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**Contractual Flexibility or Rigidity for  
Public Private Partnerships? Theory and  
Evidence from Infrastructure Concession  
Contracts**

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# Contractual Flexibility or Rigidity for Public Private Partnerships? Theory and Evidence from Infrastructure Concession Contracts\*

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## Abstract

In practice, contract design for Public Private Partnerships (PPPs) involves the challenge of including the “appropriate” level of flexibility: too much, and undesirable opportunistic renegotiations are likely to be necessary, too little, and opportunities for welfare-enhancing renegotiations will be lost. In this article, we address this issue by focusing on the way parties adjust prices over time in PPPs. We argue that the peculiarities of PPPs ensure that prices have the function of limiting the *ex post* adjustment costs. In order to highlight the trade-offs at stake between contractual flexibility and rigidity in the design of price provisions, we develop a model that includes renegotiation and maladaptation costs. We assess the empirical validity of our theoretical predictions using original data from 71 toll-road concession contracts taken from a range of different locations worldwide. Our results point to the importance of concerns related to economic efficiency, as well as for the political process, in the design of PPP contracts.

Keywords: Contractual Design, Public Private Partnerships, Concession Contracts, Price Provisions, Toll Adjustments, Incomplete Contracting

*JEL codes:* D23, D82, H11, H54, L9, L14, L24

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# 1 Introduction

In the last couple of decades, the use of PPPs has become increasingly common in many countries, and a variety of administrative arrangements have been used for them (see Grout and Stevens (2003)). At the same time, there has been some negative feedback following experiences in Latin American countries (Guasch (2004), Estache (2006)) and also in developed countries (Chong, Huet, and Saussier (2006), Engel, Fischer, and Galetovic (2006)). Significant contractual costs, together with difficulties in designing and adapting contractual agreements over time between public authorities and private operators are often put forward to explain this mixed picture (Spiller (2008)). It has often been noted that many such agreements are standardized and that “A key concern with long-term PPP contracts is the level of flexibility that they offer to authorities to make changes either to the use of assets or to the level and type of services offered” (PWHC (2005)). Nevertheless, significant concerns have also been raised regarding the high incidence of renegotiation of such contracts (Guasch (2004), Engel, Fischer, and Galetovic (2006), Estache (2006), Martimort and Straub (2006), Guasch and Straub (2006); Guasch, Laffont, and Straub (2008)). In practice, the design of contracts is often affected by the challenge of including the “appropriate” level of flexibility: too much, and undesirable opportunistic renegotiations are likely to be necessary; too little, and opportunities for welfare-enhancing renegotiations will be lost.

In this paper, we address this issue by focusing on the ways in which parties adjust prices over time in PPPs. The literature on the contractual design of price provisions has already been extensively developed. In the literature on incentive contracting, price provision mainly has the function of incentive alignment, in addition to risk allocation (Iossa and Martimort (2008), Martimort and Pouyet (2008)). In contrast, in the literature on property rights, ownership and its effect on incentives is the key to understanding the optimal form of procurement (Hart (1995), Hart, Shleifer, and Vishny (1997), Hart (2003), Bennett and Iossa (2006)) regardless of price provisions. We herein adopt a transaction cost perspective. We argue that the peculiarities of PPPs lend prices another - more important - function, that of limiting the *ex post* adjustment costs. In fact, because of the long-term nature of PPPs, any incomplete contract between a public authority and a private partner is prone to the costly enforcement of prices, necessitating a further distinction between price cap and cost plus contracts in accounting for the level of adaptability of price provisions over time.

In order to highlight the trade-offs at stake between contractual flexibility and rigidity in the design of price provision, we begin by building a simple descriptive model that mixes incomplete contract theory (Hart (1995)) and transaction cost theory (Williamson (1985)). More specifically, we propose an incomplete contract theory model that includes renegotiation and maladaptation costs. We study two kinds of contractual agreement: rigid contracts framed by contracting parties to avoid renegotiation on the one hand, and flexible contracts for which contracting parties accept and forecast *ex post* negotiation on the other. We introduce to the analysis a particular characteristic of such public-private contracts, namely the potential for renegotiation even if the price provisions are completely rigid. This is in contrast with previous empirical studies that use a transaction cost framework, and consider that rigidity and completeness are synonymous, both reflecting a lower probability of renegotiation (Crocker and Masten (1991), Crocker and Reynolds (1993), Bajari and Tadelis (2001)). Thus, in our model, contracting parties face a choice between a flexible contract, in which parties agree to renegotiate on price if uncertainty occurs, and a rigid contract, in which although parties cannot commit not to renegotiate, they will attempt to prevent renegotiation. Our model thus makes predictions about the ways in which contractual choices vary between projects,

contracting parties and institutional environments. Our predictions are intuitive and consistent with those of previous studies that use a transaction cost framework, but our model predicts the conditions under which they hold and highlights the fact that incomplete contract models might also be useful to analyze price provisions. Beyond these theoretical contributions, we also contribute to the empirical literature by using an original database.

In particular, we assess the empirical validity of our theoretical predictions using data from concession contracts for 71 toll road schemes taken from around the world. In our data set, we observe a great variety of toll adjustment provisions, from the very rigid such as firm, fixed price provisions in which tolls are fixed for the whole length of the concession, to the very flexible, containing so-called renegotiation provisions, which consist in the determination of *ex ante* periodic *ex post* negotiations of the initial toll adjustment provision. This observed variety of price provisions is in sharp contrast with the rigidity of the PPP contracts often advanced in the literature. We complement the data on the design of toll adjustment provisions with data gathered from contracts and other sources that describe the type of concessionaires, the uncertainty of traffic flows that characterises each project, the number of bidders, the institutional framework of the country concerned, the experience of the public authority, the number of repeated interactions between the concessionaire and the public authority, the political leanings, and so on. Our main predictions are to a large extent corroborated by the data, and our results suggest an important role for considerations of economic efficiency, as well as the political process, in the design of PPP contracts.

The remainder of the paper is organized as follows. In Section 2, we describe the relevant literature and state the contributions of this paper. In Section 3, we present a simple model that leads to our theoretical propositions. In Section 4, we describe the institutional details of the infrastructural concession contracts and the contractual toll adjustment processes observed in our data set. In Section 5, we present the original data used in the empirical section and Section 6 contains our empirical methodology, together with the econometric results obtained. Section 7 is concerned with robustness checks, and we provide our concluding remarks in the final section.

## 2 Literature Review

### 2.1 Contractual Choices

The economic literature generally distinguishes between two types of complete contract: contingent-claims contracts and comprehensive contracts. Contingent-claims contracts are contingent on all the variables relevant to the fulfillment of the contract. In the Arrow-Debreu model, typical examples are contracts based on rationality and assumptions of symmetric information. All states of nature are observable and verifiable, so there is no possibility of adverse selection or moral hazard.

In the presence of private information, however, complete contingent-claims contracts are no longer feasible. Complete (or comprehensive) contracts can nevertheless be made, provided they take into account all the relevant information and are contingent on verifiable variables, thereby making it possible to specify the obligations of each party in every conceivable eventuality (Tirole (1988)). The main contention of the literature in this field is that the use of efficient sharing rules will balance the incentives for one party against the inefficient bearing of risk by that party; larger shares tend to be assigned to the party that has (i) a lower aversion to risk and (ii) a higher marginal productivity of effort. The trade-off generally occurs as a choice between price-cap and cost-plus oriented contracts, without considering their *ex post* adjustment costs.

Measured against the complete-contract benchmark, an incomplete contract is therefore one

that does not take into account all the relevant variables. This state of affairs may result from a lack of verifiability of the variables that pertain to contract fulfillment as argued by Hart (1995). Thus, as pointed out by Hart and Moore (1999), an incomplete contract is analyzed as one in which “the parties would like to add contingent clauses, but are prevented from doing so by the fact that the state of nature cannot be verified (or because states are too expensive to describe *ex ante*)”. In general, this theoretical framework predicts an all-or-nothing solution, in that the contract is either complete or totally incomplete (i.e. no contract is signed). Previous research that used an incomplete contract framework focused on the make-or-buy issue, thereby leading to criticisms that this theory was only a property right theory and had nothing to say about alternative contractual choices.

Another strand of the literature analyzes the question of contractual choices building on transaction cost economics (Williamson (1985)). The starting point for these is that contractual incompleteness relies on the bounded rationality of economic actors. In this literature, the more uncertain the environment, and the harder it is to accommodate changing circumstances within the contract, the more likely it is that parties will sacrifice the precision and ease of implementation of definite contract terms for more cumbersome but more flexible “relational” contract terms that define performance obligations less precisely or establish procedures for the negotiation of adjustments in the terms of trade contained in the contract (Masten and Saussier (2000)). Specific investments and uncertainty are thus at the root of the problem in this case. It is usually argued that the more complex the contract is, the more complete it is, and the less likely it is to be renegotiated (Crocker and Masten (1991); Crocker and Reynolds (1993); Saussier (2000)).

