Regulation with a risk-averse principal*

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Abstract

We construct the optimal regulation contract between a risk-averse principal, such as a small municipality, and a risk-neutral private "public service" operator, such as a large multinational firm.

With adverse selection, moral hazard and socially costly transfers, we show that the more risk-averse the principal, the more result oriented the contract. We also show that, for a given degree of the regulator's risk aversion, the larger the number of operators supervised by one regulator, the more high powered the incentive scheme.

In a two period dynamic setting, we focus on the commitment issue. We define a measure of the social value of a regulator's ability to sign binding long term contracts, and we obtain that this increases with the degree of the principal's risk aversion.

We discuss some political implications of these results in terms of regulatory institutions' design. Such issues like the efficiency of the contract, credibility or independence of the regulator are tackled with this concept of regulator's risk aversion.

Key words: Regulation, Asymmetric Information, Risk Aversion, Political commitment, Regulatory Design.

JEL Classification: L51, D81, D82

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1 Introduction

With increasing privatization of public utilities and services, the activity of public authorities is becoming more centered on the regulation of private firms. Even if the public authority which previously managed the utility often becomes the regulator, this transition is not always the optimal one. In fact, the best level of the public authority's hierarchy at which to regulate local public services is often difficult to pinpoint from a normative point of view. Identifying who is the best informed as to the private operator costs and the network infrastructure, the best qualified to negotiate, the most credible and the least corruptible is never a simple matter.

From a positive point of view, there exist many different answers to the best level from which to regulate public services. For example, in France, municipalities have long been responsible for providing local public services. A significant decentralization law reinforced this tradition some twenty years ago. In Germany, the regulation activity is in the hands of the länder, which correspond roughly to French regions and America States. In England and Wales, regulation activity is in the hands of independent entities like the Office of Water distribution (OFWAT) and the Office of Telecommunications (OFTEL), which regulate local public services in their respective industries.

These various approaches are not neutral with respect to the manner of conducting regulation activity. In the normative design of the optimal level of decentralization, the usual literature generally puts forward a trade-off between the better information of local authorities and national regulator's greater bargaining power, as in Caillaud et al. (1996, a, c), or higher capacity to take into account externalities, as in Caillaud et al. (1996, b).

The objective of this paper is more limited in scope. Rather than finding an unlikely optimal level of decentralization, we adopt a positive approach which consists in analysing the influence of the regulator's risk aversion on the characteristics of a contract signed with a private operator, not only from a static, but also from a dynamic point of view. To that end, we assume that each level of regulation has its own specific degree of risk aversion, with local regulators being more risk-averse than regional ones, who are in turn more risk-averse than national ones. This could come from the greater opportunity for national regulators to share out risk among more people. This could also be due to the fact that a local regulator is often more subject to lobbying activity and to the pressure of his electors than an independent national regulator. The structure of information, objective function and bargaining power are assumed to be the same whatever the level of regulation.

Very few works have analyzed the influence of the principal's risk aversion on the form of a contract. Indeed, the usual literature on regulation typically assumes that either both the regulator and the operator are risk-neutral, as in Laffont-Tirole (1993) and Baron-Myerson (1982), or that only the firm is risk-averse as in Laffont-Rochet (1998).

Nevertheless, risk aversion at the regulator's level is a reasonnable assumption in many applications. Lewis and Sappington (1995) derive the optimal design of capital structure when a risk-averse regulator faces a risk-neutral operator who is privately informed about his productivity parameter and his effort level. They justify the principal's risk aversion by explaining that, "risk aversion for the principal is natural in situations where the project in question constitutes a large portion of her portfolio and where diversification is difficult or costly."

In a paper who analyzes the effect of bureaucratic risk aversion on the decision to privatize production, Leyden and Link (1993) suggest several other reasons to support this hypothesis. Their list includes the concavity of the budget function offered by the government, which makes the preferences of the bureaucrat risk-averse and the different natures of private and public entreprises, which might lead more risk-averse individuals to self-select public jobs rather than private jobs.

More generally, network industries with strong local specificities necessitating local regulation are concerned with the principal's risk aversion hypothesis. For example, in France, more than 36000 municipalities, the size of which is very different one from the other, must each face the responsability of providing local public utilities and services which are so essential to the economic and social activity. This responsability is even more crucial when the bargaining power of municipalities is low with respect to that of private operators. This is particularly true when competition between private operators is very poor. For example, in the French water industry, only two or three huge private operators are able to provide this type of services.

Even if we focus on the regulation of large private operators by small municipalities, the idea to add risk aversion on the principal's side is not specific to this sector. The relationship between a manager, who owns his firm, with his employees fits as well with the concept of principal's risk aversion: the larger the firm, the lower the aversion of the manager. Others applications such like the landowner/farmer relationship could also be analyzed.

The paper is organized as follows. In section 2, we present the static model. We characterize the optimal contract when the regulator is risk-averse. In section 3, we address the issue of the regulator's political commitment in a dynamic setting. We describe the different types of political commitment and we define their social value. We show how this social value of commitment varies with the degree of the regulator' risk aversion. In the last section, we derive some political insights to the debate concerning the optimal level of decentralization and the independence of the regulator.

2 The static model

We consider an extension of the Laffont and Tirole's static model of regulation (1993), where the regulator is risk-averse. We set up the discrete model and we study the impact of risk aversion on the optimal contract, first when the regulator is perfectly informed and second, when there is an asymmetry of information.

2.1 Objectives and constraints in the two-type framework

We consider the case of an indivisible public project with social value S. A single operator can realize the project. Its cost function is

$$C = \beta - e,$$

where $\beta \in \{\underline{\beta}, \overline{\beta}\}$ is an efficiency parameter and e is the effort exerted by the operator. The disutility of effort (expressed in monetary terms) is $\varphi(e)$, where $\varphi' \geq 0$, $\varphi'' \geq 0$, $\varphi''' \geq 0$, $\varphi(0) = 0$ and $\lim_{e \to \beta} \varphi(e) = +\infty$.

We assume that the regulated firm has private information about β whereas the regulator only knows that the operator has an efficient type, $\underline{\beta}$, with probability $\frac{1}{2}$, or is inefficient, $\overline{\beta}$, with probability $\frac{1}{2}$. Moreover, we assume that e is unobserved by the regulator whereas the cost C is observable. We adopt the accounting convention that cost is reimbursed to the firm by the regulator. To accept to work for the regulator, the operator must be compensated by an additional monetary transfer, t, on top of the cost reimbursement.

Let U be the operator's utility level, obtained by subtracting the disutility of effort from the net monetary transfer,

$$U = t - \varphi(e).$$

Let $\lambda > 0$ denote the shadow cost of public funds. That is, distortionary taxation generates disutility $\$(1+\lambda)$ on taxpayers for each \$1 levied by the regulator in order to reimburse the cost C and pay the net transfer to the operator.

