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"Highway to Sell"

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Working paper

HIGHWAY TO SELL[1]

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ABSTRACT. Motivated by the forthcoming terminations of most highways concessions in France, we propose a versatile model of dynamic regulation and contract renewals that describes a long-term relationship between the public authority and an incumbent operator with private information about its costs that may face potential entrants. We discuss various issues including the nature of discriminatory biases towards entrants, their consequences on investments, the public or private nature of the management of concessions, the role of the operator's financial constraints, the consequences of allotments. So doing, we isolate a few principles that should guide policy-makers when deciding upon concession renewals.

KEYWORDS. Procurement, concession contracts, contract renewal, highways, transportation, auctions, asymmetric information.

JEL CODES. D82, D86, L51, L91, L98.

1. INTRODUCTION

Due to the financial stakes involved and its fundamental role for growth and development, one of the most significant sectors in public procurement is the transportation sector, particularly when it comes to the national network of roads and highways. Over time and across the world, public services in this sector have been provided under a variety of contractual arrangements, ranging from pure public ownership to more modern forms of public-private partnerships.[1] To illustrate, historically, the construction and management of French highways have been carried out through concession contracts. Within this institutional framework, private operators were granted a (so-called) *public service delegation* to build and operate the infrastructure over a typically very long period; while construction and maintenance costs had to be covered by tolls directly paid by users. Between 1957 and 1971, seven major highway concession contracts turned out to be signed along those lines. Unlike more recent concession contracts, these older contracts were

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[1]Iossa and Martimort (2011).

not awarded through competitive bidding but rather negotiated by mutual agreement between the State and key players of the construction sector. Because these agreements were of very long duration, several rounds of renegotiations following unforeseen contingencies turned out to be necessary, for instance to undertake additional investments that could not have been figured out at the time of the initial contract design.[2] To avoid excessive toll increases, these additional works were mainly financed by extending the duration of the concessions. As a result, these historical contracts have been significantly extended since their inception. Initially ranging from 22 to 41 years, this duration has been approaching an average of 34 years.[3] This overall picture may have left observers and citizens with the impression that the private sector may have unduly benefited throughout the negotiation process and that these projects did not generate sufficient social value relative to the public funds invested. Indeed, the extension of concessions presents the same drawbacks as signing long-term contracts at the outset. It mechanically increases the likelihood of facing unforeseen situations and, consequently, the need for additional renegotiations, creating a vicious circle with no escape. Due to the continued pressure on public spending, French law n°2015-990 of August 6, 2015, on growth, economic activity, and equal economic opportunities, stipulated that it would no longer be possible, without legislative authorization, to finance operations on the concessionary highway network through extensions of the existing concession. In response, Article L. 122-4 of the Highway Code now states that the financing of additional works or asset improvements not initially planned *"can only be covered by an increase in toll rates."* As a result, between 2031 and 2036, the seven main concessions, representing more than 90% of the overall concessionary network, will expire. With the potential for large-scale reallocation at stake and the expected end life of many existing assets, the coming years will be decisive not only in terms of the renewal of those assets but also in terms of the accompanying possible changes in the institutional framework of French highway networks.

In those times of increasing pressure on public spending, awarding highway concessions at the lowest possible cost remains high on the public agenda. The key issue is to select the best concessionaires, with the primary objective of public authorities being to achieve the lowest procurement costs. To this end, competitive bidding procedures have appeared particularly appealing to regulators; especially in the French context.

As illustrated by the recent 2023 Report on Highway Concessions (France), relying more extensively on auction procedures is often perceived by practitioners and regulators as a way to overcome the various dilemmas that have affected existing contractual

[2] Arve and Martimort (2016) analyze how the possibility of such contractual add-ons alters long-term contracts. Arve and Martimort (2024) show how, by anticipating these potential add-ons, operators adjust their bidding behavior during the tendering stage. These authors pay particular attention to scenarios where operators face strong financial constraints.

[3] Engel et al. (2001) model how such contract extensions can help operators cope with demand uncertainty.

arrangements.[4] First, at the end of the current historical concessions, the geographical scope of the contracts could be reduced to promote competition and facilitate entry. Although highway infrastructure operations are, to some extent, characterized by economies of scale, and reducing lot sizes may require duplicating existing investments (related to control stations, traffic information centers, camera networks, toll systems, etc.) to ensure operational continuity, reducing the size of the networks would nonetheless help lower entry barriers, thereby increasing competitive intensity and the quality of bids. Second, and in the same vein, shorter contract durations than those granted to historical concessions are certainly appealing to limit the need for renegotiations. Third, concession auctions should be designed to avoid granting incumbent concessionaires an undue advantage.

The goal of this paper is to understand how to design the best mechanism to renew or not a given concession to the incumbent operator. There might not be a single model to understand all the complex issues at stake. Yet, we try below to gather our findings as much as possible around a single model. This versatile approach allows us to gather in a unified framework results that might have been available under close-by forms in the existing literature but that remain scattered under different formulations making a synthetic vision hard to grasp.

There are many questions that a good design of a re-tendering procedure should try to solve. First, is there any benefit of competition at all? After all, why would not automatically renew concessions with the incumbent operator if the quality of services has been judged as convenient? And, if competition is the chosen option, is it the case that an incumbent operator and potential competing entrants should be treated similarly or should some sort of discrimination be preferred and, if so, why? What role could that discrimination play to secure investments? Second, political forces and sometimes public opinion have called for bringing back those services under the umbrella of public management and ownership. The argument goes on observing that the end of existing concessions could be the right time to consider this change in ownership structures. But overall, does the management model matter and, if yes, why and what are the determinants of the choice between management regimes? Third, and turning to financial constraints that put a significant burden not only on public finance but also on private companies nowadays, how should be designed the respective shares of the public and the private sectors in covering the large needs for investment? Finally, if competition is an option, how should regulators design allotments, i.e., split large existing concessions into smaller pieces, to create a more active playing field that could facilitate entry and what are the possible adverse effects that this competitive bias could have?

Organization. Section 2 reviews the relevant literature; spanning contributions from

[4] $https://www.autorite-transports.fr/wp-content/uploads/2023/01/0431-22_{a}rt_{r}ap-eco-grl-22.pdf$

general models of regulatory economics to more specific works dealing with transportation. Section 3 introduces a simple dynamic regulation model that describes a long-term relationship between the public authority and an incumbent operator with private information about its costs. The following sections show how putting an incumbent operator and a potential entrant in competition requires a differentiated treatment of these actors. Section 4 specifically discusses the benefits of competition between the incumbent operator and a potential competitor during a concession renewal auction. In Section 5, we examine the scenario of a return to direct public management of the infrastructure. Section 6 analyzes the various potential distortions in the investment choices made by the incumbent operator when concession renewal is not automatic. Section 7 explores how the financial constraints faced by incumbents may limit additional investments throughout the life of the contract. Section 8 also shows how the gradual revelation of uncertainty regarding future costs affects contract renewal. Section 9 examines the consequences of allotment, that is, the public authority's ability to divide an existing concession into smaller concessions, thereby facilitating market entry but limiting the benefits of economies of scale. Finally, Section 10 offers some concluding remarks and try to isolate a few principles that should guide policy-makers when deciding upon concession renewal.

2. RELATED LITERATURE

A growing body of the literature in transportation research has analyzed how to design and regulate highway concessions in a way that aligns private incentives with social efficiency, especially in settings characterized by long-term contracts, demand uncertainty, and budget constraints. Meng and Lu (2017) provide a recent survey of the literature on road infrastructure concessions and identify several key issues that shape both theoretical models and policy debates.

First, the literature traditionally emphasizes the balance between profitability and social welfare, typically coordinated through toll pricing, capacity, and contract duration (Lindsey and Verhoef, 2001; Tan and Yang, 2012; Song et al., 2017). Seminal results on the optimal congestion service along the lines of Spence (1975) (see also Xiao et al., 2007; Wu et al., 2011; Tan et al., 2010; Wang et al., 2013) and on the self-financing principle proposed by Mohring and Harwitz (1962) and Strotz (1964) (and further examined by Guo and Yang, 2009; Li and Sheng, 2014; Lu and Meng, 2018; Yang and Meng, 2002) underpin optimal contract design under complete information.

Second, considerable attention has been devoted to the optimal design of concession contracts, regarding the allocation of demand, construction, and operational risks between the public and private parties. For instance, Goncalves and Gomes (2012) suggest that the allocation of risks has direct effects on a concessionaire's incentives to maintain road quality because it depends critically on demand conditions. Low or quality-insensitive demand leads to early underinvestment, while high and quality-sensitive demand incentivizes early maintenance and better long-term road quality. Thus, the duration of the concession and the structure of demand should guide policy, including the use of minimum quality standards.

Given the prevalence of uncertainty, governments also often provide guarantees or adopt revenue-risk-sharing mechanisms to induce private participation (Engel et al., 2001; Feng et al., 2015; Meng and Lu, 2017; Song et al., 2018, Rouhani et al. 2018), and scholars have classified concession contracts into first-best and second-best regimes based on minimum profit constraints (Chen and Subprasom, 2007; Qiu and Wang, 2011; Ubbels and Verhoef, 2008). To illustrate, a major focus concerns the role of traffic forecasting and the challenge of managing demand uncertainty, which is central to determining the financial viability of concession projects. To mitigate demand risk while preserving incentives, Engel et al. (2001) introduced the concept of Least-Present-Value-of-Revenue (LPVR) auctions, which adjust contract duration endogenously to actual traffic flows. While attractive in theory, Vassallo (2010) points out that the choice of the discount rate embedded in such contracts plays a critical role in allocating risks and rewards, and that resistance from private operators often limits adoption due to the fact that these contracts cap the potential upside without offering a corresponding floor in case of losses.

Third, the presence of asymmetric information on costs, effort, and quality has prompted applications of incentives theory to public-private partnerships (see e.g. Martimort and Pouyet, 2008; Auriol and Picard, 2013), as well as numerous other applications in the transportation research community (see e.g. Feng et al., 2016; Shi et al., 2016; Lu and Meng, 2023). Among diverse issues, whether infrastructure should be privately or publicly operated remains a contested issue. Iossa et Martimort (2015) provide a normative framework comparing public and private provision under different regulatory and informational regimes. They argue that the nature of externalities, transaction costs, and the observability of effort are key determinants of the optimal institutional choice.

The literature also examines the financial structuring of such projects, including the use of guarantees and other mechanisms to enhance bankability and attract investors. Engel, Fischer and Galetovic (2022) provide extensive discussions of the role of private finance in concessions for public infrastructure and whether it can improve resource allocation.