A substantial body of literature also exists that concerns the formal and informal dimensions of contractual agreements. The nature of informal agreements, together with the existence of implicit and relational contracting, has been the subject of many papers (Bull (1987), Klein and Murphy (1988), Baker, Gibbons, and Murphy (1994), Klein (1996), Poppo and Zenger (2002) and more recently Board (2008), Halac (2008), Gil and Marion (2009) and Iossa and Spagnolo (2009)). In this literature, these authors have studied the emergence of informal contracting when formal contracting may yield suboptimal outcomes, thereby emphasizing that informal agreements will only emerge where they offer improvements to the results of formal agreements. Another common theme rests in the fact that the sustainability of these forms of contract depends on the capacity of the participants to enforce these agreements themselves, thereby leveraging the gains derived from any future interactions between them. Thus it is stressed that past behavior (reputational concerns) and the prospect of future trade may reduce the cost of contractual incompleteness and of any *ex post* adjustment.

We herein propose a simple model that combines incomplete contract theory (Hart (1995)) and transaction cost theory (Williamson (1985)). More specifically, we adopt an incomplete contract perspective and propose a mixed approach by acknowledging that bounded rationality may give rise to transaction costs (i.e. *ex post* adjustment costs). We further argue that a more complete contract is not always more secure against renegotiation. More precisely, we argue that renegotiation is also possible, if not that common, in contracts that do not include such an eventuality, leading contracting parties to consider the reputational capital of their trading partners. Our model thus departs from incomplete contract theory by incorporating *ex post* adjustment costs.<sup>1</sup> As a consequence, renegotiation no longer ensures that all organizational choices yield efficient outcomes *ex*

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<sup>1</sup>A new strand of literature building on incomplete contract theory incorporates *ex post* inefficiency in trade, arguing that contracting parties exercise shading powers when they feel the terms of exchange are unfair (Hart and Moore (2008)).

*post.* Our model also leads to some original propositions compared with those of previous empirical studies of transaction cost, and finally shows that the theory of incentives is not the only one able to make formalised predictions in contractual design and more especially concerning payment schemes. This global approach is supported in the characteristics of PPP contracts, particularly those of infrastructure concession contracts, as highlighted in the following sections.

## 2.2 PPP contracts

Our paper also contributes to a more applied literature that documents the efficiency of PPP contracts. In order to develop their infrastructure, public authorities (States or local authorities) may decide to resort either to traditional procurement contracts or to PPPs. The key difference between PPPs and traditional procurement contracts is that under PPPs, the private sector delivers services for the duration of the contract, and not assets, although the provision of assets is often integral to the services concerned. They are therefore not only responsible for the delivery of assets, but also for the overall management of the project, its implementation, and its successful operation for several years thereafter. PPPs are thus complex long-term agreements that involve non-verifiable investments, usually for the delivery of complex services, or at least of services in which the degree of uncertainty is high.

The imperfect verifiability of services in public-private contracts has been widely emphasized.<sup>2</sup> For example, it is clear that it can be extremely difficult to demonstrate (and propose) that amendments to the contractual terms are required as a result of the concessionaire's lack of ability, rather than as a result of any unexpected external factors. Furthermore, the public authority does not generally sue a concessionaire for partial non-fulfillment of its obligations, because litigation can be costly and produce uncertain results, while certainly worsening the relationship (Williamson (1976)). Finally, the risks discharged on the contracting party cannot be unlimited. For this reason, the extent of the penalties cannot always be in proportion to the damage caused by the imperfect fulfillment of the conditions of contract. Such characteristics can impede the drafting of complete contracts (Hart (1995)).

The incompleteness of PPPs as described above also gives rise to an important strand of literature that tackles the issue of renegotiation of contracts in less developed countries (Guasch (2004), Laffont (2005), Guasch and Straub (2006), Guasch, Laffont, and Straub (2008), Engel, Fischer, and Galetovic (2009)) as well as in developed countries (Engel, Fischer, and Galetovic (2006), Spiller (2008)). For example, in a study of more than 1,000 concession contracts awarded in Latin America in the 1990s, Guasch (2004) found that within three years, the terms had been changed substantially in over 60% of the contracts concerned. In addition, Engel, Fischer, and Galetovic (2009) found in a study of 50 concession contracts signed in Chile between 1993 and 2007 that these contracts generated 147 unexpected renegotiations. This strand of the literature identifies the different causes of renegotiation, namely adverse selection and lack of commitment (Guasch and Straub (2006)), issues of corruption (Guasch, Laffont, and Straub (2008)), political issues (Guasch, Laffont, and Straub (2006), Engel, Fischer, and Galetovic (2009)) and third party and accountability issues (Spiller, 2008). These studies also highlight the effect of contractual choices (*i.e.* price-cap vs. cost plus) on the probability that renegotiation will be required. However, they also stress the multidimensional

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<sup>2</sup>In the literature, a contractual aspect is deemed to be perfectly verifiable when 1) a third party can verify the case that occurred in relation to this aspect; 2) the cost of litigation that falls upon the Principal is not greater than the benefit that it can obtain from a ruling in its favour; 3) the value of the penalties is not subject to any limitation. If one of these three requisites is not satisfied, there is a risk of not being able to obtain the full enforcement of the contract (Doni (2006)).

causes of renegotiation and hence the inability of the contracting parties to design a contract that is immune from renegotiation.

We herein assume that whatever the contractual choices, renegotiation may occur. We therefore complement the existing literature from a different perspective; rather than studying the causes of renegotiation, and incidently the impact of contractual choices on renegotiation, we instead focus on contractual choices with contracting parties in the knowledge that renegotiation may occur. This leads us to make propositions concerning the optimal contractual choices for such an environment.

### 3 The Model

In the following section, we present a simple descriptive model to provide a structure for the ways in which contractors may decide on their contractual strategies.

#### 3.1 Structure of The Model

We herein consider two contracting parties, namely the State or its representative (e.g. a local public authority), and a private operator. The contract is such that the private party is essentially responsible for capital and human investments. This is in line with our observations for many PPPs, and is also considered by Hart (2003) as being a specific characteristic of such relationships.

We herein make the assumption that a part of the investment made by the private investors is non-verifiable (but not necessarily specific) and that it would be impossible or too costly for the State or a third party to check the investment made by the private operator (see Section 2.2 of this paper for a discussion of this topic). We denote these investments as  $i$ . They generate a surplus, denoted as  $R(i)$ . We also make the classical assumptions that  $R' > 0$ ,  $R'' < 0$  and  $R''' < 0$ .

In order to realize the transaction, the parties may sign two kinds of incomplete contract:

- a rigid contract, in which the contracting parties attempt to specify the means of coordination according to future states of nature. In other words, in such a contract, parties try to prevent renegotiation, essentially by deciding the price to be charged by the private operator for the whole duration of the contract.
- a flexible contract, in which the parties do not try to avoid renegotiation and plan to renegotiate price once any uncertainty unfolds.

We note that  $f \in ]0, 1[$ , where  $\underline{f}$  ( $\bar{f}$ ) represents the impact on the *ex post* surplus of a rigid (flexible) contract. We thus make the assumption that the *ex post* realized surplus of the transaction is a function not only of the investments but also of the adequacy of the contract to address any future states of nature and  $f$  is a measure of the level of this adequacy. A rigid contract generates maladaptation costs (*i.e.* a realized surplus for the private operator  $\underline{f}R(i) < R(i)$ ). A flexible contract generates renegotiation costs (*i.e.* a realized surplus  $\bar{f}R(i) < R(i)$  to be shared between the contracting parties).

