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Abstract. In the literature on price regulation, the *price cap* is seen as a very powerful incentive mechanism. We analyze incentive regulation under perfect information and incomplete contracts, in a scenario in which the investment decision of the firm suffers from hold-up. We show that the incentives to invest in cost reduction innovations can be fostered by a price-cap contract, while with "cooperative" investments, such as quality, the same contract does not help. We, then, show that separation of regulatory powers can increase the incentive to invest in "cooperative" investments. We conclude by sketching a model of endogenous institutional design, where we show that even a benevolent policymaker sometimes prefers to separate regulatory powers.

JEL Classification: C70, K12, L51

Key words: *price regulation, investments, incomplete contracts, institutional design.*

1. Introduction

In the literature and in the practice of regulation one of the most interesting mechanisms is the *price cap*. Its main virtue is the powerful incentives it provides the firm to be efficient. Given the fix revenue, the more the firm reduces her costs the higher will her profit be. This is certainly a powerful incentive in terms of cost reduction, at least in a "static" situation[1]. However, this strong incentive is limited to a particular set of investments. For instance, let us consider an investment in the quality of the product. For an unregulated firm the incentives to increase quality would come from the possibility to raise the price or to increase her market share. For a regulated firm the increase of price is not possible, furthermore if we consider monopolistic firms in utility sectors, the scope for increasing market shares is also very small. This is because the demand is quite rigid in sectors such as water, electricity or gas. We, actually, consider a monopolistic firm facing a rigid demand, where the firm cannot obtain any direct benefit

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[1]We define a *static* situation as a two-period game, one period in which the firm invests and another in which the contract is executed. A *dynamic* situation consists of a sequence of *static* games, so that the firm and the regulator can adjust their behavior to actions taken in the previous periods. For an overview of the issues and problems arising in a dynamic setting see Armstrong et al. (1994).

from an increase in the quality of the service. We show that, as a consequence, a fixed-price contract, such as the price-cap, does not provide any incentive in this direction. We refer to this kind of investments as *cooperative*, following the terminology introduced by Che and Hausch (1999), because the firm needs the cooperation of the regulator in order to obtain a return these investments.

Our theoretical approach is based on "contract theory". In this literature, the majority of models consider optimal price and quality regulation under the assumption of asymmetric information and complete contracts. For an excellent review of this literature see Laffont and Tirole (1993). The same authors, however, recognize that the assumption of complete contracts is not always appropriate. We, therefore, focus on a model of incomplete contract, but we assume perfect information. Assuming incomplete contracts means that the parties cannot write a contract contingent on every future state of the world. This can be justified in two ways: (i) it is unlikely that any possible future contingency can be forecasted, and even if possible, the cost of writing such a contract would be very high; (ii) even if we assume parties can perfectly forecast and the cost of writing a comprehensive contract is not too high, it seems plausible to assume that the effect of the investment is *not verifiable*, i.e. it cannot be enforced by a court of law. For these reasons, we proceed by assuming that the contract cannot be (completely) contingent on the investment made by the firm. In particular, we refer to the *incomplete contract* approach, developed mainly by Grossman, Hart and Moore[2].

We propose a two-period model in which the firm can make an investment in the first period and then the original contract is executed or renegotiated in the second period. We can think of a price-cap contract lasting for n years, where the firm can invest and then firm and regulator can renegotiate the contract before the end of the n-year period. We assume that the investment is relationship-specific and that the cost is sunk. This is a typical situation[3] in which a problem of hold-up is likely to arise. Hence, without a complete contract, the firm is *held up* in her investment decision, i.e. the firm will invest less that the optimal level. We show that, in line with Aghion et al. (1994), a price-cap mechanism gives the firm full ex-ante incentive to invest in cost reduction. However, in line with Che and Hausch (1999) we show that other types of investments do not receive the same incentive. The key point is that the hold-up arises because the firm fears to be let down by the regulator, once the cost of the investment is sunk. In case of cooperative investment, the regulator could refuse to pay for it. Since it is relationship-specific,

[2]For a good reference to this approach see Hart and Moore (1988), Hart (1995) and Bolton and Dewatripont (2005).

[3]See Klein et al. (1978) for an exhaustive treatment of the hold-up problem.

the firm cannot use the innovation in another industry. In case of a cost-reducing investment, the firm does not need the regulator to pay, but it is afraid the regulator could rip the contract off, and contact another firm. A price-cap contract based on few verifiable variables, such as the quantity and the price of the service, can insure the firm against the defection of the regulator. Hence, it can provide full incentive for cost reduction. However, as long as, the contract is incomplete, it cannot protect the cooperative investment of the firm.