Moreover, a significant body of research investigates how auction formats and bidding mechanisms influence competition, pricing, and the propensity for post-award renegotiation (see e.g. De Silva et al. (2003) on auctions for highway procurement).[5] Renegotiation itself is a recurrent theme, with studies emphasizing its frequency and potential for opportunistic behavior, calling for contractual safeguards, but also highlighting benefits in

[5]In the railways sector, Lalive et al. (2024) and Carnehl and Weiergraeber (2023) both offer interesting analysis based on reduced forms as well as on structural auction frameworks to investigate the design of procurement auctions. They find that using auctions, instead of directly awarding the contracts to the incumbent, substantially reduce prices, markups, and select more efficient suppliers, thereby reducing costs.

terms of adaptability over time (Beuve and Saussier, 2021). Another crucial issue is how the possibility of contract renegotiation shapes initial bidding behavior and long-term investment. Arve et Martimort (2016, 2024), already quoted above, show that renegotiation clauses, especially when coupled with tight financial constraints on operators, can induce inefficient underinvestment or excessive risk-taking.

Case studies like Bitran et al. (2013) further illustrate that re-municipalization, i.e. bringing services back under public control, is not uncommon, especially when political or social legitimacy is at stake. They analyze 61 road concession contracts in Chile, Colombia, and Peru between 1993 and 2010, revealing that over 540 renegotiations occurredmostly initiated by governments within three years of contract signing. Empirical evidence suggests State-led renegotiations were often opportunistic, especially during final years in office, leading to costlier modifications and a higher deferral of fiscal costs.

It appears that introducing competition in road maintenance procurement is challenging due to several practical constraints. Firstly, Wheat (2017) highlights that economies of scale play a key role, with small local authorities potentially saving up to 17% by sharing services. Secondly, geographical factors affect competition: the proximity to asphalt plants influences bidding costs, making some areas less competitive (Bajari et al., 2014; Krasnokutskaya, 2004). Thirdly, road contracts are often incomplete due to discrepancies between estimated and actual quantities, leading to costly renegotiations and possible opportunistic behavior (Bajari et al., 2014). The efficiency of competitive tendering thus relies heavily on contract design and management (Anastasopoulos et al., 2010). Empirical results are generally mixed. While privatization in Denmark and Norway has reduced costs (Blom-Hansen, 2003; Odeck, 2014; Arve et al., 2022), competition remains limited in some regions due to market structure (Yarmukhamedov et al., 2020).

3. A SIMPLE MODEL OF DYNAMIC REGULATION: THE RENT/EFFICIENCY TRADE-OFF

To start our analysis and familiarize readers with the key trade-off at stake, we first propose a simple model of a dynamic regulation for highway services. An incumbent operator provides one unit of highway service over two periods $T = 1, 2$. We denote by δ the discount rate, common to all parties. The cost incurred by the operator associated with providing the service remains constant over time and is represented by the parameter θ. We assume that this parameter is drawn from a probability distribution with density function f and cumulative distribution function F over the support $\Theta = \left[\underline{\theta}, \bar{\theta}\right]$. In line with the literature, we assume that the monotone hazard rate property holds; meaning that F/f is increasing.[6]

This cost of the service is assumed to be private information for the operator. The benefit of one unit of service that accrues to users (and, more broadly, to Society as a whole) is denoted by S, and we assume $S > \bar{\theta}$ to ensure that the service is always socially

[6] Bagnoli and Bergstrom (2006).

desirable in a full information scenario regarding the value of the operators costs.

The public authority proposes a compensation scheme, a long-term contract, to the operator that covers both periods. We will denote by p and p^* the compensations for the service offered for each of these periods. For simplicity, we will first assume that the authority can commit to this pricing scheme.

The operator is willing to provide the service as long as the discounted value of its profits is positive; a condition that we can express as follows:

$$p + \delta p^* = (1+\delta)\theta^* \geq (1+\delta)\theta. \tag{3.1}$$

This event thus has a probability given by

$$Proba\,\{p + \delta p^* \geq (1+\delta)\theta\} = F\left(\frac{p+\delta p^*}{1+\delta}\right).$$

The condition (3.1) defines a threshold for the cost value θ^* for which the operator is exactly indifferent between committing to produce the service or refusing to do so. More efficient operators (such as those with $\theta \leq \theta^*$) earn a positive rent from providing the service:

$$p + \delta p^* - (1+\delta)\theta = (1+\delta)(\theta^* - \theta) \geq 0.$$

Less efficient operators ($\theta \geq \theta^*$) prefer not to provide the service at such prices.

The public authority in charge of regulation, for its part, seeks to maximize the expected consumer surplus:[7]

$$((1+\delta)S - p - \delta p^*)F\left(\frac{p+\delta p^*}{1+\delta}\right). \tag{3.2}$$

For future reference, it may be useful to express this expected net surplus in terms of the marginal type θ^* as:

$$(1+\delta)(S-\theta^*)F\left(\theta^*\right). \tag{3.3}$$

This expression simply illustrates the usual trade-off between rent extraction and information rent that is familiar from the screening literature.[8]

The Rent/Efficiency. Maximizing the expression (3.3) leads to select an optimal threshold value θ^* that balances, on the one hand, the net consumer surplus for each

[7]We could follow Baron and Myerson (1982) and suppose that the regulator gives a positive weight (albeit less than one) to the operator's profit in its objectives with no changes in any of the insights below.

[8]See Laffont and Martimort (2002) for a textbook treatment.

period, $S - \theta^*$, which decreases as prices increase and when a less efficient operator is now likely to provide the service, and on the other hand, the probability $F(\theta^*)$ that the service will be provided, which increases at the same time.

The optimal critical value θ^*_m is then determined by the simple cut-off condition:

$$S = h(\theta^*_m) \tag{3.4}$$

where the term

$$h(\theta) = \theta + \frac{F(\theta)}{f(\theta)} \tag{3.5}$$

now designates the *virtual cost* of the incumbent operator.[9]

In fact, we know from the work of Baron and Myerson (1982), Laffont and Tirole (1986), and Laffont and Martimort (2002) that, in an asymmetric information context, the concept of cost must be replaced by that of the *virtual cost*. The latter takes into account the fact that the operator, holding private information, derives a rent from it, and this rent is costly for the Society. The virtual cost captures the informational cost induced by the operator's strategies of manipulating information. It is higher than the production cost alone and leads to distortions in the decision to award the concession to the operator. This notion of virtual cost is key to understand how competition, investment, and ownership structures might affect the choice of who should operate the assets at the renewal stage.

For the time being, we can summarize our results as follows.

Principle 1 Optimal Dynamic Regulation.

1. *Only the most efficient operators (with cost parameters such as* $\theta \leq \theta^*_m$*) provide the service and, in doing so, obtain an information rent* $U(\theta)$ *that is costly for the public authority:*

$$U(\theta) = (1+\delta)\max\{\theta^*_m - \theta; 0\} \geq 0 \tag{3.6}$$

2. *Only the discounted value of the payments* (p, p^*) *is entirely determined:*

$$p_m + \delta p^*_m = (1+\delta)\theta^*_m. \tag{3.7}$$

The first point has already been extensively discussed earlier. The trade-off between extracting information rent and seeking efficiency is a central theme of incentives regulation. Further on in this paper, we will examine how this trade-off is affected by concerns related to the investments that the operator can make or by the possibility for the public authority to call upon a potential competitor in the second period.

[9] The monotonicity assumption of the hazard rate, i.e., F/f increasing, leads to the existence of a unique and interior solution for equation (3.4) as long as $\underline{\theta} < S < \bar{\theta} + 1/f(\bar{\theta})$.

The second point is more specific to the context studied here. Only the intertemporal distribution of the payments remains indeterminate. the payments received by the operator is relevant to determining whether they will engage in providing the service. Also the nature of payment is irrelevant; it could be tolls paid for usage by customers or direct subsidies.

Among all possible payments profiles, the stationary profile of prices

$$p_m = p_m^* = \theta^*$$

may appear particularly attractive, at least on simplicity groups. Indeed, this profile would be optimal if the operator had some form of risk aversion and was concerned with smoothing the revenue from the service over time.[10]

Equipped with the characterization of the optimal dynamic regulation in a stationary environment with a unique service provider, we are now ready to understand the role of competition among potential service providers, the possible asymmetry between incumbents and entrants and the distortions on long-term investment that such competition may introduce. Of course, the consideration of all those additional ingredients boils down to fine modifications of the rent-efficiency trade-off stressed in this section. Analyzing those modifications is the purpose of the rest of the paper.

4. THE BENEFITS OF COMPETITION AT THE RENEWAL STAGE

The Chicago School approach to the regulation of a natural monopoly (Demsetz, 1968; Stigler, 1968; Posner, 1972) suggests that a monopoly franchise should be awarded to the firm that offers to provide the good under the best conditions. Competition among potential operators is sufficient to erode rents. The argument is very simple and can be easily exposed. The amount that an operator is willing to pay to secure the right to

[10]Let v denote the utility function of this operator. Let us assume that v is increasing ($v' > 0$) and strictly concave ($v'' < 0$), with a normalization such that $v(0) = 0$. The participation constraint (3.1) is now replaced by:

$$v(p - \theta) + \delta v(p^* - \theta) \geq 0. \tag{3.8}$$

The cut-off is now defined by the indifference condition:

$$v(p - \theta^*) + \delta v(p^* - \theta^*) \geq 0. \tag{3.9}$$

The public authority's problem is to maximize:

$$((1 + \delta)S - p - \delta p^*)F(\theta^*) \tag{3.10}$$

subject to the constraint (3.9). It is clear that the public authority must then choose a stationary payment flow in order to smooth the operator's income, thus obtaining:

$$p_m = p_m^* = \theta_m^*$$

where θ^* is again defined by (3.4).

provide the service is precisely the associated monopoly profit. If it were to propose a lower amount, a competitor would be able to outbid and seize the deal while still making positive net gains.

This solution is, of course, appealing, but it overlooks the informational problems inherent to these contractual situations. A given operator is likely to have a more accurate knowledge of its own costs than its competitors, especially if it has previously provided the service and the auction concerns the renewal of the concession as in the case of highways that is our focus here. Similarly, the incumbent operator and potential entrants may have different assessments of the demand for this same service or for any requested extension.[11] In a context of asymmetric information, operators are likely to derive an information rent from their private knowledge of their own costs or from their more or less accurate estimates of demand. Nevertheless, competition among operators to secure the right to provide the service remains a powerful incentive that reduces these rents.

Just like any other bilateral contract between private actors, concession auctions are likely to be repeated over time to adapt to new circumstances that were not contractually specified in advance or to encourage the entry of a competitor deemed more efficient and offering better terms. This entry is often accompanied by the transfer of physical assets (equipment) or human assets (workforce, know-how, and experience). In other words, the incumbent operator may have developed specific assets and skills that must be passed on to its successor if the latter wins the market.

To illustrate our point, let us now suppose that the public authority has at its disposal a potential competitor capable of operating the service in the second period. This new operator can provide the service at a cost c_e, which is drawn from a probability density function g and a cumulative distribution function G over the support $\mathcal{C}_e = [0, \bar{c}]$. For simplicity, we will first assume that this cost is common knowledge or at least that there is no asymmetry between the public authority and the entrant regarding their values. This assumption is justified if the operator is itself poorly informed, given that it has not yet operated the service. The parameter c_e is thus an expected cost whose exact realization will only be known later.