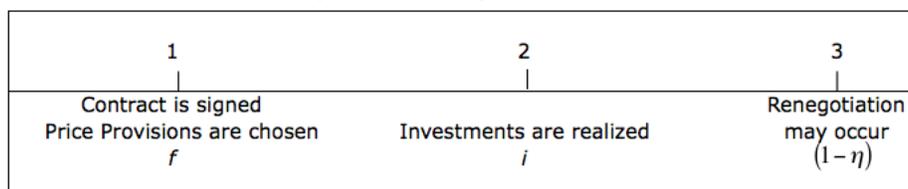
We denote  $r(i)$  as the value of the outside option of the private operator in the case of an *ex post* contract breach. We make the assumption that  $r(i) = \alpha.R(i)$  with  $\alpha$  as the level of investment specificity. When  $\alpha \rightarrow 0$  then the investments made by the private operator do not generate any surplus when used outside the contractual relationship. Investments are therefore totally specific to the relationship concerned.<sup>3</sup>

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<sup>3</sup>Note that the asset specificity herein concerns the non verifiable investment  $i$ , that is not only the road itself

Finally, as has already been explained, we consider the likelihood of contract renegotiation to be exogenous and we denote as  $(1 - \eta)$ , with  $0 \leq \eta \leq 1$  the probability that a rigid contract can be renegotiated. This is another dimension of our model that reflects the specific nature of PPPs. More precisely, the contracting parties are often in an asymmetric position, and such contracts are linked to political decisions in that such arrangements could be renegotiated independently of what was initially agreed in the contracts (Guasch (2004); Laffont (2005); Engel, Fischer, and Galetovic (2009)). The timing of the model is standard and is as shown below:

Figure 1: Timing of the Model



## 3.2 Investment Levels and Contract Design

### 3.2.1 First Best

As a benchmark, it is useful to specify the first-best solution, which would pertain if the investments were verifiable. Contracting parties would then choose investment levels in a way that would maximize the total economic surplus  $S$  generated by the contractual relationship given by

$$S = B_0 - C_0 + R(i^*) - i^* \quad (1)$$

where  $B_0$  and  $C_0$  are positive constants, and represent respectively the social benefit and cost of providing the basic service without any investment. Thus, the optimal level of investment  $i^*$  is such that

$$i^* \mid R'(i^*) = 1 \quad (2)$$

The optimal investment level is then such that its marginal benefits equal its marginal costs.

### 3.2.2 Flexible Contracting

When parties decide to sign a flexible contract, they accept the fact that they must renegotiate after the initial investments have been made. Since the private operator is now entrenched as the provider, his bargaining power is not reduced by competition from other potential operators (given that it provides the service at, at least, the basic level specified in the initial contract). We therefore assume that the private operator and the public authority have equal bargaining powers, and hence

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but also the human capital investment involved. The road investments correspond to the case of site investments as highlighted by Williamson (1985). In the case of a contract breach, their value would be too small for the private operator and the public authority would have no choice other than to buy back the contract (See Joskow (1987) for one of the first empirical studies of this issue concerning US power utilities and coal mines). It is also reasonable to assume that any investment in human capital (to find innovations that could improve the quality of the public service) will be lost to both contracting parties in the case of a contract breach. This is due to the fact that, in the case of a contract breach, the private provider does not implement the innovation, and that his investments  $i$  have been revealed to the public authority and, according to the type of the innovation, the public authority can find no alternative private operator able to implement the innovation discovered by the former one. Note also that the private operator has for most of the time had no alternative purchaser for this particular incremental investment. Hence, in the case of a contract breach, there is a loss of value for both partners.

consider a renegotiation where the surplus generated by the non verifiable investments,  $R(i)$ , is shared between the parties<sup>4</sup> through a Nash-bargaining solution.<sup>5</sup>

A private operator's objective function is profit, where

$$\pi_c = P_0 - C_0 + r(i) + \frac{1}{2} [\bar{f}R(i) - r(i)] - i \quad (3)$$

where  $P_0$  is the payment that the private operator would obtain if service provision were to be at its basic level. He chooses a level of investment  $i^f$  such that

$$i^f \mid R'(i^f) = \frac{2}{(\bar{f} + \alpha)} \quad (4)$$

When the parties sign a flexible contract, the investments  $i$  deviate from the first-best, with the exception of the particular case where  $\bar{f} = 1$  (*i.e.* there are no renegotiation costs) and  $\alpha = 1$  (*i.e.* there are no specific investments). The surplus generated by such a contract is sub-optimal because of the low incentives for the operator to invest, because he anticipates that he will lose a part of the surplus generated by his investments when renegotiation occurs ( $i^f \leq i^*$ ).

Consumer surplus is then given by  $CS^f$ , where

$$CS^f = B_0 - P_0 + \frac{1}{2} [\bar{f}R(i^f) - r(i^f)] \quad (5)$$

The social surplus  $S^f$ , which is the sum of consumer surplus and the profit of the private operator is:

$$S^f = B_0 - C_0 + \bar{f}R(i^f) - i^f \quad (6)$$

### 3.2.3 Rigid Contracting and Parties Cannot Commit not to Renegotiate

When parties sign a rigid contract, as previously discussed, there is always a risk that this contract will not be applied *ex post* and will need to be renegotiated, thereby leading to the case of an initial flexible agreement (See Appendix 1 for the analysis of the case of a rigid contract where parties can commit not to renegotiate). Hence, a rigid contract appears as a “double bet”: The first concerns the ability to foresee future events and to devise *ex ante* adequate actions; the second concerns the ability to avoid renegotiation of the contract. If we assume that a rigid contract may be renegotiated with a probability  $(1 - \eta)$ , the profit generated by such a contract for the private contractor is given by

$$\pi_c = \eta [P_0 - C_0 + \underline{f}.R(i) - i] + (1 - \eta) \left[ P_0 - C_0 + \frac{1}{2} [\bar{f}.R(i) + r(i)] - i \right] \quad (7)$$

The optimal level of investment is then given by

$$i^{rr} \mid R'(i^{rr}) = \frac{2}{\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \underline{f})} \quad (8)$$

<sup>4</sup>The way the surplus is shared is nevertheless affected by the outside options of each party.

<sup>5</sup>Thus, following Hart, Shleifer, and Vishny (1997), we assume that the public authority does not maximize the global surplus during renegotiations: its utility function is given by the welfare of the rest of society, excluding the private operator. A justification for this is that the political process aligns the interests of the public authority with those of society (since the private operator has negligible voting power, his interests receive negligible weight). Of course, if the government placed the same weight on the private operator's utility as it did on the rest of society, the first-best could be achieved.

We observe that when  $\eta = 1$  (*i.e.* when the probability of renegotiating a rigid contract is zero), we find the results that would occur when the government can credibly commit not to renegotiate (equations 8 and 13 in Appendix (1) are the same). Also, when  $\eta = 0$ , this boils down to the flexible contracting scenario.

Consumer surplus is then given by

$$CS^{rr} = \eta [B_0 - P_0 + (1 - \underline{f})R(i^{rr})] + (1 - \eta) \left[ B_0 - P_0 + \frac{1}{2} [\bar{f} \cdot R(i^{rr}) - r(i^{rr})] \right] \quad (9)$$

It follows that the total surplus is

$$S^{rr} = B_0 - C_0 + (1 - \eta) \bar{f} R(i^{rr}) + \eta R(i^{rr}) - i^{rr} \quad (10)$$

### 3.3 Comparisons

#### 3.3.1 Contractual Choices and Global Surplus

In order to be able to generate propositions about socially optimal contractual choices, and thus to rank rigid and flexible contracting, we must compare the total surplus generated under the two types of contracting.

More precisely, a rigid contract – but one renegotiated with a probability  $(1 - \eta)$  – will be preferred to a flexible one when

$$\bar{f} R(i^f) - i^f < \bar{f} R(i^{rr}) - i^{rr} + \eta [R(i^{rr}) (1 - \bar{f})] \quad (11)$$

Because both investment levels  $i^{rr}$  and  $i^f$  are increasing with respect to  $\bar{f}$ , but at different rates, it is not easy to find clear propositions that focus on comparisons of the surplus (*i.e.* a change in the level of  $\bar{f}$  has a direct impact and an indirect impact through the investment levels concerned). The partial derivatives used to disentangle the direct and indirect effects for each of our parameters are presented in Appendix 2, leading to the following propositions.

We now define the following conditions (1) to (4):

$$(1) \quad \bar{f} > \alpha$$

$$(2) \quad \eta > 0$$

$$(3) \quad \eta > \frac{R(i^{rr}) - R(i^f)}{R(i^{rr})}$$

$$(4) \quad i^{rr} > i^f$$

**PROPOSITION 1.** *If condition (1) holds, then the higher the maladaptation costs (*i.e.* the lower  $\underline{f}$ ), the more efficient a flexible contract is compared to a rigid one.*

*Proof.* (See Appendix 2)

The assumption  $\bar{f} > \alpha$  is, in our case, a realistic assumption. As previously discussed (See Fn 3), investments made in road infrastructure are highly specific to the relationship (*i.e.*  $\alpha \rightarrow 0$ ). Proposition 1 is intuitive. The use of a flexible contract is a way of avoiding maladaptation costs. The higher the maladaptation costs, the more interesting it is to avoid them through the use of a flexible contract. Other trade-offs highlighted by our derivatives depend crucially on the investment level considered under each contractual form.

