Contractual Design and Renegotiation: Impacts on Yardstick Competition Efficiency

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Abstract

The theoretical models on yardstick competition systematically assume a perfect regulatory commitment. The economic theory thus shows that yardstick competition makes it possible to provide strong incentives to the regulated firms, while decreasing the informational asymmetries between the parties. For that purpose, the theoretical works on this regulation mode assume a single method which remains within in the signature of rigid and non renegotiated contracts between the regulator and regulated firms. However, in reality, we observe that, (1) on the one hand, there are various methods of yardstick competition which provide more or less incentives to regulated firms and which are more or less constricting; (2) one the other hand, renegotiation sometimes occurs when this regulation mode is implemented. This paper aims at introducing the limited regulatory commitment assumption into a model of yardstick competition. It results in a renegotiation of this type of regulatory contract that is dependent on a particular probability. We then show that the regulator must arbitrate between different contractual designs. We find that the contractual design choice depends on the renegotiation efficiency, the cost of public funds as well as the regulator's ability to face endogenous and exogenous pressures (and thus the probability of renegotiating a rigid contract).

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1 Introduction

Since the end of the eighties, network industries (electricity, gas, telecommunications, railroads, postal service. . .) have faced deep reforms concentrating mainly on introducing competition wherever possible. The reforms imply a vertical unbundling of potentially competitive segments. These segments are separated from those with natural monopoly characteristics. Concerning the regulation of network activities, monopolies were traditionally regulated by a "cost of service" mechanism. However, in most countries, an important part of the reforms relies on the introduction of incentive mechanisms. The goal is to prevent the operator from reflecting his rise in costs in his prices. S. Littlechild proposed a price regulation based on a "price cap"[1] and implemented it for the first time for the case of *British Telecom*.

The information available to the regulatory body is an important element for an efficient regulation (Laffont [2005]). Regulated firms have more solid information than the regulator, concerning the costs for instance. Firms may thus try to take advantage of this situation. Yardstick competition[2] makes it possible to reduce this information asymmetry. As a result of this method, the regulated company's profits depend on its relative performance compared to the performance of the other regulated companies of the sector. More precisely, this incentive regulation consists of evaluating and remunerating the performances of an economic agent in relation to those realized by other agents (whose characteristics are sufficiently close to make comparisons). Therefore, the regulator introduces a "virtual" competition between local monopolies. The yardstick competition mechanism is based on the measurement of firms' performance and on the financial consequences of the comparisons.

Yardstick competition is used more and more in various sectors and countries (see table 1). This is the case for electricity and gas distribution in the Netherlands, Italy and soon Germany, for water distribution, sewer systems and railway infrastructures in Great Britain as well as for the bus networks in Norway[3]. . .
In reality, we observe that there are various forms of yardstick competition, depending on the countries and sectors of activity. The applications are more or less constraining and inciting for the regulated companies. Thus there is no single method, as stated in theory, but rather several methods of designing and implementing this type of regulatory contract. Four different forms of yardstick competition can be distinguished according to the intensity of pressure that each mechanism exerts on the costs of the monopolies involved.
"*Assisted benchmarking*" is the less constricting and inciting method. The firms are usually included in the elaboration process along with the regulator, in order to stress

[1]Other hybrid forms of price regulation such as the "revenue cap", "sliding scale" or "profit sharing" are also developed in many countries. In the middle of the eighties, this new form of incentive regulation was introduced into the regulated segments of gas, electricity, telecommunications as well as water sectors, in countries such as Great Britain, New Zealand, Australia or the United States.

[2]For a theoretical analysis of yardstick competition, see for example Shleifer [1985], Sobel [1999], Auriol [2000], Laffont and Boyer [2000], and Choné Lesur [2001].

[3]See Lévêque [2005] for a review of yardstick competition implementation.

Activity sector	Country	Type of use
Hospital	Various	Various
Public construction	Malaysia	Sunshine regulation
Infrastructure	Australia	Assisted benchmarking
Railway infrastructures	Great Britain	Assisted benchmarking
Railroad	Japan	Costs regulation
Bus network	Norway	Costs regulation
Water	Great Britain Portugal	Assisted yardstick competition Sunshine regulation
Electricity	Various	Various

Table 1: Different applications of yardstick competition

the weaknesses of each company. The firms can then shape strategies, assisted by the regulator, to improve their practices. With a "*sunshine regulation*"[4], the regulator publishes the results of his benchmarking and distributes the information regarding the relative performances of the regulated firms. If a firm appears less efficient than the others, this mechanism will have a negative effect on the firm's reputation. The distribution of the comparison results will act as an indirect competition pressure, exerted above all by stakeholders (users, medias, politicians, NGOs...). However, with these methods, the regulator has no coercive power. In the first case, the inefficient firms will not be punished if they do not improve their performances. In the second case, the regulator's authority depends on his ability to mobilize public opinion. In comparison with the two methods described hereafter, these forms of yardstick competition do not really constitute tariff regulatory contracts. Indeed, the link between benchmarking and price setting is not explicit.
When a regulator implements an "*assisted yardstick competition*", the regulator occasionally resorts to comparisons, in order to decrease informational asymmetries. It can be a matter of solving a particular technical point, such as the determination of the productivity gains within a price cap mechanism. The regulated companies then have an incentive to improve their performance under the pressure of the shareholders[5]. Lastly, the comparisons with "*costs regulation*"[6] are directly used to set the base for costs reimbursement. It is a very incentive form of yardstick competition, which approaches the normative models. Each firm is compensated for an amount equal to the costs average of its counterparts. Therefore, each firm is incited to reduce its costs in such a manner that they are lower than the average of the sector. This regulatory mechanism requires nevertheless that the regulators have an extended degree of power, enabling them to sanction the relatively inefficient firms and conversely, to reward the most efficient firms.

Indeed, there are different ways of designing and implementing this type of regula-

[4]Henry [1997] analyses the case of Sweden. Marques and De Witte [2007] analyze the case of the Portuguese Institute of Regulation of Water and Waste (IRAR).

[5]See Cowan [1997] for the case of the English water distribution and sewage treatment.

[6]Dalen and Gómez-Lobo [2003] explain how Norway implemented this method in the bus network.

tory contract. Moreover, in reality, renegotiation sometimes occurs. For instance, the Italian gas regulator envisaged, in 2005, implementing a revenue cap with "*assisted yardstick competition*". Finally, following many conflicts between the regulator and regulated firms, the regulatory authority alleviated the regulatory rules, to turn to a form of "*assisted benchmarking*". Similarly, the Dutch regulator changed the "rules of the game" in the application of a "*costs regulation*" in the gas sector. He planned and announced a rigid regulatory contract with *ex post* penalties. However, following the results of the benchmarking, relatively inefficient firms asked the regulator for more time to improve their performance without being penalized. The regulator accepted this new rule and "*costs regulation*" thus turned into "*assisted yardstick competition*".
In a general way, if the regulator wants to apply a price regulation contract, he should theoretically commit to not change the contract's terms during the regulatory lag, whatever new information or external shocks are revealed *ex post*. For instance, let us assume that we are in the second year of a four year regulatory lag of yardstick competition. Let us also assume that the regulator acquires new information revealing that some companies realize negative profits (that can lead to bankruptcy), which are thus lower than those anticipated in the initial contract. Theoretically, with yardstick competition, the regulator should not use this information until the next price review. Without this commitment, incentives would be reduced or even eliminated. In most cases, the duration of yardstick contracts is between 3 and 5 years long, which is quite long given the amount of new information that may arise during this period. This may explain the possibility of renegotiation occurring *ex post*.

However, on the one hand, theory does not explain that several methods can be used. On the other hand, the theoretical models don't explain *ex post* renegotiation. Indeed, the theoretical models of yardstick competition systematically assume a perfect regulatory commitment[7]. The theoretical assumption of a perfect regulatory commitment relies on complete[8] and rigid yardstick contracts, which are never renegotiated. However, it is now recognized that regulatory contracts are incomplete and that regulators often have a limited commitment (Laffont [2003,2005]).
Even if the regulator commits not to renegotiate, he may be wrong when he specifies the terms of the initial contract. Therefore, we assume that the level of commitment first depends on his ability to face endogenous pressures (coming from the regulated firms), and second, on his ability to deal with exogenous pressures and shocks. These two elements (ability to face endogenous and exogenous pressures) create a trade-off concerning the "contractual design" of yardstick competition.