As soon as this entrant is called upon, the price at which the service is provided must cover the service costs without leaving any excess margin for this new entrant:

$$p_e = c_e. \tag{4.1}$$ [12]

Naturally, calling upon the entrant is only attractive if its costs remain below the value

[11] Engel et al. (2011) analyse how the length of highway franchises should be tailored to demand realizations to improve risk-sharing between operators and their regulator.

[12] Of course, a margin could be possible if c_e were private information of the operator. Costly information rent would once again have to be given up by the public authority.

of the service:

$$S \geq c_e. \tag{4.2}$$

Allocation rule and "bidding parity". The possibility of selecting the potential entrant in the second period is now a powerful incentive tool for the public authority in charge. Generally, the authority can offer the incumbent a dynamic contract of the form $(p, p^*(Q))$. The payments p and p^* continue to ensure the coverage of costs over the two periods. The novelty is that the second-period payment is now contingent on the probability Q with which the contract with the incumbent is renewed. This payment can be seen as compensation given to the incumbent for transferring the existing assets to a new operator[13] or as a penalty for breaking the long-term contract between the public authority and the incumbent operator in case of early termination.[14]

By allowing the incumbent to choose from the offered menu of options, the authority implicitly makes the incumbent reveal its costs. An efficient operator will then face a low probability of entry, while this probability will be higher for less efficient operators. Thus, the temptation for the incumbent operator to exaggerate its costs and demand higher payments diminishes under the threat of a higher probability of entry. Entry has a disciplinary role to facilitate cost revelation for the incumbent and thus it helps extracting rent.

If the costs of the incumbent operator were known, the decision to call on the entrant would always be efficient and would occur when

$$c_e \leq \theta. \tag{4.3}$$

This simple rule is referred to as *"bidding parity"* in the literature. Even though this concept must, of course, be reconsidered in the context of asymmetric information, it remains true the market should always be awarded to the entrant as long as their cost is sufficiently low. We write this condition as

$$c_e \leq \beta(\theta) \tag{4.4}$$

where $\beta(\theta)$ is a cut-off that must be optimally determined by the public authority. Note that the corresponding probability of entry is then expressed in terms of this cut-off as

$$Q(\theta) = 1 - G(\beta(\theta)). \tag{4.5}$$

The intertemporal profit of the incumbent operator is obtained when this operator

[13] Harstad and Crew (1999).
[14] Aghion and Bolton (1987).

"chooses" an entry probability that it deems optimal, given its knowledge of its own costs. The corresponding incentive constraint allows us to express these profits as follows:

$$U(\theta) = \max_{\hat{\theta}} p - \theta + \delta(p(Q(\hat{\theta})) - \theta(1 - Q(\hat{\theta}))). \tag{4.6}$$

Let θ^* denote the identity of the marginal incumbent operator, indifferent between operating the service over the two periods (with the prospect of not being renewed) or not participating at all. The information rent of an operator with lower costs ($\theta \leq \theta^*$) is then expressed as:

$$U(\theta) = \theta^* - \theta + \delta \int_{\theta}^{\theta^*} G(\beta(\tilde{\theta}))d\tilde{\theta}. \tag{4.7}$$

This expression of the incumbent's information rent is interpreted as the cost difference between the operator of type θ and the marginal operator θ^*. The intuition is as follows. In an asymmetric information setting, an efficient operator may behave like a less efficient operator, be compensated by the corresponding payments, but provide the service at a lower cost. It gains an information rent from this strategy.

The expression for the expected consumer surplus is obtained by subtracting the information rent of the incumbent operator from the total surplus. This surplus can thus be expressed as:

$$\int_0^{\theta^*} \left(S - h(\theta) + \delta \left((S - h(\theta))(1 - G(\beta(\theta))) + \int_0^{\beta(\theta)} (S - c_e) dG(c_e) \right) \right) dF(\theta) \tag{4.8}$$

The term $S - h(\theta)$ is familiar from our analysis in Section 4. It is the virtual surplus associated with one unit of the service when produced by the incumbent operator. This scenario here applies for the first period only. The discounted bracketed term in the integRAND is also a version of the virtual surplus but it now takes into account that the public authority may switch to the entrant according to the switching rule (4.4). This second expression captures the social value of competition.

The optimal allocation rule. The public authority must choose an intertemporal payment profile, or equivalently critical values θ^* and $\beta(\theta)$, that maximize the expression (4.8) for the net consumer surplus. It is thus led to choose:

$$\beta_c(\theta) \equiv h(\theta). \tag{4.9}$$

According to condition (4.9), the optimal decision consists of replacing the incumbent operator as soon as the entrant has a lower cost than the virtual cost of this operator.

Indeed, the probability of renewing the contract is:

$$Q(\theta) = 1 - G(h(\theta)), \tag{4.10}$$

which is a decreasing function of θ as long as the monotonicity property of the hazard rate is satisfied. Intuitively, more efficient incumbent operators are more often renewed.

Importantly, this condition implies that the entrant can be less efficient than the incumbent operator and still be chosen with a positive probability. It is possible for c_e to be greater than θ, and nevertheless, the authority might choose to opt for the entrant when:

$$\theta \leq c_e \leq h(\theta).$$

The allocation of the new concession contract is thus necessarily biased in favor of the entrant. The optimal auction for the second period thus has a discriminatory character, although this discriminatory character is less pronounced when the incumbent operator is more efficient (since then the virtual cost $h(\theta)$ is closer to the true cost θ).

Participation. Equipped with the rule (4.9), we can rewrite the expected surplus as

$$\int_0^{\theta^*} \left(S - h(\theta) + \delta\left((S - h(\theta))(1 - G(h(\theta))) + \int_0^{h(\theta)} (S - c_e)dG(c_e)\right)\right) dF(\theta)$$

or

$$\int_0^{\theta^*} \left(\underbrace{(1+\delta)(S - h(\theta))}_{\text{incumbent operator}} + \underbrace{\delta \int_0^{h(\theta)} dG(c_e))}_{\text{gains from entrant}} \right) dF(\theta). \tag{4.11}$$

This decomposition reveals two terms:

- The net surplus that consumers would obtain if the incumbent operator remained systematically in place for the second period

$$(1+\delta)(S - h(\theta));$$

- The gains obtained when the entrant is deemed more efficient, as Society can pay a lower net price by ending the relationship with the incumbent operator

$$\delta \int_0^{h(\theta^*)} G(c_e)dc_e.$$

The choice of the marginal incumbent operator θ^*, indifferent between participating or not upfront, is therefore such that

$$S + \frac{\delta}{1+\delta}\int_0^{h(\theta_c^*)} G(c_e)dc_e = h(\theta_c^*). \tag{4.12}$$

PRINCIPLE 2 BENEFITS OF COMPETITION.

1. EFFICIENCY GAINS. *The incumbent operator is more likely to operate the service than in the absence of competition:*

$$\theta_m^* \leq \theta_c^*. \tag{4.13}$$

2. REDUCTION OF INFORMATION RENT . *The incumbent operator receives an information rent as long as it is sufficiently efficient ($\theta \leq \theta_c^*$). This rent is smaller than it would have been in the absence of competition:*

$$\max\left\{\theta_c^* - \theta + \delta\int_\theta^{\theta_c^*}(1 - G(h(\tilde{\theta})))d\tilde{\theta}; 0\right\} \leq (1+\delta)\max\left\{\theta_c^* - \theta; 0\right\}. \tag{4.14}$$

Potential competition from an entrant works here through two channels, both of which affect the trade-off between efficiency and the extraction of information rent from the incumbent operator.

- *Efficiency Effect.* The comparison of (4.12) and (3.4) fshows that competition first increases the consumer surplus for the second period, since Society can pay a lower price for the service by turning to an efficient entrant. This increase in surplus is captured by the term

$$\frac{\delta}{1+\delta}\int_0^{h(\theta_c^*)} G(c_e)dc_e.$$

  Choosing a more attractive intertemporal payment profile for the incumbent operator, meaning selecting a higher cut-off θ_c^* than in the absence of competition, increases this net surplus. This creates a virtuous circle. In doing so, it also makes it more attractive for less efficient operators to provide the service.
- *Sampling Effect.* For a given value of θ^*, there is always a probability $G(h(\theta^*))$ of opting for the entrant in the second period. In this event, the incumbent operator no longer benefits from any information rent , which constitutes a striking contrast with the situation where this operator is not threatened by competition. This sampling effect is well known in the literature on static auctions.[15] It causes the incumbent operator to limit the exaggeration of its costs to ensure the renewal of the concession and thus leads to a better extraction of its information rent .

[15] Laffont and Tirole (1987), Auriol (1996).

Finally, let us note that the optimal allocation can be obtained using the following payment profile

$$p = \theta_c^*; \text{ and } p^*(Q) = \vartheta(Q)Q + \int_{\vartheta(Q)}^{\theta_c^*} (1 - G(h(\tilde{\theta})))d\tilde{\theta} \tag{4.15}$$

where $\vartheta(Q)$ corresponds to the type of the operator who is renewed with probability Q.[16] The first-period payment is a fixed payment whose virtue is to cover the costs of the marginal operator of type θ_c^*. In the second period, the payments are, as expected, contingent on the probability of renewing the incumbent operator.

Literature Review. In the case of concession renewal, the tender procedure is necessarily between asymmetric actors. The incumbent operator most certainly benefits from an informational advantage over potential competitors from having previously run the service in the past. Demski, Sappington, and Spiller (1987) propose a *"second sourcing"* model in which the buyer may choose the entrant rather than the incumbent. In Demski et al.'s model, the production costs of the incumbent and the entrant are drawn from asymmetric distributions. More precisely, the incumbent's cost distribution is assumed to stochastically dominate that of the entrant. In the model we study here, the entrant does not have any information rent because its cost parameter is known to the authority.

More generally, the consequences of potential asymmetries between participants in auctions are well known in static auction theory, with contributions from Myerson (1981) and McAfee and McMillan (1983) for optimal auctions, and Maskin and Riley (2000a, 2000b) for more specific formats like the first-price auction. These authors demonstrated how the optimal auction can sometimes rely on discriminatory practices, treating potential operators differently if they are not symmetric. When the incumbent operator is the most efficient in producing the service at a low cost (referred to as a *strong bidder* in the literature), it is preferable to bias the optimal auction towards the entrant (referred to as a *weak bidder*). The intuition behind this might seem paradoxical. The fact that the *strong bidder* is statistically more efficient allows it to propose the service provision while taking a larger margin without being genuinely threatened by the price offered by the *weak bidder*. The *strong bidder* thus extracts a significant information rent , leading to a reduction in the consumer surplus. Biasing the auction towards the *weak bidder* is, therefore, a way for the public authority to extract information rents.[17]

An Informed Entrant. Now, suppose that the entrant also has private knowledge of

[16] Formally, $\vartheta(Q)$ is defined as such that $Q = 1 - G(h(\vartheta(Q)))$.