At this point, instead of looking for a contract that could solve the hold-up problem for cooperative investments, we turn to analyze the institutional scenario in which regulation takes place. In particular, we propose a model with separate regulatory powers, where two separate regulators deal with two different issues. Contrasting this model with an integrated regulator scenario we show that, under certain conditions, the incentive to invest in *cooperative* innovation is actually enhanced by separation of regulatory powers. We then try to make the institutional design endogenous, by introducing a policymaker which decides whether to set up a one-regulator or two-regulator regime. The interesting policy implication is that, even with a benevolent policymaker, it might be convenient to opt for separation of regulatory powers. This result is quite counterintuitive, because we normally think that an integrated regulator internalizes all the externalities and, as such, it should be the privileged regime for a policymaker who seeks the maximization of the social welfare.

To sum up, the model we propose contributes to the debate on regulation, by advocating separation of powers to foster the investment incentive of the regulated firm. Moreover, it also provides some insight on how to separate regulatory powers. In fact, the positive effect of separation arises only for powers that are likely to be affected in an opposite way by the investment of the firm.

As a last remark notice that most of the models on separation of regulators rely on the assumption of no collusion among regulators. Our model, however, does not need this assumption, we will show that the mechanism we use is actually collusion-proof.

The paper is organized as follows: in the next section we present the general framework of the analysis; then, we introduce a one-firm one-regulator model in which we contrast incentives for cooperative and non cooperative investments; in section 4 we introduce the model with separation of regulatory powers; then we model the choice of the policymaker; and finally we conclude by summarizing our results and proposing directions for further research.

2. The Model

We consider a model with one regulator and one firm. The firm produces either a good or a service, hereafter we will just refer to the produce of the firm as a service. This service is worth R_0 to the regulator. The contract of regulation prescribes the firm to provide quantity R_0, and the regulator to transfer P. In case of a procurement contract, this is just a one shot situation, the firm produces the service and the regulator transfers P. In case of a regulated industry, in which the firm directly provides the service to the public, P represents the price actually payed by consumers. In both cases we assume that the level of P is set once and for all at the beginning of the period, and that the regulator cannot unilaterally change it. This is justified by the assumption of verifiability of the quantity of service provided R_0 and the transfer of money P. We use a fixed-price model as a proxy for price-cap regulation.

The model is characterized by two periods: in the first period the firm can make two types of investments, in the second the firm and the regulator can renegotiate the terms of the original contract. Under the assumption of complete contracts there would be no problem of incentives, the contract would be contingent on any level (and type) of investment the firm can make. We find this assumption quite unrealistic.

We assume that both investments would result in two innovations that the firm can decide whether to introduce or not in the second period. The cost of both innovations is sunk, and the innovations are relatioship-specific, i.e. the firm cannot use them otherwise[4]. These are sufficient ingredients to have an hold-up problem.

The firm can invest in two different types of activities: reduction of costs, e; and increase in the quality of the product, i. In both cases, the cost is sunk and, with a slight abuse of notation, equal to e and i, respectively. We assume that the investment will result in an innovation, e.g. a new production process which reduces costs, and/or increases the quality of the good. In particular, the investment in cost reduction produces an innovation which, if introduced, would reduce the cost by $\phi(e)$, an increasing and concave function of e; while the investment in quality produces an innovation which, if introduced, would increase the payoff of the regulator by $\theta\gamma(i)$ with $\theta > 0$ and $\gamma(i)$ increasing and concave[5]. We assume that these two investments are independent and that the firm is not wealth constrained. It is clear that the quality enhancement investment is

[4]These seem quite reasonable assumptions. For instance, in the water industry a firm introducing an innovation for the transport of water, is unlikely to use it in any other sector which does not involve water. The fact that costs are sunk reflects the idea that, once produced, this innovation is difficult to resell. Because, usually the firm is a monopolist in that industry.

[5]At this point, the parameter θ does not play any significant role. We decided to introduce it because it will be determinant when we separate regulatory powers.

the *cooperative* one, because while not providing any direct revenue to the firm, it increases the regulator's payoff. Hence, a cooperative behavior between regulator and firm is necessary.

In this set up the ex-post payoff of the regulator is

$$R = (R_0 - P) + \theta\gamma(i) - t \tag{2.1}$$

The term in brackets represents the verifiable part of the contract, the quantity of the service and the price. The rest represents the effect of the introduction of the quality innovation. This last part is not verifiable.

The ex-post payoff of the firm is

$$\pi = P - (C - \phi(e)) - i - e + t \tag{2.2}$$

The firm obtains a revenue given by: the fixed price, P; the cost of production, C, less the cost reducing innovation; the sunk costs e and i; and the parameter t, which represents the transfer the regulator could pay the firm for the quality innovation to be introduced.

From equation 2.1 and 2.2, we can see that i is a cooperative investment, the firm gets no direct benefit from it, while e is a "selfish" investment the firm gets all the benefits.