Therefore, the diversity of the yardstick competition applications results from the fact that the regulators can choose between:

[7]See for example Shleifer [1985]: "*It is essential for the regulator to commit himself not to pay attention to the firms' complaints [...]. Unless the regulator can credibly threaten to make inefficient firms lose money [...], cost reduction cannot be enforced*".

[8]According to Hart [1995], contractual incompleteness appears when: "*the parties would like to add contingent clauses, but are prevented from doing so by the fact that the state of nature cannot be verified (or because states are too expensive to describe ex ante).*"

A rigid contract, where no renegotiation is expected. This does not mean that the regulator is able to commit to 100% that no renegotiation will occur. Indeed, as Athias and Saussier [2007] noted in the case of toll infrastructure concession contracts, " *When parties sign a rigid contract, there is always a risk that this contract will not be applied ex post and will be renegotiated [...]*". We can be in a situation in which (1) the regulator chooses a credible rigid contract, making it possible to provide strong incentives to regulated firms ; (2) the regulator chooses a rigid contract, but the regulated firms anticipate that the rules of the game could be still modified during the regulatory lag. It decreases or even eliminates the incentives provided to the firms that can receive rents from renegotiation. The rigid contract becomes more or less credible, according to the probability of renegotiation (i.e. depending on the regulator's ability to face endogenous and exogenous pressures).
To avoid problems related to the renegotiation of a rigid contract, a rational regulator may take the renegotiation probability into account, by choosing instead:

A contract that compensates the firms' losses, so that the ex post profits are never negative and no renegotiation occurs. This type of contract approaches the methods of "assisted benchmarking" and "sunshine regulation" previously described. The firms are not penalized for bad relative performances and there is no risk of ex post negative profits with these non constricting methods. However, the regulator faces all the risks, that is all the more expensive than the cost of public funds is high.

In order to take a limited commitment into account, while limiting the costs for the regulator, the contracting parties may choose a flexible contract. Indeed, as Athias and Saussier [2007] noted, a rigid contract which will be renegotiated leads to the case of an initial flexible agreement. The parties plan to renegotiate some contractual terms once uncertainty is revealed. The regulator knows that he can make errors by setting certain criteria *ex ante*. For instance, if a firm cannot reach its contractual objectives, there are several interpretations. This company can have provided insufficient "efforts" (in terms of investments for instance), but it can also be a forcecast error. A relatively weak performance can be due to the fact that the volume of activity is below the expected activity. A flexible contract makes it possible to avoid the maladaptation costs associated with rigid contracts.

Regarding the implementation of yardstick competition, we observe that rigid contracts are rare. On the one hand, renegotiation may occur, and on the other hand, the contractual choices lack incentive.

We show that the introduction of a limited regulatory commitment creates a trade-off in terms of contractual design and leads to potential renegotiation of yardstick contracts. Section 2 analyzes the impact of a limited commitment on the efficiency of yardstick competition, resulting from the introduction of a likelihood of renegotiation. We determine whether there is an optimal level of rigidity for yardstick contracts, or in other words, whether there is an optimal level of renegotiation. We use the models developed by Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008]. Their works focus on the enforcement problems with an individual incentive regulation. We apply these models to the case of yardstick competition. We show that the choice of the contractual design depends on the efficiency (or the cost) of renegotiation, the cost of public funds as well as the regulator's ability to manage endogenous and exogenous pressures (i.e. the probability that a rigid contract is renegotiated). Section 3 discusses the results of our model and the practical implications of our propositions. Section 4 concludes.

2 The model

The concept of yardstick competition was initially developed by Shleifer [1985][9]. The works dealing with this regulatory mode implicitly assume that, *ex post*, the regulator will systematically apply the price rule announced *ex ante*. No renegotiation is expected *ex ante*, and firms anticipate that the regulatory rule will not be changed during the regulatory lag, whatever the future contingencies. Similarly, neither strategic behaviour nor external shocks can modify this initial rule. Therefore, the regulator must be able to commit not to change the regulatory rules, without errors. Generally, to reach the first best with yardstick competition, it is necessary that the regulator be able to commit to applying prices and transfers according to an *ex ante* fixed rule, and that, *ex post*, the regulated firms believe that this rule will be applied.

Sections 2.1 and 2.2 introduce the variables of our model as well as its timing. Section 2.3 analyses a model of yardstick competition in which the regulator is assumed to be perfectly able to commit not to renegotiate, and thus where there are no enforcement difficulties. We assume that the regulated firms face an exogenous shock that is realized ex post. It introduces heterogeneity between the local monopolies. We show that, for yardstick competition to be efficient, the regulator must be able to enforce negative ex post profits, and thus he must commit to let the firms go bankrupt. Therefore, we highlight the problems associated with the strong assumption of perfect regulatory commitment, which does not seem realistic insofar as yardstick competition is often implemented for the regulation of public services. Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008] stressed the enforcement difficulties that may occur with an individual incentive regulation. We use their work to introduce the variables relating to a limited regulatory commitment in our model of yardstick competition (section 2.4). Therefore, we show that (1) on the one hand, a limited regulatory commitment impacts choices in terms of contractual design; (2) on the other hand, the regulator should prefer one design rather than another depending on the institutional environment. In this context, we show that the models of yardstick competition studied so far, i.e. with a regulator who is perfectly able to commit not to renegotiate, are actually particular cases.

[9] In addition, Holmström [1982] proposed a yardstick competition mechanism in which he takes moral hazard into account, while Auriol and Laffont [1992] showed that with adverse selection problems, comparisons improve the information available to the regulator.

2.1 Technology and preferences

We assume that there are two risk neutral regional monopolies under the supervision of a regulator, which provide a public service. In each region, market demand is inelastic and, for simplicity reasons, we assume that there is a unit demand. Furthermore, we assume that the consumer surplus $S_i > 0$, $i = 1, 2$ is such that production is always desired[10]. Each region is being served by a local firm i, $i = 1; 2$ whose technology is characterized by the following cost function:

$$C_i = \beta + \varepsilon_i - e_i$$

Costs depend on an exogenous productivity parameter β_i which is a common variable[11], noted $\beta \in \{\underline{\beta}, \overline{\beta}\}$, with $\underline{\beta} < \overline{\beta}$, so that the productivity in the industry is higher when $\underline{\beta}$ is realized. Moreover, we assume that $Pr[\beta = \underline{\beta}] = \nu$.
ε_i is a shock that is realized ex post and is specific to each firm i. We assume that $\varepsilon_i \in \{\varepsilon^U, \varepsilon^F\}$, with $\varepsilon^U > 0$ and $\varepsilon^F < 0$[12]. We also assume that $Pr[\varepsilon_i = \varepsilon^F] = \omega$.
Therefore, during the operational phase of the project, some events having a negative or positive impact on the firms' ex post production costs may occur. This impact is specific to each firm i, which introduces a degree of heterogeneity between the regulated monopolies. However, the parties are not able to anticipate ex ante the realization of this shock, which does not seem unrealistic for the network industries that we study here[13].
When putting in an amount of effort e_i, the firms could bring down their costs. This effort involves, for instance, investments in research or improvements in the production management. However, efforts are costly in terms of disutility, noted $\varphi(e_i)$.
We assume:

$$\varphi(0) = 0 \qquad \varphi(e_i) > 0 \quad si \quad e_i > 0 \qquad \varphi'(e_i) > 0 \qquad \varphi''(e_i) > 0$$

Local monopolies are regulated by a regulatory authority. However, the regulator is in a position of informational asymmetry: he does not know the exact productivity level β_i nor he is able to monitor efforts e_i. He can only observe the realized cost of each firm C_i. He is, however, able to disaggregate the costs into their components through an adequately designed incentive contract.
In order to request the private information that exists on β, the regulator implements an information revelation mechanism. Appealing to the revelation principle, we could restrict our attention to direct revelation mechanisms, where the regulator commits to pay transfers and set a cost target according to the firms' direct reports on their β_i.
We assume that the regulator will totally compensate the firms for their production costs C_i, while at the same time make a net transfer t_i to each firm to serve the market[14]. Hence, we can write each firm's rent as:

$$U_i = t_i - \varphi(e_i) \qquad i = 1, 2$$

[10]This is not an unrealistic assumption, especially when dealing with industries which produce essential infrastructure goods such as gas, electricity, water...

