$\Delta E[\overline{\pi}] \equiv E\left[\overline{\pi}^D\right] - E\left[\overline{\pi}^C\right] = \frac{E[H]}{\beta(1+z)}\left(zE[\psi] + \Delta\overline{\varphi}E[H]\right)$$

$$+\frac{z^2\left(cov[c,H] + \left(1-\overline{\varphi}^D\right) var[H]\right) + \Delta\overline{\varphi} var[H]}{\beta(1-z^2)} = E^\pi + V^\pi, \tag{44}$$

where E^π is the term on the first line of (44) driven by expectations and V^π is the term on the second line arising from variances. Notice that E^π (which equals zero for $z=0$) is positive if $zE[\psi] > -\Delta\overline{\varphi}E[H]$, that is, when the market interdependence effect more than compensates the lobbying effect, which occurs for $z \in (0, z^*)$. It is immediate to see that V^π (which equals zero for $z=0$) changes at a lower rate than E^π for z low enough. This implies that there exists a threshold value z_π^D such that for $z \in \left(0, z_\pi^D\right)$ we have $E^\pi > V^\pi$, and then decentralization increases (expected) profits. Notice that E^π is negative if $-\Delta\overline{\varphi}E[H] > zE[\psi]$, that is, when the lobbying effect prevails, which occurs for $z \in (0, z^*)$. For z high enough, a sufficiently powerful lobbying effect can make V^π also negative (which occurs for $var[H]$ large enough), and then there exists another threshold value z_π^C such that for $z \in \left(z_\pi^C, 1\right)$ centralization increases profits. Notice that the interests of consumers and firms go in the same direction.

Social welfare Using (6) expected social welfare can be written after some manipulations as

$$E[W] = 2(\alpha - E[c] - E[H])E[q] - 2(cov[c,q] + cov[H,q])$$

$$-\beta(1+z)(E[q])^2 - \beta var[q] - \gamma cov[q_1, q_2] \tag{45}$$

Using (24) and (27) of equilibrium yields

$$E\left[\overline{W}^D\right] = 2\frac{\alpha - E[c] - E[H]}{\beta}E[\psi] - \frac{1+z}{\beta}(E[\psi])^2$$

$$+\frac{var[c] + 2cov[c,H] + \left(1 - \left(\overline{\varphi}^D\right)^2\right)var[H]}{\beta} \tag{46}$$

and

$$E\left[\overline{W}^C\right] = 2\frac{\alpha - E[c] - E[H]}{\beta(1+z)}\left(\alpha - E[c] - \left(1 - \overline{\varphi}^C\right)E[H]\right)$$

$$-\frac{\left(\alpha - E[c] - \left(1 - \overline{\varphi}^C\right)E[H]\right)^2}{\beta(1+z)}$$

$$+\frac{var[c] + 2cov[c,H] + \left(1 - \left(\overline{\varphi}^C\right)^2\right)var[H]}{\beta(1-z^2)}. \tag{47}$$

Subtracting (47) from (46) yields the difference in expected social welfare $\Delta E\left[\overline{W}\right] \equiv E\left[\overline{W}^D\right] - E\left[\overline{W}^C\right]$, which can be written as

$$\Delta E\left[\overline{W}\right] = \frac{zE[\psi] + \Delta\overline{\varphi}E[H]}{\beta(1+z)}\left(\Delta\overline{\varphi}E[H] - zE[\psi] - 2\overline{\varphi}^D E[H]\right)$$

$$-z^2\frac{var[c] + 2cov[c,H] + \left(1 - \left(\overline{\varphi}^D\right)^2\right)var[H]}{\beta(1-z^2)} - \Delta\overline{\varphi}\frac{\overline{\varphi}^D + \overline{\varphi}^C}{\beta(1-z^2)}var[H]. \tag{48}$$

Combing terms in (48) we get

$$\Delta E\left[\overline{W}\right]=\frac{zE\left[\psi\right]+\Delta\overline{\varphi}E\left[H\right]}{\beta\left(1+z\right)}\left(\Delta\overline{\varphi}E\left[H\right]-zE\left[\psi\right]-2\overline{\varphi}^{D}E\left[H\right]\right)$$

$$-z^{2}\frac{var\left[\psi\right]+2\overline{\varphi}^{D}\left(1-\overline{\varphi}^{D}\right)var\left[H\right]+2\overline{\varphi}^{D}cov\left[c,H\right]}{\beta\left(1-z^{2}\right)}$$

$$+\frac{\left(\Delta\overline{\varphi}\right)^{2}var\left[H\right]-2\overline{\varphi}^{D}\Delta\overline{\varphi}var\left[H\right]}{\beta\left(1-z^{2}\right)},$$