2.1. **First Best.** The ex-ante optimal level of cost reduction and quality investment is obtained by maximizing the total surplus, given by the revenue of the firm and the regulator[6],

$$\max_{e,i} \qquad W = [\theta\gamma(i) + \phi(e)] - e - i \tag{2.3}$$

$$\frac{\partial W}{\partial e} \qquad \phi'(e^*) = 1 \tag{2.4}$$

$$\frac{\partial W}{\partial i} \qquad \gamma'(i^*) = \frac{1}{\theta} \tag{2.5}$$

where e^* and i^* are the first best quantity of cost-reducing and quality investment, respectively. In both cases, the optimal level is such that the marginal benefit is equal to the marginal cost.

3. One Regulator One Firm Model

We consider a two-player two-stage perfect information game, with the following sequence of actions:

Date 1: the firm invests i and e;

Date 2: the firm and the regulator can renegotiate the terms of the original contract.

[6]We have omitted the verifiable part of the contract because it does not influence the investment choice of the firm.

The subgame at date 2 is modelled as a bargaining game between the firm and the regulator. The Nash-Bargaining solution is obtained assuming an exogenous bargaining power of the firm equal to $\alpha \in [0, 1]$. The Subgame Perfect Equilibrium (SPE) of the whole game is characterized by the action which maximizes the firm's profit at date 1, given the possible equilibrium at date 2.

Lemma 1. *The Nash-bargaining solution is given by the firm obtaining a share of the surplus equal to $\pi' = \phi(e) + \alpha(\theta\gamma(i))$, and the regulator a share $R' = (1 - \alpha)\theta\gamma(i)$.*

Proof. The proof of this result comes from the application of the Nash-Bargaining solution formula, where the default payoff of the firm is $\pi^d = \phi(e)$, while the default payoff of the regulator is $R^d = 0$. The surplus to be divided is the sum of the effects of the two innovations, i.e. $\theta\gamma(i) + \phi(e)$. Applying the formula we get, $\pi' = \phi(e) + \alpha[\theta\gamma(i) + \phi(e) - \phi(e) - 0]$. The bargaining power of the regulator is $(1 - \alpha)$, applying the formula we get the same value as in the proposition. □

The payoff of the regulator in case of disagreement is $R = R_0 - P$, the firm does not introduce the quality innovation. The payoff of the firm, in case of disagreement, is $\pi = P - (C_0 - \phi(i)) - i - e$, the firm does not receive any transfer, but notice that it can completely enjoy the returns from the cost-reducing investment.

3.1. **Investment decision.** At date 1, the firm will anticipate the Nash-Bargaining solution of date 2, and it will chose e and i in order to maximize,

$$\max_{e,i} \qquad \pi = P - C - e - i + \pi' \tag{3.1}$$

$$\frac{\partial \pi}{\partial e} \qquad \phi'(e) = 1 \tag{3.2}$$

$$\frac{\partial \pi}{\partial i} \qquad \gamma'(i) = \frac{1}{\alpha\theta} \tag{3.3}$$

Let $\hat{i}$ be the value of investment that satisfies condition 3.3.

Proposition 1. *The strategy $\{e^*, \hat{i}\}$ in the first stage and $\{t = \alpha\theta\gamma(i), \mathit{introduce\,innovation}\}$ in the second stage, is the unique Subgame Nash Equilibrium of the game.*

In other words, the equilibrium strategy of the game is the firm investing e^*, the first best, and $\hat{i}$, in the first stage, while in the second stage the regulator will transfer $t = \alpha\theta\gamma(i)$ to the firm and the firm will *introduce innovation*.

It is immediately clear that the quality investment level is lower than the first best, because $\alpha \in [0, 1]$. Only if the firm has full bargaining power, i.e. $\alpha = 1$, its level of investment would be the first best.

The cost-reduction incentive is full, the firm will make a first best investment $e = e^*$. This latter point is due to the presence of a specific-performance contract which binds the parties to execute the verifiable part of it[7]. The power of the price-cap regulation as an incentive to reduce costs, derive from this possibility to bind the parties to some verifiable actions. As long as the contract can be enforced by a court of law, the incentive for the firm is full.

The fixed-price contract is not that powerful with other types of investments, though. When the investment is "cooperative", like the quality investment, the firm is *held up* in her investment decision. This point was showed for a general type of contracts by Che and Hausch (1999).

Notice that the effort devoted to quality enhancement is lower than the first best, even if the firm is not wealth constrained. Although we did not formally address this point, we expect that a wealth constrained firm would devote more resources to cost-reduction than quality enhancement. We leave this point for future research.