[11]β can be considered as the global productivity level of the sector.

[12]ε^U represents an **unfavourable** shock to the firm, whereas ε^F is an ex post **favourable** shock.

[13]For instance, in the case of gas distribution, some incidents on the network could impact the ex post costs and could be difficult to anticipate.

[14]This is an accounting agreement normally adopted in the regulatory economics literature.

under the ex ante participation constraints[15]: $U_i \geq 0 \quad i = 1, 2$.
To finance the transfer t, the regulatory authority must raise taxes with a price of public funds[16] $1 + \lambda$ with $\lambda > 0$.
Hence, consumers' net utility is:

$$V = S - (1 + \lambda)\widehat{t} \qquad with \quad \widehat{t} = t + (\beta - e)$$

Assuming that the regulator seeks to maximize total social welfare, we have[17]:

$$W = \sum_i U_i + V$$

$$W = S - (1 + \lambda) \sum_i (\beta_i + \varepsilon_i - e_i + \varphi(e_i)) - \lambda \sum_i U_i \tag{1}$$

We are interested here in the enforcement problems of yardstick contracts. Laffont's [2003,2005] and Guasch, Laffont and Straub's [2006,2008] papers deal with individual incentive regulations. They show that the regulator faces enforcement difficulties when the firm i is inefficient ($\beta_i = \overline{\beta}$), because in equilibrium, its ex post profit is negative. However, these enforcement problems don't exist when the regulator decides to implement a yardstick competition, under the assumption that the firms are perfectly correlated. For instance, Chong and Huet [2006] and Chong [2006] showed that under certain conditions, a truthful reports is a (Bayesien-)Nash equilibrium, and ex post profits are never negative. More generally, Le Lannier [2008] shows that the enforcement difficulties encounterd with the individual incentive regulation (as developed by Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008]) disappear with yardstick competition. However, in reality, we notice that enforcement problems also exist in the case of yardstick competition and that renegotiation may occur. Hence, we assume that these enforcement difficulties may come from new information or exogenous shocks that occur ex post. These idiosyncratic shocks introduce a degree of specificity of the region i and therefore a degree of heterogeneity between the regulated firms. Auriol and Laffont [1992] and Auriol [1993,2000] analyzed the impact of heterogeneity in the case of yardstick competition. They consider that the firms have imperfectly correlated costs and they introduce ex ante shocks. Here, we take an ex post shock into account. It introduces enforcement difficulties in the regulatory contracts, which do not exist in previous works.

2.2 Timing of the model

In order to analyze the enforcement difficulties that may occur with yardstick competition, we use the timing of Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008].

1. The regulator offers the regulatory contract based on yardstick competition.

[15]Without loss of generality, we normalize the reservation utility to 0.

[16]See Laffont and Tirole [1993] for the concept of "shadow costs of public funds".

[17]See Laffont [2003,2005] or Guasch, Laffont and Straub [2006,2008] for calculation of the social welfare.

2. The firms accept or refuse the contract. If the firm refuses to participate in the market, it has a utility level U_1^0, which captures its outside option. We assume that $U_1^0 = 0$.

3. The firms observe the realized β and this is their private information.

4. The regulator performs benchmarking and the firms must report their type $\overline{\beta}$ or $\underline{\beta}$.

5. The firms choose an effort level e_i and an idiosyncratic shock ε_i is realized. As we previously noted, if this shock is null ($\varepsilon_i = 0$), then there is no enforcement problem since all the ex post profits are positive or null. Unlike the previous works, we assume that a shock is realized after the signature of the regulatory contract and the realization of β. We consider that a firm may undergo a positive or negative shock, like a incident on the network for instance, after the observation of the productivity level.

6. According to their reports, gross transfers are paid out to the firms as specified in the regulatory contract.

7. Renegotiation may occur when the ex post profit is negative, i.e. when an ex post unfavourable shock is realized.

2.3 Yardstick competition and perfect regulatory commitment

2.3.1 The complete information case

The first best situation is defined by a case of complete information between the contracting parties. The regulator can observe β and e_i. The regulator maximizes the social welfare and implements the solution of the following program:

$$\begin{cases} \max_{e_i, U_i} & S - (1+\lambda)\sum_i(\beta_i + \varepsilon_i - e_i + \varphi(e_i)) - \lambda \sum_i U_i \\ \text{s.c} & U_i \geq 0 \end{cases}$$

Hence, in this situation the optimal regulation satisfies the following constraints $\forall i = 1, 2$:

$$\begin{aligned} \varphi'(e^{\text{FI}}) &= 1 \\ U_i^{\text{FI}} &= 0 \end{aligned}$$

In the first best situation, the effort level is such that its marginal cost for the society (here, the disutility for the firm) is equal to its marginal benefice. Moreover, since the rents left to the firms are costly in terms of social welfare, the optimal regulation is such that the net transfer under the full information contract is set at $t^{FI} = \varphi(e^{FI})$ to accurately compensate the firms for their disutility of efforts. Allocation and production efficiency can be achieved, since the regulator shares the same information as the firms.

2.3.2 The informational asymmetric case

Now, the regulator can observe the firms' realized costs, but does not know the true value of β. Therefore, he cannot divide the ex post production costs and ensure that the firms realize the socially optimal effort. In order to implement his regulation policy, the regulator must request the information on β. Accordingly, the regulator can directly ask the firm i to report its type β_i. The regulator proposes certain transfers which depend on reports of the companies, in order to encourage them to reveal their private information. In our case, since the β_i are perfectly correlated between the firms[18], the direct revelation mechanism may be considered as a pair of contracts: $\{t(\tilde{\beta}_i; \tilde{\beta}_j, \beta), C(\tilde{\beta}_i; \tilde{\beta}_j, \beta)\}$.
$\tilde{\beta}_i$ is firm i's report on the industrywide productivity parameter. $C(\tilde{\beta}_i)$ is the cost target for report $\tilde{\beta}_i$. $t(\tilde{\beta}_i)$ is the transfers associated with report $\tilde{\beta}_i$.
Yardstick competition can then make it possible for the regulator to provide an incentive to the firms to reveal their private information[19]. In the event that the regulator does not know his asymmetric information position and proposes the full information contract, and that $\overline{\beta}$ is realized, it is straightforward to show that a regulated firm will have an incentive to truthfully report $\overline{\beta}$: cheating on that part of the regulator will leave the firm with negative rents. However, the firm will receive a positive rent if it reports $\overline{\beta}$ whereas $\underline{\beta}$ is realized.
Given that the productivity parameter is perfectly correlated, and that firms have no incentive to report $\underline{\beta}$ when the realized productivity parameter is $\overline{\beta}$, any incompatible reports will let the regulator know that: (1) the true realized productivity parameter is $\underline{\beta}$, and (2) the firm reporting $\overline{\beta}$ is lying.

