The regulation of interdependent markets

Raffaele Fiocco* and Carlo Scarpa†

Abstract

This paper examines the regulatory design of interdependent markets for substitutable goods, when regulated firms engage in lobbying activities. Under centralized regulation, a single regulator is established, whose mandate is to maximize aggregate welfare. Under decentralized regulation, each market is assigned to a regulator charged with maximizing welfare in that market. With asymmetric cost information, centralized regulation results in a negative externality between firms when engaging in lobbying. Decentralized regulation removes this externality and reduces lobbying. Since this benefit comes at the cost of a market coordination failure, a trade-off results which favors decentralized regulation when goods are substitutes enough.

Keywords: asymmetric information, energy markets, lobbying, public transport, regulation.

JEL classification: D82, L51.

*Corresponding author. Institute for Economic Theory I, Humboldt University of Berlin, Spandauer Str. 1, D-10178 Berlin, Germany. E-mail: raffaele.fiocco@staff.hu-berlin.de. Tel.: +49.30.2093.5819. Fax: +49.30.2093.5938.

†Department of Economics, University of Brescia. E-mail: cscarpa@eco.unibs.it.

1. Introduction

Should a country establish a single energy regulator, or rather different agencies for gas and electricity? Is it better to have a single transport authority, or rather a regulator for railways separate from those regulating motorways or airports?

Our paper provides an attempt to explore this issue, focusing on how to devise the regulatory structure of interdependent markets with substitutable goods. In this setting, we examine the possibility that regulation is susceptible to lobbying by the industry. Regulated firms typically exert pressure activities on regulators in several manners, for instance by organizing events or presenting position papers which try to support the idea that the country's long term interests by and large coincide with their own interests.

In practice, a number of countries, such as the UK, France and Italy, have established a single energy authority for electricity and gas. In the UK, the regulation of railways, motorways and airports has been split among different agencies. Other countries have adopted a more centralized regulatory structure. For instance, the Canadian Transportation Agency oversees air and rail services. Furthermore, some agencies jointly regulate electricity, gas and railways, such as the Bundesnetzagentur (Federal Network Agency) in Germany and some State Public Utility Commissions in the US.

In this paper, we study the regulatory design of interdependent markets where two monopolists operate by providing substitutable goods and can engage in lobbying activities. Two regulatory structures are investigated. Under centralized regulation, a single regulator controls the whole market and is charged with maximizing aggregate social welfare. Under decentralized regulation, two agencies regulate one market each and are assigned the mandate to maximize the welfare generated in their own market.

In the absence of regulatory informational constraints, regulated firms cannot obtain rents in equilibrium and therefore they do not have any incentive to lobby the relevant regulator. Clearly, we find that centralized regulation outperforms decentralized regulation, which entails a miscoordination cost since the regulator for one market neglects the welfare generated in the other market.

This natural result may be reversed when the regulator is not omniscient. In practice, firms usually have a privileged knowledge of their costs. It is well established in the incentive regulation literature (e.g., Baron and Myerson 1982; Laffont and Tirole 1986) that regulated firms can command some rents from their private information. In our setting, this implies that each firm exhibits an incentive to lobby the relevant regulator in order to increase its rents. Specifically, it undertakes lobbying expenditures aimed at persuading the regulator to increase the weight attached to the firm's profits in the regulatory objective function. Clearly, this yields a distortion of regulation towards the firm's interests. We show that, in a centralized regulatory setting, each firm imposes a negative externality upon the other when engaging in lobbying activities. As goods are substitutes, a higher quantity (and a higher profit) from the firm's lobbying activities in one market reduces the social value of the good in the related market. Since a single regulator internalizes this effect, a lower quantity (and a lower profit) results for the firm operating in the related market. Consequently, a negative externality between firms arises when engaging in lobbying activities. This entails an overinvestment in lobbying, since each firm lobbies the single regulator excessively. The lobbying problem is more severe with a higher degree of substitutability between goods.

A decentralized regulatory structure alleviates lobbying activities, because the regulator in one market does not internalize the welfare generated in the other market and this removes the negative lobbying externalities between firms. Consequently, the lobbying problem is mitigated at the cost of a market coordination failure. Since centralized regulation aggravates the lobbying problem with higher degrees of substitutability, decentralized regulation entails a trade-off that is welfare improving when goods are substitutes enough.

Our analysis emphasizes the relevance of lobbying activities for the optimal allocation of regulatory responsibilities, and provides testable predictions about the levels of lobbying that will arise under different regulatory structures and in the presence of different degrees of product heterogeneity. Although the focus is on a regulatory setting, our results may also shed some light on the broader issue of power separation in governments and organizations.

2. Related literature

The regulatory design of interdependent markets is an issue which, despite its theoretical and empirical relevance, has been only touched by the literature on optimal regulation, so that several gaps remain.[1]

The economic literature has explored the relationship between one regulated firm and an administrative structure which may consist of one or more agencies. One of the first papers on this topic is Baron (1985), which examines the regulation of a non-localized externality by

[1] We refer to Armstrong and Sappington (2007) for a survey on optimal regulation.

two different agencies and compares the non-cooperative equilibrium with the case where the agencies are allowed to coordinate their activities. Contrary to our work, regulation involves only one firm and regulatory capture is not an issue. Another model closely related to ours is Martimort (1996), which builds on Baron (1985) by adding the possibility that the firm, regulated by two agencies, may lobby to capture their benevolence. The main result is that the duplication of non-benevolent regulators may improve social welfare.

Along these lines, Laffont and Martimort (1999) consider the problem of monitoring a regulated firm which has private information about some pieces of its activity. They find that 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 is desirable since it reduces regulatory discretion in engaging in socially wasteful activities. In our paper, we show that decentralized regulation mitigates the capture problem in the presence of interdependent markets because it removes the negative externalities each firm imposes upon the other when engaging in lobbying activities.[2]

The terms "centralization" and "decentralization" have been used with substantially different meanings from the one we adopt. For instance, a relevant stream of literature analyzes the optimal "vertical" structure of economic organizations.[3] Laffont and Martimort (1998) show that under certain conditions a decentralized hierarchical structure can alleviate the problem of collusion if there are limits on communication between the principal and the agents. Another related aspect that the literature investigates is whether regulation should be implemented by one "national" government (centralization) or by "local" authorities (decentralization).[4] With this literature we share the assumption that the delegation process is imperfect, and that regulators may exhibit private agendas. However, the main results are driven by substantially different forces from those operating in our setting, where the interdependencies between markets and regulatory capture are basic ingredients.

The literature on strategic delegation is also relevant for our purposes. The seminal papers of Vickers (1985), Fershtman (1985), Fershtman and Judd (1987), and Sklivas (1987) show

[2] 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. In a model which examines the demand and supply for regulation, Mulligan and Shleifer (2005) emphasize the role of population size and argue that larger jurisdictions tend to establish more regulators since they incur lower fixed costs.

[3] We refer to Poitevin (2000) for a review on this topic.

[4] See e.g. Bardhan and Mookherjee (2000) and Laffont and Pouyet (2004). Jullien et al. (2010) analyze the relationship between a national regulator and a local government in a setting where investments in a new network are undertaken.

that a firm's profit maximizer owner may find it optimal to provide managers with incentives that differ from his own preferences. Along these lines, in our paper decentralized regulation is assigned an objective which diverges from aggregate social welfare. However, differently from the aforementioned contributions, in our setting strategic delegation aims at removing negative externalities from lobbying.

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 favors 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]

After Stigler, a wide literature has developed, and we refer to Dal Bò (2006) for a broad survey. To our aims, a particularly relevant paper is Grossman and Helpman (1994). In line with their approach, we suppose that regulated firms engage in lobbying activities 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 government may choose into a contribution level. Afterwards, the government sets a policy and collects from each lobby the contribution associated with the policy in order to maximize a weighted sum of total political contributions and aggregate social welfare.

The rest of the paper is organized as follows. Section 3 sets out the formal model. Section 4 considers the full information benchmark, where centralized regulation is welfare superior. Section 5 examines the case of asymmetric information and shows that under certain circumstances decentralized regulation is welfare improving since it acts as an institutional device to mitigate regulatory capture. Section 6 concludes. All proofs are provided in the Appendix.