Consequently, the net surplus of the consumers/taxpayers is obtained by subtracting the social cost of public expenses from the gross value of the project,

$$S - (1+\lambda)(C+t).$$

The ex post utilitarian social welfare is found by summing the consumers surplus and the operator's profit,

$$W = S - (1+\lambda)(C+t) + U = S - (1+\lambda)(\beta - e + \varphi(e)) - \lambda U.$$

This paper departs from Laffont and Tirole (1993) by assuming that the regulator is risk-averse. We assume that the regulator is characterized by a strictly positive, increasing, concave utility function $V(.)$ defined over social welfare W. Then, the regulator looks for the optimal menus of effort and rent, $\{\underline{e}, \underline{U}\}$ for the efficient type and $\{\overline{e}, \overline{U}\}$ for the inefficient type, which maximises the expected welfare function:

$$\begin{aligned} \max_{\{\underline{e},\underline{U},\overline{e},\overline{U}\}} \quad E_\beta V(W) = \quad & \frac{1}{2}\left[V(S - (1+\lambda)(\underline{\beta} - \underline{e} + \varphi(\underline{e})) - \lambda \underline{U})\right] \\ & + \frac{1}{2}\left[V(S - (1+\lambda)(\overline{\beta} - \overline{e} + \varphi(\overline{e})) - \lambda \overline{U})\right] \end{aligned}$$

under the participation constraints:

$$\underline{U} \overset{def}{=} U(\underline{\beta}, \underline{\beta}) = \underline{t} - \varphi(\underline{\beta} - \underline{C}) \geq 0 \quad (\underline{PC})$$

$$\overline{U} \overset{def}{=} U(\overline{\beta}, \overline{\beta}) = \overline{t} - \varphi(\overline{\beta} - \overline{C}) \geq 0 \quad (\overline{PC})$$

and the incentive constraints:

$$U\left(\underline{\beta},\underline{\beta}\right)=\underline{t}-\varphi\left(\underline{\beta}-\underline{C}\right)\geq U\left(\underline{\beta},\overline{\beta}\right)=\overline{t}-\varphi\left(\underline{\beta}-\overline{C}\right)\quad(\underline{IC})$$

$$U\left(\overline{\beta},\overline{\beta}\right)=\overline{t}-\varphi\left(\overline{\beta}-\overline{C}\right)\geq U\left(\overline{\beta},\underline{\beta}\right)=\underline{t}-\varphi\left(\overline{\beta}-\underline{C}\right)\quad\left(\overline{IC}\right),$$

where $U(x,y)$ represents the utility of the type x operator $\left(x\in\left\{\underline{\beta},\overline{\beta}\right\}\right)$ when pretending to be of type y $\left(y\in\left\{\underline{\beta},\overline{\beta}\right\}\right)$, and where $\underline{C}$ and $\overline{C}$ are the respective costs observed for each level of effort.

The participation constraints ensure that the operator will agree to build the project, whatever his type. The incentive constraints ensure that each type of operator will reveal his type truthfully to the regulator.

2.2 Complete information

Under complete information, the incentive constraints disappear. Since the regulator can observe the type of the operator she contracts with, she maximises, for each of them, her welfare function taking into account the social cost of public funds and the participation constraint. Since transfers are socially costly, she will saturate the participation constraint for both types $\left(\underline{U}=\overline{U}=0\right)$. The program of the regulator reduces to two independent problems:

$\max_{e}\quad V(W)=V(S-(1+\lambda)(\beta-e+\varphi(e)))$, for each type of operator.

Differentiating with respect to e yields:
$(1+\lambda)(\varphi'(e)-1)\,V'(.)=0.$

Since $V'(.)$ is strictly positive, we obtain:
$\varphi'(e)=1\Rightarrow\underline{e}=\overline{e}=e^{*}$, where e^{*} is the first-best level of effort in the no-aversion case, that is when $V'(.)$ is constant.

The result comes from the absence of moral hazard variable in the model since the total cost is observable ex post. The regulator's risk aversion is only based on the welfare variance associated with the unknown technological parameter of the operator.[1]

[1] Adding a true moral hazard variable to the model would only change the first-best result with complete information, but would not modify the substance of the results obtained with asymmetry of information.

2.3 Asymmetry of information

Under asymmetry of information, the structure is the same as before, except that we must add the incentive constraints. Indeed, in the case of asymmetric information, the regulator does not know, with certainty, the type of the operator he contracts with. Then, the menu of contracts she will offer must be such that each operator chooses to truthfully reveal his type. Concerning the set of constraints, we can apply the usual arguments to show that (see Laffont and Tirole (1993)):

- $\left(\overline{PC}\right)$ and $(\underline{IC})$ imply $(\underline{PC})$. We can thus ignore this last constraint.
- the participation constraint of the inefficient type will always be binding at the optimum $\left(\overline{U}=0\right)$ because of costly transfers.
- Let us rewrite the incentive constraint of the efficient type in the following manner:

$$\begin{aligned}(\underline{IC}): \quad & \underline{U} \geq \overline{t} - \varphi\left(\underline{\beta} - \overline{C}\right) \\ & \Leftrightarrow \underline{U} \geq \overline{U} + \varphi\left(\overline{\beta} - \overline{C}\right) - \varphi\left(\underline{\beta} - \overline{C}\right) \\ & \Leftrightarrow \underline{U} \geq \overline{U} + \phi\left(\overline{e}\right), \text{ where } \phi\left(\overline{e}\right) = \varphi\left(\overline{e}\right) - \varphi\left(\overline{e} - \Delta\beta\right), \text{ with } \phi'\left(.\right) \geq 0,\end{aligned}$$

where $\Delta\beta = \overline{\beta} - \underline{\beta}$ and $\phi\left(\overline{e}\right)$ determines the extra rent of the efficient type by measuring the decrease in disutility of effort associated with a better technology. We can directly write that the incentive constraint of the efficient type will also be binding at the optimum $\underline{U} = \overline{U} + \phi\left(\overline{e}\right)$.

- Finally, the last constraint $\left(\overline{IC}\right)$ will be checked ex-post.

Substituating the two binding constraints $\left(\overline{U}=0,\text{ and } \underline{U} = \overline{U} + \phi\left(\overline{e}\right)\right)$ into the program of the regulator, we have to solve:

$$\begin{aligned}\max_{\underline{e},\overline{e}} \quad E_{\beta}V\left(W\right) = \; & \frac{1}{2}\left[V(S-(1+\lambda)(\underline{\beta}-\underline{e}+\varphi\left(\underline{e}\right))-\lambda\phi\left(\overline{e}\right))\right] \\ & +\frac{1}{2}\left[V(S-(1+\lambda)(\overline{\beta}-\overline{e}+\varphi\left(\overline{e}\right)))\right]\end{aligned}$$

Differentiating this program, with respect to $\underline{e}$ and $\overline{e}$, gives the two levels of effort:[2]

$$\begin{aligned} \varphi'(\underline{e}) &= 1 \Rightarrow \underline{e} = e^* & (1) \\ \varphi'(\overline{e}) &= 1 - \frac{\lambda}{1+\lambda}\phi'(\overline{e})\frac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}, & (2) \end{aligned}$$

where $W_{\underline{\beta}}$ and $W_{\overline{\beta}}$ are the equilibrium levels of utilitarian welfare obtained, respectively, with a good and a bad type.

Then, we can state the following proposition:

Proposition 1 *When the regulator is hindered by asymmetry of information and risk aversion, the optimal contract is characterized by:*

► *an optimal level of effort for the efficient type* $\underline{e} = e^*$

► *a lower distortion of effort for the inefficient operator as compared with the risk-neutral case.*

Proof. The risk aversion assumption ($V'' < 0$) added to the fact that the level of utilitarian welfare is decreasing with the type of the operator ($\frac{dW}{d\beta} < 0$) implies $\frac{dV'}{d\beta} > 0$. Since $\underline{\beta} < \overline{\beta}$ by assumption, we have $V'\left(W_{\underline{\beta}}\right) < V'\left(W_{\overline{\beta}}\right)$.