PROPOSITION 2. *If conditions (1), (2) and (4) hold, then the higher the probability of renegotiating a rigid contract, the more efficient a flexible contract is compared to a rigid one.*

Proof. (See Appendix 2)

PROPOSITION 3. *If conditions (1), (2) and (4) hold, then the higher the level of asset specificity (i.e. the lower the value of  $\alpha$ ), the less efficient a flexible contract is compared to a rigid one.*

Proof. (See Appendix 2)

Proposition 2 highlights the fact that a rigid contract may be useful only as long as the contracting parties believe that it has a fairly high probability of being enforced. There is no point in signing a rigid contract if it is clear that it will be renegotiated. Proposition 3 stresses the fact that rigid contracts, by defining *ex ante* the way the surplus (generated by the investments made by the operator) is to be shared, lend security to the operator.

PROPOSITION 4. *If conditions (1), (3) and (4) hold, then the lower the renegotiation costs, the more efficient a flexible contract is compared to a rigid one.*

Proof. (See Appendix 2)

As soon as we consider the case where the maladaptation costs are bounded compared to the renegotiation costs<sup>6</sup>, then the lower the renegotiation costs, the more efficient a flexible contract is compared to a rigid one, but only if the probability of not renegotiating a rigid contract is sufficiently high (condition (3)). If the probability of renegotiating the contract is near to one, there is then no advantage in using a flexible contract compared to a rigid one, because rigid and flexible contracts tend to be similar in these cases.

The propositions listed above are intuitive. Nevertheless, they differ from previous models that use incomplete contract theory. Previous research using an incomplete contract framework has focused on the make-or-buy issue, opening it up to criticisms that incomplete contract theory is only a property right theory, and has nothing to say about alternative contractual choices. Our framework is a step towards such an analysis. In addition, our results highlight the fact that the trade-offs are complex, and do not totally correspond with previous propositions that make use of a transaction cost framework. More precisely, previous research has argued that a rigid contract is preferred as long as specific investments are high. In our model, this proposition is true, but only if other conditions concerning the maladaptation and renegotiation costs are met, as well as if there is a high probability of the contract being enforced. Finally, our results suggest that the institutional environment in which the contract is embedded is important.

## 4 Toll Adjustment Processes in Infrastructure Concession Contracts

In order to test our propositions, we compiled a dataset that consisted of 71 toll road concession contracts (highways, bridges, tunnels). These 71 contracts included 45 original contracts and 26 renegotiated contracts, referred to as “supplemental agreements”. These supplemental agreements

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<sup>6</sup>Condition (4) constrains maladaptation costs to be bounded compared to renegotiation costs because  $i^{rr} > i^f$  implies that  $\underline{f} > \frac{\bar{f} + \alpha}{2}$ .

correspond to non-anticipated, agreed modifications to the original contracts concerned, and the fact that these entailed the creation of new and different arrangements between the parties make it possible to consider them as new contracts (See Crocker and Reynolds (1993) for a similar methodology). The majority of projects in the sample (76%) are French, with the remainder being contracts in Greece, the United Kingdom, Canada, Portugal, Benin, Chile and Thailand. The contracts were devised with a range of different operators. The oldest contracts in the sample were implemented in 1970, and the latest in 2005.

#### 4.1 Institutional Details of Infrastructure Concession Contracts

We believe that infrastructure concession contracts deserve special attention because they are subject to the particular difficulties inherent in PPPs. More specifically, in these contracts, concessionaires undertake the design, building, financing and operation of the relevant facility and their main source of revenue is the tolls that they can charge to users during the lifetime of the concession. They are long-term contracts (often over 30 years) and involve a large amount of specific investment early on, and a degree of uncertainty that is much greater than that found in most ordinary contracts. Indeed, forecasts of traffic flows are notoriously unreliable (Skamris and Flyvbjerg (1997); Flyvbjerg, Holm, and Buhl (2002); Flyvbjerg, Bruzelius, and Rothengatter (2003); Odeck (2004); Athias and Nunez (2008)), meaning that toll road concessions are very risky. The high degree of uncertainty surrounding concession contracts makes them particularly prone to pervasive renegotiations (Engel et al. 2006). In fact, whenever bidders expect a high likelihood of renegotiation that renders it possible to avoid losses, they then have a strong incentive to submit bids that contain promises that are difficult to honour, with the sole purpose of being awarded the tender. This phenomenon is often described by the term “lowballing”. Uncertainty in forecasting is then used strategically by bidders, and is exacerbated by the information asymmetries that exist in concession projects (Athias and Nunez (2008)).

The design of the process of contractual compensation in infrastructure concession contracts is not regulated, *i.e.* there are no rules that determine the set of allowable toll adjustment processes. Concession contracts are most often awarded under an open bidding procedure, usually in two stages. In the first stage, private consortiums submit their technical qualifications, following the rules defined by the public authority concerned. In the second stage, the qualifying consortiums, *i.e.* those consortiums selected at the end of the first stage, are allowed to bid for the concession. The concession is then awarded to the consortium with the best bid (sometimes there is an additional stage between the second stage and the selection of the best bid, in which the two best bidders are asked to submit their Best and Final Offers in a final stage). Most toll road concession contracts are awarded via lowest-bid auctions, with adjudication criteria that include the lowest toll, the lowest public subvention requirement, and the shortest concession. When the best offer has been selected, there is then the so-called “preferred bidder phase”, during which the public authority negotiates the final terms of the contract with the preferred bidder. During this phase, the public authority and the private operator have the opportunity to make the contract more rigid or more flexible through negotiation. This feature of the award process for toll infrastructure concessions introduces reputational considerations into the selection of contractual terms, making the study of such selections of particular interest.

## 4.2 Toll Adjustment Types

We now turn our attention to the detail of the toll adjustment processes used in our sample as summarized in Table 1. Toll – or price – adjustment processes can be divided into two categories, rigid and flexible.

### 4.2.1 Rigid Adjustment Processes

Among the rigid adjustment processes, the most stringent is the “firm-fixed price” contract (FFP), in which price is specified to be independent of future events. FFP contracts are rarely used in infrastructure concessions, however, as a result of the high degree of uncertainty involved in them. More common are the automatic provisions that adjust tolls periodically, according to a predefined formula. The most extreme, rigid form in this category is a definite escalator (DE), that adjusts tolls according to an explicit, predefined schedule, increasing tolls, for example, at a specified rate. Some parties have also devised DE contracts that provide greater flexibility, by allowing the concessionaire a predefined margin around the adjusted price (DE/MARG). In contrast, fixed-price with economic price adjustment (EPA) contracts attempt to relate contract tolls to market conditions as they unfold. The process of compensation is formulaic, and the equation used ties the tolls to market data such as the consumer price index or specific indices of labor or materials. In practice, the flexibility of such a contract depends upon the number and importance of the indexed categories. For this reason, we have distinguished between those contracts that use fixed-price with partial economic price adjustment, which use the consumer price index to determine tolls according to an agreed compensation formula (FP/CPI), and those that use a fixed-price with economic price adjustment, which use cost indices (FP/COST). In both cases, implementation remains straightforward, while the tolls become more flexible. However, the requirement that the contingencies and compensation formulas be explicitly prespecified constrains the flexibility of such contracts. The possibility for the concessionaire to be guaranteed a fixed minimum increase in price using a predefined escalator (FP/EPA/DE), or to have a predefined margin around the adjusted price (FP/EPA/MARG), or a traffic variation indexation (FP/EPA/TRAFFIC) in the compensation formula, does not eliminate these drawbacks, even if it provides greater flexibility. These first eight price adjustment processes are sufficiently rigid to work without any external intervention. They are clearly rigid toll adjustments that take account of maladaptation costs in order to avoid *ex post* renegotiation.

### 4.2.2 Flexible Adjustment Processes

Some parties have also devised adjustment provisions such as not-to-exceed price (NTEP). NTEP is specified at the outset and the concessionaire must negotiate with the public authority the determination of a firm price at or below this ceiling. NTEP contracts are thus not purely automatic adjustment processes, in that the final price is the result of negotiation, but neither do they contain renegotiation provisions in that the contracting parties do not specify *ex ante* the periodic negotiation of the toll adjustment process. In addition, in all the contracts that resort to this NTEP adjustment, the toll ceiling is loosened by indexing the tolls to the consumer price index (NTEP/CPI) or to prespecified cost indices (NTEP/COST). Parties have also devised contracts that have a not-to-exceed-price with economic price adjustment – CPI or COST or both – that either ensure the concessionaire a fixed minimum increase of the NTEP through a predefined escalator (NTEP/DE/EPA), or an indexation to traffic variation (NTEP/TRAFFIC/EPA),

or a margin of prices (NTEP/EPA/MARG). The most flexible option in this category affords the concessionaire the total freedom to determine and impose tolls over a ten-year period, and then establishes a NTEP with adjustment via indexation to cost indices for the remainder of the concession (FREE/NTEP/COST). Some parties in our sample have also devised renegotiation provisions (RENEG) that consist in determining *ex ante* periodic *ex post* negotiations of the initial adjustment process. The parties thus periodically take into account the full range of relevant information before reaching agreement on the toll. These provisions therefore afford the transaction a considerable degree of flexibility. Nevertheless, the parties may structure the negotiation process by, for example, defining in the contract the sequence of offers and acceptances, or specifying the defaults if agreement cannot be reached.