[17] Note, however, that Jehiel and Lamy (2015) also show that optimal discrimination takes a completely different form when the decision to allow a new operator to enter is endogenous. The equilibrium that minimizes expected payments in fact stipulates that no discrimination should be applied to entrants, regardless of their ex ante characteristics. Furthermore, operators who always participate must be discriminated against and entrants must be favored, regardless of their strength.

its costs. The logic of the previous arguments applies *mutatis mutandis*. To do so, we simply define the virtual cost of the entrant as

$$\varphi(c) = c + \frac{G(c)}{g(c)}. \tag{4.16}$$

This virtual cost is now distributed according to the distribution function

$$\tilde{G}(\varphi(c)) \equiv G(c).$$

The allocation rule for the concession then consists of awarding it to the entrant when its virtual cost is lower than that of the incumbent operator and, of course, when it is below the value of the service, i.e., when

$$\min\{S, h(\theta)\} \geq \varphi(c). \tag{4.17}$$

If the cost distributions for the entrant and the incumbent operator are identical, the allocation rule is efficient, and the entrant is selected only if its cost is lower than that of the incumbent, i.e., when

$$\theta \geq c \text{ and } S \geq \varphi(c). \tag{4.18}$$

We are therefore led to conclude.

Principle 3 Informed Entrant.

1. *When the entrant is also privately informed, the bias in its favor is less advantageous compared to when its costs are known.*
2. *Conditional on the service provision being deemed attractive, there is no bias in favor of the entrant when the distribution of its possible costs is identical to that of the incumbent operator.*

5. WHAT ABOUT A RETURN TO PUBLIC MANAGEMENT?

In the French context, recent political discourses have shown that governments may be inclined to nationalize concessions upon their renewal, or at least to use that threat in view of improving bargaining positions. Beyond short-term political concerns and rhetorical effects, economic theory helps to understand the potential consequences of such nationalization.

First and foremost, it may be useful to recall in our context the *Neutrality Theorem* due to Sappington and Stiglitz (1987). This *Theorem* demonstrates that, under certain conditions, public management cannot improve on private production.The argument starts by observing that both modes of management, private and public, involve a significant delegation of authority and that such delegation comes with agency costs. There is equivalence between management structures when those modes of delegation entails the same agency costs. The corresponding conditions maybe quite stringent, and it is easy to find situations where one or the other management mode is preferable.[18] One possible difference between the two modes lies in the transaction costs the government faces when attempting to interfere in delegated production activities. This intervention is generally less costly in the case of public ownership since it requires only to exert authority while interference may be more complex for a private firm since it might require changes on regulation that would require changing legislation. The increased ease of intervention under public management may be attractive; however, the fact that a promise of non-intervention ex post is more credible under private management can also have beneficial incentive effects from an ex ante viewpoint. This argument, inspired by Williamson (1996)'s celebrated theory of *selective intervention*, was developed in a bare-bone model of vertical integration by Riordan (1990). The terms of the trade-off are well known. On the one hand, public management likely allows the public owner to learn the operator's costs, which means a better extraction of the operator's information rent. On the other hand, committing to forgoing such information rent to a private operator certainly improves its incentives to perform invest that may increase those rents.

To illustrate this trade-off more formally, let us first assume that the distribution of the entrants costs $G(\cdot|i_e)$ depends on its investment i_e. We will assume that greater investment improves this distribution in the sense of first-order stochastic dominance, shifting the distribution toward lower cost values:

$$G_{i_e}(\cdot|i_e) \geq 0.$$

- *Public Management.* Under public management, the entrants cost c_e is known to the government, and there is no need to forgo any information rent to this public operator. The decision to opt for public management is dictated by rule (4.9). Recall that this decision is then significantly biased towards the entrant.
- *Private Management.* The cost c_e then remains private information of the entrant, who benefits from the associated information rent . The allocation rule is determined by (4.17); it is therefore less biased towards the entrant. This rule also allows us to write the expected information rent of the entrant as:

$$(5.1) \qquad \int_0^{\bar{c}} G(c|i_e) \left(\int_\Theta Proba\{\varphi(c, i_e^*) \leq h(\theta)\} dF(\theta) \right) dc > 0.$$

The entrant has thus some incentives to invest since it is now possible for the

[18] Martimort (2006) provides an extensive overviews of those conditions.

marginal benefit of the investment to exceed its marginal cost:

$$\int_0^{\bar{c}} G_{i_e}(c|i_e)\left(\int_\Theta Proba\{\varphi(c,i_e^*)\leq h(\theta)\}dF(\theta)\right)dc > 1. \quad (5.2)$$

Principle 4 Public Management versus Private Management. *Public management of concessions leads to biases towards the public operator but zero investment. Private management leads to lesser biases but also ensure a positive investment.*

Overall, whether public or private management is preferred depends on the magnitudes of those two effects. It is worth stressing that public authorities might find pretty difficult to assess those magnitudes; one possible reason is might be the non-verifiability of the cost-shifting investment.

6. HOW TO DESIGN SAFEGUARDS FOR INCUMBENT OPERATOR'S INVESTMENTS?

In a series of significant works, Williamson (1985, 1996) highlighted the problems associated with the potential transfer of assets between the incumbent operator, who invested in these assets, and a new entrant who inherits their management once the concession is renewed. Capital, whether physical or, even more so, human, is not always easily transferable from one company to another. If the incumbent operator fully benefits from an investment i in terms of reducing its future costs, the entrant will only perceive a fraction ki (where $k \in [0,1]$) in case of concession attribution. Moreover, investments can either be easily verifiable by accessing the incumbent operator's accounting records, which allows for the determination of the financial burden on the company, or more difficult to quantify, as is the case when these investments are intangible in nature (learning, know-how, etc.).

Verifiable Investments. Let us first assume that investments are verifiable and that their level can be monitored and contracted upon by the public authority. The public authority can therefore require the operator to invest at a level it deems socially optimal, and this calculation must, of course, take into account the deadweight losses associated with the non-transferability of investments to a new operator at the time of contract renewal.

These investments affect the incumbent operator's costs in an a priori ambiguous manner. They immediately increase costs through the addition of a financial burden, but they also have positive value as they can reduce future costs or improve service quality.

For simplicity, we will assume that the financial cost of an investment i, incurred in the first period before the parameter θ is known, is $\frac{i^2}{2}$, but that this investment also reduces second-period costs by an amount i if the operator benefits from the renewal of the concession and by a lesser amount si (where $s \in (0,1)$) if this concession is transferred to the entrant.

The expression of the expected consumer surplus is obtained by modifying (4.11) to account for the costs and benefits of investments. This surplus is thus written as

(6.1)
$$\int_0^{\theta^*}\left(S-h(\theta)-\frac{i^2}{2}+\delta\left((S-h(\theta)+i)(1-G(\beta(\theta)))+\int_0^{\beta(\theta)}(S-c_e+si)dG(c_e)\right)\right)dF(\theta).$$

Maximizing this expression leads to choosing a concession attribution rule to the entrant, which is also modified by the presence of investments. Entry is now more costly as it is accompanied by a loss of asset value. We obtain here

$$\beta(\theta)\equiv h(\theta)-(1-s)i\leq h(\theta). \tag{6.2}$$

It is therefore the comparison between the virtual cost of the incumbent operator and the total cost of the entrant, including losses in transferring asset, that is relevant here.

The optimal investment is obtained by arbitrating between the first-period financial costs and the second-period benefits, even though the latter remain partial in the event of a concession transfer to the entrant. We derive the following expression for the optimal investment:

$$i_v=\delta\mathbb{E}_\theta\left(1-\underbrace{(1-s)G(h(\theta)+(1-s)i_v)}_{\text{Imperfect Transferability}}|\theta\leq\theta^*\right)<\delta=i^o. \tag{6.3}$$

In the scenario where the incumbent operator is always reappointed, all the benefits of the initial investment would be reflected in the second-period costs. The optimal investment i^o would depend solely on the actors' preferences for the future, and thus on the interest rate. The benefit of transferring assets to a more efficient new entrant is accompanied by a deadweight loss that leads to reduced investments, especially as the probability of transfer increases.

We can now turn to determining the marginal incumbent operator, who is indifferent between committing to providing the service and not doing so. Maximizing the expected surplus (6.3) with respect to θ^* then leads to choosing a cut-off θ_v such that:

$$\underbrace{S-\frac{(i_v)^2}{2(1+\delta)}+\frac{\delta}{1+\delta}\left(1-(1-s)G(h(\theta_v)-(1-s)i_v)\right)i_v}_{\text{Net Investment Value}} \tag{6.4}$$

$$+ \quad \underbrace{\frac{\delta}{1+\delta}\int_0^{h(\theta_v)-(1-s)i_v} G(c)dc}_{\text{Efficiency Gains with the Entrant}} \quad = h(\theta_v).$$

This expression is similar to (4.12). However, it differs by, on the one hand, a reduction in the probability of non-renewal of the concession with the incumbent operator, and on the other hand, the consideration of the net investment value in determining the cut-off θ_v. These two effects reinforce each other and may lead to selecting a possibly less efficient operator in the first period.

We will summarize our results with a few simple principles.

Principle 5 Verifiable Investments.

1. *The fact that assets can only be imperfectly transferred leads to biases in concession renewals that should favor the incumbent operator.*
2. *Investments are lower than their value in the absence of a possible transfer to the entrant.*
3. *The prospect of having to invest biases first-period decisions in favor of less efficient incumbent operators.*

Non-Verifiable Investments. Now suppose that investments are non-verifiable. The public authority can no longer dictate their value. The only incentive tool remains the contract, and thus the dynamic flow of payments and the probability of concession renewal. The non-verifiability of investments then leads to a hold-up problem.[19] The public authority takes past investments as given and adjusts its decision to choose an entrant based solely on ex post cost considerations. At the same time, the investment is chosen by the incumbent operator, knowing that it will not influence the public authority's allocation rule.

The entrant's selection rule now takes the form:

$$\beta(\theta) \equiv h(\theta) - (1-s)i_{nv} \tag{6.5}$$

where i_{nv} is the investment by the incumbent operator, which is perfectly anticipated at equilibrium by the public authority.

At equilibrium, expectations are correct, and the investment i_{nv} is chosen by the incumbent operator to maximize its expected profit:

$$i_{nv} = \arg\max_i -\frac{i^2}{2} + i\delta\mathbb{E}_\theta\left(1 - G(h(\theta) + (1-s)i_{nv})|\theta \le \theta^*_{nv}\right),$$

[19]A phenomenon highlighted by Harstad and Crew (1999).

or alternatively:

$$i_{nv} = \delta \mathbb{E}_\theta \left(1 - G(h(\theta) + (1-s)i_{nv}) | \theta \leq \theta^*\right). \tag{6.6}$$

Compared to the condition specifying optimal investment (6.3) when it is verifiable, this condition shows that the incumbent operator under-invests due to the potential hold-up of these investments when the public authority opts for the entrant.