Then, $\varphi'(\overline{e}) > \varphi'(\overline{e}_0) \overset{def}{=} 1 - \frac{\lambda}{1+\lambda}\phi'(\overline{e}_0)$, where $\overline{e}_0$ is the inefficient firm's level of effort when the regulator is risk-neutral. Consequently, $\overline{e}_0 < \overline{e} < e^*$. ■

To obtain a further insight in comparative statics, we consider a Taylor expansion limited to degree 2 of the marginal utility function of the regulator $V'(.)$ to exhibit the regulator's coefficient of absolute risk aversion denoted ρ

[2] It remains to check $\left(\overline{IC}\right) : \overline{U} \geq \underline{U} - \phi\left(\overline{\beta} - \underline{C}\right)$ or $0 \geq \phi\left(\overline{\beta} - \overline{C}\right) - \phi\left(\overline{\beta} - \underline{C}\right)$. Since $\underline{e} \geq \overline{e}$ (and therefore $\overline{C} \geq \underline{C}$) and $\phi' > 0$, the incentive constraint of the inefficient type is satisfied.

$\left(\rho = \frac{-V''}{V'} \geq 0\right)$. This can result either from the fact that $\underline{\beta}$ and $\overline{\beta}$ are not very different or that the utility function is quadratic [3].

Then, we can write that:

$V'(W_\beta) = V'\left(W_{\underline{\beta}}\right) + \left(W_\beta - W_{\underline{\beta}}\right) V''\left(W_{\underline{\beta}}\right)$.

So,

$V'(W_{\overline{\beta}}) = V'\left(W_{\underline{\beta}}\right) + \left(W_{\overline{\beta}} - W_{\underline{\beta}}\right) V''\left(W_{\underline{\beta}}\right)$, and

$$\begin{aligned} \frac{V'\left(W_{\underline{\beta}}\right)}{V'(W_{\overline{\beta}})} &= \frac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\underline{\beta}}\right) + \left(W_{\overline{\beta}} - W_{\underline{\beta}}\right) V''\left(W_{\underline{\beta}}\right)} \\ &= \frac{1}{1 + \left(W_{\overline{\beta}} - W_{\underline{\beta}}\right) \dfrac{V''\left(W_{\underline{\beta}}\right)}{V'\left(W_{\underline{\beta}}\right)}} = \frac{1}{1 + \rho \Delta W}, \end{aligned}$$

where $\Delta W = W_{\underline{\beta}} - W_{\overline{\beta}} > 0$.

We can, now, deduce the following corollary:

Corollary 1 *The more risk-averse the regulator, the lower the distorsion of effort of the bad type.*

Proof. By differentiating (2) with respect to the coefficient of risk aversion, we obtain:

$$\frac{d\overline{e}}{d\rho} = \frac{-\lambda \phi'(\overline{e}) \dfrac{d\left(\dfrac{V'\left(W_{\underline{\beta}}\right)}{V'(W_{\overline{\beta}})}\right)}{d\rho}}{(1+\lambda)\varphi''(\overline{e}) + \lambda \phi''(\overline{e}) \dfrac{V'\left(W_{\underline{\beta}}\right)}{V'(W_{\overline{\beta}})}}.$$

[3] It could also be possible to introduce some concept of prudence in the model, and to analyze the influence of the regulator's degree of prudence $\left(p = -\frac{V'''}{V''}\right)$ on the form of the contract (see Eeckhoudt and Kimball (1991)).

Since $\dfrac{d\left(\dfrac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}\right)}{d\rho} = -\dfrac{\Delta W}{(1+\rho\Delta W)^2} < 0$, we can conclude that $\dfrac{d\overline{e}}{d\rho} > 0$. ■

The intuition for this result is that the risk-averse regulator intends to smooth the level of welfare obtained with each type. Since the level of effort of the efficient operator, in the risk-neutral case, is the first best level of effort $(\underline{e} = e^*)$, there is no advantage in distorting it in the risk-averse case. On the contrary, increasing the effort of the inefficient operator has two consequences, which both tend to equalize welfare levels:

- an increase in the inefficient type's efficiency, and thus an increase of the welfare obtained with this agent

- an increase in the rent given to the efficient type, and so a decrease of the welfare obtained with this agent.

Finally, welfare levels tend to equalize with a rising degree of the regulator's risk aversion. This increase of the rent given to the efficient operator, due to the increase in the level of effort asked to the inefficient operator, can be interpreted as an insurance premium paid by the regulator. In order to insure himself against facing the bad type, the regulator is forced to pay a higher insurance premium to the efficient operator. This insurance premium is the higher, the more risk-averse the regulator.

In comparing different levels of regulation, we have not envisioned the fact that a regulator can be assigned to regulate several firms operating in the same industry. We can wonder how the optimal contract will be affected if the regulator must regulate several operators simultaneously.

Let us consider a risk-averse regulator who has to regulate two firms operating in the same industry, for example water distribution, but in different regions. Suppose that each region is identical, so that the social value of each project, S, is the same. We also suppose that the operators are independent of each other.[4] They have the same cost function: $C = \beta - e$. Each of them can be of type $\underline{\beta}$ or $\overline{\beta}$ with the same probability $\frac{1}{2}$. We assume the same

[4] Without this hypothesis, the regulator could try to implement some sort of Yardstick competition since the information extracted from one agent could be used to regulate the others (Schleifer (1985)).

asymmetry of information as before on the regulator's side. Then, we obtain the following corollary:

Corollary 2 *For a risk-averse principal, the larger the number of operators under her control, the lower the distorsion of effort of the bad type.*

Proof. Since the participation and incentive constraints are independent of the degree of the regulator's risk aversion, they are also binding in the same way as before. We can directly write the program of the centralized regulator in the following manner:

$$\begin{aligned}\max_{\{\underline{e},,\overline{e},\}} \underset{\beta}{E}\, V(W) = \; & \frac{1}{4} V\left[2S - 2(1+\lambda)(\underline{\beta} - \underline{e} + \varphi(\underline{e})) - 2\lambda\phi(\overline{e})\right] \\ & + \frac{1}{4} V[2S - (1+\lambda)(\underline{\beta} - \underline{e} + \varphi(\underline{e}) - \lambda\phi(\overline{e}) \\ & - (1+\lambda)(\overline{\beta} - \overline{e} + \varphi(\overline{e}))] \\ & + \frac{1}{4} V\left[2S - 2(1+\lambda)(\overline{\beta} - \overline{e} + \varphi(\overline{e}))\right]\end{aligned}$$

Differentiating this program with respect to the levels of effort gives:

$$\varphi'(\underline{e}) = 1 \Rightarrow \underline{e} = e^* \quad (1)$$

$$\varphi'(\overline{e}) = 1 - \frac{\lambda}{1+\lambda}\phi'(\overline{e}) \left[\frac{2V'\left(2W_{\underline{\beta}}\right) + V'\left(W_{\underline{\beta}} + W_{\overline{\beta}}\right)}{V'\left(W_{\underline{\beta}} + W_{\overline{\beta}}\right) + 2V'\left(2W_{\overline{\beta}}\right)}\right] \quad (3)$$