3.2. **Some evidence in support of our results.** Deterioration of quality, when incentive contracts are used, seems to be an accepted concept in the theoretical literature and the practice of regulation. Laffont and Tirole put it in this way:

> Price-cap regulation is about constraining margins. With low margins, the regulated firm has mild incentives to provide quality. It bears the full cost of the provision of quality and reaps a small fraction of its benefits to the extent that demand expansion is multiplied by a small margin. It is for this reason that price cap regulation is often accompanied by the introduction of measurements of new indicators of quality (Laffont and Tirole, 2000).

From a theoretical point of view, Laffont and Tirole (1993) provide an exhaustive reference. In particular, they consider a model of asymmetric information in which the firm can decide the effort level for both quality and cost reduction. In this respect the model is similar to ours. They indeed acknowledge the importance of the market structure. If the quantity sold is influenced by the quality, then sales are an indicator of quality, and the analysis of the optimal regulation for quality (and cost) effort is analogous to the analysis of optimal regulation for a multi-product firm, with the quality treated as one of the products. However, if demand does not depend on

[7] Aghion et al. (1994) show that the hold-up problem can be solved by a simple specific-performance contract.

quality, i.e. very rigid (such as in the utility industry), then the only way to provide incentives for quality is through "reputation" in a dynamic model. Companies seems to be concerned about their reputation: "companies vied with each other not to be at the bottom of the quality of service league tables" (Littlechild, 2003). Since our model considers a monopolistic firm facing a rigid demand, i.e. the quantity if fixed at the beginning in the contract, in a static setting, our results are in line with Laffont and Tirole (1993), with the difference that, instead of incomplete information, our results are driven by the incompleteness of contracts.

From an empirical point of view, the English experience is quite illuminating. At the beginning of the '80s the British government adopted a policy of privatization and regulation of many utility sectors. In many of this sectors a price-cap mechanism was introduced. This led to an under investment in infrastructures and in quality of the service, at least at the beginning. As a consequence, the government introduced a (costly) monitoring of the quality through quality standards. This increased the level of quality but, still, the firm incentive is to increase the level of quality just up to the minimum *verifiable* standard required.

However, a recent survey of the empirical literature on the retail telephone service quality, by Sappington (2003), does not find unequivocal results. Some studies, like Banerjee (2003), using data for the period 1990-1999, found that incentive regulation, such as price-cap, does not reduce the quality of the service. Other studies, like Façanha and Resende (2003) and Clements (2004), suggests a deterioration of the quality under price-cap if compared with rate-of-return regulation. Sappington (2003) concludes that this indeterminacy is due to a non clear definition of the quality of the service. We reckon that another factor to take into consideration is the competition effect. Price-cap mechanisms are likely to have no effect on quality in markets without any competition (monopolies), while in regulated market with some degree of competition, such as telecommunication or electricity production, a firm can get a larger share of the market as a consequence of a rise in the quality of services.

Estache et al. (2003), investigates the effects of the introduction of price-cap regulation, in Latin American countries. They show that this mechanism produced a reduction of costs, which was not pass-through to consumers, and most importantly (for the argument in our paper!) there has been a reduction in investment levels. They use a data base of 954 concession contracts awarded between the mid 1980s and 2000, in the Latin America countries. They found that contracts based on price-cap are more likely to be renegotiated, ahead of the scheduled tariff revision, than contracts based on rate-of-return[8]. Notice that according to our model the firm invest and then renegotiate with the regulator, prior to the end of the period. We might think that the firm initiates this process, because it is the firm who has obtained an innovation. The data of Estache et al. (2003) show that in 86% of the cases is the firm to initiate the renegotiation process[9]. This evidence supports the assumption of incomplete contracts and renegotiation.

4. Separation of Regulatory Powers

The analysis in the previous section suggests that the hold-up problem cannot be overcome by a contract when the investment is cooperative. Instead of looking for a contract that "magically" solves[10] all our investment problems, we propose an institutional modification of the previous model. We introduce two separate regulators and restrict the analysis to cooperative investments, i.e. the firm can only invest in a cooperative innovation. Our objective is to investigate how the ex-ante incentive changes with the institutional scenario.

We consider a reduced-form payoff function for the firm and the regulator(s), consisting only of the payoff stemming from the innovation. This is without loss of generality because, as we have seen in the previous section, the fixed-price contract does not influence the cooperative investment decision of the firm. The following is the reduced-form payoff of the two separate regulators:

$$R_1 = B_0 + \theta_1 \gamma(i) \tag{4.1}$$

$$R_2 = E_0 + \theta_2 \gamma(i) \tag{4.2}$$

Let B_0 and E_0 be two characteristics of the service that are provided when no innovation is introduced. We can think of B_0 as a certain level of quality, while E_0 can be a certain level of environmental protection. According to the value of θ_1 and θ_2 we have different cases: in case of (i) both θ_1 and θ_2 either positive or negative, the innovation has the same effect on both regulators; in case of (ii) θ_1 and θ_2 with opposite sign, the innovation has an *opposite* effect on the regulators.