As a consequence, condition (8.4) leads the public authority to opt more often for the entrant than if investments were verifiable, further exacerbating the hold-up problem.

Principle 6 Non-Verifiable Investments.

1. *The non-verifiability of assets leads the incumbent operator to under-invest.*
2. *The decision to opt for the entrant is more likely than if investments were verifiable.*

Literature Review. Laffont and Tirole (1988) were the first to investigate bidding parity in an asymmetric information context. They consider a more complex model than the one we developed here since it entails both adverse selection (the operator's innate cost is private information) and moral hazard (the operator may undertake a cost-reducing effort that is non-verifiable). They are mostly interested in the dynamics of the slope of the incentive schemes and whether the incumbent operator should be paid under a fixed-price or a cost-plus contract. This question was also addressed in Gagnepain et al. (2013). Although their model does not model explicitly competition for renewal, those authors show that renegotiation of long-term concessions tilts the rent/efficiency trade-off towards efficiency and thus raises cost-reducing investments even when non-observable. The latter form is certainly preferred when investments are observable and their cost can be reimbursed upon. To the extent that switching to an entrant has the features of splitting the intertemporal service between operators, the above model is also related to the literature on the (potential) benefits of second sourcing in a procurement context. On this front, Anton and Yao (1989) argued that a buyer may want to split awards between competing service providers to foster incentives to innovate while a winner-takes-it-all mechanism destroys such incentives. Instead, Riordan and Sappington (1989) demonstrated that the benefits of dual sourcing are limited.

7. Financial Constraints and Additional Services

Arve and Martimort (2024) consider an auction for the provision of a long-term basic service to which an additional infrastructure, with a priori uncertain costs, must later be added. Potential service providers, i.e., ex ante competitors, are symmetric and have private information about the costs they incur in providing the basic service. The company winning the auction is also responsible for implementing the additional element. The public authority finds itself ex post facing a monopoly; the other potential service providers lack the capacity or expertise to submit a credible bid for this additional infrastructure. In other words, and contrary to the scenario studied previously, the auction here precedes the monopoly situation.

To finance activities aimed at reducing the costs associated with this additional element, this ex-post monopoly company may need external financing. The fact that the cost reduction effort for providing this additional infrastructure is not verifiable creates a moral hazard problem vis--vis external financiers. This agency problem makes the profit function of the company for the second period concave. This concavity generates two important effects. Firstly, it makes postponing payments more attractive to facilitate the revelation of information about the cost of the basic service: a Revenue Effect. Secondly, the uncertainty regarding the cost of the additional element introduces an underlying risk that requires a risk premium: a Risk Effect. In this context, Arve and Martimort (2024) also characterize the optimal intertemporal structure of payments offered to the winning company.

THE MODEL. Let us consider an addition to an existing infrastructure. This additional project requires an investment amount denoted i. Even if the operator benefits from a fixed financial flow π associated with the revenues from the basic service, these gains may prove insufficient to cover the financing of this additional investment. This investment could be covered by public subsidies, but these subsidies are costly due to the existence of a positive public fund cost λ. Recourse to financial markets is therefore inevitable.

The additional project can be provided in a standard form or in a more innovative form whose value γ is positive. This improved version of the project is not obtained with certainty but only with a probability e, where e is a non-verifiable effort exerted by the operator. This effort is thus a moral hazard variable if we use the jargon of incentive theory.[20] The cost of the effort is denoted by $\psi(e)$ where the function ψ satisfies standard assumptions ($\psi(0) = 0$, $\psi' > 0$, $\psi'' > 0$). Inducing an effort level e in such a moral hazard context requires leaving an information rent $R(e) = e\psi'(e) - \psi(e)$ to the operator due to its financial constraints.

The presence of moral hazard makes external finance costly.[21] Projects with associated agency costs that turn out to be too expensive are then abandoned. Arve and Martimort (2004) thus show that the operator's net gains are captured through an indirect utility function v which is written as follows:

$$v(\pi) = \begin{cases} \pi \text{ for } \pi \in [0, \hat{\pi}), \\ \pi - I + \gamma e^{sb}(\pi) - \psi(e^{sb}(\pi)) = R(e^{sb}(\pi)) \text{ for } \pi \in [\hat{\pi}, I), \\ \pi - I + R(e^{fb}) \text{ for } \pi \geq I. \end{cases}$$

[20] Laffont and Martimort (2002, Chapter 4).

[21] Jensen and Meckling (1976), Holmström and Tirole (1997), Tirole (2010).

The effort $e^{sb}(\pi) \leq e^{fb}$ is a second-best effort level reached when the operator can use a stable financial flow π associated with the revenues from the basic service as collateral in its contractual relationship with its financiers.

This expression shows that these flows must guarantee a minimum profit level $\hat{\pi}$ for external finance to find its participation in the project attractive. The concavity of v beyond this minimum scale shows the reduction of agency costs when a larger fraction of the additional project can be financed based on these guaranteed flows, thus reducing the reliance on financial markets.

Below this minimal level, innovative projects are simply not funded. This property introduces a fundamental non-concavity in the expression of the gain function v. Furthermore, note the existence of a "Multiplier Effect": An additional euro in terms of stable flow for the operator results in a marginal net gain greater than one (formally, $v'(\pi) > 1$ for $\pi > \hat{\pi}$).

Optimal Dynamic Regulation. In this context where the second-period utility function is endogenously derived from the existing financial constrait, the intertemporal participation constraint of the marginal operator θ^*, who is compensated for the service by prices p and p^* in each period, is written as follows:

$$p - \theta^* + \delta v(p^* - \theta^*) = 0. \tag{7.1}$$

As previously, only operators for whom the marginal cost of the service θ is below the critical value θ^* accept such dynamic regulation.

Public authorities also face increasing public fund costs due to more pressing budgetary constraints in the second period. The expected surplus expression is therefore written as follows:

$$\left(S - p + \delta \left(S - \underbrace{(1+\lambda)}_{\text{Cost of public funds}} p^* \right) \right) F(\theta^*). \tag{7.2}$$

The choice of optimal regulation follows from maximizing this expression while considering the participation constraint (7.1). Assuming that the optimum obtained lies on the concave part of the function v, we are led to write a first optimality condition with respect to the price of the service for the second period p^* as follows:

$$\underbrace{v'(p_f^* - \theta^*)}_{\text{Marginal cost of external finance}} = \underbrace{1 + \lambda > 1}_{\text{Marginal cost of public funds}}. \tag{7.3}$$

This condition shows that the price p_f^* for the basic service must ensure that the marginal operator enjoys a financial flow $\pi_f = p_f^* - \theta_f^*$ such that, if it turns out that an additional unit of investment must be made, there would be indifference between financing this additional investment through public subsidies or by resorting to financial markets. This condition necessarily implies that:

$$p_f^* - \theta_f^* \geq \hat{\pi}. \tag{7.4}$$

In other words, the public authority must guarantee the operator sufficiently high revenues from the provision of the basic service to allow its access to financial markets to finance the residual. The complementarity between public and private sources of financing is essential here.

The counterpart of these promises of future gains on the basic infrastructure is that, in the first period, the marginal operator θ^* must be willing to incur a loss. The commitment capacity of public and private actors is therefore crucial in the implementation of such a scheme. Formally, we obtain:

$$\underbrace{p_f^* - \theta_f^*}_{\text{Gains in the second period}} = v'^{-1}(1+\lambda) > \hat{\pi} > 0 > \underbrace{p_f - \theta_f^*}_{\text{Losses in the first period}} = -\delta v(v'^{-1}(1+\lambda)). \tag{7.5}$$

Arve and Martimort (2024) finally note that, in a more uncertain environment for the second period (an uncertainty that may concern both the operator's costs and the demand for an additional service), the function v becomes "more" concave over the relevant domain. This characteristic leads to an increase in stable flows associated with the basic service for the second period and thus to the creation of a precautionary financial reserve that will facilitate access to financial markets.

Principle 7 Financial Constraints and Additional Services.

1. *Additional investments are covered both by stable and significant flows on basic services and by access to financial markets. The marginal agency cost associated with this external finance is equal, at the optimum, to the cost of public funds.*
2. *The operator in charge must be willing to accept losses in the first period on the remuneration of the basic service. These losses are compensated by a promise of gains on this service for the second period. These gains are necessary to attract private investors whose contribution of funds is essential.*

Strategies in a First-Price Auction. Consider now a scenario where $n+1$ potential operators compete in the first period for the provision of the basic service over both periods. This competition takes the form of an auction among operators who have private information about their costs and are therefore unaware of those of their competitors. Moreover, these operators anticipate that they will have to provide an additional service at a price p_f^* for the second period, where the price p_f^* captures the sharing rule between public and private funding that we have already mentioned:

$$p_f^* - \theta_f^* = v'^{-1}(1+\lambda). \tag{7.6}$$

In the first period, an operator with marginal cost $\theta \leq \theta_f^*$ offers a price $p_f(\theta) \leq p_f(\theta^*) = p_f$ for the service. Assuming increasing price strategies, the probability that an operator wins the auction by deviating with a bid $p_f(\hat{\theta})$ when its competitors do not deviate is $F(\hat{\theta})^n$. The expected profits associated with such a deviation are therefore:

$$(p_f(\hat{\theta}) - \theta + \delta v(\theta_f^* - \theta + v'^{-1}(1+\lambda)))(1 - F(\hat{\theta}))^n. \tag{7.7}$$

Choosing a price $p_f(\theta)$ is an optimal strategy for the operator with marginal cost θ. This choice optimally balances the gains from exaggerating costs and claiming a higher price from the first period with the risks of not being awarded the service by no longer being the most competitive.

This incentive condition leads to the following expression:

$$p_f(\theta) - \theta + \delta v(\theta_f^* - \theta + v'^{-1}(1+\lambda)) = \frac{1}{(1-F(\theta))^n} \int_\theta^{\theta_f^*} (1 + \delta v'(\theta_f^* - \tilde{\theta} + v'^{-1}(1+\lambda)))(1 - F(\tilde{\theta}))^n d\tilde{\theta}. \tag{7.8}$$

The pricing strategy is similar to that in a first-price auction without financial constraints. Recall that in this case, this strategy would consist of opting for a price $p_u(\theta)$, identical for each period, and such that it remains above the marginal cost as indicated in the following relation:

$$p_u(\theta) - \theta = \frac{1}{(1-F(\theta))^n} \int_\theta^{\theta_f^*} (1 - F(\tilde{\theta}))^n d\tilde{\theta}. \tag{7.9}$$

If the marginal operator θ_f^* operates at a price that allows it to just cover its costs, operators with lower costs benefit from a positive margin, a margin that becomes smaller as the number of potential operators increases.