3. The model

Preferences and markets We investigate a setting with two interdependent markets for substitutable goods. Following Singh and Vives (1984), the consumer surplus gross of payments

[5] Many of these issues (separation of powers and lobbying) are particularly relevant in developing countries (e.g., Bardhan and Mookherjee 2006). Estache and Wren-Lewis (2009) provide a critical survey of the numerous problems at stake.

to firms can be expressed as follows

$$U\left(q_1,q_2\right)=\alpha q_1+\alpha q_2-\frac{1}{2}\left(\beta q_1^2+2\gamma q_1q_2+\beta q_2^2\right), \tag{1}$$

where q_i is the quantity for good $i=1,2$ and $\alpha,\ \beta>0$. The parameter $\gamma\in[0,\ \beta)$ denotes the degree of substitutability between goods.

The markets are run by regulated monopolies. The profit of firm $i=1,2$ gross of lobbying costs (see below) is

$$\pi_i\left(q_i,T_i\right)=T_i-C_i\left(q_i\right), \tag{2}$$

where T_i represents the transfer payment to firm i via the regulatory process. The total cost of firm i is $C_i\left(q_i\right)=c_iq_i+f$, where $c_i\in[\underline{c},\overline{c}]$ denotes the marginal cost of firm i and $f>0$ is the (common) fixed cost of production. Each firm privately knows its costs c_i. We assume that costs are independently and identically distributed (i.i.d.) according to a (continuous and differentiable) cumulative distribution function $F\left(c_i\right):[\underline{c},\overline{c}]\rightarrow[0,1]$.

Social preferences are represented by

$$W\left(q_1,T_1,q_2,T_2\right)=U\left(q_1,q_2\right)-T_1-T_2, \tag{3}$$

which aggregates consumer surplus net of transfers to firms.[6] The market control involves two layers, a political one and an administrative one. The political entity, which we label "Congress", maximizes the welfare standard in (3) and decides on the structure of the institutions that regulate the markets at stake. This is in line, among others, with Laffont and Tirole (1990), who assume that regulatory institutions result from a constitution drafted by some benevolent "founding fathers" or "social planners".

[6] Notably, Never and Röller (2005) suggest a consumer standard such as in (3) in the presence of lobbying. Notice that (3) is a social welfare function à la Baron and Myerson (1982) with zero weights on profits. Baron (1988) provides theoretical foundations for a greater regulatory concern with consumer welfare than firm profits. Without loss of generality, we neglect in (3) the shadow cost of public funds (e.g., Laffont and Tirole 1986) due to distortionary taxation that finances transfers to firms. This cost increases unnecessarily further the weight of taxation in the social welfare function, without affecting the qualitative results (Armstrong and Sappington 2007).

Regulation Market regulation is delegated to an administrative entity. In a centralized setting, a single regulator is assigned the mandate to maximize aggregate social welfare in (3). In a decentralized setting, the mandate of a regulator for market i is to care about the welfare generated in his own market, which is specified as

$$W_i(q_i, T_i) \equiv W(q_i, T_i, 0, 0) = U(q_i, 0) - T_i.$$

This represents welfare arising in market i in isolation, namely, without considering the presence of the other market ($q_j = T_j = 0$). We show that Congress may find it optimal to assign regulation a mandate which focuses on market-specific welfare rather than on aggregate welfare.[7]

Regulation can be partially captured by industries. The result of this partial capture is the distortion of regulatory activity in favor of industry's interests.[8] Following Martimort (1996), this is formalized as a weight on profits in the regulatory objective function. The payoff of a single regulator becomes

$$V^c(q_1, T_1, q_2, T_2) = U(q_1, q_2) - T_1 - T_2 + \varphi_1^c \pi_1 + \varphi_2^c \pi_2, \tag{4}$$

where $\varphi_i^c \in [0,1]$ is the weight attached to firm i's profits.

The payoff of a decentralized regulator for market i becomes

$$V_i^d(q_i, T_i) = U(q_i, 0) - T_i + \varphi_i^d \pi_i, \tag{5}$$

where $\varphi_i^d \in [0,1]$ is the weight on firm i's profits.[9] It is worth stressing that the choice of the objective function is not central to our analysis and the results we obtain. Significantly,

[7] The notion of market-specific welfare reflects the definition of "stand-alone" cost, which is the cost of providing one service of a multiproduct firm on its own, without producing any of the firm's other services. Significantly, in Appendix 2 we show that our qualitative results carry over if the regulator for each market maximizes welfare for an exogenously given level of the output in the related industry (possibly different from zero). Finally, notice that centralized regulation could achieve the same outcome as decentralized regulation if it were assigned the mandate to maximize the welfare generated in each market. To this end, a centralized agency should establish two different divisions, which act non-cooperatively and are charged with controlling one market each. This entails a decentralized structure in line with the one described in our model.

[8] Next subsection clarifies how this structure can be derived from standard lobbying models.

[9] It is reasonable to assume that each firm is able to capture only the regulator established in its market since they have a direct relationship. Moreover, the mandate under decentralized regulation implies that the regulator for market i ignores firm j's profits irrespective of the weight attached ($q_j = T_j = 0$).

nothing substantial would change if we assumed that the social welfare function (i.e., Congress' objective) in (3) exhibits a positive weight on profits, and firms lobby to increase that weight in the regulatory objective functions (4) and (5).[10]

The regulatory instruments are the quantity and the transfer to the firm in each market.[11] In line with the optimal regulation literature (e.g., Baron and Myerson 1982; Laffont and Tirole 1986), we assume that regulatory agencies are granted the command on resources to be used to subsidize regulated firms.[12]

Lobbying Prior to the determination of the regulatory contract, the firms can engage in lobbying activities, trying to convince the regulator that he should bend the policy towards the firms' interests. Lobbying can mean several things, including corruption. In our setting, we feel that a much more typical situation is that regulated firms try to persuade regulators that their interests reflect to a large extent the country's long term interests. Other approaches, based on monetary contributions to decision makers, appear to be more appropriate to represent the funding of political parties rather than the pressure exerted onto independent "technical" regulators.

Following Martimort (1996), we assume that capture can only be partial, and that it materializes in the weights $\varphi_i^c \in [0,1]$ and $\varphi_i^d \in [0,1]$ regulation attaches to profits in the objective functions (4) and (5). The firms incur lobbying costs to distort regulation in favor of profits.[13] This approach enables us to endogenize Martimort's (1996) black-box formulation of lobbying and explicitly derive the regulatory weights on profits.

Formally, each firm faces a schedule $\varphi \in [0,1] \rightarrow \nu(\varphi) \in R_+$ which maps every profit weight $\varphi \in \left\{\varphi_i^c, \varphi_i^d\right\}$ into the amount of expenditure $\nu(.)$ needed to get that weight. The lobbying cost function $\nu(.)$ (with $\nu(0) = 0$) is increasing in φ ($\nu' > 0$).[14] This represents the intuitive idea that the firm must incur higher costs to induce the regulator to attach a greater weight

[10] In our setting of imperfect delegation, Congress does not have time, resources and expertise to detect the lobbying activities exerted by firms and cannot provide the regulator with adequate monetary incentives to completely internalize her objectives.

[11] We do not consider prices in our model. This typically identifies a procurement problem. Standard arguments show that our results can be replicated in a more sophisticated setting where prices are also included.

[12] Most EU countries envisage explicit subsidies to a large portion of regulated public transport firms. US railway companies receive federal funds (net of taxes paid) of the order of magnitude of one billion dollars per year (see http://www.bts.gov/publications/federal_subsidies_to_passenger_transportation/).

[13] This is in line with the rent-seeking literature (e.g., Tullock 1980), which assumes that the effort of each contestant (firm) affects the share of "prize" (profits) it receives. In his original formulation, Tullock (1980) assumes that effort increases the probability of winning, which can be interpreted as the share of prize. Interestingly, contrary to Tullock, we endogenize the prize since profits are the outcome of lobbying activities.