In the appendix, we prove that $\left[\frac{2V'\left(2W_{\underline{\beta}}\right) + V'\left(W_{\underline{\beta}} + W_{\overline{\beta}}\right)}{V'\left(W_{\underline{\beta}} + W_{\overline{\beta}}\right) + 2V'\left(2W_{\overline{\beta}}\right)}\right]$ is smaller than $\frac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}$, for any given degree of the regulator's risk aversion. This result can be easily extended to the case of n operators. ■

This result completes our proposition. When we had only one operator, we showed that a regulator with high risk aversion, presumably a local regulator, would give more "efficient" contracts [5] than a national regulator with

[5] The contracts are said to be more "efficient" when the optimal levels of effort are closer to the first best level of effort e^*. Our intention here is not to make comparisons in

lower risk aversion (corollary 1). Still, we did not take into account the fact that a national regulator generally controls more than one operator, as in the British case. Corollary 2 above deals with this situation, and tells us that the larger the number of operators regulated by a national regulator, the more "efficient" the concession contracts will be. This effect comes from the assumed absence of correlation beteween the type of each operator and can be compared with the portfolio effect on credit markets: risk-averse investors prefer to hold diversified assets.

We can also study the effect of a greater difference in technical efficiency, $\Delta\beta = \overline{\beta} - \underline{\beta}$, between the two types of operators.

Proposition 2 *When the regulator is risk-averse, a higher $\Delta\beta$ induces two conflicting effects on the level of effort of the inefficient type:*

▶ *the first effect is the standard rent reduction effect "à la Laffont-Tirole", which induces more distortion of the inefficient operator's level of effort,*

▶ *the second one is the risk aversion effect, which induces less distortion in order to equalize welfare levels.*

Proof. By differentiating (2) with respect to $\Delta\beta$, we can characterize these two effects:

$$\frac{d\overline{e}}{d\Delta\beta} = \frac{-\lambda\varphi''\left(\overline{e}-\Delta\beta\right)\dfrac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}}{D} - \frac{\lambda\phi'\left(\overline{e}\right)\dfrac{d\left(\dfrac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}\right)}{d\Delta\beta}}{D}, \quad (4)$$

with $D = (1+\lambda)\,\varphi''\left(\overline{e}\right) + \lambda\phi''\left(\overline{e}\right)\dfrac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}$.

Since D is positive, the first part of the equation is negative and represents the rent reduction effect: in order to prevent the efficient type from lying on his type (which is easier when the difference between types increases), the regulator must limit the rent obtained when mimicking by reducing the level of effort asked to the inefficient type.

absolute terms (i.e. with the Pareto criterion) between different levels of regulation, which would necessitate more structure in the model.

In the second part of the equation, the term $\dfrac{d\left(\dfrac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}\right)}{d\Delta\beta}$ can be written as $-\dfrac{\rho\left(\dfrac{\partial\Delta W}{\partial\Delta\beta}\right)}{\left(1+\rho\Delta W\right)^2}<0$. Since $\dfrac{\partial\Delta W}{\partial\Delta\beta}=1+\lambda\left(1-\varphi'\left(\overline{e}-\Delta\beta\right)\right)$ is strictly positive, we deduce that the second part of the equation is positive and characterizes the risk aversion effect: in order to reduce the difference of welfare obtained with each type of operator (which is higher when the difference of types increases), the regulator must increase the level of effort asked to the inefficient type. ■

The following proposition tells that there exists a cutoff for ρ such that when the degree of risk aversion is low, the results remain qualitatively the same as under risk neutrality but change when the degree of risk aversion is above this cutoff.

Proposition 3 *There exists a* ρ^o *such that:*

► $\forall\rho<\rho^o$, *the rent reduction effect dominates the risk aversion effect, and then* $\dfrac{d\overline{e}}{d\Delta\beta}\leq 0$.

► $\forall\rho>\rho^o$, *the risk aversion effect dominates the rent reduction effect, and then* $\dfrac{d\overline{e}}{d\Delta\beta}\geq 0$.

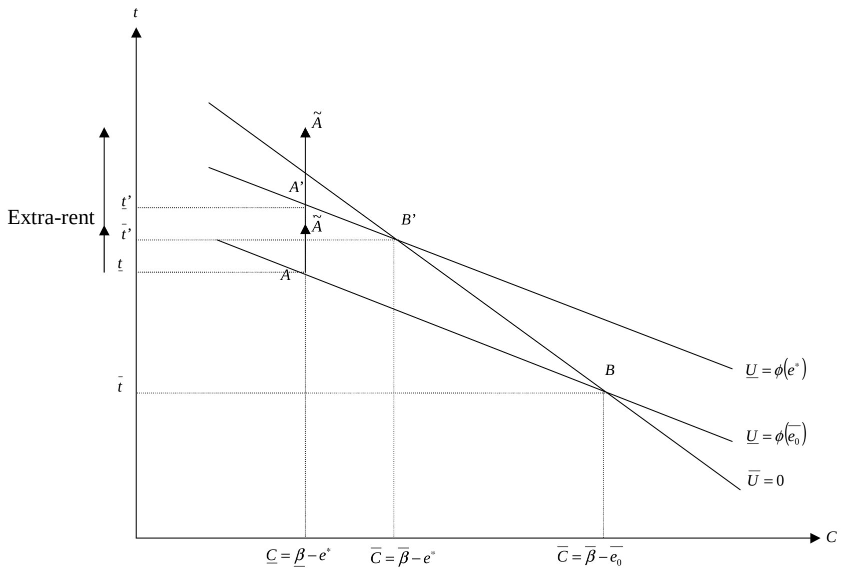
Proof. Replacing $\dfrac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}$ by $\dfrac{1}{1+\rho\Delta W}$ in (4) allows to calculate the threshold ρ^o for which the sign of the numerator of (4) changes:

$$\rho^o\overset{def}{=}\frac{\varphi''\left(\overline{e}-\Delta\beta\right)}{\phi'\left(\overline{e}\right)\left[1+\lambda\left(1-\varphi'\left(\overline{e}-\Delta\beta\right)\right)\right]-\Delta W\varphi''\left(\overline{e}-\Delta\beta\right)}. \blacksquare$$

Under high risk aversion and contrary to risk neutrality, since bad outcomes are more likely to occur when $\overline{\beta}$ goes far from $\underline{\beta}$, the regulator has an incentive to make a "very inefficient firm" work more than a "relatively inefficient firm."

Figure 1 summarizes our results. On the horizontal axis, we plot the cost of the contract C. On the vertical axis, we plot the transfer t associated to the cost. The menu of contracts (A, B) characterizes the optimal menu when the regulator is risk-neutral. When he is risk-averse, the cost of the efficient type remains the same $\left(\underline{C} = \underline{\beta} - e^*\right)$, but his level of transfer shifts upwards $(A \rightarrow A')$ because of the higher level of effort of the inefficient type. On the other hand, the cost of the inefficient operator decreases $\left(\overline{C} = \overline{\beta} - \overline{e}\right)$, while his transfer shifts to the north-west $(B \rightarrow B')$ along his binding participation constraint.