For the firms to reveal their private information, the following incentive constraints must be satisfied[20]:

$$U_i(\underline{\beta}, \underline{\beta}, \underline{\beta}) = t_i(\underline{\beta}, \underline{\beta}, \underline{\beta}) - E_\varepsilon[\varphi(\underline{\beta} - C(\underline{\beta}, \underline{\beta}, \underline{\beta}))] \geq t_i(\overline{\beta}, \underline{\beta}, \underline{\beta}) - E_\varepsilon[\varphi(\underline{\beta} - C(\overline{\beta}, \underline{\beta}, \underline{\beta}))] \quad (2)$$

$$U_i(\overline{\beta}, \overline{\beta}, \overline{\beta}) = t_i(\overline{\beta}, \overline{\beta}, \overline{\beta}) - E_\varepsilon[\varphi(\overline{\beta} - C(\overline{\beta}, \overline{\beta}, \overline{\beta}))] \geq t_i(\underline{\beta}, \overline{\beta}, \overline{\beta}) - E_\varepsilon[\varphi(\overline{\beta} - C(\underline{\beta}, \overline{\beta}, \overline{\beta}))] \quad (3)$$

E_ε is the firm's expectation of ε_i. $U_i(\tilde{\beta}_i, \tilde{\beta}_j, \beta)$ is the firm i's profit when its reports $\tilde{\beta}_i$ whereas the firm j reports $\tilde{\beta}_j$ and β is realized, with : $\tilde{\beta}_i, \tilde{\beta}_j, \beta \in \{\underline{\beta}, \overline{\beta}\}$.

These constraints simply indicate that the regulation mode should be such that the company i has an interest in revealing its real private information, knowing that the company j has honestly revealed this information. This is the case if the utility of the firm i is higher if it honestly reveals its private information (knowing that the company $j = -i$ does) than in the opposite case. This perfect correlation of private information makes it possible for the regulator to obtain honest reports from firms without cost. Suppose that the firm's reports are incompatible and that the regulator refuses to pay a transfer to firms, i.e. $t(\underline{\beta}, \overline{\beta}) = t(\overline{\beta}, \underline{\beta}) = 0$ and that

[18] We assumed that $\beta_1 = \beta_2 = \beta$

[19] Chong and Huet [2006] and Chong [2006] describe how a regulator can detect incompatible reports.

[20] Here, we mobilize the concept of Nash-Bayesien solution.

each company expects that the other company will honestly reveal its private information. Then the firm that manipulates its report will have an ex post deficit. Therefore, in equilibrium, the firms report the true private information $\beta_i = \beta$. The incentive constraints are thus satisfied and the regulator is able to obtain private information without giving up any additional rents to firms, and thereby achieve the full information equilibrium.

Since the firm must accept or reject the contract before it knows its type (β), its participation constraint must be written ex ante:

$$\nu U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) + (1-\nu) U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \geq 0$$

Therefore, according to equation (1), with yardstick competition, the regulator will determine the regulatory contract such that the following program is maximized:

$$\left\{ \begin{array}{ll} \max\limits_{\substack{e_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta}),U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta}),\\ e_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta}),U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})}} & S - \nu[(1+\lambda)\sum_i(\underline{\beta} + \varepsilon_i - e_i + \varphi(e_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta})) \\ & -\lambda \sum_i U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta})] \\ & +(1-\nu)[(1+\lambda)\sum_i(\overline{\beta} + \varepsilon_i - e_i + \varphi(e_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})) \\ & -\lambda \sum_i U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})] \\ \text{s.c} & \nu U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) + (1-\nu) U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \geq 0 \end{array} \right. \quad (4)$$

To simplify calculations, we will note:

$$\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \widetilde{\beta}) = S - (1+\lambda)\sum_i(\beta_i + \varepsilon_i - e_i + \varphi(e_i)) \quad (5)$$

As in the case of full information, the regulator renders the ex ante participation constrainst binding. Moreover, the first best conditions show that the regulatory contract leads to:

$$\begin{aligned} \varphi'(e_i(\underline{\beta}, \underline{\beta}, \underline{\beta})) &= 1 \\ \varphi'(e_i(\overline{\beta}, \overline{\beta}, \overline{\beta})) &= 1 \end{aligned}$$

Therefore, the yardstick contract provides incentive to the firms to realize the socially optimal effort.

The transfers are thus such that:

$$\begin{aligned} t_i(\underline{\beta}, \underline{\beta}, \underline{\beta}) &= \omega\varphi(e(\underline{\beta}, \underline{\beta}, \underline{\beta}) + \varepsilon_i^F) + (1-\omega)\varphi(e(\underline{\beta}, \underline{\beta}, \underline{\beta}) + \varepsilon_i^U) \\ t_i(\overline{\beta}, \overline{\beta}, \overline{\beta}) &= \omega\varphi(e(\overline{\beta}, \overline{\beta}, \overline{\beta}) + \varepsilon_i^F) + (1-\omega)\varphi(e(\overline{\beta}, \overline{\beta}, \overline{\beta}) + \varepsilon_i^U) \end{aligned}$$

However, we note that the firms' ex post profits may be negative. Indeed, if ε_i^U is realized ex post, the firm i will have a utility such that:

$$\begin{aligned} U_i^{\varepsilon^U}(\underline{\beta}, \underline{\beta}, \underline{\beta}) &= \omega\varphi(e(\underline{\beta}, \underline{\beta}, \underline{\beta}) + \varepsilon_i^F) + (1-\omega)\varphi(e(\underline{\beta}, \underline{\beta}, \underline{\beta}) + \varepsilon_i^U)) - \varphi(e(\underline{\beta}, \underline{\beta}, \underline{\beta}) + \varepsilon_i^U) \\ &= \omega[\varphi(e(\underline{\beta}, \underline{\beta}, \underline{\beta}) + \varepsilon_i^F) - \varphi(e(\underline{\beta}, \underline{\beta}, \underline{\beta}) + \varepsilon_i^U)] < 0 \end{aligned}$$

$$
\begin{aligned}
U_i^{\varepsilon^U}(\overline{\beta},\overline{\beta},\overline{\beta}) &= \omega\varphi(e(\overline{\beta},\overline{\beta},\overline{\beta})+\varepsilon_i^F)+(1-\omega)\varphi(e(\overline{\beta},\overline{\beta},\overline{\beta})+\varepsilon_i^U))-\varphi(e(\overline{\beta},\overline{\beta},\overline{\beta})+\varepsilon_i^U) \\
&= \omega[\varphi(e(\overline{\beta},\overline{\beta},\overline{\beta})+\varepsilon_i^F)-\varphi(e(\overline{\beta},\overline{\beta},\overline{\beta})+\varepsilon_i^U)]<0
\end{aligned}
$$

Since $\varphi'(\cdot)>0$ and $\varepsilon^U>\varepsilon^F$, we have:

$$
\varphi(e(\underline{\beta},\underline{\beta},\underline{\beta})+\varepsilon_i^F)<\varphi(e(\underline{\beta},\underline{\beta},\underline{\beta})+\varepsilon_i^U)
$$

and

$$
\varphi(e(\overline{\beta},\overline{\beta},\overline{\beta})+\varepsilon_i^F)<\varphi(e(\overline{\beta},\overline{\beta},\overline{\beta})+\varepsilon_i^U)
$$

We have shown that when an unfavourable ex post shock makes an impact on the costs of regulated firms, the ex post profits are negative in equilibrium, despite the fact that firms have honestly disclosed their private information.
If we assume a perfect regulatory commitment, both positive[21] and negative ex post profits will be enforced. However, if we change this assumption, the regulator may have difficulty in enforcing the initial contract (and thus negative *ex post* profits). It introduces a probability of renegotiation of yardstick contracts.

Proposition 1 *Suppose that there are two symmetric firms ($\beta_1=\beta_2=\beta$) and that there is no ex post shock ($\varepsilon=0$). Yardstick competition prevents the problem of enforcement from occurring by use of an individual incentive regulation. However, when an ex post unfavourable shock occurs, the firms' ex post profits may be negative and enforcement difficulties appear with yardstick competition.*

2.4 Yardstick competition and limited regulatory commitment

2.4.1 Yardstick competition and enforcement difficulties

Generally, it is widely recognized that the regulatory authorities, like the State, have a limited ability to commit. The limited commitment may be due, on the one hand, to the regulator's ability to manage endogenous pressures and lobbying. This element represents, in some ways, the perception by regulated firms of the likelihood that the regulator changes the rules of the game during the regulatory lag. However, even if the regulator is able to commit not to renegotiate, he may still make mistakes when designing the yardstick contract. Therefore, the limited ability to commit may also be due to difficulties in managing uncertainty and environmental complexity. In other words, it is now the perception by the regulator of the likelihood of renegotiation, since he may himself anticipate that he may be wrong. He thus would be tempted to renegotiate the regulatory contract.