[14] For technical concerns, we also assume $\nu'' > 0$ and $\nu''' < 0$.

on its profits. The shape of the lobbying cost function reflects the regulator's attitude towards listening to lobbies, which depends on a number of variables such as the personal objectives of the regulatory staff or the extent to which the regulator sincerely shares Congress' view on the definition of social welfare.[15]

The cost of lobbying is financed through the profits the firm anticipates to receive. Hence, each firm chooses the weight which maximizes its (net) profits. The weight the regulatory regime (centralized or decentralized regulation) $k \in \{c, d\}$ attaches to the profits of firm i is therefore the outcome of the following problem

$$\max_{\varphi_i^k \in [0,1]} E\left[\pi_i^k\left(\varphi_i^k, \varphi_j^k; c_i\right)\right] - \nu\left(\varphi_i^k\right). \tag{6}$$

Following Stigler (1971), lobbying activities are such that in equilibrium their (expected) marginal benefits equal marginal costs. Expected profits are relevant since lobbying takes place before firms know their costs. This reflects the idea of lobbying as a long term activity, aimed at affecting the long term regulatory attitude towards firms, before they can learn the details of their production costs.[16]

Our modeling strategy is formally in line with one of the seminal references for lobbying, namely, Grossman and Helpman (1994). They model the objective function of a public decision maker as a weighted sum of social welfare and contributions received from lobbies, which are contingent on the policy chosen. An application of the Grossman and Helpman model to our setting entails regulatory objective functions such as

$$\begin{aligned} \widetilde{V}^c &= W\left(q_1, T_1, q_2, T_2\right) + a\left[B\left(\pi_1\left(q_1, T_1\right)\right) + B\left(\pi_2\left(q_2, T_2\right)\right)\right] \\ \widetilde{V}_i^d &= W_i\left(q_i, T_i\right) + aB\left(\pi_i\left(q_i, T_i\right)\right), \end{aligned}$$

where a is an exogenous weight on contributions $B(.)$. Notice that the regulatory objective is profit-biased in line with our model, which includes weighted profits into the regulatory objective

[15] The shape of the lobbying cost function is the same under the two regulatory regimes. This allows the derivation of the results without imposing any arbitrary asymmetric bias to capture.

[16] An opposite timing is sometimes used in the literature (Laffont and Tirole 1993, ch. 11), when collusion between the regulator and the firm deals with the concealment of costs from the principal, which is not an issue here. Our choice also removes signaling problems which would make the analysis less transparent.

functions (4) and (5). This reflects the common idea that interest groups are motivated to make contributions by the prospect of affecting policy.

The main difference is that in the Grossman and Helpman model contributions are paid by the lobbies directly contingent on the policy chosen. This approach highlights the role of decision makers as fund-raisers for financing future campaigns, which may capture quite well the behavior of politicians and governments. In our model, lobbying costs materialize ex ante and are not directly associated with the policy selected. Each firm spends money in order to persuade the regulator to (partially) internalize its interests, with the (rational) expectation that this will lead to a certain regulatory decision.[17] Therefore, we consider lobbying as a persuasion activity exerted by pressure groups to render the decision maker more lenient with them. We feel that our approach is more appropriate in a "normal" (i.e., non-corrupt) regulatory environment, where the agency's staff does not act as a collector of funds, but may be affected by the firms' pressure activities.[18] Although our idea mainly reflects the notion of lobbying as a persuasion activity, the formal similarity with other approaches is such that our results may also be relevant to the cases of corruption and bribing.

Timing We consider the following sequence of events. First, Congress decides on the regulatory structure.[19] Second, the firms can lobby the relevant regulator. Third, firm $i = 1, 2$ privately learns its cost type $c_i \in [\underline{c}, \overline{c}]$. Fourth, the relevant regulator makes a (simultaneous) take-it-or-leave-it offer of a policy to each firm. If the firm refuses the offer, it receives its reservation utility (normalized to zero). If the firm accepts, the policy is implemented.

In summary, our model is a two-stage game. In the first stage, the firms engage in lobbying activities. In the second stage, regulation takes place. We solve this game by backward induction.

4. The full information benchmark

To suitably study the effects of asymmetric information, we first examine the benchmark case of a fully-informed regulator.

[17] Our view of lobbying process shares some similarities with the Tullock (1980) all-pay auction (e.g., Baye et al. 1993; Boylan 2000).

[18] Interestingly, we could also add in (4) and (5) (a fraction of) the firm's total expenditure in the form of (non-)monetary incentives that increase regulatory payoff, such as monetary bribes or future employment for commissioners with the regulated firms (e.g., Laffont and Tirole 1991). Without loss of generality, we neglect this term since it is only contingent on the profit weight and inconsequential for the policy setting.

[19] In line with some relevant literature (e.g., Iossa 1999) we assume that Congress chooses the regulatory regime before the firms learn their costs.

4.1. Centralized regulation

Replacing T_1 and T_2 with π_1 and π_2 from (2), the second-stage problem of a single regulator is to maximize his payoff in (4) as follows

$$
\begin{aligned}
&\max_{\{q_1,\pi_1,q_2,\pi_2\}} \alpha q_1 + \alpha q_2 - \frac{1}{2}\left(\beta q_1^2 + 2\gamma q_1 q_2 + \beta q_2^2\right) - C_1\left(q_1\right) - C_2\left(q_2\right) \\
&- \left(1-\varphi_1^c\right)\pi_1 - \left(1-\varphi_2^c\right)\pi_2 \\
&s.t. \quad \pi_1 \geq 0; \quad \pi_2 \geq 0.
\end{aligned}
$$

Since $\varphi_i^c \in [0,1]$, the maximand decreases with π_1 and π_2, and therefore the regulator does not hand out any rent, irrespective of the profit weights induced by lobbying activities in the first stage. This entails from (6) a profit weight $\varphi_i^c = 0$ in equilibrium. The firms do not have any incentive to capture regulation since lobbying is unprofitable.

Defining $z \equiv \frac{\gamma}{\beta} \in [0,1)$, we can now show the main features of the regulatory mechanism in a centralized setting.

Lemma 1 *Under full information, centralized regulation entails* $q_i^c = \frac{\alpha - c_i - z(\alpha - c_j)}{\beta(1-z^2)}$ *and* $\pi_i^c = 0$.

A single regulator, who internalizes all relevant market interconnections, sets a quantity for each good which depends on the features of the other market, according to the (relative) degree of substitutability z. As goods are substitutes, a higher output in one market reduces the social value of the good in the other market. This translates into lower production in each market.

4.2. Decentralized regulation

Replacing T_i with π_i from (2), the second-stage problem of the regulator for market i is to maximize his payoff in (5) as follows

$$
\begin{aligned}
&\max_{\{q_i,\pi_i\}} \alpha q_i - \frac{1}{2}\beta q_i^2 - C_i\left(q_i\right) - \left(1-\varphi_i^d\right)\pi_i \\
&s.t. \quad \pi_i \geq 0.
\end{aligned}
$$

Since $\varphi_i^d \in [0,1]$, the maximand decreases with π_i, and decentralized regulation also does not provide firms with any rents. This clearly implies a profit weight $\varphi_i^d = 0$ in equilibrium.

The following lemma formalizes the main features of the regulatory policy in a decentralized setting.

Lemma 2 *Under full information, decentralized regulation entails* $q_i^d = \frac{\alpha - c_i}{\beta}$ *and* $\pi_i^c = 0$.

Decentralized regulators are assigned the mandate to care about the welfare generated in their own market, which prevents the internalization of market interdependencies. This results in an output regulatory strategy that maximizes welfare in each market considered in isolation and therefore is unresponsive to the features of the other market.

4.3. Equilibrium lobbying activities

We are now in a position to formalize a result of some relevance.

Lemma 3 *Under full information, the regulated firms do not engage in lobbying activities.*

This observation corroborates the well-known idea that, in the absence of asymmetric information, regulated firms are unable to get any rent and therefore do not have any incentive to lobby the relevant regulator.

4.4. Welfare comparisons

Using the results in Lemmas 1 and 2, we find

$$q_i^d - q_i^c = z \frac{\alpha - c_j - z(\alpha - c_i)}{\beta(1 - z^2)} \geq 0, \tag{7}$$

where the equality holds if and only if $z = 0$ $(q_j^c > 0)$. Since lobbying is absent under full information, a single regulator perfectly internalizes Congress' welfare standard, while two decentralized regulators neglect the interdependencies between markets. Hence, decentralized regulation entails a market miscoordination cost, which results in excessive quantities in equilibrium.

This observation drives the following conclusion.

Proposition 1 *Under full information, centralized regulation improves social welfare.*

In the following, we show that this intuitive result may be reversed when the regulator is not omniscient.