To sum up, when the regulator's risk aversion increases, the menu of the optimal contract (A^*, B^*) shifts from (A, B) toward (A', B'), where the latter is characterized by inducing the optimal level of effort for both types $(\underline{e} = \overline{e} = e^*)$, but also by a high level of rent for the efficient operator $(\phi(e^*))$. Note that the (A', B') menu is never attained unless the regulator is characterized by an infinite degree of risk aversion.



The optimal menu of contracts with a risk-averse principal.

Until now, we have considered only one period, which means that the contract is optimal only from a static point of view. In the next section, we add a second period to address the regulator's commitment issue.

3 The dynamic model

When a private operator accepts to manage a public utility service, he knows that he will have to make substantial specific investments to make his project succeed. The realisation of these investments requires that the private operator obtain some guaranty against the regulator's opportunistic behavior. The private agent needs to be sure that the regulator will not renegotiate or breach the contract, that the regulator be trustworthy and to consider how the regulator's risk aversion influences her ability to credibly commit herself over several periods.

To answer these concerns, we describe the different types of commitment available to the regulator. Then, we define a measure of the social value of the regulator's political commitment. Finally, we show how this value varies with the degree of the regulator's risk aversion.

3.1 The different types of commitment

When a public authority signs a contract with a private operator, she must choose not only the length of the term but also the type of behavior she will adopt over the course of the contract. For simplicity, we consider only two periods. If we exclude the total commitment case,[6] the combination of the two elements above allows us to define two possible types of intertemporal commitment:

- the first one (no commitment) corresponds to the situation where the public authority just accepts to sign a short term contract (a one period contract). This necessarily implies a second negotiation at the end of the first period to design a new contract for the second period.

- the second type (commitment and renegotiation) corresponds to the situation where the regulator accepts to sign a long term contract (a two period contract), but leaves room for renegotiations during the term of the

[6] By total commitment, we mean signing long term contracts that cannot be renegotiated ex post. This type of commitment is often constitutionally forbidden because it implies committing future public authorities, not yet elected, against their wishes.

contract. Since we are in a complete contracts setting, this renegotiation will be perfectly anticipated by both contractors. It results that the initial contract will be renegotiation-proof, that is neither party will want to forcibly renegotiate.

In the following section, we define a measure of the social value of the regulator's political commitment. Then, we characterize the influence of the regulator's risk aversion on this social value.

3.2 The social value of political commitment

Let us start by defining the social value of political commitment.

Definition 1 *The social value of political commitment is the difference between the value maximized welfare when the regulator can commit to sign long term contracts, but cannot commit not to renegotiate them ex post, and the value maximized welfare when the regulator can only sign short term contracts.*

This definition implicitly assumes the existence of a welfare loss between the two types of commitment. It is crucial to understand where this welfare loss comes from.

3.2.1 The extra rent

In a two period framework, when there is asymmetry of information, the regulator can use in the second period the information obtained in the first period. Anticipating the opportunistic behavior of the regulator, the operator will refuse to reveal his type in the first period. To incitate him to tell the truth about his type, the regulator must give to the efficient operator an extra rent in the first period such that the latter be just indifferent between revealing his type and not revaling it. This extra rent is made necessary by the lack of credibility of the regulator and the expectation of a renegotiation at the end of the first period. It can then be interpreted as the cost imposed by the regulator not being able to commit totally ex ante.

We can use Figure 1 to give a sketch of the problem. Initially, if the regulator proposes the (A, B) optimal static menu, the efficient operator will always choose to mimic the inefficient one and thus will choose contract B.

By doing so, not only does he obtain the static informational rent in the first period, but he also receives an extra rent in the second period due to the adverse selection problem. Instead, by proposing the contract $\widetilde{A}$ instead of A in the first period, where $\widetilde{A}$ corresponds to the same level of cost but with an extra transfer, the regulator makes the efficient type intertemporaly indifferent between contracts $\widetilde{A}$ and B.[7] As for the inefficient operator, if contract $\widetilde{A}$ is below his binding participation constraint, he strictly prefers contract B which gives him no rent.

3.2.2 The "take the money and run" strategy

The "take the money and run" strategy corresponds to the situation where the inefficient operator's interest is to mimic the efficient one in the first period, catch the extra rent, and leave at the outset of the second period. This situation only appears, first, when the extra rent given to the efficient operator in the first period is sufficiently high for contract $\widetilde{A}$ to be above the binding participation constraint of the inefficient operator inducing him to strictly prefer contract $\widetilde{A}$ to contract B, second, when there exists a possibility for the operator to quit the relation at the end of the first period contract, that is when the regulator just signs a one-period contract. On the contrary, when the regulator and the operator sign a renegotiable long term contract, it is not possible for them to breach the contract at the end of the first period.[8] Neither is it possible to modify unilaterally the terms of the contract.[9] Moreover, the regulator can condition the first period payment on the fact of the operator being present at the second period. So, this type of commitment prevents the inefficient operator from mimicking the efficient one in the first period.

Let us analyse now the impact of regulator's risk aversion on the social value of political commitment.

[7]Contrary to the static case, in the dynamic framework, there exists, at the optimum, a positive probability that the efficient operator mimics the inefficient one even if it is intertemporaly indifferent between the contracts. We leave this problem aside here. Rather, we assume that when an operator is indifferent between two contracts, he always chooses the one designed for him.

[8]For example, because the breach of contract would be very costly.

[9]This behavior would be considered as a breach.

3.3 Regulator's risk aversion and the social value of political commitment

When we consider the static case, we know that the optimal menu of contracts is characterized by the fact that the efficient type is indifferent between the two contracts. This indifference has no consequences on welfare since we only consider a static framework. On the contrary, it is no longer true when we consider a dynamic version of the model. In fact, even if the efficient type is intertemporaly indifferent between the two contracts, and, in this sense, has no particular incentive to randomize between both, the regulator can guarantee that the efficient operator chooses the optimal probability for randomizing by offering a possibly renegotiated contract with a unique continuation equilibrium, as described in Laffont and Tirole (1993). These optimal randomizing probabilities are not neutral with respect to the analysis of the relation between the social value of political commitment and the regulator's risk aversion. Indeed, if these randomization probabilities increase with the degree of regulator's risk aversion, the probability that the regulator chooses a pooling contract rather than a separating one increases and the difference between the two types of commitment is reduced. The following lemma ensures that the randomization probabilities are not varying with the regulator's risk aversion.

Lemma 1 *In the dynamic version of the model, the optimal levels of effort in the first period are independent of the regulator's risk aversion.*

Proof. see appendix. ■

In contrast with Lewis and Sappington (1995), our setting implies that more risk aversion for the regulator does not induce more pooling in the first period. Then, the separating equilibrium is still relevant in the risk averse regulator case. The difference between the two settings comes from the concealment effect, which is not considered in our model. This last effect characterizes the fact that, by pooling the different operators, the regulator does not induce the revelation of the operators' type and can thus relax the participation constraint of the financier. Still, this effect depends crucially on the presence of a third party financier and on the moral hazard problem, neither of which appear in our model.

Now, we can characterize the influence of the regulator's risk aversion on the social value of political commitment.