Once firm i discovers the type of the shock realized ex post and hence its rent, the firm may want to renege on the yardstick contract if its *ex post* profit is negative. In a country with strong institutions (a regulator with considerable powers, an efficient enforcement mechanism…), the contract is enforced in both states of nature $\underline{\beta}$ and

[21] The ex post profits will always be positive when a favourable shock is realized ex post. For instance, when $\underline{\beta}$ and ε^F are realized, the firm i's rent is such that:
$U_i^{\varepsilon^F}(\underline{\beta},\underline{\beta},\underline{\beta})=(1-\omega)\left[\varphi\left(e(\underline{\beta},\underline{\beta},\underline{\beta})+\varepsilon_i^U\right)-\varphi\left(e(\underline{\beta},\underline{\beta},\underline{\beta})+\varepsilon_i^F\right)\right]>0$

$\overline{\beta}$, whatever the reports of other regulated firms and the shock realized ex post. However, the regulator may anticipate that he will not be able to enforce a negative *ex post* utility, and ex post renegotiation may occur.
In this context, the regulator has the choice between different type of contractual designs:

A rigid contract where no renegotiation is expected *ex ante*. But it may still be renegotiated depending on a particular probability. Indeed, as noted by Athias and Saussier [2007], "*A more rigid contract is not a more complete (optimal) contract and thus a contract that is less probably renegotiated*";

A contract that compensates the firms' losses, so that the ex post profits are never negative and no renegotiation occurs[22];

A flexible contract that maintains incentives provided to firms, but expects renegotiation *ex ante*.

We analyze these different contractual designs and their impact in terms of social welfare.

2.4.2 Investments in an enforcement mechanism: a rigid contract

We assume here that the regulator has a limited ability to commit. Therefore, he will enforce *ex post* negative profits depending on a particular probability. With a probability $\mu(x)$, the regulator is nevertheless able to impose the implementation of the agreed upon contract. With probability $(1-\mu(x))$, the regulator is forced to accept a renegotiation. These probabilities depend on the expenses x incurred to finance the functioning of an efficient enforcement mechanism. $\mu(x)$ may be considered, as previously noted, as the regulator's ability to face endogenous and exogenous pressures.
We assume that:

$$\mu(0)=0 \qquad \lim_{x\to\infty}\mu(x)=1 \qquad \mu'(x)>0 \qquad \mu''(x)<0$$

With the yardstick competition models, no renegotiation will occur, since the regulator has a perfect ability to commit. The regulator is then always able to enforce a rigid and credible contract. If we change this assumption, then the regulator will have to invest in an enforcement mechanism if he wants to enforce a rigid contract that will be not renegotiated.
To model the renegotiation probability of yardstick contracts, we use, like Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008], the Nash bargaining solution, and we assume that renegotiation is costly (because it takes time). The cost of renegotiation is taken into account with $\delta \in]0,1]$. The higher δ, the more efficient

[22] According to Athias and Saussier [2007], "*In deciding how to design the contract, contracting parties face a choice between a flexible contract, in which parties plan to renegotiate price once uncertainty unfolds, and a rigid contract, in which parties cannot commit not to renegotiate but attempt to prevent renegotiation.*" In the case of yardstick competition, we introduce here another type of contractual design, in order to be able to explain the observations made concerning the concrete implementation of this regulatory mode.

(or less costly) renegotiation. Therefore, we assume that the *ex post* surplus depends on the efforts, the productivity of firms, the ex post shock but also on the cost and efficiency of renegotiation. When the regulator is unable to enforce the contract, the firm with a negative *ex post* profit receives a rent from the renegotiation of the rigid contract. It decreases the social welfare (See Annex A).

With equation (4), the social surplus associated with a rigid contract that can be renegotiated is:

$$W^R =$$
$$\nu\mu(x)\left[S-(1+\lambda)\textstyle\sum_i\left(\underline{\beta}+\varepsilon_i-e_i(\underline{\beta})+\varphi(e_i(\underline{\beta}))\right)-\lambda\sum_i U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})\right]$$
$$+\nu(1-\mu(x))\left[\delta\left(S-(1+\lambda)\textstyle\sum_i\left(\underline{\beta}+\varepsilon_i-e_i(\underline{\beta})+\varphi(e_i(\underline{\beta}))\right)\right)-\lambda\sum_i U_i^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})\right]$$
$$+(1-\nu)\mu(x)\left[S-(1+\lambda)\textstyle\sum_i\left(\overline{\beta}+\varepsilon_i-e_i(\overline{\beta})+\varphi(e_i(\overline{\beta}))\right)-\lambda\sum_i U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})\right]$$
$$+(1-\nu)(1-\mu(x))\left[\delta\left(S-(1+\lambda)\textstyle\sum_i\left(\overline{\beta}+\varepsilon_i-e_i(\overline{\beta})+\varphi(e_i(\overline{\beta}))\right)\right)-\lambda\sum_i U_i^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})\right]$$
$$-(1+\lambda)x$$

U_i^E is the rent that the firm receives from the renegotiation (See Annex A).

With equation (5), we can simplify this formula and the social surplus is then noted:

$$\begin{aligned}
&W^R = \\
&\nu\mu(x)\left[\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})-\lambda\textstyle\sum_i U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})\right] \\
&+\nu(1-\mu(x))\left[\delta\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})-\lambda\textstyle\sum_i U_i^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})\right] \\
&+(1-\nu)\mu(x)\left[\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})-\lambda\textstyle\sum_i U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})\right] \\
&+(1-\nu)(1-\mu(x))\left[\delta\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})-\lambda\textstyle\sum_i U_i^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})\right] \\
&-(1+\lambda)x
\end{aligned} \tag{6}$$

Where:
$\nu\mu(x)\,[.]$ represents the surplus when $\beta=\underline{\beta}$ and when the regulator enforces the rigid contract, despite the negative *ex post* utilities.
$\nu(1-\mu(x))\,[.]$ represents the surplus when $\beta=\underline{\beta}$ and when the rigid contract is renegotiated.
$(1-\nu)\mu(x)\,[.]$ represents the surplus when $\beta=\overline{\beta}$ and when the regulator enforces the rigid contract, despite the negative *ex post* utilities.

$(1-\nu)(1-\mu(x))\,[.]$ represents the surplus when $\beta = \overline{\beta}$ and when the rigid contract is renegotiated.
$(1+\lambda)x$ represents the cost of financing the enforcement mechanism.

Note that if $\mu(x) = 1$ (i.e. the rigid contract is not renegotiated), we find almost the same equation as equation (4), i.e. when the regulator has a perfect commitment. However, the social surplus decreases with the enforcement cost ($(1+\lambda)x$) that does not exist with a perfect regulatory commitment.

Maximizing the social surplus due to a rigid contract (equation (6)), compared to the investments in the enforcement mechanism, under the incentive constraints, we find x^* such that:

$$\frac{\partial W^R}{\partial x} = 0 \qquad \Leftrightarrow$$
$$\mu'(x^*) = \frac{1+\lambda}{\nu(1-\delta)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) + (1-\nu)(1-\delta)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})} \tag{7}$$

This equation measures the optimal level of investment in the enforcement mechanism when the regulator chooses to use a rigid yardstick contract. In other words, this equation measures the optimal probability of renegotiation of a rigid yardstick contract.

Hence, when the regulator invests in the enforcement mechanism, it increases the probability of enforcing the yardstick contract. Nevertheless, it does not eliminate the likelihood of renegotiation (except when $\mu(x) = 1$ and therefore $x \to \infty$). Some rents are left to the firms who renegotiate. In addition, the regulator faces renegotiation costs (when $\delta \neq 1$) and enforcement costs (when $x \neq 0$).
In order to avoid the case where the rigid contract is renegotiated, the regulator may choose other types of contractual designs, choosing not to invest in the enforcement mechanism (section 2.4.3). Therefore it may enable the reduction in costs associated with his limited commitment.