5. The case of asymmetric information

Invoking the revelation principle (e.g., Myerson 1979), attention can be restricted to a direct incentive compatible contract menu which induces each firm to honestly reveal its costs. Under centralized regulation, a single regulator offers firm i a menu $\{q_i(c_i, c_j), T_i(c_i, c_j)\}$, which is also contingent on firm j's declaration about its costs. Under decentralized regulation, the regulator for market i offers firm i a menu $\{q_i(c_i), T_i(c_i)\}$, which is only conditional on its own report.[20]

In both regulatory settings, the incentive compatibility constraint of firm i is

$$\pi_i(c_i, .) = \pi_i(\overline{c}, .) + \int_{c_i}^{\overline{c}} q_i(\widetilde{c}_i, .)\, d\widetilde{c}_i. \tag{8}$$

In line with the incentive regulation literature (e.g., Baron and Myerson 1982), condition (8) indicates that the profit of firm i must be equal to the profit of the most inefficient firm plus the informational rent which rewards the firm for truthfully revealing its private information.[21]

5.1. Centralized regulation

Integrating (8) by parts,[22] and replacing T_1 and T_2 with π_1 and π_2 from (2), the second-stage program of a single regulator is to maximize his payoff in (4) as follows

$$\begin{aligned}
&\max_{\{q_1(c_1,c_2),\pi_1(\overline{c},c_2),q_2(c_1,c_2),\pi_2(c_1,\overline{c})\}} \int_{\underline{c}}^{\overline{c}} \int_{\underline{c}}^{\overline{c}} \Big[\alpha q_1(c_1, c_2) + \alpha q_2(c_1, c_2) - \frac{1}{2}\big(\beta q_1^2(c_1, c_2) \\
&+2\gamma q_1(c_1, c_2)\, q_2(c_1, c_2) + \beta q_2^2(c_1, c_2)\big) - C_1(q_1(c_1, c_2)) - C_2(q_2(c_1, c_2)) \\
&- (1-\varphi_1^c)(H_1 q_1(c_1, c_2) + \pi_1(\overline{c}, c_2)) - (1-\varphi_2^c)(H_2 q_2(c_1, c_2) + \pi_2(c_1, \overline{c}))\Big]\, dF(c_1)\, dF(c_2) \\
&s.t. \quad \pi_1(\overline{c}, c_2) \geq 0, \quad \pi_2(c_1, \overline{c}) \geq 0,
\end{aligned}$$

where $H_i \equiv F(c_i)/F'(c_i)$ is the hazard rate.[23] After taking the first-order conditions,[24] the second-stage quantity for firm i is given by

[20] Reasonably, the regulator for one market cannot make his policy conditional on the other firm's report. More relevantly, decentralized regulators would not benefit from this option, since they ignore market interdependencies.

[21] See e.g. Baron (1989, pp. 1363-1369) and Fundenberg and Tirole (1991, ch. 7) for the derivation of the incentive condition (8). Incentive compatibility also requires $q_i(.)$ to be non-increasing with c_i.

[22] Notice that (8) holds in expected terms since each firm considers its expected profits based on the cost distribution of the other firm when accepting the regulatory contract.

[23] The standard assumption that H_i increases with c_i ensures the implementability of the regulatory policy.

[24] Since the maximand decreases with $\pi_i(\overline{c}, c_j)$, we have $\pi_i^c(\overline{c}, c_j) = 0$, $i, j = 1, 2$, $i \neq j$, in equilibrium. Maximizing pointwise for $q_i(.)$ yields $\alpha - \beta q_i(c_i, c_j) - \gamma q_j(c_i, c_j) - c_i - (1-\varphi_i^c) H_i = 0$.

$$\overline{q}_i^c\left(\varphi_i^c, \varphi_j^c\right) = \frac{\alpha - c_i - z\left(\alpha - c_j\right) - \left(1 - \varphi_i^c\right) H_i + z\left(1 - \varphi_j^c\right) H_j}{\beta\left(1 - z^2\right)}. \tag{9}$$

The last two terms in (9) denote the output distortions from asymmetric information which follow from the usual trade-off between allocative efficiency and rent extraction. Output distortions limit the firms' informational rents at some allocative cost. The weight φ_i^c mitigates the downward output distortion for firm i and therefore increases its rents in (8). Moreover, we have

$$\frac{\partial \overline{q}_i^c\left(\varphi_i^c, \varphi_j^c\right)}{\partial \varphi_j^c} = -\frac{z}{\beta\left(1 - z^2\right)} H_j \leq 0. \tag{10}$$

As goods are substitutes, a higher profit weight for one firm, which increases its output and profits, results in a lower output and lower profits for the other firm. Therefore, centralized regulation entails negative externalities between firms. This crucially affects the firms' lobbying activities aimed at increasing the regulatory weight on profits.

5.2. Decentralized regulation

Integrating (8) by parts and replacing T_i with π_i from (2), the second-stage problem of the regulator for market i is to maximize his payoff in (5) as follows

$$\begin{aligned} &\max_{\{q_i(c_i), \pi_i(\overline{c})\}} \int_{\underline{c}}^{\overline{c}} \left[\alpha q_i\left(c_i\right) - \frac{1}{2}\beta q_i^2\left(c_i\right) - C_i\left(q_i\left(c_i\right)\right) - \left(1 - \varphi_i^d\right)\left(H_i q_i\left(c_i\right) + \pi_i\left(\overline{c}\right)\right)\right] dF\left(c_i\right) \\ &s.t. \quad \pi_i\left(\overline{c}\right) \geq 0. \end{aligned}$$

After computing the first-order conditions,[25] we obtain the following second-stage quantity for firm i

$$\overline{q}_i^d\left(\varphi_i^d\right) = \frac{\alpha - c_i - \left(1 - \varphi_i^d\right) H_i}{\beta}, \tag{11}$$

[25] Since the maximand decreases with $\pi_i\left(\overline{c}\right)$, we find $\pi_i^d\left(\overline{c}\right) = 0$, $i = 1, 2$, in equilibrium. Maximizing pointwise for $q_i\left(.\right)$ yields $\alpha - \beta q_i\left(c_i\right) - c_i - \left(1 - \varphi_i^d\right) H_i = 0$.

where the weight φ_i^d mitigates firm i's downward output distortion from asymmetric information and thereby increases firm i's profits. As under full information, in a decentralized regulatory setting the output in each market is unresponsive to the other market. Consequently, firms do not impose any negative externality upon each other, when engaging in lobbying activities to increase the profit weight in the regulatory objective function. This observation has relevant implications for the lobbying stage.

5.3. Equilibrium lobbying activities

After deriving second-stage quantities (as functions of exogenously given regulatory weights on profits), we can proceed backwards to determine the equilibrium regulatory weights on profits arising from lobbying activities. To this end, we first compute from (8) the second-stage profits of the firms, which only depend on quantities in (9) and (11).

Using (6), in a centralized regulatory setting the weight on profits of firm i is the solution to the following program

$$\max_{\varphi_i^c \in [0,1]} \left\{ \int_{\underline{c}}^{\overline{c}} \int_{\underline{c}}^{\overline{c}} \int_{c_i}^{\overline{c}} \frac{1}{\beta (1-z^2)} \left[\alpha - \widetilde{c}_i - z(\alpha - c_j) - (1-\varphi_i^c) H_i \right. \right. \\ \left. \left. + z \left(1-\varphi_j^c\right) H_j \right] d\widetilde{c}_i dF(c_i) \, dF(c_j) - \nu(\varphi_i^c) \right\}.$$

The (interior) equilibrium value for φ_i^c satisfies the following first-order condition

$$\nu'(\overline{\varphi}_i^c) = \frac{1}{\beta(1-z^2)} \int_{\underline{c}}^{\overline{c}} \int_{\underline{c}}^{\overline{c}} \int_{c_i}^{\overline{c}} H_i d\widetilde{c}_i dF(c_i) \, dF(c_j),$$

where the marginal cost equates the marginal benefit of lobbying, namely, the (expected) marginal profit from an increase in output due to a higher profit weight. The equilibrium profit weight under centralized regulation is

$$\overline{\varphi}_i^c \equiv \overline{\varphi}^c = (\nu')^{-1} \left(\frac{\widetilde{H}}{\beta(1-z^2)} \right), \tag{12}$$

where $\widetilde{H} \equiv \int_{\underline{c}}^{\overline{c}} \int_{\underline{c}}^{\overline{c}} \int_{c_i}^{\overline{c}} H_i d\widetilde{c}_i dF(c_i) \, dF(c_j) = E\left[H_i^2\right]$, $i = 1, 2$ (costs are i.i.d.). Since the firms anticipate the same expected profits, they behave identically in the lobbying stage, which entails the same weight $\overline{\varphi}^c$ on their profits in equilibrium.