The comparison of (7.8) and (7.9) highlights two effects. On the one hand, a more efficient operator, if paid a fixed price p_f^* in the second period as the marginal operator must be, benefits from supra-marginal profits that can be used to facilitate access to financial markets. The more efficient operator selected that way suffers lower agency costs than those borne by the marginal operator. This *Revenue Effect* nevertheless increases the marginal utility for the second period compared to the scenario where financial constraints would be absent because the operator's marginal utility is greater than one. The margins required in the first period thus increase. Moreover, the existence of positive profits in the second period leads operators to adopt a more aggressive behavior in the first period. They can thus sustain negative profits at this date when their costs are sufficiently high.

Literature Review. Most of the literature on auctions with financial constraints assumes that those constraints are exogenous, be they complete information or private information of the bidders. The purpose of this paper is not to survey this burgeonning literature but to point out a few issues that could be useful in the context of highway concessions. One of the first papers in the field is Che and Gale (1988) who posit an exogenous expression for the cost that a given bidder faces when raising from financiers outside money beyond its pocket. The model by Arve and Martimort (2024) that we reviewed above goes beyond by endogenizing those agency costs. This aspect is important to understand which proportion of a new investment should be covered by public money and what should be left to private investors. Laffont and Robert (1996) and Pai and Vohra (2014) considered instead exogenous budget constraints, with the additional ingredient that the budget is private information in the second of those papers. A key finding there is that the auctioneer should never subsidize low-budget service providers. The intuition is straightforward; incentive compatibility requires to offer subsidies not only to those low-budget types but also to other less constrained operators. It might be too large a cost for the public authority. In our context, we expect small entrants to be facing harder budget constraints than the big companies which have been in charge of highway concessions in the past. What Pai and Vohra (2014)'s result suggests is that public authorities should actually refrain from distorting too much decisions towards those small entrants.

8. LEARNING COSTS GRADUALLY OVER TIME

An incumbent operator, even when previously in charge and thus somewhat familiar with the provision of the service, may not necessarily precisely know its future cost for doing so after contract renewal; for instance, because market conditions may change. In this section, we investigate the consequences such ignorance on the possible bias that the public authority might introduce towards entrants.

The Model. For simplicity, we will focus here on the case of a static scenario, in the sense that the initial period of contracting is unmodeled, and thus assume the absence of any form of discounting. We model the fact that the incumbent operator has incomplete information following the methodology proposed by Courty and Li (2000) and we thus assume that this operator has only an imperfect signal s about its future costs. This signal takes values in the interval $\mathcal{S} = [\underline{s}, \bar{s}]$ and admits the distribution function K and the corresponding positive density k. We will assume that knowing the realization of signal s refines the knowledge of the cost parameter θ which will be realized later. We will therefore denote by $F(\theta|s)$ and $f(\theta|s)$ the corresponding conditional distribution and density functions. We will also assume that these distributions can be ordered in the sense of first-order stochastic dominance. A higher signal s indicates that the cost parameter θ is likely to be higher. We thus postulate the condition

$$F_s(\theta|s) \leq 0.$$

We will assume that the operator has private information, both about its signal s which it knows ex ante at the time of entering the auction procedure but also ex post, about its costs when they are realized.

Contracts. In such a context, the operator must receive a menu of contracts that first stipulates ex ante payments $p_0(\hat{s})$. These payments are functions of the information $\hat{s}$ that the operator may disclose about the signal s at its disposal, but also a set of rules $\beta(\cdot, \hat{s})$ stipulating with what probability the public authority $G(\beta(\cdot, \hat{s}))$ will opt for a competitor whose costs c_e are under common knowledge drawn from the law G on the interval $\mathcal{C} = [0, \bar{c}]$. Ex post, once informed about the realization of its costs, the operator also receives a payment $p^*(\hat{\theta}, \hat{s})$ which is also contingent on the announcement $\hat{\theta}$ it can then make about the costs actually realized.

Information Rent. The operator's information rent is written here as

(8.1)
$$U(s) = \max_{\hat{s}} p_0(\hat{s}) + \int_0^{\theta^*(\hat{s})} u(\theta, \hat{s}) dF(\theta|s) \text{ where } u(\theta, \hat{s}) = \max_{\hat{\theta}} p^*(\hat{\theta}, \hat{s}) - \theta(1 - G(\beta(\hat{\theta}, \hat{s}))))$$

This expression characterizes how incentive constraints fit into this dynamic context where information is learned and revealed only gradually. The Revelation Principle[22] applies recursively here. The operator should find optimal to tell the truth on its signal s, anticipating that in the sequel, it will also tell the truth on its realized cost.

Familiar techniques based on the Envelope Theorem then show that an alternative expression of this rent is

$$(8.2) \qquad U(s) = -\int_s^{\bar{s}} \int_0^{\theta^*(s)} (1 - G(\beta(\theta, s))) F_s(\theta|s) d\theta.$$

On top, requirement of incentive compability with respect to θ implies that $u(\theta, \hat{s})$ should be a convex function of θ;[23] which in turn implies the following monotonicity condition

$$(8.3) \qquad \beta(\theta, \hat{s}) \text{ non-decreasing in } \theta$$

[22] Myerson (1982), Pavan et al.

[23] As a the maximum of a family of linear functions of θ.

Expected Surplus. In such a context, we can rewrite the expected surplus as being

(8.4)
$$\int_{\underline{s}}^{\bar{s}}\left(\int_0^{\theta^*(s)}\left(\left(S-\theta+\frac{K(s)}{k(s)}F_s(\theta|s)\right)(1-G(\beta(\theta,s)))+\int_0^{\beta(\theta,s)}(S-c_e)dG(c_e)\right)dF(\theta|s)\right)dK(s).$$

The Optimal Assignment Rule. This rule here depends on the signal s that the operator observes about its future costs. We find

(8.5) $$\beta_m(\theta,s)\equiv h(\theta,s)=\theta-\frac{K(s)}{k(s)}F_s(\theta|s).$$[24]

As previously, condition (8.5) characterizes an optimal decision consisting of replacing the incumbent operator as soon as the entrant has a cost lower than the virtual cost of this operator. However, the expression of the virtual cost is different in this context where information is learned gradually. The distortions compared to an efficient rule consisting of opting for the entrant as soon as its cost is lower than that of the incumbent operator are all the more significant as the signal s affects the distribution function $F(\theta|s)$ after its learning (i.e., $F_s(\theta|s)$ is quite large).

The optimal decision rule still consists of opting for the entrant more often than in complete information since

(8.6) $$\beta_m(\theta,s)\geq\theta.$$

Determination of the Marginal Operator. Here too, the contingent prices $p_0(s)$ induce participation of the incumbent operator that depends on the signal s. The identity of the marginal operator $\theta^*_m(s)$ is therefore:

(8.7) $$S+\int_0^{h(\theta^*_m(s),s)}G(c_e)dc_e=h(\theta^*_m(s),s).$$

This rule is familiar. It resembles the rule already obtained in the absence of any ex ante signal (4.12), when the operator is already informed about its costs. Under certain assumptions about the various distributions involved, it is possible to verify that operator participation is all the more facilitated ($\theta^*_m(s)$ large) when the signal s is a favorable signal about future costs (s low).

Principle 8 Partially Informed Operator.

1. A menu of options allows to distinguish operators according to the signals they have

[24]Notice that the monotonicity condition (8.3) holds provided that $1\geq\frac{K(s)}{k(s)}f_s(\theta|s)$; a condition that will be supposed to hold in the sequel and that certainly holds when the signal s is not too informative on cost realizations (i.e, $f_s(\theta|s)$ small enough).

acquired regarding the future realizations of service costs. This incentive menu leads to offering ex ante payments for the service, that is, before these costs are realized, higher to operators having more favorable signals on these future cost realizations.

2. *The assignment rule is biased towards the potential entrant.*
3. *Under certain assumptions, the operator's participation is all the more facilitated when his signal s more favorable about future costs.*

9. AUCTIONS AND ALLOTMENTS

To facilitate the entry of potential competitors to the incumbent operator, the regulator may wish to reorganize the market structure by dividing what was initially a single concession into several concessions concerning disjoint subsets of the initial network. The incumbent operator may then be led to express preferences either for operating the entirety of the lots or for a strict subset. The incumbent operator thus becomes a global actor. Conversely, potential entrants with less financial capacity can focus on smaller lots. With a number of distinct concessions being put up for tender, the auction is therefore multi-object; a particularly complex domain of economic theory, as Milgrom (2004) highlights.

Auctionning Multiple Lots: A Simple Model. Two concessions, indexed by $i = 1, 2$, are proposed for operation, and the value of this operation is S for each of them. The incumbent operator has a cost θ_m for managing each of these concessions but benefits from economies of scale $\gamma > 0$ when simultaneously operating these two concessions. The incumbent operator is thus a global actor.

Each concession is put up for auction. In market i, the operator faces a local competitor, who is solely operating in this market. The cost of this potential entrant is denoted by θ_i. We will denote the cost vector by $\theta = (\theta_1, \theta_2, \theta_m)$.

We will designate by $\mathcal{A}$ the set of deterministic market allocations between different operators. We will note q_i as the probability that concession i is allocated to the local actor and q_{im} as the probability that the global actor is chosen. An allocation is thus a quadruplet $\mathbf{q} = (q_1, q_{1m}, q_2, q_{2m})$ such that $q_i \in \{0, 1\}$ and $q_{im} \in \{0, 1\}$ for deterministic allocations and additionally, $q_i + q_{im} \leq 1$, for $i = 1, 2$.

An efficient allocation leads to choosing a vector $\mathbf{q}^*(\theta)$ maximizing the total surplus as follows

$$\mathbf{q}^*(\theta) \in \arg\max_{\mathbf{q}\in\mathcal{A}} S(\sum_{i=1,2} q_i + q_{im}) - \sum_{i=1,2} \theta_i q_i - \theta_m(\sum_{i=1,2} q_{im}) + \gamma q_{1m} q_{2m}. \tag{9.1}$$

Given that the concessions must be allocated with certainty, we necessarily have $q_i + q_{im} = 1$, an assumption we will adopt hereafter, and an efficient allocation should thus minimize costs:

$$\mathbf{q}^*(\theta) \in \arg\min_{\mathbf{q}\in\mathcal{A}} \sum_{i=1,2} \theta_i q_i + \theta_m(\sum_{i=1,2} q_{im}) - \gamma q_{1m}q_{2m}. \tag{9.2}$$

To illustrate our point, note that minimizing total costs leads to choosing the global operator for both concessions when

$$2\theta_m - \gamma \leq \sum_{i=1,2} \min\{\theta_i, \theta_m\}.\text{[25]} \tag{9.3}$$

Note finally that it is possible that each entrant is more efficient than the global actor, that is $\theta_i < \theta_m$ for $i = 1, 2$, but that the incumbent operator is nevertheless chosen when condition (9.3) is satisfied.