2.4.3 The regulator does not invest in the enforcement mechanism

The regulator may first choose to eliminate the likelihood of renegotiation (and therefore eliminate the renegotiation costs), without incurring an enforcement cost. However, with this option, the regulator commits to compensate the firms' deficit when ex post unfavourable shocks are realized, that is costly for the regulator. Second, to avoid this contract that is costly in terms of transfers paid to the firms, while taking his limited commitment into account, the regulator may choose not to limit the likelihood of renegotiation. In this context, the regulator expects that renegotiation will occur, through a flexible contract.

(*i*) The case of a contract that compensates the firms' deficit

Anticipating the outcome of the renegotiation of a rigid contract, the regulator modifies *ex ante* the contract he offers, by eliminating the probability of renegotiation.

Then, the regulator will choose a regulatory contract that maximizes the expected social welfare under the *ex post* participation constraints:

$$\underline{U}_i \geq 0 \qquad \overline{U}_i \geq 0 \qquad i = 1; 2$$

With $\underline{U}_i(\overline{U}_i)$, the modified rents once the possibility of renegotiation is taken into account by the regulator, and that $\underline{\beta}(\overline{\beta})$ is realized.
On the one hand, the regulated firm may be protected by "limited liability" (Guasch, Laffont and Straub [2006]). On the other hand, production may be sufficiently necessary, and the competitors may be few, so that the bankruptcy of a firm is not a possibility[23]. This additional *ex post* participation constraint induces that the regulator will compensate the firms' deficit when an ex post unfavourable shock is realized. This type of contractual design may correspond to certain applications of yardstick competition in the network industries ("*assisted benchmarking*" and "*sunshine regulation*"). These methods are less constricting for the regulated firms, since it limits the risks incurred by the regulated companies in case of bad relative performance.

According to equations (4) and (5), the regulator's program then becomes:

$$W^C = \nu \left[\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - \lambda \textstyle\sum_i \underline{U}_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta})\right] + (1-\nu)\left[\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - \lambda \textstyle\sum_i \overline{U}_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})\right] \tag{8}$$

s.t:

$$\nu \left[\underline{U}_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta})\right] + (1-\nu)\left[\overline{U}_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})\right] \geq 0 \tag{9}$$

$$\underline{U}_i \geq 0 \tag{10}$$

$$\overline{U}_i \geq 0 \tag{11}$$

(9) is the *ex ante* participation constraint in expected terms and including the possibility of renegotiation.
(10) and (11) are the *ex post* participation constraints.

Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008] consider that a firm may try to renegotiate the contract, when the level of its *ex post* utility after renegotiation is higher than the level of the utility specified in the initial contract ($\widetilde{U}_i^E > \widetilde{U}_i \geq 0$). We do not have this possibility in our model, because we made assumptions such that only the firms with a negative *ex post* profit will attempt to renegotiate the contract. Here, the regulator has taken this possibility into account by adding a positive *ex post* participation constraint. Therefore, there is no reason for *ex post* renegotiation to occur. We can assume that, within this framework,

[23]See Guasch, Laffont and Straub [2008]: "*We assume here that production is so valuable that shutdown of the inefficient type is not an interesting option*". These authors note that, in this case, the set of constraints is the same as if the contract was offered to the firm at the interim stage, i.e. once β is realized (See the Timing of the model in section 2.3).

firms will have more difficulty in forcing the regulator to renegotiate, since there is no longer a risk of bankruptcy. The regulator is thus less prone to endogenous and exogenous pressures that may lead him to renegotiate.

This choice of contractual design reduces the enforcement costs ($x = 0$), but creates additional costs due to the transfers paid to the firms in order to compensate their deficit (in case of ex post unfavourable shock). To avoid these types of costs, the regulator may choose to implement a flexible contract.

(ii) The flexible contract case

When a regulator chooses a flexible contract, he is not trying to avoid renegotiation. On the contrary, he expects it in the initial contract. As a result, he avoids the enforcement costs, while maintaining the incentives provided to regulated firms. The yardstick contract will be periodically renegotiated, according to the initial contract terms.

According to equations (4), (5) and Annex A, the regulator maximizes the following social surplus:

$$\begin{aligned} W^F = & \\ & \nu \left[\delta \varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - \lambda \sum_i U_i^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) \right] \\ & + (1-\nu) \left[\delta \varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - \lambda \sum_i U_i^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \right] \end{aligned} \tag{12}$$

Note that the flexible contract is identical to the rigid one (equation (6)) when $\mu(x) = 0$ and $x = 0$, since the regulator does not invest in the enforcement mechanism. When $x > 0$ et $\mu(x) = 0$, then the two surpluses are almost identical. Nevertheless, there are no longer enforcement costs with the flexible contract (measured by $(1+\lambda)x$), since the renegotiation is expected in the initial contract and the regulator does not invest to avoid it.

It may be difficult to determine whether regulators use flexible contracts. Nevertheless, with the analysis of the different contractual designs provided in this paper, we highlight the following idea: If the regulator is not sure that he will be able to enforce a rigid contract (that is expected in theory), then he should choose another contractual design. We note in practice, that regulators actually choose yardstick contracts that are less constricting for the regulated firms than rigid ones. But it is costly for the regulator in terms of transfers. Therefore, we assume the possibility of a flexible contract, that maintains the provision of incentives and takes limited commitment into account. More concretely, if the yardstick competition is used with a price cap, a flexible contract could result in a shorter regulatory lag[24], where price reviews are more frequent. Firms still have the incentive to increase their profits between two price reviews, even if the time to do so is reduced.

[24]These regulatory lags are often between 3 and 5 years long.

3 Discussion

In order to analyze the different contractual designs, we first compare the surplus previously analyzed. We show that some propositions made by Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008] are also true in the case of yardstick competition, but only under certain conditions that we will emphasize. We deduct from the extension of their model, certain implications in terms of the contractual design of yardstick competition.

3.1 Comparison of the contractual designs

3.1.1 The case of a rigid contract

According to equations (4) and (6), the loss of surplus due to the renegotiation of a rigid yardstick contract is:

$$\begin{aligned} & W - W^R = \\ & \nu(1-\mu(x))\left[(1-\delta)\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta}) + \lambda \textstyle\sum_i \left(U_i^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta}) - U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})\right)\right] \\ & +(1-\nu)(1-\mu(x))\left[(1-\delta)\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta}) + \lambda \textstyle\sum_i \left(U_i^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta}) - U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})\right)\right] \\ & +(1+\lambda)x \end{aligned} \tag{13}$$

With equation (13), we have:

$$\nu(1-\mu(x))\left[(1-\delta)\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})\right]$$

and

$$(1-\nu)(1-\mu(x))\left[(1-\delta)\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})\right]$$

that represent the costs due to the renegotiation of rigid yardstick contracts.
We also have:

$$U_i^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\widetilde{\beta}) - U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\widetilde{\beta}) \geq 0$$

because, otherwise, the company would not attempt to renegotiate the contract. This represents the rent left to the firms when the contract is renegotiated.
Furthermore:

$$(1+\lambda)x$$

represents the enforcement costs due to the fact that the regulator has a limited commitment and that he has to invest if he wants to enforce a rigid contract.

3.1.2 The case of a contract that compensates the firms' deficit

According to equations (4) and (8), the loss of surplus due to this type of contract is:

$$W - W^C =$$

$$\nu\lambda \sum_i \left[\underline{U}_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta})\right] + (1-\nu)\lambda \sum_i \left[\overline{U}_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})\right] \tag{14}$$

With $\widetilde{U}_i - U_i \geq 0$: the firms' rent avoids any renegotiation and financing of an enforcement mechanism.

3.1.3 The case of a flexible contract

According to equations (4) and (12), the loss of surplus due to the use of a flexible yardstick contract is:

$$W - W^F =$$

$$\nu \left[(1-\delta)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) + \lambda \sum_i \left(U_i^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta})\right)\right] \tag{15}$$

$$+(1-\nu) \left[(1-\delta)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) + \lambda \sum_i \left(U_i^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})\right)\right]$$

The loss of surplus is now linked to the renegotiation cost (δ), but there are no other costs related to the contract enforcement. In addition, this contract does not eliminate the incentives provided to the regulated companies.