We now emphasize the following result of some interest.

Lemma 4 *Under asymmetric information, centralized regulation entails the profit weight* $\overline{\varphi}^c(z)$ *specified in (12), which increases with* z *at an increasing rate.*

We know from the discussion following (9) and (10) that, in a centralized regulatory setting, a higher weight on the profits of one firm entails a higher output and therefore higher profits at the rival's expense.[26] The interdependencies between markets exacerbate the negative externalities the firms impose upon each other when engaging in lobbying activities.[27] This stimulates lobbying expenditures and entails a profit weight which increases with substitutability. For the sake of convenience, we focus hereafter on the values of z for which $\overline{\varphi}^c$ is an interior optimum.

To provide further intuition for this result, we compute regulatory weights if the firms could internalize the negative externalities from lobbying by maximizing joint profits. In this case, the regulatory weights are solutions to the following program

$$\begin{aligned}&\max_{\{\varphi_1^c,\varphi_2^c\}\in[0,1]}\left\{\int_{\underline{c}}^{\overline{c}}\int_{\underline{c}}^{\overline{c}}\frac{1}{\beta\left(1-z^2\right)}\left[\int_{c_1}^{\overline{c}}\left[\alpha-\widetilde{c}_1-z\left(\alpha-c_2\right)-\left(1-\varphi_1^c\right)H_1\right.\right.\right.\\&+z\left(1-\varphi_2^c\right)H_2\right]d\widetilde{c}_1+\int_{c_2}^{\overline{c}}\left[\alpha-\widetilde{c}_2-z\left(\alpha-c_1\right)-\left(1-\varphi_2^c\right)H_2\right.\\&\left.\left.+z\left(1-\varphi_1^c\right)H_1\right]d\widetilde{c}_2\right]dF\left(c_1\right)dF\left(c_2\right)-\nu\left(\varphi_1^c\right)-\nu\left(\varphi_2^c\right)\Big\},\end{aligned}$$

which entails

$$\overline{\varphi}_1^{c*}=\overline{\varphi}_2^{c*}\equiv\overline{\varphi}^{c*}=\left(\nu'\right)^{-1}\left(\frac{\widetilde{H}}{\beta\left(1+z\right)}\right)<\overline{\varphi}^c.$$

Centralized regulation results in an *overinvestment* in lobbying ($\overline{\varphi}^c>\overline{\varphi}^{c*}$), since each firm does not internalize the loss it imposes on the other. The interdependencies between markets aggravate the upward distortion in lobbying investment.[28]

[26] Since lobbying costs increase with the profit weight, this implies that, like in a standard Tullock (1980) contest, the prize (expected profit) that a contestant (firm) receives increases with its own effort (lobbying cost) but decreases with the opponent's effort.

[27] This result formally follows from (10), which decreases at an increasing rate, i.e., $\frac{\partial}{\partial z}\left(\frac{\partial\overline{q}_i^c}{\partial\varphi_j^c}\right)=-\frac{1+z^2}{\beta\left(1-z^2\right)^2}H_j\leq 0$ and $\frac{\partial^2}{\partial z^2}\left(\frac{\partial\overline{q}_i^c}{\partial\varphi_j^c}\right)=-2z\frac{3+z^2}{\beta\left(1-z^2\right)^3}H_j\leq 0$.

[28] It holds that $\overline{\varphi}^c>\overline{\varphi}^{c*}$ since $\left(\nu'\right)^{-1}$ is increasing ($\nu''>0$) and $\frac{\widetilde{H}}{\beta\left(1-z^2\right)}>\frac{\widetilde{H}}{\beta(1+z)}$. Moreover, we have

Under decentralized regulation, the weight on profits of firm i follows from

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

The first-order condition $\nu'\left(\overline{\varphi}_i^d\right) = \frac{1}{\beta}\int_{\underline{c}}^{\overline{c}}\int_{c_i}^{\overline{c}} H_i d\widetilde{c}_i dF\left(c_i\right)$ implies

$$\overline{\varphi}_i^d \equiv \overline{\varphi}^d = \left(\nu'\right)^{-1}\left(\frac{\widetilde{H}}{\beta}\right), \tag{13}$$

where the profit weight $\overline{\varphi}^d$ is the same for both firms.

The following lemma states a result of some interest.

Lemma 5 *Under asymmetric information, decentralized regulation entails the profit weight $\overline{\varphi}^d$ specified in (13), which is independent of z.*

We know from (11) that decentralized regulation ignores market interdependencies, and therefore the output in each market is unresponsive to the other market. This removes negative externalities between firms when engaging in lobbying and results in a profit weight independent of substitutability. This weight coincides with that in case of joint profit maximization.

We show a relevant implication of our analysis in the following proposition.

Proposition 2 *Define $\Delta\overline{\varphi}(z) \equiv \overline{\varphi}^d - \overline{\varphi}^c$. Then, we have $\Delta\overline{\varphi}(z) \leq 0$, with $\Delta\overline{\varphi}(z) = 0$ if and only if $z = 0$. Equivalently, under asymmetric information, the weight of profits in the regulatory objective function will be higher when regulation is centralized.*

If markets are independent ($z = 0$), the difference between the regulatory mandates is inconsequential, and therefore lobbying activities yield the same outcome. As Proposition 2 indicates, if goods are substitutes, a single regulator is *more* biased towards the firms' interests, i.e., $\overline{\varphi}^c > \overline{\varphi}^d$, as a result of lobbying overinvestment.

5.4. Equilibrium regulatory policies

The following proposition summarizes the main features of a centralized regulatory policy.

$\frac{\partial}{\partial z}\left(\overline{\varphi}^c - \overline{\varphi}^{c*}\right) = \frac{2z\widetilde{H}}{\beta\nu''\left(1-z^2\right)^2} + \frac{\widetilde{H}}{\beta\nu''(1+z)^2} > 0$, where the inequality follows from the assumptions on the parameters of the model.

Proposition 3 *Under asymmetric information, centralized regulation entails*

$$\overline{q}_i^c\left(\overline{\varphi}^c\right)=\frac{\alpha-c_i-z\left(\alpha-c_j\right)-\left(1-\overline{\varphi}^c\right)H_i+z\left(1-\overline{\varphi}^c\right)H_j}{\beta\left(1-z^2\right)} \tag{14}$$

$$\overline{\pi}_i^c\left(\overline{\varphi}^c\right)=\int_{c_i}^{\overline{c}}\frac{\alpha-\widetilde{c}_i-z\left(\alpha-c_j\right)-\left(1-\overline{\varphi}^c\right)H_i+z\left(1-\overline{\varphi}^c\right)H_j}{\beta\left(1-z^2\right)}d\widetilde{c}_i.$$

Likewise, the following proposition emphasizes the main features of a decentralized regulatory policy.

Proposition 4 *Under asymmetric information, decentralized regulation entails*

$$\overline{q}_i^d\left(\overline{\varphi}^d\right)=\frac{\alpha-c_i-\left(1-\overline{\varphi}^d\right)H_i}{\beta} \tag{15}$$

$$\overline{\pi}_i^d\left(\overline{\varphi}^d\right)=\int_{c_i}^{\overline{c}}\frac{\alpha-\widetilde{c}_i-\left(1-\overline{\varphi}^d\right)H_i}{\beta}d\widetilde{c}_i.$$

Equations (14) and (15) show that, in both regulatory settings, asymmetric information yields the usual downward output distortion relative to full information, which is mitigated by the regulatory weights $\overline{\varphi}^c$ and $\overline{\varphi}^d$. Interestingly, centralized output in (14) exhibits an additional distortion which goes in the opposite direction. This is because a single regulator internalizes the fact that, in the presence of substitutability between goods, a downward output distortion from asymmetric information in one market increases the social value of output in the other market.