These last seven adjustment processes explicitly pave the way for *ex post* negotiation and the final agreed price is then the result of negotiation between the private operator and the public authority. They are all clearly flexible toll adjustments.

The toll adjustment processes are summarized in Table 1. Such a wide range of price provisions is somewhat surprising in view of the fact that in the literature it is often claimed that one of the main drawbacks of concession contracts is their rigidity (PWHC (2005)).

Table 1: Toll Adjustment Types

Type	Negotiated <i>Ex Ante</i>	Negotiated <i>Ex Post</i>
Firm-fixed price (FFP)	Price	No negotiation <i>ex post</i>
Definite escalator (DE)	Price, escalator	Only adjustment to price according to an explicit predefined schedule
Definite escalator with a margin (DE/MARG)	Price, escalator, margin	Only adjustment to price according to an explicit predefined schedule with the flexibility afforded by a predefined margin
Fixed price with partial economic price adjustment (FP/CPI)	Price, Economic price adjustment formula based on the consumer price index	Only formulaic adjustment to price as specified <i>ex ante</i>
Fixed price with economic price adjustment (FP/COST)	Price, Economic price adjustment formula based on specific labor or materials indices	Only formulaic adjustment to price as specified <i>ex ante</i>
Fixed price with EPA and with a definite escalator (FP/EPA/DE)	Price, Economic price adjustment formula, definite escalator	Only formulaic adjustment to price as specified <i>ex ante</i> and according to an explicit predefined schedule
Fixed price with EPA and with a margin (FP/EPA/MARG)	Price, Economic price adjustment formula, margin	Only formulaic adjustment to price as specified <i>ex ante</i> with the flexibility afforded by a predefined margin
Fixed price with EPA and with traffic variation indexation (FP/EPA/TRAFFIC)	Price, Economic price adjustment formula, traffic indexation	Only formulaic adjustment to price as specified <i>ex ante</i> and to traffic variation
Not-to-exceed price with partial economic price adjustment (NTEP/CPI)	Ceiling price, Economic price adjustment formula based on the consumer price index	A firm price at or below the ceiling
Not-to-exceed price with economic price adjustment (NTEP/COST)	Ceiling price, Economic price adjustment formula based on specific labor or materials indices	A firm price at or below the ceiling
Not-to-exceed price with a predefined escalator and an economic price adjustment (NTEP/DE/EPA)	Ceiling price, definite escalator, Economic price adjustment formula	A firm price at or below the ceiling
Not-to-exceed price with a traffic variation indexation and an economic price adjustment (NTEP/TRAFFIC/EPA)	Ceiling price, Traffic variation indexation, Economic price adjustment formula	A firm price at or below the ceiling
Not-to-exceed price with economic price adjustment and with a margin (NTEP/EPA/MARG)	Ceiling price, Economic price adjustment formula, Margin	A firm price at or below the ceiling
Freedom during ten years and then NTEP/COST (FREE/NTEP/COST)	Ceiling price, Economic price adjustment formula based on specific labor or materials indices	A firm price at or below the ceiling after ten years
Renegotiation Adjustments (RENEG)	Initial automatic adjustment process, Frequency of renegotiation	A firm price

### 4.3 Toll Adjustment Types and Contractual Rigidity

The description of the toll adjustment processes found in our sample of contracts suggests that not all contracting parties determine future prices with the same degree of rigidity. As a consequence, we may rank the contract types encountered in infrastructure concessions according to a qualitative index of rigidity. The most rigid contract in this regard is clearly the FFP, which permits no toll adjustment at all. When escalated by a predefined adjustment or by an economic price adjustment tied to the consumer price index, or to the realized costs of important inputs, the contract is

less rigid, although still more rigid than NTEP contracts, and the different variations on these, which afford the concessionaire a greater degree of flexibility in determining tolls according to the actual context, but also provide substantial scope for opportunism. Nevertheless, the upper bound restrains the most opportunistic redistributive strategies, in contrast to renegotiation adjustments, which nevertheless do permit the parties to take full advantage of the most up-to-date information.

The following tables (Table 2) indicate the ranking of the price adjustment processes used in the empirical part of our study, where lower numerical values correspond to less rigid contracts. In order to perform econometric tests on toll adjustment processes, we have decided to classify our contracts in two different ways. In the first classification, we reduce the number of observed processes from 15 to 11; in the second, from 15 to 5. Using these two classifications, the robustness of our results may be demonstrated according to the way the adjustments are classified.

Table 2: Dependent Variables (11 groups & 5 groups)

TYPE	Freq.	Mean
1 if RENEG	3	6,28
2 if FREE/NTEP/COST	10	
3 if NTEP/EPA/MARG	10	
4 if NTEP/TRAFFIC//EPA	3	
5 if NTEP/DE/EPA	3	
6 if NTEP/COST or NTEP/CPI	4	
7 if FP/EPA/MARG	10	
8 if FP/EPA/DE	2	
9 if FP/EPA/DE	12	
10 if FP/COST or FP/CPI	6	
11 if DE or DE/MARG or FFP	8	

TYPE	Freq.	Mean
1 if RENEG	3	3,42
2 if FREE/NTEP/COST	10	
3 if NTEP	20	
4 if FP	30	
5 if DE or FFP	8	

Table 2 shows that the parties use a wide range of toll adjustment provisions that are fairly well distributed across our groups.

## 5 Determinants of the Toll Adjustment Processes

In this section, we present our explanatory variables and discuss how these are related to our theoretical model.

### 5.1 Relating The Model To Data

Our model yields one elementary prediction about the way in which contractual choices differ across institutional frameworks. With the view that it is useless to devise a rigid contract if it will be renegotiated later on, a first prediction is therefore that weak institutional frameworks (*e.g.* if the reliability of the contract enforcement is weak) are more likely to lead to flexible contracts.

Our model also yields two predictions about how contractual design differs depending on the characteristics of the project. Firstly, the theory suggests that contracting parties are less likely to design rigid contracts for which the uncertainty is higher (proposition 2). The contention is that maladaptation costs are a function of uncertainty, so that the higher the uncertainty, the higher the probability that the rigid contract will be poorly specified. Secondly, and following directly on from proposition 3, the theory predicts that contracting parties are more likely to devise rigid contracts for which the degree of investment specificity is high.

A further set of predictions that emerges from the theoretical framework concerns the magnitude of the renegotiation costs. The model suggests that the higher the renegotiation costs, the more likely the contracts are to be rigid. The straightforward empirical implications of this proposition involve differences in the contracting parties' characteristics as well as differences in institutional environments. In fact, the costs of *ex post* adaptation are a function of the willingness (or lack thereof) of the contracting parties to enter into conflict, haggling and friction. Thus, when parties decide to devise a flexible contract, they must account for the likely behavior of the other contracting party, because some renegotiation will inevitably occur later on. Reputation is therefore an important dimension, reducing the probability of high *ex post* renegotiation costs. Furthermore, differences in political ideology (*e.g.* left- or right-leaning public authorities) may affect the contractual choices made. Left-leaning public authorities are generally more skeptical than right-leaning ones about the delegation of public services to private operators, and hence may behave less cooperatively. More broadly, the institutional framework may affect the renegotiation costs. On the one hand, the existence of weak institutional frameworks, in which the probability of success of opportunistic behavior is high, implies the possibility of higher renegotiation costs that will then be more likely to lead to rigid contracts (Spiller (2008)). On the other hand, as already discussed, weak institutional frameworks are inefficient at avoiding renegotiation and therefore reduce the value of rigid contracts. The overall impact of the institutional environment on the contractual rigidity is therefore unclear (it has a positive impact through  $\eta$  but a negative one through  $\bar{f}$ ).

In order to test our propositions, we constructed several explanatory variables, connected with our model parameters, in order to explain the wide variety of types of toll adjustment. The definition of our variables is presented in Table 4. Table 3 indicates the correspondence between the variables of the theoretical model and those of the empirical model.