3.2 Propositions

We have shown that the introduction of a limited regulatory commitment leads to a trade-off in terms of contractual design. We now analyze in which situation a regulator should choose a more flexible or rigid contract[25].

3.2.1 The regulator's ability to face endogenous and exogenous pressures

We defined $\mu(x)$ as the probability that the regulator will enforce a rigid yardstick contract. This variable may also be interpreted as the regulator's ability to face endogenous and exogenous pressures. More precisely, it can represent the regulator's ability to manage the uncertainty and the environmental complexity, or his ability not to make errors when designing a rigid yardstick contract. In this context, x represents the investment in the enforcement mechanism, but also the regulator's experiences for example. Indeed, a specialized and experienced regulator, using

[25] We do not retain the contract that compensates the firms' deficit. Indeed, this type of contract implies that the regulator must face all the risks, whereas we assumed that firms are risk-neutral. This type of contract is too costly (compared to other designs) since the regulator faces costs of public funds.

benchmarking tools and yardstick competition, will be better able to manage difficulties relating to the complexity of his activity sector, the endogenous pressures that come from the regulated firms, or the exogenous shocks that can occur. Thus, we can consider that a regulator will be all the more able to enforce the contract than he is able to manage the complexity of the environment, since he knows that there is a low probability that he will make errors when designing and applying the regulatory contract.

According to equation (6), we have:

$$\begin{aligned} &\tfrac{\partial(W^R)}{\partial x} = \\ &\nu\mu'(x)\left[(1-\delta)\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta}) + \lambda\textstyle\sum_i\left(U^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta}) - U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta})\right)\right] \\ &+(1-\nu)\mu'(x)\left[(1-\delta)\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta}) + \lambda\textstyle\sum_i\left(U^E(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta}) - U_i(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})\right)\right] \\ &-(1+\lambda) \end{aligned} \tag{16}$$

Hence, if:

$$\frac{\partial(W^R)}{\partial x} > 0$$

the higher x, the higher the surplus related to a rigid contract.
We deduce from it the following proposition:

Proposition 2 *The higher the level of investment in the enforcement mechanism, and thus the higher the regulator's ability to manage endogenous and exogenous pressures*[26]*, i.e. the higher the probability not to renegotiate a rigid contract, the more efficient the rigid contract.*

This proposition is intuitive, but it still depends on several assumptions:

Condition 1: the cost of public funds is limited.

$$\lambda < \frac{\mu'(x)\left[\nu\,(1-\delta)\,\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\underline{\beta}) + (1-\nu)(1-\delta)\varpi(\widetilde{\beta}_1,\widetilde{\beta}_2,\overline{\beta})\right] - 1}{1-\mu'(x)\left[\nu\sum_i\left(U^E(.)-U_i(.)\right) + (1-\nu)\sum_i\left(U^E(.)-U_i(.)\right)\right]}$$

Condition 2: the renegotiation is not perfectly efficient. There is a minimum cost of renegotiation.

$$\delta \neq 1$$

Condition 3: the renegotiation is socially costly in terms of rents left to the firms.

$$U_i^E > U_i$$

Condition 4: the maladaptation costs due to a rigid contract are limited.

[26] Indeed, we assume $\mu'(x) > 0$.

When these conditions are not realized, the flexible contract will be preferred, despite the regulator's high ability to face endogenous and exogenous pressures and hence the high probability of being able to enforce a rigid contract. This can be due first to an enforcement mechanism that is too expensive (condition 1). Second, the renegotiation may be so efficient and inexpensive in terms of rents that the regulator will have an interest in renegotiating, despite the initial investments made in the enforcement mechanism. These investments are unnecessary and the regulator will have an interest in choosing a flexible contract. Indeed, when $\delta = 1$ and $U_i^E = U_i$, we have:

$$\frac{\partial(W^R)}{\partial x} = -(1+\lambda) < 0$$

As Guasch, Laffont and Straub [2006] noted, "*If global social welfare is not reduced by renegotiation, building an enforcement institution has no purpose*" (conditions 2 and 3).

Lastly, we have not explicitly modeled maladaptation costs due to a rigid contract. Nevertheless, it is obvious that the flexible contract may avoid these costs, and may be preferred to a rigid contract when these costs are high, despite the high level of investments made in the enforcement mechanism (condition 4).

3.2.2 The efficiency of renegotiation

According to equation (6), we have:

$$\frac{\partial W^R}{\partial \delta} = [1-\mu(x)]\left[\nu\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) + (1-\nu)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})\right] \geq 0 \tag{17}$$

According to equation (12), we have:

$$\frac{\partial W^F}{\partial \delta} = \nu\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) + (1-\nu)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) > 0 \tag{18}$$

Similarly, with equation (7), we have:

$$\frac{\partial^2 \mu}{\partial x \partial \delta} = \frac{1}{(1-\delta)^2} \times \frac{(1+\lambda)}{\nu\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) + (1-\nu)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})} > 0 \tag{19}$$

Therefore:

1. The more efficient or the less costly renegotiation (δ higher), the lower the level of investment in the enforcement mechanism ($\mu'(x^*)$ higher and x^* smaller). More efficient renegotiation and more enforcement are substitute instruments.

2. Conversely, the more expensive renegotiation, the higher the investments in the enforcement mechanism, and the smaller the likelihood of renegotiation.

Proposition 3 *For $x > 0$ such that $\mu(x) > 0$, the more efficient (or the less costly) renegotiation, the smaller the interest in investing in the enforcement mechanism (equation (19)), and the more efficient the flexible contract compared to a rigid one (equations (17 and 18).*

Condition:
Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008] stressed this result in the case of the individual incentive regulation[27]. In the case of yardstick competition, this intuitive proposition assumes that the probability of not renegotiating a rigid contract is sufficiently high and that the regulator has a minimum ability of facing endogenous and exogenous pressures. Indeed, if $x = 0$ and $\mu(x) = 0$, then the rigid contract will be systematically renegotiated and the two types of contracts are similar.

3.2.3 The cost of public funds

According to equation (7), we have:

$$\frac{\partial^2 \mu}{\partial x \partial \lambda} = \frac{1}{\nu(1-\delta)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) + (1-\nu)(1-\delta)\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta})} > 0 \tag{20}$$

i.e. $\mu'(x)$ increases when the cost of public funds (λ) increases.

Proposition 4 *The higher the cost of public funds (λ higher), the smaller the level of investment in the enforcement mechanism (x^* smaller). However, the smaller x^*, the higher the probability that a rigid contract will be renegotiated. We deduce from this that the higher the cost of public funds, the more efficient a flexible contract, compared to a rigid one.*

However, this intuitive proposition is verified only for a minimum level of investment in the enforcement mechanism. According to equation (6), we have:

$$\begin{aligned} &\tfrac{\partial W^R}{\partial \lambda} = \\ &-\nu\mu(x) \sum U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - \nu(1-\mu(x)) \sum U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) \\ &-(1-\nu)\mu(x) \sum U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - (1-\nu)(1-\mu(x)) \sum U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \\ &-x \leq 0 \end{aligned} \tag{21}$$

Moreover, according to equation (12), we have:

$$\frac{\partial W^F}{\partial \lambda} = -\nu \sum U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - (1-\nu) \sum U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \leq 0 \tag{22}$$

(i) If $x = 0$ and $\mu(x) = 0$
This corresponds to the case where the rigid contract is systematically renegotiated. In this case, a variation in the cost of public funds has a similar (and negative) impact on the surpluses related to rigid and flexible contracts.

(ii) If $x \to +\infty$ and $\mu(x) = 1$
This corresponds to a rigid contract that is always enforced. Then, we have:

$$\frac{\partial W^R}{\partial \lambda} = -\nu \sum U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - (1-\nu) \sum U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - x < 0$$

[27] However, they do not explicitly take contractual design into account.

and we keep the equation (22).
Hence, when:

$$x > \nu \sum \left[U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) \right] + (1-\nu) \sum \left[U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \right] \tag{23}$$

then, the increase in the cost of public funds has a smaller impact on the surplus of the flexible contract compared to the rigid contract. Therefore, for this minimum amount of investment in the enforcement mechanism, the flexible contract should be preferred compared to the rigid one, when the cost of public funds is increasing.