5.5. Welfare comparisons

We know that, under full information, lobbying is absent and a single regulator performs better since he perfectly internalizes all relevant interdependencies between markets. However, this result may no longer hold in the presence of asymmetric information. This is especially true because centralized regulation spurs lobbying activities, which are detrimental to social welfare.

We now investigate expected quantities under the two regulatory regimes, which prove to be crucial to our main results. To this end, we define $\psi_i\equiv\alpha-c_i-\left(1-\overline{\varphi}^d\right)H_i$ (with $\psi_i>0$ as $\overline{q}_i^d>0$). Moreover, we denote $E\left[H_i\right]\equiv H$ and $E\left[\psi_i\right]\equiv\psi$, $i=1,2$ (costs are i.i.d.). Using (14) and (15), the difference in expected quantities between the two regimes can be written as follows

$$E\left[\overline{q}_i^d\right] - E\left[\overline{q}_i^c\right] = \frac{z\psi + \Delta\overline{\varphi}(z) H}{\beta(1+z)}. \tag{16}$$

The sign of (16) depends on the aggregation of two components, $z\psi \geq 0$ and $\Delta\overline{\varphi}(z) H \leq 0$.[29] The first component entails higher decentralized quantities. As under full information (see (7)), this is the result of a market coordination failure under decentralized regulation. The second component stems from lobbying activities. It arises under asymmetric information and goes in the opposite direction. We know from Proposition 2 that centralized regulation makes lobbying activities more intense. This translates into higher production and higher informational rents. Therefore, the quantity difference in (16) reveals a trade-off of some relevance. If (16) is positive, decentralized regulation results in higher quantities, as under full information. If (16) is negative, the impact of lobbying on quantities outweighs the effect of a market coordination failure, and the full information result is reversed.

To our aims, it is useful to derive the (expected) quantities that maximize Congress' welfare function (3). Since Congress' objective coincides with that of a single regulator in (4) with $\varphi_i^c = 0$, we find from (14) that the welfare maximizing (expected) quantity is $E\left[\overline{q}_i^w\right] = \frac{\alpha - c - H}{\beta(1+z)}$, with $c \equiv E\left[c_i\right]$, $i = 1, 2$. Using (14) and (15), we obtain

$$\begin{aligned}
E\left[\overline{q}_i^c\right] - E\left[\overline{q}_i^w\right] &= \frac{\overline{\varphi}^c H}{\beta(1+z)} > 0 \\
E\left[\overline{q}_i^d\right] - E\left[\overline{q}_i^w\right] &= \frac{z\psi + \overline{\varphi}^d H}{\beta(1+z)} > 0.
\end{aligned}$$

Both regulatory structures entail excessive quantities in equilibrium. This is a direct consequence of the regulatory distortion in favor of industry's interests, which generates higher production to distribute higher informational rents. Under decentralized regulation, an additional upward output distortion stems from a market coordination failure. The regime which ensures lower quantities is therefore more aligned with Congress' optimal production. If (16) is positive, centralized regulation yields less distorted quantities. Otherwise, decentralized regulation exhibits output schedules which better reflect Congress' preferences.

In order to derive our main results, we establish the following intermediate step.

[29] Notice that $E\left[\overline{q}_1^k\right] = E\left[\overline{q}_2^k\right]$ for $k \in \{c, d\}$ (costs are i.i.d.).

Lemma 6 *Define* $\Gamma(z) \equiv z\psi + \Delta\overline{\varphi}(z) H$. *Then, the following is true:*

(i) $\Gamma(0) = 0$

(ii) $\Gamma(z)$ *is (strictly) concave. This implies that*

(iii) there exists (if any) a unique value $z^* \in (0,1)$ *such that* $\Gamma(z^*) = 0$

(iv) $\Gamma(z) < 0$ *if and only if* $z > z^*$.

Lemma 6 indicates that the sign of the quantity difference in (16) crucially depends on z. If goods are substitutes enough, the decentralized regulation yields lower quantities which are more aligned with Congress' preferences.[30]

The rationale for Lemma 6 will be apparent in light of the discussion about our main results, which are formalized in the following proposition. For the sake of convenience, they are expressed for the case of uniformly distributed costs.[31]

Proposition 5 *Suppose that under asymmetric information costs are uniformly distributed on* $[\underline{c}, \overline{c}]$. *If* $\nu'' \leq \frac{2\widetilde{H}\overline{\varphi}^d}{\beta\left(4-\left(\overline{\varphi}^d\right)^2\right)}$, *then*

(i) centralized regulation improves expected social welfare for $z \in (0, z^c)$, *where* $z^c \in (0, z^*)$

(ii) decentralized regulation improves expected social welfare for $z > z^*$.

We know from Proposition 2 that centralized regulation makes the lobbying problem more severe. In particular, as Lemma 4 reveals, regulatory distortion in favor of profits increases with substitutability. This is because market interdependencies aggravate the negative externality each firm imposes upon the other when engaging in lobbying. Decentralized regulation reduces lobbying activities since it removes the negative externalities between firms. This benefit comes, however, at the cost of a market coordination failure, since the regulation for each market is unresponsive to the other market. Since centralized regulation aggravates the lobbying problem with higher degrees of substitutability, decentralized regulation entails a trade-off which makes this regime more desirable with higher substitutability. Hence, as Lemma 6 indicates, if goods are substitutes enough, decentralized regulation generates lower quantities, which better reflect Congress' preferences. Proposition 5 ensures that this improves social welfare.[32] Conversely, when substitutability is relatively low, lobbying is less problematic and a single regulator, who internalizes all relevant market interdependencies, proves to be welfare superior.

[30] Notice that the threshold value $z^* \in (0,1)$ exists with commonly used distribution functions, such as the uniform distribution (see the proof of Lemma 6 in Appendix 1 for technical details).

[31] In Appendix 1 (proof of Proposition 5), we show that our results carry over with more general distribution functions.

[32] As Proposition 5 reveals, this is the case when the cost of lobbying is not too convex, so that the firms find it relatively affordable to invest in lobbying.

Regulatory capture literature has emphasized the use of different regulators as a device to mitigate lobbying problems (e.g., Laffont and Tirole 1999). In this paper, we provide further support for splitting regulatory responsibilities in a context of interdependent markets. Interestingly, our model yields non-trivial implications about how market interdependencies affect the optimal design of regulatory jurisdiction in the presence of lobbying. In particular, with higher levels of substitutability, the analysis suggests decentralizing regulation via different agencies or departments, each charged with regulating a specific market. These policy implications lend themselves for an empirical validation of our results.

6. Concluding remarks

In this paper we examine the regulatory design of interdependent markets where two monopolists provide substitutable goods and can engage in lobbying activities. Two regulatory structures are investigated. Centralized regulation assigns a single regulator the control of the whole market with the mandate to maximize aggregate social welfare. Decentralized regulation implies that two agencies regulate one firm each and are directed to maximize the welfare generated in their own market. Under full information, where lobbying is absent, centralized regulation clearly dominates decentralized regulation, which entails a miscoordination cost since the regulation for each market neglects the welfare generated in the other market.

This result may be reversed in the presence of regulatory limited knowledge, because regulated firms can obtain some rents due to their private information and therefore scope for lobbying arises. The firms undertake lobbying expenditures with the purpose of convincing the relevant regulator to increase the profit weight in the regulatory objective function. As goods are substitutes, a higher output (and higher profit) from lobbying in one market decreases the social value of output in the related market. Since a single regulator internalizes this effect, he will allow a lower output (and a lower profit) in the related market. A negative externality between firms arises, which translates into an overinvestment in lobbying under centralized regulation.

A decentralized regulatory structure reduces lobbying activities, since the unresponsiveness of the regulation for one market to the other market removes negative lobbying externalities between firms. Mitigating the lobbying problem comes, however, at the cost of a market coordination failure. A trade-off results which favors decentralized regulation when goods are substitutes enough. Hence, a decentralized structure can be a good institutional response to the lobbying problem.

We believe that much scope exists for future research in this field and our results can be extended in different settings from regulation. For instance, they may provide some interesting insights into the optimal structure of a firm's internal organization, when the manager/owner must decide whether to establish one or more divisions for the supervision of workers who perform interdependent tasks.

Appendix 1

This appendix collects the proofs.