More generally, Figure 1 presents the different configurations for optimal allocations. When parameters (θ_1, θ_2) belong to $\mathcal{D}^g$, it is optimal to allocate both concessions to the global operator. When these same parameters (θ_1, θ_2) belong to $\mathcal{D}^{im}$, it is optimal to allocate concession i to local operator i and concession $-i$ to the global operator, thus here restricted to operating only one concession. Finally, in the domain $\mathcal{D}^{12}$, only local operators intervene.

An Efficient Auction. Consider a scenario where the cost parameters $(\theta_1, \theta_2, \theta_m)$ are common knowledge for the different actors. A *menu auction* takes place in two stages. First, the different operators commit to price menus at which they are prepared to operate depending on the allocation chosen by the public authority $t_i(\mathbf{q})$. In a second stage, the public authority chooses this allocation and the required payments are made. In such a context, Bernheim and Whinston (1986) demonstrate that there exist efficient multi-object auction equilibria. These equilibria are called *truthful*. They are characterized by the following properties.

- Payment menus perfectly reflect each operator's preferences between different alternatives. These menus are written here in the form

$$t_i(\mathbf{q}) = C_i + \theta_i q_i, \quad i = 1, 2; \tag{9.4}$$

[25]Of course, this choice of global operator is only relevant if the cost θ_m is sufficiently low and more specifically, $\theta \leq \theta_m^*$ where θ_m^* satisfies the condition

$$2S = 2\theta_m^* - \gamma.$$

It is immediately verifiable that sufficiently strong economies of scale (γ high) facilitate the participation of this global operator.

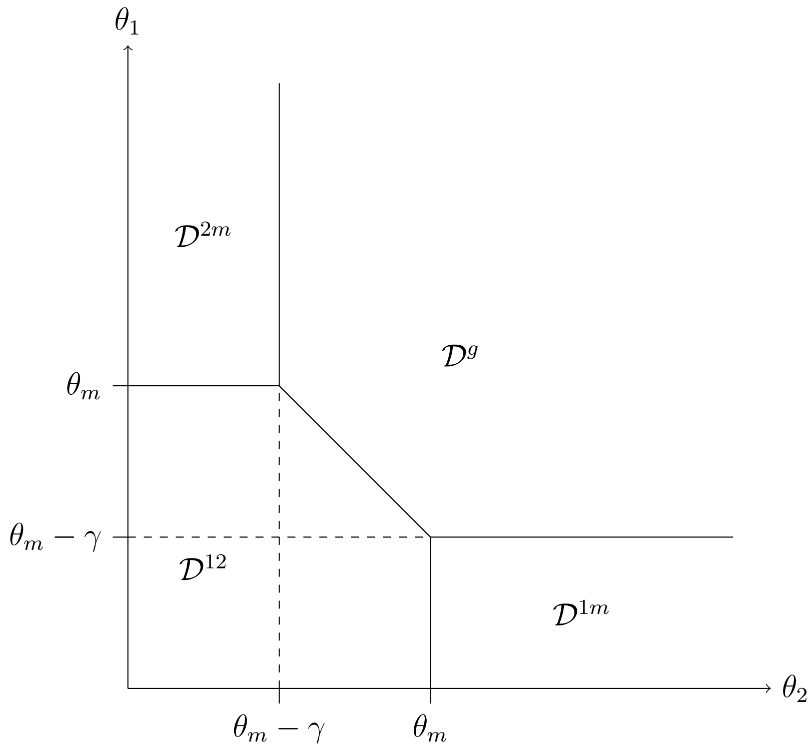

FIGURE 1.— Optimal configurations

and

$$t_m(\mathbf{q}) = C_m + \theta_m(\sum_{i=1,2} q_{im}) - \gamma q_{1m} q_{2m}. \tag{9.5}$$

The constants (C_1, C_2, C_m) represent profit levels demanded by the operators, independently of the allocation chosen by the auction organizer. In other words, each operator ensures, through such offer menus, a constant profit independent of the allocation choice.

- The public authority always chooses an efficient allocation $\mathbf{q}^*(\theta)$ by maximizing the net consumer surplus, or as we saw previously by minimizing costs,

$$\mathbf{q}^*(\theta) \in \arg\min_{\mathbf{q}\in\mathcal{A}} \sum_{i=1,2} t_i(\mathbf{q}) + t_m(\mathbf{q}). \tag{9.6}$$

In other words, the truthful menus align the preferences of the public authority, initially wanting to maximize the net consumer surplus, with the total surplus.

- The constants (C_1, C_2, C_m), which are thus interpreted as the profits required by each operator, are solutions to the following system of inequalities:

$$\sum_{i=1,2} \theta_i q_i^*(\theta) + \theta_m(\sum_{i=1,2} q_{im}^*(\theta)) - \gamma q_{1m}^*(\theta) q_{2m}^*(\theta) + \sum_{i=1,2} C_i + C_m \tag{9.7}$$

$$= \min\Big(0, \max_{\mathbf{q}\in\mathcal{A}} \theta_i q_i + \theta_m(\sum_{i=1,2} q_{im}) - \gamma q_{1m}q_{2m} + C_i + C_m, \min_{\mathbf{q}\in\mathcal{A}} \sum_{i=1,2} \theta_i q_i + C_i\Big).$$

These constraints stipulate that each operator requests a profit which, at equilibrium, leaves the public authority organizing the auction indifferent between accepting all proposed menus and its best alternative option, which is to accept a strict subset. These alternative options thus consist of either not contracting with any of these operators, or with only one of them.

Example 1. To illustrate the properties of these truthful equilibria, let us first consider a scenario, described by condition (9.3), where the global operator is efficient. It is easy to calculate the constants (C_1, C_2, C_m) solving (9.7) as being

$$C_1 = C_2 = 0; C_m = \sum_{i=1,2} \theta_i - 2\theta_m + \gamma > 0. \tag{9.8}$$

In other words, a global incumbent operator extracts efficiency gains in a truthful auction; which renders potential entrants inoperative.

The payments made by the public authority and the net consumer surplus achieved in this auction scheme are respectively given by

$$T = C_m + 2\theta_m - \gamma = \sum_{i=1,2} \theta_i$$

and

$$2S - T = 2S - \sum_{i=1,2} \theta_i.$$

The profit of the global operator is then

$$C_m = \sum_{i=1,2} \theta_i - 2\theta_m + \gamma > 0.$$

■

Example 2. Consider now an alternative scenario where entry is favored simultaneously on both markets, a configuration requiring

$$2\theta_m - \gamma \geq \sum_{i=1,2} \theta_i, \text{ and } \theta_i \leq \theta_m, \quad i = 1, 2. \tag{9.9}$$

The constants (C_1, C_2, C_m) solving (9.7) are here given by

$$(9.10) \quad C_i = \theta_m - \theta_i, \quad i = 1, 2; \quad C_m = 0.$$

When the global operator is less performant than the local actor on each concession taken separately, it acts only as potential competition limiting the gains that these new entrants can derive.

The payments made by the public authority and the net consumer surplus achieved in this configuration are respectively given by

$$T = \sum_{i=1,2} C_i + \theta_i = 2\theta_m$$

and

$$2S - T = 2(S - \theta_m).$$

The total profit of local operators being then

$$\sum_{i=1,2} C_i = \sum_{i=1,2} \theta_i - 2\theta_m > 0.$$

■

We therefore summarize these results as follows.

PRINCIPLE 9 MENU AUCTIONS. *Under complete information about operator costs, there exists an auction format where operators commit to payment menus corresponding to each market configuration that can be chosen by the public authority.*

1. *These auctions are efficient.*
2. *Operators submit payment menus that reflect their relative preferences between different possible market allocations.*
3. *The profits of operators active on each market segment are limited by competition.*

VICKREY-CLARKE-GROVES MECHANISM. Let us now turn to the more realistic scenario where operators have private information about their respective costs. The truthful payments (9.4) being manipulable in such a context,[26] we propose here an alternative guaranteeing that each operator reveals the truth about their costs, regardless of the reports made by their competitors about their own costs. In other words, we present a mechanism where, following Vickrey (1961), cost revelation remains a dominant strat-

[26] Martimort and Stole (2024).

egy. We thus generalize here the properties of the second-price auction in a complex multi-object (here, concessions) framework.

The construction of the corresponding payments relies on the work of Green and Laffont (1977) and their more general characterization of incentive mechanisms with dominant strategies. These mechanisms consist of making each operator pay for the externality that their report imposes on their competitors.

In general, an incentive mechanism determines an allocation $\mathbf{q}(\hat{\theta}_1, \hat{\theta}_2, \hat{\theta}_m)$ as well as associated payments $(t_1(\hat{\theta}_1, \hat{\theta}_2, \hat{\theta}_m), t_2(\hat{\theta}_1, \hat{\theta}_2, \hat{\theta}_m), t_m(\hat{\theta}_1, \hat{\theta}_2, \hat{\theta}_m))$ for the different operators based on their cost reports.

A Vickrey-Clarke-Groves mechanism implements an efficient allocation $\mathbf{q}^*(\theta_1, \theta_2, \theta_m)$ and to do so must align individual incentives to reveal costs with collective incentives. The corresponding payments must allow internalizing the impact that an operator's manipulation of their own costs can have on the final decision. The payments therefore only vary when the operator is pivotal and can modify the decision through their cost announcement.

The exercise thus consists of finding what these payment values might be. Consider first the global operator and payments of the form

$$(9.11) \quad t_m(\theta_i, \theta_{-i}, \hat{\theta}_m) = 2S - \sum_{i=1,2} \theta_i q_i^*(\theta_i, \theta_{-i}, \hat{\theta}_m).$$

It is easy to verify that reporting one's own costs truthfully is a dominant strategy for the global operator because the payments $t_m(\theta_i, \theta_{-i}, \hat{\theta}_m)$ align the private profit maximization objectives of this operator with the social objective of total surplus maximization.

To verify this, suppose first that the cost announcements (θ_1, θ_2) made by the local competitors are such that $(\theta_1, \theta_2, \theta_m) \in \mathcal{D}^g$.[27] Using condition (9.11), we verify that the payment for this global operator is then

$$(9.12) \quad t_m(\theta_i, \theta_{-i}, \theta_m) = 2S \quad \forall(\theta_1, \theta_2, \theta_m) \in \mathcal{D}^g$$

Similarly, if he makes a report $\hat{\theta}_m$ such that $(\theta_1, \theta_2, \hat{\theta}_m) \in \mathcal{D}^{1m}$, the global operator induces an optimal allocation such that operator i wins the market i. The corresponding payment would then be

$$(9.13) \quad t_m(\theta_i, \theta_{-i}, \hat{\theta}_m) = 2S - \theta_i \quad \forall(\theta_1, \theta_2, \hat{\theta}_m) \in \mathcal{D}^{im}.$$

Such a deviation is of course not profitable for the global operator since

$$(9.14) \quad 2S - 2\theta_m + \gamma > 2S - \theta_1 - \theta_m \quad \forall(\theta_1, \theta_2, \theta_m) \in \mathcal{D}^g.$$

[27]The mechanism is structured so that these announcements are correct at equilibrium.