Table 3: Correspondence between variables in the theoretical and the empirical models

Variables of the theoretical model	Variables of the empirical model	Expected sign
Type of Contract (rigid vs. flexible)	RIGID	Left-hand variable
Type of Contract (rigid vs. flexible)	TYPE OF ADJUSTMENT (5 GROUPS)	Left-hand variable
Type of Contract (rigid vs. flexible)	TYPE OF ADJUSTMENT (11 GROUPS)	Left-hand variable
Costs of maladaptation $\underline{f}$	The higher the traffic uncertainty, the more likely the initial contract will be maladaptated: TRAFFIC	-
Costs of maladaptation $\underline{f}$	The higher the contract duration, the higher the maladaptation costs: DURATION	-
Costs of renegotiation $\bar{f}$	The higher the number of past repeated interactions between parties, the more they developed a reputational capital and experiences that help to settle conflicts: REPEATED CONTRACT	-
Costs of renegotiation $\bar{f}$	Left-wing authorities are more reluctant to contract out than right-wing authorities: LEFT	+
Costs of renegotiation $\bar{f}$ and perceived probability to renegotiate $\eta$	Strong institutions frame renegotiation processes but also make rigid contracts credible: REGULATORY QUALITY	unclear
-	SEMI PUBLIC	control variable
-	LEARNING	control variable
-	SUPAGREE	control variable
-	NBBIDDERS	control variable
-	LOCAL AUTHORITY	control variable
-	OPERATOR	control variable
-	FRENCH	control variable
-	TREND	control variable

## 5.2 Project Characteristics

The existence of uncertainty may affect contractual choices, especially through its impact on the expected maladaptation costs. One of the primary sources of uncertainty that face contracting parties during negotiations over a road concession contract is the difficulty of forecasting future traffic flows with any confidence. This uncertainty about future demand may be more or less important depending on the context of the project. In order to quantify this uncertainty in traffic flow, we surveyed a set of managers of a French private concessionaire, asking them to rate the uncertainty surrounding the traffic flows for each project (more information about the data collection process in this regard is presented in Appendix 3). We interviewed these managers only in relation to the contracts in which their own companies were involved, either because the company won the contract or because it participated in the bid. It is also important to note that the interviewees all had more than 15 years of experience and were well able to remember how they assessed the uncertainty surrounding traffic flows in the project before the project was launched (some old records of their traffic forecasts still exist for each project). In fact, when negotiating a contract, the parties have expectations about the degree of uncertainty in these forecasts likely to be experienced during the course of the exploitation phase. We capture this uncertainty in the explanatory variable TRAFFIC, which corresponds to the average rating (between 1 and 5) given by the managers to the uncertainty of predicted traffic flows in every contract. We checked that the respondents gave consistent answers to all the questions, and undertook further probing if there was any inconsistency. The hypothesis is that increasing uncertainty in traffic flows, as reflected by an increase in the rating given by the managers interviewed, should lead to more flexible contractual arrangements.

Another important source of uncertainty stems from the difficulty of predicting future economic conditions with any confidence. We capture the increasing uncertainty associated with long time horizons in the variable DURATION, which is defined as the number of months between the completion of the infrastructure and the end of the concession. The hypothesis is that a longer duration increases the uncertainty and the costs of implementing more rigid contracts, leading to more flexible arrangements.

### 5.3 Characteristics of Contracting Parties

In relation to the magnitude of the renegotiation costs, those cases where contracting parties previously worked together on other projects may give an indication of reputational as well as learning effects (Gil and Marion (2009)). Repeated contracting helps partners to develop specific procedures and common frameworks that may help to adapt and renegotiate contracts over time, with less argument about what must be done when the environment is subject to change. We capture this effect in the variable REPEATED CONTRACT.

In addition, differences in political ideology (*e.g.* left- or right-leaning public authorities) may affect contractual choices. On the one hand, left-leaning public authorities are generally more skeptical than right-leaning ones about the delegation of public services to private operators. This means that private concessionaires may have a better reputation among right-wing public authorities. On the other hand, private operators anticipate that they may be more likely to be expropriated when the procuring authority is left-leaning. We may therefore expect that contracts negotiated with left-wing authorities are likely to be more rigid. We capture this effect in the variable LEFT.

### 5.4 Institutional Environment

Our model also yields a prediction about how contractual choices differ according to the likelihood of contractual renegotiation. We contend that this likelihood will vary across institutional and regulatory frameworks. In recent years, international institutions have developed numerous aggregate indicators of governance. To capture the reliability of contract enforcement, we used the aggregate indicator REGULATORY QUALITY, developed by the World Bank.<sup>7</sup> This indicator measures the capacity of the government to formulate and implement policies. More precisely, it includes measures of the incidence of policies that are market-unfriendly, such as price controls or inadequate bank supervision, as well as perceptions of the enforceability of contracts and the burdens imposed by excessive regulation in areas such as business development. The hypothesis is that stronger institutional frameworks are more likely to lead to rigid contracts. Nevertheless, this variable might reflect not only the probability of seeing the contract renegotiated but also the fact that renegotiation will be less costly, all other things being equal. Therefore, the expected sign may be positive or negative, depending on which of these effects dominates.

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<sup>7</sup>Kaufmann, Kraay, and Mastruzzi (2004) constructed indicators of six dimensions of governance: Voice and Accountability – measuring political, civil and human rights; Political Instability and Violence – measuring the likelihood of violent threats to government, including terrorism; Government Effectiveness – measuring the competence of the bureaucracy and the quality of public service delivery; Regulatory Quality – measuring the incidence of market-unfriendly policies; Rule of Law – measuring the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence; Control of Corruption – measuring the exercise of public power for private gain. We carried out regressions using all these indicators and all the results were similar.

## 5.5 Control Variables

In addition, we include several control variables in the regressions. Firstly, in our sample of contracts, we have 71 contracts that include 45 original contracts and 26 renegotiated contracts, referred to here as “supplemental agreements”. As pointed out previously, we consider these supplemental agreements to be new contracts (following Crocker and Reynolds (1993)). We allow for the possibility that these contracts are specific by using the dichotomous variable SUP AGREEMENT.

The ability of the procuring authority to negotiate price provisions depends also on the number of bidders. The hypothesis is that the availability of alternative suppliers increases the negotiating power of the public authority during the preferred bidder phase, leading to the adoption of more rigid contracts. Thus, we include the explanatory variable NUMBER OF BIDDERS.

Furthermore, in our sample of contracts, there are private and semi-public concessionaires. We therefore use the binary variable SEMI PUBLIC as an additional control variable.

Because our dataset consists mainly of French contracts, we deal with a possible specific ‘French’ effect using the dummy variable FRENCH in our specifications.

Finally, we incorporate the variable LEARNING, defined as the number of former contracts of the public authority with private concessionaires, and also a trend variable (TREND), as well as two binary variables in order to allow for the type of concedant (national vs. local authority - LOCAL AUTHORITY) and the identity of the private operator (OPERATOR).

The variables used in our regressions are summarized in Table 4.

Table 4: Definition of our Variables and Descriptive Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max	Definition
RIGID	71	0.53	0.50	0	1	1 if the contract belongs to groups 7 to 11 (See Table 2)
TYPE OF ADJUSTEMENT (5 GROUPS)	71	3.42	1.01	1	5	Ranking of toll adjustment types in 5 groups (See Table 2)
TYPE OF ADJUSTEMENT (11 GROUPS)	71	6.28	3.28	1	11	Ranking of toll adjustment types in 11 groups (See Table 2)
TRAFFIC	71	2.39	1.14	1	5	Average rating on uncertainty of traffic flow
LEFT	71	0.31	.46	0	1	1 if the procuring authority is a left-wing authority; 0 otherwise
REPEATED CONTRACT	71	5.27	4.21	0	11	Number of former interactions between the concessionaire and the public authority
LEARNING	71	6.78	4.59	0	16	Number of former contracts of the public authority with private concessionaires
DURATION	68	396.44	183.07	60	1164	Number of months between the completion of the infrastructure construction and the end of the concession
REGULATORY QUALITY	71	1.03	0.31	-0.48	1.82	Rating obtained by the country in question regarding this governance dimension (Source: World Bank)
SEMI PUBLIC	71	0.21	0.41	0	1	1 if the concessionaire is a semi public company; 0 otherwise
SUPAGREE	71	0.46	0.50	0	1	1 if the contract is a supplemental agreement; 0 otherwise
NUMBER OF BIDDERS	69	1.67	1.24	1	5	Number of bidders for the contract
LOCAL AUTHORITY	71	0.29	0.45	0	1	1 if the concedant is a local authority
OPERATOR	71	0.66	0.47	0	1	1 if the concessionaire is the operator that is the most frequent in our database

## 6 Empirical Methodology and Results

### 6.1 Methodology

We herein use the following probit model, which estimates the probability of choosing a flexible contract:

$$F_i = 1 [F_i^* = x_i\alpha_1 + z_i\alpha_2 + T_i\alpha_3 + e_i < 0]$$

where 1 is the indicator function, which takes a value of 1 whenever the statement in brackets is true, and 0 otherwise;  $F_i$  is the binary variable that indicates whether concession  $i$  is controlled through a flexible contract or through a rigid one;  $F_i^*$  is a latent variable;  $x_i$  is a vector of characteristics of the project, of the contracting parties and of the institutional environment;  $T_i$  is the time elapsed, in months, since the award of concession  $i$ ;  $z_i$  is a vector of additional control variables;  $e_i$  is the error term; and  $\alpha_1$ ,  $\alpha_2$ , and  $\alpha_3$  are the vectors of the parameters that correspond to  $x_i$ ,  $z_i$  and  $T_i$  respectively. Table 3 gives details of the correspondence between the key variables highlighted in the model and the proxies included in the empirical model that determine the latent variable.