Proof of Lemma 1. Taking the first-order condition for q_i in the regulator's maximization problem yields $\alpha - \beta q_i - \gamma q_j - c_i = 0$. Rearranging terms entails the results in the lemma. ■

Proof of Lemma 2. Taking the first-order condition for q_i in the regulator's maximization problem yields $\alpha - \beta q_i - c_i = 0$. Rearranging terms entails the results in the lemma. ■

Proof of Lemma 3. The proof follows directly from $\varphi^c = \varphi^d = 0$. ■

Proof of Proposition 1. Since $\varphi^c = 0$, the objective of a single regulator in (4) coincides with social welfare in (3). ■

Proof of Lemma 4. Using (12), we find after some manipulation

$$\frac{\partial \overline{\varphi}^c}{\partial z} = \frac{2z\widetilde{H}}{\beta\nu''\left(1-z^2\right)^2} \geq 0 \tag{17}$$

$$\frac{\partial^2 \overline{\varphi}^c}{\partial z^2} = 2\widetilde{H}\frac{\nu''\left(1-z^2\right)\left(1+3z^2\right) - 2z^2\left(\widetilde{H}/\beta\right)\nu'''}{\beta\left(\nu''\right)^2\left(1-z^2\right)^4} > 0, \tag{18}$$

where the inequalities follow from the assumptions on the parameters of the model. Notice that (17) holds with strict equality if and only if $z = 0$. ■

Proof of Lemma 5. Using (13) yields $\frac{\partial \overline{\varphi}^d}{\partial z} = 0$. ■

Proof of Proposition 2. Using (12) and (13), we find $\Delta\overline{\varphi}(0) = 0$. Moreover, $\Delta\overline{\varphi}(z) < 0$ for $z > 0$ follows since $\left(\nu'\right)^{-1}$ is increasing ($\nu'' > 0$) and $\frac{\widetilde{H}}{\beta} < \frac{\widetilde{H}}{\beta(1-z^2)}$. ■

Proof of Proposition 3. Substituting $\overline{\varphi}^c$ from (12) into (9) yields (14). Since $\pi_i^c(\overline{c}, c_j) = 0$, we find from (8) the value for π_i^c. ■

Proof of Proposition 4. Substituting $\overline{\varphi}^d$ from (13) into (11) yields (15). Since $\pi_i^d(\overline{c}) = 0$, we find from (8) the value for π_i^d. ■

Proof of Lemma 6. We find from (12) and (13) that $\Gamma(0) = 0$. Moreover, standard computations yield $\frac{\partial^2\Gamma}{\partial z^2} = -\frac{\partial^2\overline{\varphi}^c}{\partial z^2} H < 0$, where the inequality follows from (18). We now show that $z^* \in (0,1)$ exists with uniformly distributed costs on $[0, \overline{c}]$. In this case, we have $\Gamma < 0$ if and only if $c > \frac{z\alpha}{2z - z\overline{\varphi}^d - \Delta\overline{\varphi}}$. Since $E\left[\overline{q}_i^d\right] > 0$ requires $c < \frac{\alpha}{2-\overline{\varphi}^d}$, there exists a non-empty interval where $\Gamma < 0$. ■

Proof of Proposition 5. Using (3), expected social welfare can be written as

$$\begin{aligned} E[W] &= 2(\alpha - c - H) E[q_i] - \beta(1+z)(E[q_i])^2 - 2(cov[c_i, q_i] + cov[H_i, q_i]) \\ &\quad -\beta var[q_i] - \gamma cov[q_1, q_2], \end{aligned}$$

which yields

$$\begin{aligned} E\left[\overline{W}^c\right] &= 2\frac{\alpha - c - H}{\beta(1+z)}(\alpha - c - (1 - \overline{\varphi}^c) H) - \frac{(\alpha - c - (1-\overline{\varphi}^c) H)^2}{\beta(1+z)} \\ &\quad + \frac{var[c_i] + 2cov[c_i, H_i] + \left(1 - (\overline{\varphi}^c)^2\right) var[H_i]}{\beta(1-z^2)} \end{aligned} \tag{19}$$

$$E\left[\overline{W}^d\right] = 2\frac{\alpha - c - H}{\beta}\psi - \frac{1+z}{\beta}\psi^2 + \frac{var[c_i] + 2cov[c_i, H_i] + \left(1 - (\overline{\varphi}^d)^2\right) var[H_i]}{\beta}. \tag{20}$$

Subtracting (19) from (20) yields the difference in expected social welfare $E\left[\overline{W}^d\right] - E\left[\overline{W}^c\right]$, which can be written as

$$\begin{aligned} &\frac{z\psi + \Delta\overline{\varphi} H}{\beta(1+z)}\left(\Delta\overline{\varphi} H - z\psi - 2\overline{\varphi}^d H\right) - \Delta\overline{\varphi}\frac{\overline{\varphi}^d + \overline{\varphi}^c}{\beta(1-z^2)} var[H_i] \\ &- z^2 \frac{var[c_i] + 2cov[c_i, H_i] + \left(1 - (\overline{\varphi}^d)^2\right) var[H_i]}{\beta(1-z^2)}. \end{aligned} \tag{21}$$

With uniformly distributed costs ($var[c_i] = var[H_i] = cov[c_i, H_i]$), we find after combining terms in (21)

$$\begin{aligned} &\frac{z\psi + \Delta\overline{\varphi} H}{\beta(1+z)}\left(\Delta\overline{\varphi} H - z\psi - 2\overline{\varphi}^d H\right) - \frac{\Delta\overline{\varphi}\left(\overline{\varphi}^d + \overline{\varphi}^c\right) + z^2\left(4 - (\overline{\varphi}^d)^2\right)}{\beta(1-z^2)} var[c_i] \\ &= E_w(z) + V_w(z), \end{aligned} \tag{22}$$

where E_w is the term driven expectations and V_w is the term driven by (co)variances. We first show that V_w is non-negative for $\nu'' \leq 2\widetilde{H}\overline{\varphi}^d/\beta\left(4 - (\overline{\varphi}^d)^2\right)$. To see this, notice that $V_w \geq 0$

if and only if $\overline{\varphi}^c \geq \sqrt{(1-z^2)\left(\overline{\varphi}^d\right)^2 + 4z^2} \equiv \Omega(z)$. Since $V_w = 0$ for $z = 0$, to our aims it is sufficient to show that $\frac{\partial \overline{\varphi}^c}{\partial z} \geq \frac{\partial \Omega}{\partial z}$ for any z. Using (12), we find that this is the case if and only if

$$2\frac{\widetilde{H}}{\beta} \geq \frac{\nu''\left(1-z^2\right)^2\left(4-\left(\overline{\varphi}^d\right)^2\right)}{\sqrt{(1-z^2)\left(\overline{\varphi}^d\right)^2+4z^2}}. \tag{23}$$

The left-hand side of (23) is independent of z, while the derivative of the right-hand side can be written after some manipulations as

$$\frac{4z\left(\widetilde{H}/\beta\right)\nu'''\left((1-z^2)\left(\overline{\varphi}^d\right)^2+4z^2\right)-2z\nu''\left(1-z^2\right)\left(3\left(\overline{\varphi}^d\right)^2\left(1-z^2\right)+12z^2+4\right)}{\left(4-\left(\overline{\varphi}^d\right)^2\right)^{-1}\sqrt{\left[(1-z^2)\left(\overline{\varphi}^d\right)^2+4z^2\right]^3}}<0,$$

where the inequality follows from the assumptions on the parameters of the model. Then, sufficient condition for (23) to hold for any z is that it is satisfied for $z = 0$, which entails $\nu'' \leq 2\widetilde{H}\overline{\varphi}^d/\beta\left(4-\left(\overline{\varphi}^d\right)^2\right)$. Therefore, if $\nu'' \leq 2\widetilde{H}\overline{\varphi}^d/\beta\left(4-\left(\overline{\varphi}^d\right)^2\right)$, we have $V_w \geq 0$. E_w is positive if and only if $-\Delta\overline{\varphi}H > z\psi$ (the expression in round brackets in (22) is negative), namely, if $z > z^*$, where z^* is defined in Lemma 6. Then, the expression in (22) is positive for $z > z^*$ and decentralized regulation improves (expected) social welfare. Conversely, E_w is negative if and only if $z\psi > -\Delta\overline{\varphi}H$, i.e., if $z \in (0, z^*)$. Moreover, E_w changes at a faster rate than V_w for z low enough, since $\frac{\partial V_w}{\partial z}\big|_{z=0} = 0 < \frac{\partial |E_w|}{\partial z}\Big|_{z=0} = \frac{2\overline{\varphi}^d H}{\beta}\psi$. Since $E_w = V_w = 0$ for $z = 0$, there exists a threshold value $z^c \in (0, z^*)$ such that the expression in (22) is negative for $z \in (0, z^c)$ and centralized regulation improves social welfare. For $z \in (z^c, z^*)$ either regime may improve social welfare, but a clear relation cannot be established between the best regulatory structure and z since E_w and V_w change with z in a non-monotonic way. Applying the same approach, there exists an interval for ν'' such that we have $V_w \geq 0$ for $var\left[H_i\right] \geq \max\left\{var\left[c_i\right], cov\left[c_i, H_i\right]\right\}$ in (21). Therefore, the qualitative result in the proposition holds for more general distribution functions, such as the power distribution. ■