which finally yields

$$\Delta E\left[\overline{W}\right]=\frac{zE\left[\psi\right]+\Delta\overline{\varphi}E\left[H\right]}{\beta\left(1+z\right)}\left(\Delta\overline{\varphi}E\left[H\right]-zE\left[\psi\right]-2\overline{\varphi}^{D}E\left[H\right]\right)$$

$$+\frac{\left(\Delta\overline{\varphi}\right)^{2}var\left[H\right]-2\overline{\varphi}^{D}\Delta\overline{\varphi}var\left[H\right]}{\beta\left(1-z^{2}\right)}$$

$$-z^{2}\frac{var\left[\psi\right]+2\overline{\varphi}^{D}cov\left[c,H\right]+2\overline{\varphi}^{D}\left(1-\overline{\varphi}^{D}\right)var\left[H\right]}{\beta\left(1-z^{2}\right)}=E^{SW}+V^{SW},\quad(49)$$

where E^{SW} is the term on the first line of (49) driven by expectations and V^{SW} is the term on the other two lines arising from variances. Notice that E^{SW} is positive if $-\Delta\overline{\varphi}E\left[H\right]>zE\left[\psi\right]$ (the term in round brackets is negative), which occurs if the lobbying effect prevails over the market interdependence effect, i.e. for $z\in\left(z^{*},1\right)$. The term V^{SW} can also be positive for z high enough, which can be the case for $-\Delta\overline{\varphi}var\left[H\right]$ large enough. Hence, there exists a threshold value z_{SW}^{D} such that for $z\in\left(z_{SW}^{D},1\right)$ decentralization improves (expected) social welfare. Conversely, E^{SW} (which equals zero for $z=0$) is negative if $zE\left[\psi\right]>-\Delta\overline{\varphi}E\left[H\right]$, that is, when the market interdependence effect dominates, which occurs for $z\in\left(0,z^{*}\right)$. It is immediate to see that V^{SW} (which equals zero for $z=0$) changes at a lower rate than E^{SW} for z low enough. This implies that there exists a threshold value z_{SW}^{C} such that for $z\in\left(0,z_{SW}^{C}\right)$ centralization improves social welfare.

Finally, notice that these results go in the opposite direction of what we have found about consumer surplus and profits. This means that taxpayer interests prevail in social welfare, and then there exist threshold values z_{S}^{C} and z_{S}^{D} such that for $z\in\left(0,z_{S}^{C}\right)$ centralization gives lower (expected) subsidies and for $z\in\left(z_{S}^{D},1\right)$ the opposite occurs.

Appendix F

With perfectly correlated costs, i.e. $c_1 = c_2 = c$, distributed according a density function $f(c)$, the participation and incentive compatibility constraints reduce to

$$\pi_i(c) \geq 0 \tag{50}$$

$$\pi_i(c) = \pi_i(\overline{c}) + \int_c^{\overline{c}} q_i(\widetilde{c})\, d\widetilde{c}. \tag{51}$$

Despite the assumption of perfectly correlated costs, the regulator is not able to extract information from firms costlessly. As the literature on yardstick competition has long ago emphasized, this may depend on a number of sensible reasons, like limited liability constraints which prevent the regulator from punishing the cheating firm.[31]

At the second stage, a decentralized regulator maximizes (10) in expected value subject to (50) and (51). Following the same approach as in Appendix C we find after some manipulations

$$\overline{q}_i^D\left(\varphi_i^D\right) = \frac{1}{\beta}\left[\alpha - c - \left(1 - \varphi_i^D\right) H(c)\right], \tag{52}$$

which is equal to (24) for $c_1 = c_2 = c$. In line with Appendix D, from (8) centralized regulation yields[32]

$$\overline{q}_i^C\left(\varphi_i^C, \varphi_j^C\right) = \frac{\alpha - c - \left(1 - \varphi_i^C\right) H}{\beta(1+z)} + z\frac{\varphi_i^C - \varphi_j^C}{\beta(1-z^2)} H, \tag{53}$$

which corresponds to (27) for $c_1 = c_2 = c$.

[31] See on this topic the seminal contribution of Demski and Sappington [1984]. Sequential regulation could allow to save informational rents, since the second firm would be given zero profits. It can be easily shown that this does affect qualitatively our results, the only difference being that the lobbying effect would be active only in the market regulated first (where asymmetric information persists). As long as the Congress does not have the power to impose (and monitor the implementation of) this regulatory timing, sequential regulation will never be pursued, since it reduces the amount of contributions the regulator gets from lobbying.

[32] Notice that the incentive compatibility constraints have the same form as with decentralization.