Because we believe that it is also of interest to consider contracts as devices that lie on a continuum between being totally rigid and totally flexible, we also performed ordered logit estimates taking into account the fact that contracts can be ranked from very rigid to very flexible.<sup>8</sup>

## 6.2 Results

The results are shown in Table 5. We show fewer observations than there are in our whole dataset because data on the number of bidders were not available for two of the contracts and data on duration were not available for concession contracts awarded through Present-Value-of-Revenue auctions.<sup>9</sup>

Model (1) represents our probit model (Rigid vs. Flexible). We present the results with all the independent variables we can include in the regression.<sup>10</sup> The second set of estimates is based on our classification of toll adjustment types in 11 or 5 groups, using an ordered probit (Models (2), (3), (4) and (5)). Firstly, we present results using the same set of explanatory variables as Model (1) (in Models (2) and (3)). We then present results using the whole set of explanatory variables (Models (4) and (5)). We also add for each classification (Models 6 and 7) the results we would have obtained if our dependent variable had been continuous rather than qualitative - to check the robustness of our results - using OLS (See Fn8).

Our results suggest that the uncertainty of traffic flow is clearly an important variable for all the models (at the 1% or 5% significance levels), and drives the choice of toll adjustment type. More specifically, the higher the traffic uncertainty, the more flexible the toll adjustment provision. In addition, contracts of longer duration appear to favor more flexible toll adjustment processes according to our estimates, although this effect is not always significant in view of the econometric specifications used here. These results confirm Proposition 1, which states that the higher the probability of a rigid contract being maladapted *ex post*, the higher the probability that a flexible contract will be used.

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<sup>8</sup>In this case, it is not possible to use an ordinary least squares model because it imposes cardinality on the ordinal variables TYPEADJUST5 and TYPEADJUST11. Using an ordered probit model, we consider the relationship  $F_i^* = x_i\alpha_1 + z_i\alpha_2 + T_i\alpha_3 + e_i$  with  $(i = 1, 2, \dots, n)$ , where  $F_i^*$  is an unobserved latent variable,  $(x, z, T)$  is a set of explanatory variables and  $e$  is a random disturbance. If we consider that  $F_i^*$  is in our case the price provision rigidity level of concession  $i$ , we cannot observe  $F_i^*$  directly, but we can observe a category  $j$ , if  $\mu_{j-1} \leq F_i^* \leq \mu_j$ . The use of an ordered probit model results in estimates of the thresholds as well as of the distance between them. The use of an OLS model exogenously assigns both. Nevertheless, we provide the two types of estimates to check the robustness of our results.

<sup>9</sup>These auctions differ from auction mechanisms where the public authority sets a fixed concession term and firms bid using toll values. Indeed, under a Present-Value-of-Revenue auction, bidders compete on the present value of the toll revenue they require to finance the project. The concession ends when the present value of the toll revenue is equal to the concessionaire's bid. Thus the concession term is undefined. For a precise description of such an auction mechanism, see Engel, Fischer, and Galetovic (1997).

<sup>10</sup>It was not possible to add all our explanatory variables, especially some of our control variables, because of empty cell problems - *i.e.* some of our control variables predict our model perfectly.

Table 5: Estimation Results

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Variable	RIGID	5 GROUPS	11 GROUPS	5 GROUPS	11 GROUPS	5 GROUPS	11 GROUPS
Sample	Whole						
Estimator	Probit	Ord. Probit	Ord. Probit	Ord. Probit	Ord. Probit	OLS	OLS
TRAFFIC	-6.801** (2.559)	-1.272*** (0.326)	-1.063*** (0.225)	-1.380*** (0.359)	-1.183*** (0.248)	-0.414** (0.124)	-1.386** (0.413)
REPEATED CONTRACT	-0.948* (0.375)	-0.104 (0.078)	-0.124+ (0.068)	-0.069 (0.094)	-0.119 (0.074)	-0.012 (0.034)	-0.179+ (0.103)
DURATION	-0.013** (0.005)	-0.002* (0.001)	-0.002+ (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.000 (0.000)	-0.002 (0.001)
LEFT	1.848* (0.894)	1.340** (0.508)	1.293** (0.405)	1.425** (0.518)	1.374** (0.433)	0.435* (0.172)	1.475* (0.583)
REGULATORY QUALITY	-3.471** (1.322)	-3.284** (1.146)	-1.975* (0.918)	-5.389*** (1.368)	-3.784*** (1.082)	-1.659*** (0.331)	-3.863*** (0.930)
FRENCH	0.922 (1.430)	-3.470* (1.617)	-3.514* (1.713)	-3.538+ (1.926)	-3.523 (2.176)	-1.243+ (0.685)	-2.856 (1.881)
SUPAGREE	-1.447* (0.618)	0.340 (0.330)	-0.309 (0.305)	1.045** (0.398)	0.345 (0.325)	0.283* (0.136)	-0.014 (0.387)
LEARNING	0.451* (0.180)	0.338+ (0.182)	0.300 (0.186)	0.327+ (0.173)	0.268 (0.173)	0.115+ (0.060)	0.355* (0.169)
TREND	0.025 (0.056)	-0.066 (0.051)	-0.029 (0.049)	-0.099 (0.065)	-0.054 (0.063)	-0.033 (0.024)	-0.073 (0.077)
NBBIDDERS				0.792* (0.345)	0.781** (0.295)	0.258* (0.112)	0.771* (0.356)
SEMI PUBLIC				3.604*** (1.072)	3.424*** (0.966)	0.978* (0.366)	4.468** (1.332)
OPERATOR				2.168** (0.782)	1.879* (0.810)	0.645+ (0.356)	1.887 (1.199)
LOCAL AUTHORITY				0.083 (1.631)	0.061 (1.613)	0.017 (0.510)	1.733 (1.561)
INTERCEPT	-22.350 (110.297)					71.189 (47.673)	157.628 (155.192)
r2/pseudo r2	0.84	0.58	0.36	0.66	0.42	0.86	0.87
N	68	68	68	66	66	66	66
Rivers-Vuong Test: p-value	0.22	0.87	0.70	0.35	0.61	0.58	0.61

Significance levels: + 0.10 \* 0.05 \*\* 0.01 \*\*\* 0.001; Robust standard errors in parentheses.

When we incorporate the characteristics of the contracting parties in the regression variables, we observe that they all have a significant impact on the price provisions used. Firstly, the REPEATED CONTRACT variable has a negative effect on the selection of the rigidity of the toll adjustment process. This effect is not always significant, depending on the specification used. Nevertheless, the sign is consistently negative, which suggests that any increase in the number of former interactions between the contracting parties will decrease the rigidity of the selected toll adjustment provision. As previously discussed, this result may reflect the fact that past interactions between the same partners may be characterized by their experience and ability to communicate with each other, and hence to adapt through renegotiation without conflict. Secondly, our variable LEFT is significant regardless of the specification chosen, and is positively correlated with the use of rigid contracts. This may reflect the fact that left-leaning authorities are generally rather reluctant to enter into a

contract with private operators for public services, leading them to try to secure everything *ex ante* by signing rigid contracts. This finding runs counter to a recent study by Levin and Tadelis (2008), in which the authors find that there is little correlation between voters' broader political preferences and the contracting practices used<sup>11</sup>, and recommend further investigation of the political drivers involved.

Following our identification of a relationship between the rigidity of the toll adjustment provision and the characteristics of projects and contracting parties concerned, we also find a significant correlation between the rigidity of the toll adjustment provision and the institutional environment. In particular, our measure of the reliability of contract enforcement is negatively correlated with the rigidity of the contract concerned. In other words, the stronger the institutional environment, the more flexible the toll adjustment provisions. As previously discussed, efficient institutions may reduce the probability of seeing the contract renegotiated (hence providing an incentive to the parties to devise rigid contracts), but it may also be responsible for reducing the cost of renegotiations (hence providing incentives to the parties to devise flexible contracts). Our results suggest that it is the latter effect that prevails, *i.e.* strong institutions constitute an important impediment to the opportunism of contracting parties during renegotiation phases, thereby leading to flexible contracts.<sup>12</sup>

Finally, turning now to our control variables, we observe that the number of bidders impacts positively and significantly on the probability of adopting a rigid contract. The availability of alternative suppliers increases the rigidity of the contractual agreements used. The results also show that we may observe an impact from the type of the concessionaire, *i.e.* private or semi-public, on the toll adjustment provision selected. The fact that the concessionaire is a semi-public company appears to make the contract more rigid. A simple explanation in our case is that semi-public concessionaires do not try to negotiate more flexible contractual terms, because they have the same interests as the public authority. If any renegotiation takes place, it will not be characterized by haggling or friction, in contrast with renegotiations with private concessionaires. The identity of the private partner concerned may also be important. Our variable OPERATOR, which takes a value of 1 when the private operator concerned is the most represented in our dataset suggests that some operators might be more associated with rigid forms of contract than others.