Proposition 4 *The more risk-averse the regulator, the higher the social value of political commitment.*

Proof. As explained in lemma 1, the optimal first period levels of effort do not depend on the degree of the regulator's risk aversion. Thus, we deduce that the inefficient operator's incentive constraint will be more binding if and only if the extra rent given to the efficient operator in the first period increases with the degree of the regulator's risk aversion. Since the inefficient operator's second period level of effort increases with the degree of the regulator's risk aversion, because $\varphi'\left(e^*_{\pi^0}\right) = 1 - \frac{\lambda}{1+\lambda}\frac{\pi^0}{1-\pi^0}\phi'\left(e^*_{\pi^0}\right)\frac{V'_{\pi^0}}{V'_{1-\pi^0}}$, the extra rent also increases with the degree of the regulator's risk aversion. This directly implies that the more risk averse the regulator, the more often the "take the money and run" strategy will appear. Since the occurence of this socially inefficient strategy is at the origin of the welfare loss, we can conclude that the more risk averse the regulator, the higher the social value of political commitment. ■

The intuition of the proof can be found from Figure 1. This figure tells us that risk aversion shifts the optimal contract menu toward contracts with higher incentives, and thus leads to giving up more static informational rent at the first period. If we consider a given extra rent, we can infer that the higher the degree of the regulator's risk aversion, the higher the static informational rent, and then the higher the probability of having contract $\widetilde{A}$ strictly above the inefficient type's binding participation constraint.

As for the static version, this result could be extend to the case where the regulator is assigned to regulate several firms operating in the same industry. It is likely that *when the principal is risk-averse, the larger the number of operators under her control, the higher the social value of political commitment.*

The intuition for the proof should proceed as for proposition 4 and can be catched with Figure 1. When the number of private regulated firms increases, the regulator make the optimal static contract menu shift toward contracts with higher incentives (corollary 2). Thus, for a given extra-rent, the higher the number of regulated firms, the higher the static informational rent, and then the higher the probability of having contract $\widetilde{A}$ strictly above the inefficient type's binding participation constraint.

After characterizing the theoretical impacts of the principal's risk aversion on the characteristics of the contract, we discuss in the next section the political implications of this hypothesis.

4 Political implications

The design and organization of the regulatory institutions are one of the major concerns for governments. With increasing involvment of private sector in the providing of public utilities and services, not only the precise role, but also the competencies of public authorities need to be better defined. The two major effects we derived concerning the influence of the principal's risk aversion on the form of the contract, namely the incentive effect and the commitment effect, have both strong implications regarding the political choice of these regulatory institutions. We discuss these two effects in the situation where we assume a negative correlation between the position of the regulator in the administrative hierarchy (local/national) and her degree of risk aversion: the higher in the hierarchy, the higher degree of risk aversion. We discuss, then, the optimal level of regulation when the cost of public funds, respectively, increases and decreases with the regulator's risk aversion.

4.1 The incentive effect

The incentive effect characterizes the impact of the principal's risk aversion on the static optimal contract. We distinguished two factors pushing the static contract toward higher powered incentives: the degree of regulator's risk aversion (corollary 1) and the number of private regulated operators (corollary 2).

Assuming a negative correlation between the level of regulation (local/national) and the degree of risk aversion,[10] the first effect says that, for a given cost of public funds, λ, a local regulator with high risk aversion will afford more rent to the private operator than a national regulator who has lower risk aversion. On the contrary, a local regulator will be preferred to a national regulator,

[10]This could be, for example, because the national regulation authority has the opportunity to distribute management of risk among more people than the local authority.

in terms of efficiency, because she leads to less effort distortion (corollary 1). This result can cast some light on the debate over the independence of the regulation authority. While in France and Canada, the regulation is in the hands of local mayors, and thus subject to strong political influence, the U.K. adopted a more independent way of regulating local public services. If we suppose that the mayor is more risk-averse because she must face more lobbying, we can infer that the contracts signed with municipalities are more "efficient" than those signed with the British independent regulator. The obvious corrolary is that the operators will extract more informational rents than the "English" ones.[11]

Nevertheless, another factor comes to offset the first one. While a local regulator is presumably more risk-averse than a national one, the latter often regulates more operators. As corrolary 2 shows us, the number of private regulated operators implies the same incentive effect.

Since the two factors imply the same incentive effect, they are inconclusive about the question of the optimal level of regulation.

4.2 The commitment or credibility effect

Since the wave of privatization of public utilities started in the 80's, there has been great concern about how the short-term rent-seeking behavior of private operators could impede public service obligations, which necessitate a long-term perspective. The credibility of regulatory rules is often crucial in inducing private operators to adopt a more long-term perspective. As Vickers and Yarrow say: "...because of the lack of credibility with respect to future public policies, there is a real danger of underinvestment in a privatized industry..." (1996, pp. 410).

The commitment or credibility effect characterizes the impact of regulator's risk aversion on her ability to commit. As for the incentive effect, we distinguished two factors pushing the dynamic contract toward more commitment for the regulator: the degree of regulator's risk aversion (proposition 4) and the number of private regulated operators.

When we suppose a positive correlation between the social value of commitment and the credibility of the regulator, proposition 4 says that the more risk-averse the regulator, the more credible she will be. We can infer that a

[11] The World Bank largely supports the idea that the regulator should maintain an arm's length relationship with political authorities (see World Bank (1996)).

contract signed with a small municipality having high risk aversion will be less subject to renegotiation than a contract signed with a larger municipality having lower risk aversion. Focussing on the comparison between French local and British national regulation of public services, proposition 4 allows to infer that the local regulation, although it gives up more rent to the operator, tends to be more credible than a national one. In a sense, as pointed out by Defeuilley (1998), it seems that a local French-style regulation will permit more stable regulatory rules than a national British-style regulation. To illustrate this conjecture, note that the French municipalities, which were famous for being reluctant to renegotiate, recently started to renegotiate more often. This increasing tendency for renegotiating probably originates in the recent creation of a mayors' association (Public 2000 association), whose aim is to increase the bargaining power of mayors in the contractual relation with the operator, and thus, corollarily, to decrease the degree of the mayors' risk aversion. This tendency could also come from the "intercommunality" phenomeneon which permits municipalities to gather together to manage or to regulate public utilities services.

In the same way, if we suppose a positive correlation between the social value of commitment and contract duration, we can infer that the reauctioning of contracts will happen less often with a small municipality than with a large one. This result can also shed some light on the debate about the "softness" of French municipalities in regulating private operators, as compared with British regulators' "toughness". While in France regulation is often seen as a long term and global activity, which needs only to define the broad lines of the concession contract, British regulation often concentrates on the more short term aspects and generally prefers to sign very detailed contracts with the private operator. This relative "toughness" of the British regulation may originate from the lower degree of risk aversion, which reduces the value of commitment, and thus the incentive to sign long term contracts.

Nevertheless, a second factor comes to balance these interpretations for decentralization. Contrary to a local regulator which is generally concentrated on no more than one operator, national regulation often implies the control of several firms operating in the same industry. When the number of operators controlled by one regulator increases, the regulator gives more incentives to the operators in the first period (corollary 2), then the probability that the inefficient "take the money and run" strategy arises is higher in the no commitment case, and so the higher will be the welfare difference between the two types of commitment.

Thus, for the same reason than for the incentive effect, the two factors prevent us from concluding on the optimal level of regulation. In the next sub-section, we discuss the optimal level of regulation when the cost of public funds is correlated with the degree of regulator's risk aversion.

4.3 Optimal regulatory design and cost of public funds

Until now, we derive all these results with the hypothesis that the social cost of raising public funds λ is independent of whether the decision is local or national. But the cost of public funds is likely different from one municipality to the other. When we consider some variations of this parameter with the degree of risk aversion, we can have an idea of the optimal regulatory institution.