We start by analyzing the case of opposite signs, i.e. $\theta_1 > 0, \theta_2 < 0$ or viceversa. The investment of the firm has an *opposite* effect on the two regulators. For instance, if we have a

[8]In general, 38.1% of price-cap contracts were renegotiated against 12.8% of rate-of-return contracts. In the water sector these percentages rise to 88% and 14.3%, respectively.

[9]Note that with a rate-of-return contract the firm initiate a renegotiation only in the 26% of the cases.

[10]In order to reduce the hold-up, economists mainly looked at contracts in dynamic settings. See for instance Che and Sakovics (2004).

regulator concerned with quality and another concerned with the environment, it could be that the innovation, at the same time, increases quality and the environmental impact.

In the second stage, the firm offers the right to introduce the innovation through a *competitive bidding*[11]. The firm can exploit the competition between them in order to get an higher return on the investment. This is exactly how the separation of regulator can reduce the hold-up problem.

Our benchmark is given by a unique integrated regulator who takes care of both issues. The payoff of this regulators is simply the sum of the payoffs of the two regulators,

$$R = B_0 + E_0 + (\theta_1 + \theta_2)\gamma(i) - t \tag{4.3}$$

With respect to the model in the previous section, we have just divided the effect of the quality investment into two "sub-effects", i.e. $\theta = \theta_1 + \theta_2$.

4.1. **Benchmark equilibrium.** The equilibrium is the same as in the previous model. In particular, proposition 1 still applies for the part concerning the quality investment, with $\theta = \theta_1 + \theta_2$. The firm share of the surplus is $\pi' = \alpha(\theta_1 + \theta_2)\gamma(i)$. At date 1 the firm will invest according to the maximization problem,

$$\begin{aligned} \max_i \qquad & \pi = \alpha(\theta_1 + \theta_2)\gamma(i) - i \\ \frac{d\pi}{di} \qquad & \gamma'(i^b) = \frac{1}{\alpha(\theta_1 + \theta_2)} \end{aligned} \tag{4.4}$$

Let i^b be the value of i which satisfies equation 4.4. Analogously to the result in the previous section, the ex-ante level of investment is lower than the first best.

4.2. **Ex-ante First Best.** The ex-ante *first best* level of investment depends on whether the innovation is ex-post efficient. Note that in the previous section assuming $\theta > 0$, we implicitly imposed an efficient innovation. Now we drop that restriction and allow for the possibility of ex-post inefficient innovation. The innovation is ex-post efficient if $(\theta_1 + \theta_2) > 0$. Consider the following maximization of the social welfare, W,

$$\begin{aligned} \max_i \qquad & W = (\theta_1 + \theta_2)\gamma(i) - i \\ \frac{\partial W}{\partial i} \qquad & \gamma'(i^*) = \frac{1}{\theta_1 + \theta_2} \end{aligned} \tag{4.5}$$

[11] This is because regulators have an opposite interest on the innovation and the firm can exploit the competition between them. See for a detailed discussion of this mechanism, Bartolini (2006).

The first best level of investment is $i^* > 0$ in case of efficient innovation and $i^* = 0$ in case of inefficient innovation.

Given the objective of the present work, we focus on ex-post efficient innovations, because our concern is on the incentives to introduce an innovation which increases the social welfare[12].

4.3. **Separate regulators equilibrium.** There are two possible cases, the effect of the innovation is the same on both regulators, or it is opposite. The latter is the most interesting case, because the firm can exploit the conflict between regulators.

In Bartolini (2006), we show that the equilibrium of the competitive bidding with *opposite* externalities is given by:

- if $\{\theta_1 > 0, \theta_2 < 0\}$, Regulator 1 makes a transfer $t_1 = |\theta_2|\gamma(i)$ to the firm and the innovation is introduced;
- if $\{\theta_1 < 0, \theta_2 > 0\}$, Regulator 2 makes a transfer $t_2 = |\theta_1|\gamma(i)$ to the firm and the innovation is introduced;

The intuition for this result is that the regulator which receives a benefit from the introduction of the innovation is willing to pay for it a value which can top the maximum offer of the other regulator. The regulator who receives a negative effect from the innovation is willing to pay, to avoid its introduction, a monetary transfer up to its negative effect.

Without loss of generality, let us consider the case of $\theta_1 > 0$ and $\theta_2 < 0$, i.e. the innovation produces a benefit for regulator 1, but a negative effect for regulator 2. The firm, at date 1, would face the following maximization problem,

$$\max_i \qquad \pi = |\theta_2|\gamma(i) - i \tag{4.6}$$

$$\frac{d\pi}{di} \qquad \gamma'(i) = \frac{1}{|\theta_2|} \tag{4.7}$$

Let i^s be the level of investment that satisfies equation 4.7. Note that this level is not necessarily lower than the first best.