Of course, we do not disturb the incentives by subtracting from this price scheme an independent function of θ_m. Let us choose

$$h_m(\theta_1, \theta_2) = 2S - (\theta_1 + \theta_2).$$

This expression actually corresponds to the total surplus in the absence of the global operator.

We thus obtain the Clarke mechanism, a special case of Vickrey-Clarke-Groves mechanisms for which the payments are written as follows:

$$(9.15)\quad t_m^C(\theta_i, \theta_{-i}, \theta_m) = \begin{cases} \theta_1 + \theta_2 \text{ and } & \forall(\theta_1, \theta_2, \theta_m) \in \mathcal{D}^g\ , \\ \theta_{-i} \text{ and } & \forall(\theta_i, \theta_{-i}, \theta_m) \in \mathcal{D}^{im}\ , \\ 0 \text{ and } & \forall(\theta_1, \theta_2, \theta_m) \in \mathcal{D}^{12}. \end{cases}$$

If we want to align the private profit maximization objectives with the social objective of total surplus maximization, operator i should, in the same manner, receive a payment

$$(9.16)\quad t_i(\hat{\theta}_i, \theta_{-i}, \theta_m) = 2S - \theta_{-i} q_{-i}^*(\hat{\theta}_i, \theta_{-i}, \theta_m) - \theta_m \Big(\sum_{i=1,2} q_{im}^*(\hat{\theta}_i, \theta_{-i}, \theta_m)\Big) + \gamma q_{1m}^*(\hat{\theta}_i, \theta_{-i}, \theta_m) q_{2m}^*(\hat{\theta}_i, \theta_{-i}, \theta_m)$$

It is easy to verify that truthful reporting of costs is thus a dominant strategy for operator i. Thus, applying the general formula (9.16), we first find

$$(9.17)\quad t_i(\theta_i, \theta_{-i}, \theta_m) = \begin{cases} 2S - \theta_m \text{ and } & \forall(\theta_i, \theta_{-i}, \theta_m) \in \mathcal{D}^{im}, \\ 2S - \theta_{-i} - \theta_m \text{ and } & \forall(\theta_i, \theta_{-i}, \theta_m) \in \mathcal{D}^{-im}, \\ 2S - \theta_{-i} \text{ and } & \forall(\theta_i, \theta_{-i}, \theta_m) \in \mathcal{D}^{12}, \\ 2S - 2\theta_m + \gamma \text{ and } & \forall(\theta_i, \theta_{-i}, \theta_m) \in \mathcal{D}^g. \end{cases}$$

We can again subtract from these transfers an independent function of θ_i without disturbing the incentives. Let us choose such a function

$$h_i(\theta_{-i}, \theta_m) = 2S - \min\{2\theta_m - \gamma; \theta_m + \theta_{-i}\}$$

which is nothing other than the net surplus obtained in the absence of operator i.

We thus obtain another payment function that also respects the incentives. The Clarke payments thus obtained are written as

$$t_i^C(\theta_i,\theta_{-i},\theta_m) = \begin{cases} \theta_m - \gamma \text{ and } & \forall(\theta_i,\theta_{-i},\theta_m) \in \mathcal{D}^{im}, \\ 0 \text{ and } & \forall(\theta_i,\theta_{-i},\theta_m) \in \mathcal{D}^{-im}, \\ \theta_m \text{ and } & \forall(\theta_i,\theta_{-i},\theta_m) \in \mathcal{D}^{12}, \\ 0 \text{ and } & \forall(\theta_i,\theta_{-i},\theta_m) \in \mathcal{D}^{g}. \end{cases} \quad (9.18)$$

Clarke Mechanism and Second-Price Auction. The Clarke payments (9.15) and (9.18) generalize the payments as stipulated in such a single second-price auction. Recall that in such an auction, the highest bidder wins the concession and pays the second-highest price. In our example, if only one concession were to be allocated between the global operator and the corresponding local operator, the latter, when winning, would receive a price θ_m and benefit from a profit $\theta_m - \theta_i$ that is positive or zero. The global operator, if winning, would receive a payment θ_i and obtain a profit $\theta_i - \theta_m$ that is positive.

The Clarke mechanism indeed has truthful cost revelation by the operator as a dominant strategy. This mechanism also induces an efficient decision. It ensures positive profits when the operator wins and zero otherwise. Finally, an operator is only paid when it is effectively the best bidder. The price paid by the public authority for the service is nothing other than the opportunity cost of not calling upon the less costly competitor.

The Clarke mechanism payments (9.15) and (9.18) are also positive in all circumstances. They thus ensure that an operator winning concession i always makes a positive profit. For the global operator, these payments correspond to the opportunity cost of not calling upon the less costly competitors. In the case of simultaneous allocation of both concessions to the global operator, this opportunity cost is the sum $\theta_1+\theta_2$ of the local operators' costs. In the case of allocation of a single concession i to this global operator, this opportunity cost is the cost θ_i of the local operator i who is the least costly in this market.

For local operators, the notion of opportunity cost is more complex. Not calling upon the global operator in market 1 can have an induced cost of losing the benefit of economies of scale and thus having to call upon the local operator in market 2. This is the case when $(\theta_2, \theta_2, \theta_m) \in \mathcal{D}^{1m}$ and the price paid for operator 1's services takes into account the fact that the opportunity cost of not selecting the global operator includes these economies of scale. This is not the case when $(\theta_1, \theta_{-2}, \theta_m) \in \mathcal{D}^{12}$ since the global operator is not the best bidder in market 2 and opting for the latter in market 1 does not allow benefiting from economies of scale.

Implementation. It results from this reasoning that the local markets cannot be treated separately. It would thus be illusory to want to implement an efficient allocation with two second-price auctions organized separately for each market. Such a procedure, although quite simple, would lead to choosing local operators too often.

Minimal Payments. Suppose that the types $(\theta_1, \theta_2, \theta_m)$ all belong to the interval $\Theta = [\underline{\theta}, \bar{\theta}]$ and are independently and identically distributed in this interval. Note that the Clarke mechanism is such that local operators of type $\theta_i = \bar{\theta}$ never win and thus have zero expected gains. More efficient operators have a non-zero probability of winning the associated concession and thus a positive expected profit. A similar reasoning shows that the global operator of type $\theta_m = \bar{\theta}$ obtains a minimal expected profit, being able to operate both concessions simultaneously only when $2\bar{\theta} - \gamma \leq \theta_1 + \theta_2$.

A fundamental result of incentive theory, is that mechanisms implementing the same allocation lead to expected profits for operators that differ only by a constant. In other words, all VCG mechanisms that ensure positive profits for local operators lead to higher expected profit levels than those obtained with the Clarke mechanism. Consequently, these alternative mechanisms lead to higher payments than in the Clarke mechanism.

Principle 10 Vickrey-Clarke-Groves Auctions. *Under incomplete information about operators' costs, the Vickrey-Clarke-Groves auction guarantees allocation efficiency but can lead to high payments.*

The Clarke mechanism minimizes payments to local operators.

The Optimal Auction in Asymmetric Information. The previous analysis was developed assuming that the parameter γ representing the economies of scale potentially realized by the global operator is known. Consider now a scenario where γ is private information for this operator. This parameter follows a distribution function F, and has a density f on the support $\Gamma = [0, \bar{\gamma}]$. The hazard rate monotonicity assumption stipulating that $\frac{1-F(\gamma)}{f(\gamma)}$ is decreasing is assumed to be satisfied. The parameter $\theta = (\theta_1, \theta_2, \theta_m)$ is, for its part, common knowledge.

Under asymmetric information, we now know that the parameter γ must be replaced by its virtual version

$$\gamma - \frac{1 - F(\gamma)}{f(\gamma)}$$

which is always lower. In other words, the effective economies of scale are lower than their complete information values, and this helps limit the information rent of the global operator.

Observe then that it may be efficient to choose the incumbent operator in complete information and to prefer the entrants on each concession separately in asymmetric information. This scenario requires a constellation of parameters satisfying the following inequalities:

$$2\theta_m - \gamma \leq \sum_{i=1,2} \theta_i < 2\theta_m - \gamma + \frac{1 - F(\gamma)}{f(\gamma)}. \tag{9.19}$$

We can thus state the following result.

Principle 11 Auctions with Asymmetric Information on the incumbent operator's Economies of Scale. *Under asymmetric information, the optimal auction can be biased in favor of local operators. If the entry of local operators is facilitated in this case, the benefit of economies of scale is attenuated.*

10. CONCLUDING REMARKS

The collections of results that were presented above by means of slight variations of a versatile model could leave policy-makers in charge of deciding whether and how to renew concessions a bit lost. What are the key lessons that come out of those models? Is there some common guiding principles conveyed by those models? Fortunately, the answer to those questions is certainly yes and it relies on a good understanding of the basic principle of information economics.

First, notice that the decision to switch to an entrant is easy under complete information. Had the public authority in charge got a complete knowledge of the incumbent's and the potential entrants' cost, it would suffice to choose the least costly service provider and opt for that operator at the renewal stage. Of course, even this simple rule might be amended at times. When the incumbent operator has invested in assets that can only be imperfectly transferred to new operators, the former costs must account for those extra opportunity costs and the switching rule should be amended accordingly.

Asymmetric information challenges this simple rule but, in a sense, does not change its mere philosophy. When operators have private information, costs have just to be replaced by virtual costs to find the optimal switching rule. Asymmetric information may also come with difficulty in verifying investments and thus rewarding those investments. The switching rule has to be biased so as to counter any possible hold-up that incumbent operators may face when they cannot recoup the benefits of their (non-verifiable) investments.

So, *in theory*, the exercise is straightforward. First, policy-makers have to figure out which information structure is more likely to prevail (for instance, they should be able to answer whether both the incumbent operator and potential entrants know their future costs or not). Second, they should then pick up within the collection of existing scenarios which bias in switching decisions they should introduce. Those two steps are just easy to figure out for expert regulators. More subtle is how to quantify the possible distortions in switching decisions. The notion of virtual cost is deeply associated with a Bayesian environment; i.e., to the assumption that the regulator has been able to figure out the possible distributions of the cost parameters that pertain to both the incumbent operator and potential entrants. Things are more difficult on this ground. Of course, we may expect that the long-lived relationship between the incumbent operator and the public authority may have generated enough data on past performances to improve the regulator's information. This could be true, but the Lucas' Critique might also apply here. Anticipating that their past performances could be used to extract more of their profit, operators may refrain from generating faithful data. More interesting is the fact that, in the highways sectors, multiple concessions are run by different operators at the same time, and those strategic concerns would disappear had the public authority relied on what it learns from one operator to estimate a possible cost distribution for the other.[28] Based on such benchmarking procedures, there would be thus scope for building efficient estimates of the cost distribution of an incumbent on a given concession; facilitating the implementation of the various policies suggested in this paper.

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