Lobbying activity at the first stage clearly yields the same outcome as with i.i.d. costs (see Proposition 2) since it takes place before firms know their private information. Using (52) and (53) of equilibrium, we get after some manipulations

$$E\left[\overline{p}^{D}\right]-E\left[\overline{p}^{C}\right]=-\Delta\overline{\varphi}E\left[H\right]-zE\left[\psi\right]=-\overline{I}\left(z\right)+\overline{L}\left(z\right), \tag{54}$$

where $\overline{I}\left(z\right)$ and $\overline{L}\left(z\right)$ are defined by (34) and (35). It is immediate to see that the results in Lemma 5 derived for i.i.d. costs also apply to the case of perfect correlation. We now compare the two regimes, focusing on social welfare.

Substituting (52) and (53) of equilibrium into (2) we find after some manipulations the difference in expected consumer surplus between decentralization and centralization

$$\Delta E\left[\overline{CS}\right]=\frac{E\left[z\left(2+z\right)\psi^{2}+\Delta\overline{\varphi}H\left(2\psi-\Delta\overline{\varphi}H\right)\right]}{\beta\left(1+z\right)}.$$

which yields after some computations

$$\Delta E\left[\overline{CS}\right]=\frac{E\left[\left(z\psi+\Delta\overline{\varphi}H\right)\left(z\psi-\Delta\overline{\varphi}H+2\psi\right)\right]}{\beta\left(1+z\right)}. \tag{55}$$

Replacing (52) and (53) of equilibrium into (4), we obtain the difference in expected subsidies between the two regulatory regimes

$$\Delta E\left[\overline{S}\right]=\frac{E\left[z\psi\left(\left(1+z\right)\psi+\overline{\varphi}^{D}H\right)+\Delta\overline{\varphi}H\left(\psi+\overline{\varphi}^{C}H\right)\right]}{\beta\left(1+z\right)}.$$

which implies after some manipulations

$$\Delta E\left[\overline{S}\right]=\frac{E\left[\left(z\psi+\Delta\overline{\varphi}H\right)\left(-\Delta\overline{\varphi}H+\left(1+z\right)\psi+\overline{\varphi}^{D}H\right)\right]}{\beta\left(1+z\right)}. \tag{56}$$

Using (55) and (56) we compute the difference in expected social welfare

$$\Delta E\left[\overline{W}\right]=\frac{1}{\beta\left(1+z\right)}E\left[\left(\Delta\overline{\varphi}H+z\psi\right)\left(\Delta\overline{\varphi}H-z\psi-2\overline{\varphi}^{D}H\right)\right],$$

which can be written after some computations

$$\Delta E\left[\overline{W}\right]=\frac{\Delta\overline{\varphi}E\left[H\right]+zE\left[\psi\right]}{\beta\left(1+z\right)}\left(\Delta\overline{\varphi}E\left[H\right]-zE\left[\psi\right]-2\overline{\varphi}^{D}E\left[H\right]\right)$$

$$+\frac{\left(\Delta\overline{\varphi}\right)^{2}var\left[H\right]-2\overline{\varphi}^{D}\Delta\overline{\varphi}var\left[H\right]-z^{2}var\left[\psi\right]-2\overline{\varphi}^{D}zcov\left[H,\psi\right]}{\beta\left(1+z\right)}. \quad (57)$$

Notice from (49) and (57) that the assumption of perfectly correlated costs clearly affects the difference in (expected) social welfare between the two regimes. However, this is only a minor change, since the lobbying and market interdependence effects still drive the results in the same direction as with i.i.d. costs. The first term is negative when the latter effect dominates, i.e. $zE\left[\psi\right]>-\Delta\overline{\varphi}E\left[H\right]$, which occurs $z\in\left(0,z^{*}\right)$. Notice that the second term changes at a lower rate than the first one for z low enough. This implies that there exists a threshold $\widetilde{z}_{SW}^{C}$ such that for $z\in\left(0,\widetilde{z}_{SW}^{C}\right)$ centralization improves (expected) social welfare. Conversely, the first term is positive when the lobbying effect pravails, i.e $-\Delta\overline{\varphi}E\left[H\right]>zE\left[\psi\right]$ or $z\in\left(z^{*},1\right)$. The second term also can be positive for z high enough (when $var\left[H\right]$ is sufficiently large), so there exists a threshold $\widetilde{z}_{SW}^{C}$ such that for $z\in\left(\widetilde{z}_{SW}^{D},1\right)$ decentralized regulation will be socially preferred.

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. (1985) "Noncooperative Regulation of a Nonlocalized Externality", in *Rand Journal of Economics*, Vol. 16, No. 4, 553-568.