If we suppose that the cost of public funds increases with the degree of risk aversion, such that the lower in the adminsitrative hierarchy, the higher risk aversion, and thus the higher the social cost of raising public funds, then we can infer that centralized regulation is better than local regulation. Indeed, the two types of regulation have the same incentive and commitment effects, but centralized regulation benefits, in addition, from a lower cost of public funds.

On the contrary, when we suppose that it is less distorting for a local regulator than for a national entity to levy tax, we obtain that decentralized regulation is better than centralized regulation.

Appendix

Proof of corollary 2 To complete the proof in the text, we have to show that

$$\frac{2V'\left(2W_{\underline{\beta}}\right)+V'\left(W_{\underline{\beta}}+W_{\overline{\beta}}\right)}{V'\left(W_{\underline{\beta}}+W_{\overline{\beta}}\right)+2V'\left(2W_{\overline{\beta}}\right)}\leq\frac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}.$$

Using a Taylor expansion of the marginal utility V', we can write

$$\frac{V'\left(W_{\underline{\beta}}\right)}{V'\left(W_{\overline{\beta}}\right)}=\frac{1}{1+\rho\Delta W}.$$

The left-hand side of the inequality can, equivalently, be written:

$$\frac{1}{\dfrac{V'\left(W_{\underline{\beta}}+W_{\overline{\beta}}\right)}{2V'\left(2W_{\underline{\beta}}\right)}+\dfrac{V'\left(2W_{\overline{\beta}}\right)}{V'\left(2W_{\underline{\beta}}\right)}}+\frac{1}{\dfrac{V'\left(W_{\underline{\beta}}+W_{\overline{\beta}}\right)}{V'\left(W_{\underline{\beta}}+W_{\overline{\beta}}\right)}+\dfrac{2V'\left(2W_{\overline{\beta}}\right)}{V'\left(W_{\underline{\beta}}+W_{\overline{\beta}}\right)}}$$

$$=\frac{1}{\dfrac{1+\rho\Delta W}{2}+(1+2\rho\Delta W)}+\frac{1}{1+2\left(1+\rho\Delta W\right)}.$$

Checking that this expression is lower than $\frac{1}{1+\rho\Delta W}$ for any degree of risk aversion completes the proof.

Proof of lemma 1

We have to consider respectively the two types of commitment.

Let us consider the commitment and renegotiation case (two period contract).

We first introduce some notation:

- x_0 is the probability that the efficient operator chooses the separating contract

- $(1-x_0)$ is the probability that the efficient operator chooses the pooling contract

- $\pi^1 = \dfrac{\frac{1}{2}(1-x_0)}{\frac{1}{2}+\frac{1}{2}(1-x_0)} = \dfrac{(1-x_0)}{(2-x_0)}$ is the revised probability that the regulator thinks the operator is efficient in period 2, when she has observed the contract designed for the inefficient operator in the first period.

- $\underline{e}_1,\underline{e}_2$ are the levels of effort of the efficient operator at each period
- $\overline{e}_1,\overline{e}_2$ are the levels of effort of the inefficient operator at each period
- δ is the discount rate.

The program of the regulator is written in the following manner:

$$\max_{\{\underline{e}_1,\overline{e}_1,x_0\}} EV(W) =$$

$$\frac{1}{2}x_0 V\begin{bmatrix} S-(1+\lambda)(\underline{\beta}-\underline{e}_1+\varphi(\underline{e}_1))-\lambda\phi(\overline{e}_1) \\ +\delta\left(S-(1+\lambda)(\underline{\beta}-e^*+\varphi(e^*))-\lambda\phi(e_{\pi^1})\right) \end{bmatrix}$$
$$+\frac{1}{2}(1-x_0)V\begin{bmatrix} S-(1+\lambda)\left(\underline{\beta}-(\overline{e}_1-\Delta\beta)+\varphi(\overline{e}_1-\Delta\beta)\right)-\lambda\phi(\overline{e}_1) \\ +\delta\left(S-(1+\lambda)(\underline{\beta}-e^*+\varphi(e^*))-\lambda\phi(e_{\pi^1})\right) \end{bmatrix}$$
$$+\frac{1}{2}V\begin{bmatrix} S-(1+\lambda)\left(\overline{\beta}-\overline{e}_1+\varphi(\overline{e}_1)\right) \\ +\delta\left(S-(1+\lambda)(\overline{\beta}-e_{\pi^1}+\varphi(e_{\pi^1}))\right) \end{bmatrix}$$

With probability $\frac{1}{2}x_0$, the operator is efficient and chooses to reveal his type in the first period. He exerts an effort $\underline{e}_1$ in the first period. In the second period, since the regulator is informed about his type, she asks the efficient operator to provide the optimal level of effort e^*. The latter obtains the static informational rent $\phi(\overline{e}_1)$, which depends positively on the inefficient operator's level of effort $\overline{e}_1$, plus an extra rent $\delta\phi(e_{\pi^1})$, equal to the second period rent obtained when not revealing his type in the first period.

With probability $\frac{1}{2}(1-x_0)$, the operator is efficient but chooses not to reveal his type in the first period. Then, he exerts an effort $\overline{e}_1-\Delta\beta$ in the first period. In the second period, the regulator offers him the optimal static menu revised with the new probability, π^1, that the operator be efficient. His level of effort in the second period is then optimal, and he obtains the same level of rent as compared with the case where he chooses the contract designed for him $\phi(\overline{e}_1)+\delta\phi(e_{\pi^1})$.

Finally, with probability $\frac{1}{2}$, the operator is inefficient. He exerts the level of effort $\overline{e}_1$ in the first period, e_{π^1} in the second one, and he obtains no rent.

The randomization probability x_0 must be such that the welfare obtained when the efficient operator chooses the separating contract $V(W(x_0))$ is just equal to the welfare obtained he chooses the pooling contract $V(W(1-x_0))$:

$$V(W(x_0)) = V(W(1-x_0)) \qquad (5).$$

We can, equivalently, rewrite this condition in the following way:

$$\Delta\beta - e^* + \varphi(e^*) - (\overline{e}_1 - \varphi(\overline{e}_1 - \Delta\beta)) = 0 \qquad (5').$$

If we differentiate $(5')$ with respect to the degree of the principal's risk aversion, ρ, we obtain:

$$\frac{\partial \overline{e}_1}{\partial \rho}(1 - \varphi'(\overline{e}_1 - \Delta\beta)) = 0.$$

Since $(1 - \varphi'(\overline{e}_1 - \Delta\beta)) \neq 0$, this implies that $\frac{\partial \overline{e}_1}{\partial \rho} = 0$, and then $\frac{\partial x_0}{\partial \rho} = 0$. Thus, the first period effort does not depend on the level of the regulator's risk aversion.

When we turn to the no commitment case (one period contract), we know that the inefficient operator can also be incited to randomize between the two contracts because of the "take the money and run" strategy. Thus, we have to introduce the following new notations:

- y_0 is the probability that the inefficient operator chooses the separating contract
- $(1-y_0)$ is the probability that the inefficient operator chooses the pooling contract
- $\pi^0 = \dfrac{\frac{1}{2}x_0}{\frac{1}{2}x_0 + \frac{1}{2}y_0} = \dfrac{x_0}{x_0 + y_0}$ is the revised probability that the regulator thinks the operator is efficient in period 2, when the former has observed the contract designed for the efficient operator in the first period.