Comparing this result with the first best equilibrium and the benchmark equilibrium, we can determine under what conditions the separation of regulatory powers increases the incentive for cooperative investments. The following proposition and figure 1 illustrate this point.

Proposition 2. *For $\theta_1 > 0$, and $\frac{\alpha}{1+\alpha}\theta_1 \leq |\theta_2| \leq \frac{1}{2}\theta_2$, the following relationship is true: $i^b \leq i^s \leq i^*$.*

[12]For a general discussion of the possibility to have investments on inefficient innovations, see Bartolini (2006). In that paper we show that an inefficient innovation is never introduced.

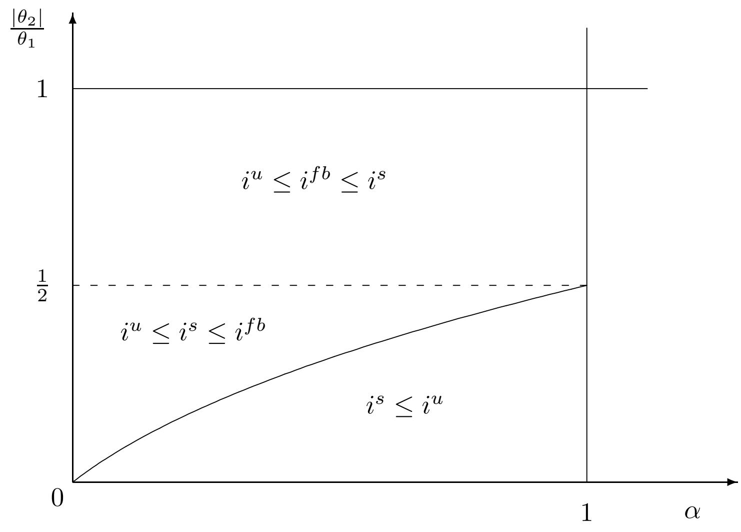

Figure 1. Comparison among equilibria with respect to the bargaining power α, in the case of $\theta_1 > |\theta_2|$.

The result is based on the concavity of $\gamma(\cdot)$, and it is obtained by simple comparison of the level of i in the first best, the benchmark and the separation scenario. Proposition 2 shows that, for a certain range of values of θ_1 and θ_2, separation of regulators can actually reduce the hold-up problem. This range depends on the bargaining power of the firm facing a unique regulator. If we assume that the firm has no bargaining power, $\alpha = 0$, then separation of regulators provides always a better incentive to invest. In economic environments in which the discretionary power of the regulator is very high, it seems to be always a good idea to separate regulatory powers. However, there is the possibility that the incentive to invest is too large, i.e. $i^s > i^*$. When θ_1 and θ_2 are too close, in absolute term, then competition is very fierce and the firm receives an incentive higher than the first best. In fact, if the negative effect on regulator 2 is very small, comparing to the positive effect on regulator 1, the transfer to the firm won't be too large. The important insight is that competition between regulators reduces the threat of the firm to be held up. In other words, competition between regulators reduces their discretionary power by decreasing their bargaining power. However, when the competition is too fierce there is a risk of over investment.

In case of θ_1 and θ_2 with the same sign, there is no competition among players. The allocation mechanism (competitive bidding) is not useful, because the two regulators can collude – they do not have any incentive to overbid each other.

To sum up, separation of regulators can be useful when the introduction of the innovation is likely to have an opposite effect on the two regulators. This is an important result because, contrary to many previous models, the results we obtained implies that separation of regulatory powers must be done accordingly to the likely effect of the innovation. Creating two regulators that care for a similar dimension of quality does not reduce the hold-up problem.

4.3.1. *Numerical example:* Let us consider a firm in the electricity industry. The firm can introduce an innovative production process which reduces the environmental impact, but increases the possibility of service disruptions at peak hours. This is a case in which the innovation is good for the environment and bad for the quality of the service. Let us assume that $\theta_1 < 0$ is the impact on quality and $\theta_2 > 0$ the impact on the environment. The innovation is introduced only if $(\theta_1 + \theta_2) > 0$, i.e. if the positive effect on the environment compensate for the reduction of quality. The ex-ante level of investment is i^* s.t. $\gamma'(i) = \frac{1}{\theta_1+\theta_2}$. The incentive to invest in case of integrated regulator is i^b s.t. $\gamma'(i) = \frac{1}{\alpha(\theta_1+\theta_2)}$. This level is lower than the first best. With separation of regulatory powers we have an ex-ante incentive equal to i^s s.t. $\gamma'(i) = \frac{1}{|\theta_1|}$, which is closer to the first best than i^b. The innovation increases the social welfare, however, with only one regulator the level of investment is not optimal, two separate regulators induce a level of investment closer to the optimal social welfare level.