Appendix 2

We suppose that, under decentralized regulation, the regulator for market i is directed to maximize social welfare (i.e., consumer welfare net of transfers) for an exogenously given output level $\widehat{q}_j \geq 0$. In the presence of full information, the second-stage regulatory problem can be expressed in the following way

$$\max_{\{q_i,\pi_i\}} \alpha q_i + \alpha \widehat{q}_j - \frac{1}{2}\left(\beta q_i^2 + 2\gamma q_i \widehat{q}_j + \beta \widehat{q}_j^2\right) - C_i\left(q_i\right) - \left(1-\varphi_i^d\right)\pi_i$$
$$s.t. \quad \pi_i \geq 0.$$

Taking the first-order condition for q_i yields $q_i = \frac{\alpha - c_i - \gamma \widehat{q}_j}{\beta}$. As the proof of Lemma 1 reveals, whenever $\widehat{q}_j$ differs from the optimal level under centralized regulation, the result in Proposition 1 strictly holds. Applying the same rationale, our results under asymmetric information in Proposition 5 qualitatively hold for any given $E\left[q_j\right] \geq 0$ such that $E\left[\overline{q}_i^w\right] \leq E\left[\overline{q}_i^d\right] \leq E\left[\overline{q}_i^c\right]$.

Acknowledgments We thank Helmut Bester, Carlo Cambini, Alberto Iozzi, Bruce Lyons, Alessandro Petretto and Roland Strausz for helpful comments. We also thank the participants at the DIME Workshop in Neaples 2010, the CCRP Workshop in London 2010, the EARIE Conference in Istanbul 2010. Financial support from the Deutsche Forschungsgemeinschaft via SFB 649 "Ökonomisches Risiko" is gratefully acknowledged.

References

Armstrong, M., & Sappington, D. E. M. (2007). Recent developments in the theory of regulation. In M. Armstrong, & R. Porter (Eds.), *Handbook of Industrial Organization* (pp. 1557-1700). Amsterdam: Elsevier Science Publishers.

Bardhan, P. K., & Mookherjee, D. (2000). Capture and governance at local and national levels. *American Economic Review*, 90(2), 135-139.

Bardhan, P. K., & Mookherjee, D. (2006). Decentralization and accountability in infrastructure delivery in developing countries. *Economic Journal*, 116(508), 101-127.

Baron, D. P. (1985). Noncooperative regulation of a nonlocalized externality. *Rand Journal of Economics*, 16(4), 553-568.

Baron, D. P. (1988). Regulation and legislative choice. *Rand Journal of Economics*, 19(3), 467-477.

Baron, D. P. (1989). Design of regulatory mechanisms and institutions. In R. Schmalensee, & R. D. Willig (Eds.), *Handbook of Industrial Organization* (pp. 1347-1447). Amsterdam: Elsevier Science Publishers.

Baron, D. P., & Myerson, R. B. (1982). Regulating a monopolist with unknown costs. *Econometrica*, 50(4), 911-930.

Baye, M. R., Kovenock, D., & de Vries, C. G. (1993). Rigging the lobbying process: An application of the all-pay auction. *American Economic Review*, 83(1), 289-94.

Bernheim, B. D., & Whinston, M. D. (1986). Menu auctions, resource allocation, and economic influence. *Quarterly Journal of Economics*, 101(1), 1-31.

Boylan, R. T. (2000). An optimal auction perspective on lobbying. *Social Choice and Welfare*, 17(1), 55-68.

Dal Bò, E. (2006). Regulatory capture: A review. *Oxford Review of Economic Policy*, 22(2), 203-225.

Estache, A., & Wren-Lewis, L. (2009). Toward a theory of regulation for developing countries: Following Jean-Jacques Laffont's lead. *Journal of Economic Literature*, 47(3), 729-770.

Fershtman, C. (1985). Managerial incentives as a strategic variable in duopolistic environment. *International Journal of Industrial Organization*, 3(2), 245-253.

Fershtman, C., & Judd, K. L. (1987). Equilibrium incentives in oligopoly. *American Economic Review*, 77(5), 927-940.

Fundenberg, D., & Tirole, J. (1991). *Game Theory*. Cambridge, MA: MIT Press.

Grossman, G. M., & Helpman, E. (1994). Protection for sale. *American Economic Review*, 84(4), 833-850.

Iossa, E. (1999). Informative externalities and pricing in regulated multiproduct industries. *Journal of Industrial Economics*, 47(2), 195-219.

Jullien, B., Pouyet, J., & Sand-Zantman, W. (2010). Public and private investments in regulated network industries: Coordination and competition Issues. *Review of Network Economics*, 9(4), Art. 3.

Laffont, J.-J., & Martimort, D. (1998). Collusion and delegation. *Rand Journal of Economics*, 29(3), 280-305.

Laffont, J.-J., & Martimort, D. (1999). Separation of regulators against collusive behavior. *Rand Journal of Economics*, 30(2), 232-262.

Laffont, J.-J., & Pouyet, J. (2004). The subsidiarity bias in regulation. *Journal of Public Economics*, 88(1), 255-283.

Laffont, J.-J., & Tirole, J. (1986). Using cost observation to regulate firms. *Journal of Political Economy*, 94(3), 614-641.

Laffont, J.-J., & Tirole, J. (1990). The politics of government decision making: Regulatory institutions. *Journal of Law, Economics, & Organization*, 6(1), 1-31.

Laffont, J.-J., & Tirole, J. (1991). The politics of government decision-making: A theory of regulatory capture. *Quarterly Journal of Economics*, 106(4), 1089-1127.

Laffont, J.-J., & Tirole, J. (1993). *A Theory of Incentives in Procurement and Regulation.* Cambridge, MA: MIT Press.

Martimort, D. (1996). The multiprincipal nature of government. *European Economic Review*, 40(3-5), 673-685.

Martimort, D. (1999). The life cycle of regulatory agencies: Dynamic capture and transaction costs. *Review of Economic Studies*, 66(4), 929-947.

Mulligan, C. B., & Shleifer, A. (2005). The extent of the market and the supply of regulation. *Quarterly Journal of Economics*, 120(4), 1445-1473.

Myerson, R. B. (1979). Incentive compatibility and the bargaining problem. *Econometrica*, 47(1), 61-73.

Never, D. J., & Röller, L. H. (2005). Consumer standard versus welfare standard in a political economy model. *International Journal of Industrial Organization*, 23(9), 829-848.

Poitevin, M. (2000). Can the theory of incentives explain decentralization?. *Canadian Journal of Economics*, 33(4), 878-906.

Singh, N., & Vives, X. (1984). Price and quantity competition in a differentiated duopoly. *Rand Journal of Economics*, 15(4), 546-554.

Sklivas, S. D. (1987). The strategic choice of managerial incentives. *Rand Journal of Economics*, 18(3), 452-458.

Stigler, G. J. (1971). The theory of economic regulation. *Bell Journal of Economics and Management Science*, 2(1), 3-21.

Tullock, G. (1980). Efficient rent seeking. In J. M. Buchanan, R. D. Tollison, & G. Tullock (Eds.), *Toward a Theory of the Rent-Seeking Society* (pp. 97-112). College Station: Texas A&M University Press.

Vickers, J. (1985). Delegation and the theory of the firm. *Economic Journal*, 95, 138-147.