When:

$$x < \nu \sum \left[U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) \right] + (1-\nu) \sum \left[U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \right]$$

the increase in the cost of public funds does not result in the preference of a flexible contract. The impact of this increase in cost is weak since the level of investment is low.
Therefore, for a minimum amount of investment in the enforcement mechanism, defined by the equation (23), the higher the cost of public funds, the lower the regulator's interest in attempting to resist endogenous and exogenous pressures, and the more efficient the flexible contract compared to the rigid one.

(iii) IF $x > 0$ AND $0 < \mu(x) < 1$
In this case, a rigid contract may be renegotiated, depending on the probability $\mu(x)$. Then, we have new conditions on the level of investment in order to satisfy our proposition.
Indeed, when:

$$x > \nu\mu(x) \sum \left[U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) \right] + (1-\nu)\mu(x) \sum \left[U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \right]$$

the increase in the cost of public funds results in the preference of a flexible contract.

When:

$$x < \nu\mu(x) \sum \left[U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \underline{\beta}) \right] + (1-\nu)\mu(x) \sum \left[U^E(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) - U_i(\widetilde{\beta}_1, \widetilde{\beta}_2, \overline{\beta}) \right]$$

the increase in the cost of public funds results in the preference of a rigid contract. The level of investment in the enforcement mechanism is low and the impact of an increase of the cost of public funds (on the surplus of a rigid contract) is not significant.

4 Conclusion

As shown by Joskow [2005], the application of incentive regulation is far more complex than what is foreseen *a priori*. Resorting only to the economic theory is not sufficient when we consider all the stakes linked to this specific type of regulation.

Therefore, he stresses that the practical implementation of incentive regulation often diverges from the theory.
The various applications of yardstick competition in network industries show a lack of consensus regarding the way this type of regulatory contract is designed and implemented. In addition, reality shows that yardstick contracts may be renegotiated. In order to explain these observations (which can not be included in the existing models on yardstick competition), we assume that the regulator has a limited commitment. This leads to a trade-off in terms of contractual design.
We show that taking a limited regulatory commitment into account does not prevent the implementation of yardstick competition, but requires an adaptation of the contractual design. In practice, we note that the regulators seem to choose less constricting yardstick contracts than what the theory demonstrates ("*assisted benchmarking*", "*sunshine regulation*"). To avoid it, we propose a third type of contractual design: a flexible contract that makes it possible to take the probability of renegotiation into account, without limiting incentives.
We have shown that the choice of the contractual design depends on the cost of public funds, the renegotiation efficiency and the probability that a rigid contract will be renegotiated (that is to say on the amount invested in the enforcement mechanism). These propositions are intuitive and, for some of them, they reflect the results of Laffont [2003,2005] and Guasch, Laffont and Straub [2006,2008]. However, we show that many conditions must be satisfied in order to verify these propositions in the case of yardstick competition.

We assumed that an enforcement mechanism is financed when a rigid contract is applied. It is advantageous to invest in this mechanism only when the social surplus obtained with the initial contract is larger than the one resulting from renegotiation or when the negotiation fails[28]. This enforcement mechanism is imperfect and its quality is defined by the equation (7).

Moreover, we consider that the regulatory commitment differs from one institutional context to another, and that these institutions impact the regulation mode that can be applied[29]. Generally, our variables could be linked to institutional factors according to each country.
As Guasch, Laffont and Straub [2006,2008] noted, contracts sometimes contain specific clauses meant to deal with the potential occurrence of renegotiation, as for example the existence of a formal set of arbitration rules in case of disputes. These arbitration rules are processes to help settle disputes, thereby making renegotiation less costly (i.e. increase δ). An increase in δ decreases the investments in the enforcement mechanism (lower x^*) and increases the probability of renegotiation of rigid yardstick contracts. Like Guasch, Laffont and Straub [2006,2008], we would thus expect that the existence of formal arbitration rules (higher δ) would increase

[28]For simplicity calculations, we have not taken this possibility into account in our model. See Guasch, Laffont and Straub [2006,2008] for the introduction of a probability of failure of renegotiation in the context of an individual incentive regulation.

[29]See Levy and Spiller [1994]: "*The country's institutional endowment, the character of distributive politics, and the nature of its regulatory governance structure all affect the potential for successful design of regulatory incentives*", p208.

the probability of renegotiation.
The renegotiation cost may also be linked to the functioning of the Courts. They may be more or less efficient in the resolution of disputes. This leads to various renegotiation costs (in terms of time for instance).
Furthermore, we saw that the probability of enforcing a rigid contract ($\mu(x)$) depends on the level of investment in the enforcement mechanism. Such investments may, first, depend on the financial resources allocated to the regulator, or his degree of autonomy and independence degree (in terms of budget, staff recruitment and so on.).
This variable may also be linked to the degree of corruption, as Guasch, Laffont and Straub [2006,2008] noted, or to the independence of the Courts[30] (For instance, the fact that the Courts do not always agree with one or the other contracting party.).
The probability of renegotiating a rigid contract may depend on the past experiences of the regulator. More regulatory experience in yardstick contract and in benchmarking tools will decrease the probability of renegotiation due to the obvious effect of greater expertise in contracting, and thus a lower probability of making mistakes.

These points (enforcement problems of yardstick contracts and choice of the contractual design) are not taken into account in the literature dealing with this mode of regulation. However, as regards concrete implementation made by regulators, it seems that they are key variables in understanding the reality of yardstick competition.

In this article, we considered the situation in which regulated firms may want to renegotiate the yardstick contract when an unfavourable ex post shock is realized and the firms' profits are negative. However, we notice that when the ex post shock is favourable for the firms, the companies have a positive ex post profit. Therefore, future works would take into account the fact that the regulator may want to renegotiate the yardstick contract, in order to capture a part of the rents left to the firms when a favourable ex post shock is realized.

[30]See Levy and Spiller [1994].

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A Annexes: Yardstick competition and the Nash bargaining solution

We assume that the firm i may want to renegotiate the yardstick contract if its *ex post* rent is negative. If the negotiation fails, we assume that the firm's utility is $U_i^0 = 0$ and that the regulator obtains a status quo payoff $W_0 = -R$. This can be interpreted as a loss of reputation or as the difficulty level to replace a firm if it goes bankrupt.

Equation (1) gave:

$$W = S - (1+\lambda)\sum_i(\beta_i + \varepsilon_i - e_i + \varphi(e_i)) - \lambda\sum_i U_i \qquad i = 1;2$$

According equation (5), we have:

$$\varpi(\widetilde{\beta}_i, \widetilde{\beta}_j, \beta) = S - (1+\lambda)\sum_i(\beta_i + \varepsilon_i - e_i + \varphi(e_i))$$

Therefore:

$$W = \varpi(\widetilde{\beta}_i, \widetilde{\beta}_j, \beta) - \lambda\sum_i U_i \tag{24}$$

The outcome of renegotiation solves[31]:

$$Max\left(U_i^E - U_i^0\right)\left(\delta\varpi(\widetilde{\beta}_i, \widetilde{\beta}_j, \beta) - \lambda U_i^E - W_0\right) \qquad i = 1;2 \tag{25}$$

We find:

$$U_i^E = \frac{\delta\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \beta) + R}{2\lambda} \qquad i = 1;2 \tag{26}$$

which represents the firm i's rent from renegotiation.

$$W^E = \frac{\delta\varpi(\widetilde{\beta}_1, \widetilde{\beta}_2, \beta) - R}{2} \tag{27}$$

which represents the social surplus when renegotiation occurs.

Note that the weaker the regulator's position in case of unsuccessful renegotiation (the higher R), the lower the social welfare. When the regulator is unable to enforce the contract, the firm having an *ex post* negative profit receives a rent from the renegotiation of the rigid contract. It reduces the social surplus.

[31] See Binmore, Rubinstein and Wolinsky [1986] for a detailed explanation of the renegotiation "à la Nash" and the form of our maximization function.