Let as assume that the bargaining power of the firm when facing one regulator is $\alpha = 0.5$, i.e. they have the same bargaining power. We explicitly consider that an investment "produces" an innovation $\gamma(i) = 2\sqrt{i}$. This function is concave, with $\gamma(0) = 0$, $\gamma'(i) = \frac{1}{\sqrt{i}} > 0$ and $\gamma''(i) = -\frac{1}{2}(i^{-\frac{3}{2}}) < 0$. We assume that the effect of the innovation is $\theta_1 = -1$ and $\theta_2 = 2$, i.e. reduction in quality and positive effect on the environment. The innovation is efficient $(\theta_1 + \theta_2) \equiv (-1 + 2) = 1$. The optimal level of investment is,

$$i^* : \qquad \frac{1}{\sqrt{i}} = \frac{1}{(-1+2)} \quad \Rightarrow \quad i^* = 1$$

The level of investment with one regulator is,

$$i^b : \qquad \frac{1}{\sqrt{i}} = \frac{1}{0.5(-1+2)} \quad \Rightarrow \quad i^b = \frac{1}{4}$$

The level of investment with two regulators is,

$$i^s : \qquad \frac{1}{\sqrt{i}} = \frac{1}{|-1|} \quad \Rightarrow \quad i^s = 1$$

It is clear that the separation of regulatory powers increases the incentive to invest of the firm. In this particular case, the incentive to invest is actually equal to the first best. This is a fortunate case, due to the fact that the positive effect on the environment is exactly the double of the negative effect on quality. With a larger θ_2, competition between regulator would decrease, and the incentive of the firm decreases, too. For instance, let us assume $\theta_2 = \frac{5}{2}$. In this case we obtain, $i^* = \frac{9}{4}$, $i^b = \frac{9}{16}$, and $i^s = 1$. Separation of regulatory powers produces and incentive that, although not equal to the first best, it is larger than the incentive provided by a unique regulator.

5. The role of the policymaker: endogenous institutional design

In this section we want to explore the policy implications of our model. In order to do so we add one stage, in which a policymaker decides the division of powers among regulators. The timing of this new game is as follows:

Date 0: the policymaker decides for a unique-regulator or a separate-regulator scenario;

Date 1: the firm decide to invest in the production of an innovaiton;

Date 2: division of the surplus generated by the innovation.

The strategy space of the policymaker is $G = \{b, s\}$, where b (our benchmark) represents the unique-regulator set up and s the separate-regulator set up. Let us assume a benevolent policymaker, whose aim is to maximize the social welfare W,

$$\max_{x\in\{b,s\}} W(x;\theta_1,\theta_2) \qquad s.t. \quad i \leq i^* \tag{5.1}$$

where $W(b;\theta_1,\theta_2)$ represents the social welfare in case of integrated regulator, and $W(s;\theta_1,\theta_2)$ the social welfare in case of separate regulators, given the value of θ_1 and θ_2. The restriction on the value of i is necessary to prevent the policymaker adopting separation of regulatory powers when it would lead to over-invest. Since we do not know whether to prefer over-investment to under-investment, we assume the policymaker does not want over-investment. Hence, each time separation produces over-investment the policymaker optimal choice is the unique-regulator set up.

The policymaker will anticipate the equilibrium of the subgames in stage 2 and 3, and choose b or s according to which gives him the highest W.

Without loss of generality we present the result only for $\theta_1 > \theta_2$,

Proposition 3. *The policymaker optimal choice is 's' for* $\frac{\alpha}{1+\alpha}\theta_1 \leq |\theta_2| \leq \frac{1}{2}\theta_2$*, the optimal choice is 'b' otherwise.*

In other words, since the objective of the regulator is to maximize the social welfare, the maximum is given by the level of investment closer to the first best.

Given a benevolent policymaker we would expect the optimal choice to be always an integrated regulator, because it internalizes all externalities. However, even a benevolent policymaker, may find it optimal to set up an institutional scenario with two separate regulators. If the policymaker is benevolent and there are no problems related to incomplete information, the prevailing literature tells us that there would be no need for an independent regulator. Notice, that our model provide a rational for independent regulators (at least two) even if there are no problems of information acquisition.

A possible objection to our results would be: why not to have a potential infinite separation of regulatory powers? Notice that the policymaker has not a clear cut strategy, it depends on the values of θ_1 and θ_2, only when the policymaker believes that the two parameters have opposite signs it is convenient to opt for separation. It is sensible to think that an innovation produces opposite effect over very different topics. For instance, if θ_1 refers to the quality of the product and θ_2 to the environmental impact, it is more likely to have opposite effect than if both θ_1 and θ_2 represents environmental issues. The conclusion we draw is that regulatory powers should be separated in broad areas, implicitly limiting the possible number of separate regulators. It would make no sense to have an environmental regulator for each industry, while it makes sense to have one economic regulator for each industry, because environmental issues are similar across all industries, while economic issues are not. Our results are in support, for instance, of the UK water regulatory regime, consisting of three separate regulators: OFWAT (Office for Water) concerned with the pricing of water, DWI (Drinking Water Inspectorate) concerned with the quality of water, and the Environmental Agency.