The program of the regulator is now:

$$\max_{\{\underline{e}_1,\overline{e}_1,x_0,y_0\}} \quad EV(W) =$$
$$\frac{1}{2}x_0 V\left[\begin{array}{c} S-(1+\lambda)(\underline{\beta}-\underline{e}_1+\varphi(\underline{e}_1))-\lambda\phi(\underline{e}_1+\Delta\beta) \\ +\delta\left(S-(1+\lambda)(\underline{\beta}-e_{\pi^0}+\varphi(e_{\pi^0}))-\lambda\phi(e_{\pi^0})\right)\end{array}\right]$$
$$+\frac{1}{2}(1-x_0)V\left[\begin{array}{c} S-(1+\lambda)\left(\overline{\beta}-\overline{e}_1+\varphi(\overline{e}_1-\Delta\beta)\right)-\lambda\phi(\overline{e}_1) \\ +\delta\left(S-(1+\lambda)(\underline{\beta}-e_{\pi^1}+\varphi(e_{\pi^1}))-\lambda\phi(e_{\pi^1})\right)\end{array}\right]$$
$$+\frac{1}{2}y_0 V\left[\begin{array}{c} S-(1+\lambda)\left(\underline{\beta}-\underline{e}_1+\varphi(\underline{e}_1+\Delta\beta)\right) \\ +\delta\left(S-(1+\lambda)(\overline{\beta}-e_{\pi^0}+\varphi(e_{\pi^0})\right)\end{array}\right]$$
$$+\frac{1}{2}(1-y_0)V\left[\begin{array}{c} S-(1+\lambda)\left(\overline{\beta}-\overline{e}_1+\varphi(\overline{e}_1)\right) \\ +\delta\left(S-(1+\lambda)(\overline{\beta}-e_{\pi^1}+\varphi(e_{\pi^1})\right)\end{array}\right]$$

under the inefficient operator's incentive constraint $\left(\overline{IC}\right)$, which can be binding in this case: $\phi(\underline{e}_1+\Delta\beta)+\delta\phi(e_{\pi^0})=\phi(\overline{e}_1)+\delta\phi(e_{\pi^1})$.[12]

With probability $\frac{1}{2}x_0$, the operator is efficient and chooses to reveal his type in the first period. He puts forth an effort $\underline{e}_1$ in the first period and obtains the static informational rent $\phi(\underline{e}_1+\Delta\beta)$. In the second period, the regulator observes the first period contract, and deduces that the operator is efficient with probability π^0, and inefficient with probability $1-\pi^0$. She offers, then, the optimal contract taking into account the asymmetry of information at this date.

With probability $\frac{1}{2}(1-x_0)$, the operator is efficient, but chooses not to reveal his type. He exerts an effort $\overline{e}_1-\Delta\beta$ in the first period and obtains the static informational rent $\phi(\overline{e}_1)$. In the second period, the regulator observes the first period contract, and deduces that the operator is efficient with probability π^1, and inefficient with probability $1-\pi^1$. She offers, then, the optimal contract taking into account the asymmetry of information at this date.

With probability $\frac{1}{2}y_0$, the operator is inefficient, but decides not to reveal his type. He exerts an effort $\underline{e}_1+\Delta\beta$, and obtains no rent. In the second period, the regulator observes the first period contract and deduces that the operator is efficient with probability π^0, and inefficient with probability $1-\pi^0$. She offers, then, the optimal contract taking into account the asymmetry of information at this date.

Finally, with probability $\frac{1}{2}(1-y_0)$, the operator is inefficient and chooses

[12] In the no commitment case, we only consider the equilibrium where both incentive constraints are binding since it is the unique equilibrium where the "take the money and run" strategy can appear.

to reveal his type. He exerces an effort $\overline{e}_1$ and obtains no rent. In the second period, the regulator observes the first period contract and deduces that the operator is efficient with probability π^1, and inefficient with probability $1-\pi^1$. He offers, then, the optimal contract taking into account the asymmetry of information at this date.

Like in the commitment and renegotiation case, the randomization probabilities x_0, y_0 must be such that the welfares obtained when each operator chooses the separating contract $V(x_0)$ and $V(y_0)$ are just equal to the respective welfares obtained when each operator chooses the pooling contract $V(1-x_0)$ and $V(1-y_0)$:

$$V(x_0) = V(1-x_0) \qquad (6)$$

$$V(y_0) = V(1-y_0) \qquad (7)$$

We can, equivalently, rewrite (6) and (7) in the following way:

$$\begin{aligned}(6) \Leftrightarrow\ & (1+\lambda)\left[\Delta\beta - \overline{e}_1 + \underline{e}_1 + \varphi(\overline{e}_1 - \Delta\beta) - \varphi(\underline{e}_1)\right] + \lambda\phi(\overline{e}_1) - \lambda\phi(\underline{e}_1 + \Delta\beta) \\ & = \delta\left[(1+\lambda)(e_{\pi^1} - e_{\pi^0} + \varphi(e_{\pi^0}) - \varphi(e_{\pi^1})) + \lambda\phi(e_{\pi^0}) - \lambda\phi(e_{\pi^1})\right] \\ (7) \Leftrightarrow\ & (1+\lambda)\left[(\Delta\beta - \overline{e}_1 + \underline{e}_1 + \varphi(\overline{e}_1) - \varphi(\overline{e}_1 - \Delta\beta))\right] \\ & = \delta\left[(1+\lambda)(e_{\pi^1} - e_{\pi^0} + \varphi(e_{\pi^0}) - \varphi(e_{\pi^1}))\right]\end{aligned}$$

By using the $\left(\overline{IC}\right)$ in (6), we obtain:

$$\begin{aligned}(6) \Leftrightarrow\ & (1+\lambda)\left[\Delta\beta - \overline{e}_1 + \underline{e}_1 + \varphi(\overline{e}_1 - \Delta\beta) - \varphi(\underline{e}_1)\right] + \lambda\delta\phi(e_{\pi^0}) - \lambda\delta\phi(e_{\pi^1}) \\ & = \delta\left[(1+\lambda)(e_{\pi^1} - e_{\pi^0} + \varphi(e_{\pi^0}) - \varphi(e_{\pi^1})) + \lambda\phi(e_{\pi^0}) - \lambda\phi(e_{\pi^1})\right]\end{aligned}$$

Substituting (7) into (6), and rearranging, we finally obtain the following equation:

$$\phi(\underline{e}_1 + \Delta\beta) - \phi(\overline{e}_1) = 0.$$

By differentiating this last equation with respect to the degree of the regulator's risk aversion, ρ, we have:

$\dfrac{d\underline{e}_1}{d\rho}\phi'(\underline{e}_1 + \Delta\beta) = \dfrac{d\overline{e}_1}{d\rho}\phi'(\overline{e}_1)$, which, automatically, gives us: $\dfrac{d\underline{e}_1}{d\rho} = \dfrac{d\overline{e}_1}{d\rho} = 0$ to be satisfied. Thus, the optimal x_0^* and y_0^* are such that the first period effort does not depend on the degree of the regulator's risk aversion.

These last equalities ensure us that $\frac{dx_0}{d\rho} = \frac{dy_0}{d\rho} = 0$.

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