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

[4] Baron, D. P. (1989) "Design of Regulatory Mechanisms and Institutions", in *Handbook of Industrial Organization*, Vol. 2, edited by R. Schmalensee and R. D. Willig, Elsevier Science Publisher B. V., 1347-1447.

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

[6] Bernheim, B. D. and M. D. Whinston (1986) "Menu Auctions, Resource Allocation, and Economic Influence", in *Quaterly Journal of Economics*, Vol. 101, No. 1, 1-31.

[7] Boylan, R. T. (2000) "An Optimal Auction Perspective on Lobbying", in *Social Choice and Welfare*, Vol. 17, No. 1, 55-68.

[8] Bushnell, J. B., Mansur, E. T. and C. Saravia (2008) "Vertical Arrangements, Market Structure, and Competition: An Analysis of Restructured US Electricity Markets", in *American Economic Review*, Vol. 98, No. 1, 237-266.

[9] Calzolari, G. and C. Scarpa (2009) "Footloose Monopolies: Regulating a National Champion", in *Journal of Economics & Management Strategy*, Vol. 18, Issue 4, 1179-1214.

[10] Demski, J. and D. Sappington (1984), "Optimal Incentive Contracts with Multiple Agents", in *Journal of Economic Theory*, Vol. 33, No. 1, 152-171.

[11] Egging, R. G. and S. A. Gabriel (2006) "Examining Market Power in the European Natural Gas Market", in *Energy Policy*, Vol. 34, Issue 17, 2762-2778.

[12] Gilbert, R. J. and M. H. Riordan (1995) "Regulating Complementary Products: A Comparative Institutional Analysis", in *Rand Journal of Economics*, Vol. 26, No. 2, 243-256.

[13] Grossman, G. M. and E. Helpman (1994) "Protection for Sale", in *American Economic Review*, Vol. 84, No. 4, 833-850.

[14] Holz, F., von Hirschhausen, C. and C. Kemfert (2008) "A Strategic Model of European Gas Supply", in *Energy Economics*, Vol. 30, Issue 3, 766-788.

[15] Iossa, E. (1999) "Informative Externalities and Pricing in Regulated Multiproduct Industries", in *Journal of Industrial Economics*, Vol. 47, No. 2, 195-219.

[16] Laffont, J.-J and D. Martimort (1998) "Collusion and Delegation", in *Rand Journal of Economics*, Vol. 29, No. 3, 280-305.

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

[18] Laffont, J.-J. and J. Tirole (1986) "Using Cost Observation to Regulate Firms", in *Journal of Political Economy*, Vol. 94, No. 3, 614-641.

[19] Laffont, J.-J. and J. Tirole (1990) "The Politics of Government Decision Making: Regulatory Institutions", in *Journal of Law, Economics, & Organization*, Vol. 6, No. 1, 1-31.

[20] Laffont, J.-J. and J. Tirole (1991) "The Politics of Government Decision-Making: A Theory of Regulatory Capture", in *Quarterly Journal of Economics*, Vol. 106, Issue 4, 1089-1127.

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

[22] Martimort, D. (1996) "The Multiprincipal Nature of Government", in *European Economic Review*, Vol. 40, Issues 3-5, 673-685.

[23] Martmort, D. (1999) "The Life Cycle of Regulatory Agencies: Dynamic Capture and Transaction Costs", in *Review of Economic Studies*, Vol. 66, No. 4, 929-947.

[24] Miller, J. C. III, Shughart, W. F. II and R. D. Tollison (1984) " A Note on Centralized Regulatory Review", in *Public Choice*, Vol. 43, No. 1, 83-88.

[25] Myerson, R. B. (1979) "Incentive Compatibility and the Bargaining Problem", in *Econometrica*, Vol. 47, No. 1, 61-73.

[26] 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, Issues 9-10, 829-848.

[27] Poitevin, M. (2000) "Can the Theory of Incentives Explain Decentralization?", in *Canadian Journal of Economics*, Vol. 33, No. 4, 878-906.

[28] Singh, N. and X. Vives (1984) "Price and Quantity Competition in a Differentiated Duopoly", in *Rand Journal of Economics*, Vol. 15, No. 4, 546-554.

[29] Stigler, G. J. (1971) "The Theory of Economic Regulation", in *Bell Journal of Economic and Management Science*, Vol. 2, No. 1, 3-21.

[30] Tullock, G. (1980) "Efficient Rent Seeking", in *Toward a Theory of the Rent-Seeking Society*, edited by J. M. Buchanan, R. D. Tollison and G. Tullock, College Station, Texas A&M University Press, 97–112.

[31] Tirole, J. (1988) *The Theory of Industrial Organization*, MIT Press, Cambridge (Mass.).