6. Comparison with the existing literature on separation of regulators

Laffont (2005) considers three possible ways of separating regulators:

(i) geographical decentralization;
(ii) industrial scope;
(iii) functional separation.

Our model refers to the last concept of separation: separation of regulatory powers. The question our model addresses is whether to have separate regulators for price control, quality control and environmental control? In particular, we propose a way of discriminating between centralization and separation of regulatory powers.

A result similar to ours, is obtained by Laffont and Pouyet (2002). Their model consider competition among national regulators, and show that centralization can be dominated by decentralization. However, they assume a non benevolent policymaker, so that decentralization is a measure to reduce the discretionary power of the non benevolent central government.

Other works address the issue of commitment. Separation of regulatory powers may increase the commitment of each regulator (or, in other words, reduce its discretionary power). For instance, Olsen and Torsvik (1995) and Martimort (1999), consider an asymmetric information model, in which the regulator(s) cannot commit not to renegotiate the contract after new information is disclosed. In this set up, they find that separation of regulatory powers reduces the problem of commitment, so that the renegotiation-proof contract they achieve is more efficient than the one achieved by a unique regulator. In our model ex-post renegotiation is actually efficient. The problem arises because of the bargaining power of the regulator, so that, when separation consists in competing regulators, their bargaining power is reduced. In both Martimort (1999) and our model the idea is that separation of regulators reduces their discretionary power, and this is good because it reduces the rent left to the firm in Martimort and increases the incentive to invest in my model.

Another stream of the literature focuses on the possibility of regulatory "capture". The idea is that the firm could "bribe" the head of the regulatory body by offering a high paid job. Laffont and Martimort (1999) show that separate regulators can reduce the risk of capture. Note that also in this case separation is seen as a reduction of the discretionary power of the regulator. In their paper, separate regulators have less discretionary power and therefore the firm needs to bribe them all.

Our model provides not only another motivation for separation of regulators, but also indicates the degree of decentralization of the regulatory powers. This last point did not emerge from the previous literature. For instance, in Martimort (1999) is not clear why not to create three or four of five ... regulators.

As a last remark, note that all the above mentioned models implicitly rely on the assumption of no collusion among the separate regulators. The policy implication of these models is therefore restricted to situations in which regulators do not collude. This would reinforce the argument that separation is good for complementary tasks, where the probability of collusion is lower[13]. For instance, in the model of Laffont and Martimort (1999) regulators are identical, they only have to gather information and decide whether to report it to the government (principal), it seems reasonable that they would collude. In contrast, we do not assume away the possibility of collusion between regulators, at least for the case of opposite externalities. Notice that the player who wins the competitive bidding pays the firm a transfer exactly equal to the negative externality suffered by the other player. Collusion between the two regulators would imply one regulator making a transfer to the other which exactly offset the negative externality and then winning the competitive bidding with a very small bid, say $\varepsilon > 0$. In this case, the firm can just devise a collusion-proof mechanism by implementing the following rule: given a winner bidder k and a loser j, the winner should pay a transfer equal to $[\theta_j \gamma(i) - \varepsilon]$. As $\varepsilon \to 0$, the results of our model do not change, and there is no scope for collusion.

7. Conclusions

In this work we showed that a price-cap contract provides no incentive for cooperative innovations. The incentive is effective only for non-cooperative investments, such as cost reduction. We have also showed that an institutional scenario with two separate regulators, rather than a sophisticate contract, can increase the incentive to invest in cooperative innovations. It implies that a benevolent policymaker should devise a separate regulator regime, in some circumstances.

As a general remark separation of regulators is not a substitute for price-cap regulation, in fact, it is a complement. We believe that a regulatory regime with price-cap and separation of regulatory powers would provide a powerful incentive for both *cooperative* and *non-cooperative* investments.

Throughout the work we assumed perfect information, this is not very plausible, especially for the policymaker. A possible extension of the paper would be to introduce asymmetric information between the policymaker, on one side, and the firm and regulator(s) on the other. Another important assumption is the dynamics of the model limited to just three periods. It would be interesting to introduce the possibility for the values of θ_1 and θ_2 to change in time and the possibility for the policymaker to change the institutional scenario accordingly.

Another limit of the model is the assumption of non-distortionary taxes, i.e. the transfer made by the regulators can be financed at zero costs.

We leave all this for future research.

[13]The more the game is similar to a zero-sum game the less likely is the probability of collusion.

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