The results that relate to the other explanatory variables are less significant, depending on the specification selected. We observe a learning effect that leads to the adoption of more rigid contracts. The more that public authorities are used to contract out public services, the more they rely on rigid contracts. This might reflect the fact that (1) they have learned how to contract and hence their contracting costs are lower and (2) they have learned where future maladaptation costs may originate, thereby encouraging them to adopt rigid contracts. Furthermore, supplemental agreements do not seem to represent specific agreements, because the dichotomous variable SUPAGREE is not always significant, and may have a different sign depending on the specifications used. This is partly consistent with the results obtained by Crocker and Reynolds (1993). Finally, French contracts, which are over-represented in our dataset, seem to be characterized by a fixed effect since our FRENCH variable is significant in some of our estimates.

Our other control variables do not seem to help to explain contractual choices. In particular, our TREND variable, the aim of which is to capture the temporal evolution of contractual practices, is

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<sup>11</sup>We should note however that Levin and Tadelis (2008) are not concerned with contractual choices *per se* but with the make-or-buy decision of local authorities concerning their public services.

<sup>12</sup>This result is in line with the interpretation of Spiller (2008) concerning the impact of institutions on PPP contracts. He contends that where institutions are weak, contracting parties are more likely to adopt rigid contracts for their own protection.

not significant.

## 7 Robustness Checks

For a variety of reasons, our results suffer from a certain degree of fragility. One of the limits of our previous regressions is that the contract duration may be endogenous. Indeed, there is a potential correlation between DURATION and the error term, caused by the omission of two types of variables: the characteristics of the contracting parties (operators' characteristics), and those of the contracts themselves (regional characteristics other than political ones). The regional unobserved factors are technological or political in nature, while the operator-specific ones relate in particular to his renegotiating skills, and so on. Although we have already allowed for fixed effects related to the region and the operator, we go a step further by devising two instruments, both of which are correlated with the decision to sign a long-term contract, but not with the type of price adjustment used. These instruments are the average contract duration observed with the same operator in different regions (instrument 1), and the average contract duration in different regions (instrument 2). They are valid because the correlation between the choice of contract duration for a project with a specific operator in a given region is correlated with instrument 1 through certain aspects that by virtue of its construction, are independent of specific regional aspects. In a similar way, the choice of contract duration is only correlated to instrument 2 through aspects that by virtue of its construction are independent of effects specific to both the region and the operator. We obtained an OLS estimate of the variable DURATION, which we wished to instrument. Note that these preliminary estimates are fairly satisfactory (see Model (8) in Table 6). We test for the exogeneity of the contract duration under scrutiny in our Models (1) to (7), using the Rivers and Vuong (1988) approach, which simply consists in running the standard probit estimation augmented by the residuals of the first stage estimates (see also Wooldridge (2002)). The test largely fails to reject the exogeneity of duration, suggesting that endogeneity is not an issue in this case.<sup>13</sup> The p-values for the Rivers-Vuong test are in the last row of Table 5.

Another issue that arises from our previous results is the fact that our dataset is mainly comprised of French contracts. We have dealt with a possible specific French effect using the dummy variable FRENCH in our previous specifications. Nevertheless, in order to go a step further, we present estimates based on a subsample of French contracts (Models (9) to (11) in Table 6). As with the previous estimates, we performed a Rivers-Vuong test for each specification. When the exogeneity of the contract duration cannot be rejected (Model (9)), we estimate the equations using the above instrumented variables in two stages. Because we performed the two stages separately, we needed to adjust the standard errors in the second stage. We present the bootstrapped standard errors for the instrumental variables (IV) estimations (Model (10)). The results of the robustness checks are presented in Table 6.

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<sup>13</sup>We ran two-stage least-squares regressions using the instrumented variable DURATION. This had no effect on the results given in Table 5. The results are not provided in this paper but are available on request.

Table 6: Results of Robustness Checks

Model	(8)	(9)	(10)	(11)
Dependent Variable	DURATION	GROUP 5	GROUP 5	GROUP 11
Sample	Whole	French	French	French
Estimator	OLS	Ord. Probit	Ord. Probit	Ord. Probit
TRAFFIC	20.948 (32.106)	-1.268* (0.559)	-1.082* (0.535)	-1.060** (0.348)
REPEATED CONTRACT	0.746 (10.326)	-0.353* (0.175)	-0.261* (0.123)	-0.144 (0.132)
DURATION		-0.001+ (0.001)		-0.001 (0.003)
DURATION (IV)			-0.005 (0.042)	
LEFT	17.329 (50.080)	2.314** (0.720)	2.539** (0.939)	1.619** (0.565)
REGULATORY QUALITY	33.825 (105.036)	-3.442 (2.457)	-3.775 (2.360)	-4.297+ (2.209)
SUPAGREE	-30.394 (54.495)	2.419*** (0.740)	2.471* (1.019)	0.655+ (0.363)
LEARNING	1.814 (16.757)	0.130 (0.299)	0.090 (0.309)	0.034 (0.270)
TREND	3.746 (6.613)	-0.080 (0.089)	-0.067 (0.083)	-0.042 (0.086)
NBBIDDERS	60.240* (25.788)	-0.016 (0.640)	0.799 (0.619)	0.510 (0.635)
SEMI PUBLIC	-343.737*** (94.637)	10.050*** (1.691)	8.859*** (1.432)	4.032*** (1.053)
OPERATOR		2.795*** (1.065)	1.760** (0.665)	1.965+ (1.098)
LOCAL AUTHORITY	-272.641+ (139.648)	-1.804 (2.170)	-3.704 (2.880)	-1.088 (1.833)
INSTRUMENT1	0.284** (0.099)			
INSTRUMENT2	5.658 (4.271)			
INTERCEPT	-9518.197 (13277.188)			
r2	0.55	0.67		0.47
N	66	53	53	53
Rivers-Vuong Test: p-value		0.025		0.52

Significance levels: + 0.10 \* 0.05 \*\* 0.01 \*\*\* 0.001; Robust standard errors in parentheses.

The results are mainly confirmed, lending a degree of confidence to our results, although we do note minor differences specific to the French subsample.

## 8 Conclusion

We have herein studied the contractual design of price provisions in public private partnerships (PPPs). We have presented a simple theoretical model that captures in an original way the most important trade-offs between contractual flexibility and rigidity for PPPs. We show that contractual design varies mainly according to the relative magnitude of the maladaptation and renegotiation costs and the probability of contract renegotiation, highlighting the fact that no single type of contractual design is always dominant.

Our empirical work provides evidence that toll adjustment provisions in infrastructure concession contracts show significant diversity, a finding that has not previously been demonstrated. This really does call into question the common belief that PPPs are only ever rigid contracts. In addition, our empirical results lend a significant degree of support to our main predictions. We find that contracts that are characterized by a high degree of uncertainty in the traffic flow forecasts are likely to be less rigid, and we provide strong evidence that the characteristics of the contracting parties affect the contract's design. In particular, an increase in the number of former interactions between the contracting parties decreases the rigidity of the toll adjustment provision used. In the same way, we find that contracts devised with left-leaning procuring authorities are likely to be more rigid. These results confirm and emphasize the importance of trust in such agreements, between a public authority and a private operator. Finally, we also provide strong evidence that institutional environments impact on contract design, so that contracts designed in a strong institutional environment are likely to be more flexible. Thus, concerns related to economic efficiency, as well as those related to politics, play an important role in the design of PPP contracts.

These results are important and constitute the main contribution of this research. They also point to the need for further studies to shed light on the selection process for concessionaires in public-private contracts. Indeed, the efficiency of the observed contractual agreements are also connected to the way in which concessionaires are selected (Bajari, McMillan, and Tadelis (2009)). We may conjecture that in an environment in which there are no devices that allow the contracting parties to secure a rigid agreement, the implementation of an *ex ante* selection process is useless. It would also be interesting to investigate whether a difference between the predicted and the observed types of toll adjustment provision translates into a difference in performance.

## Appendix 1: Rigid Contracting and Parties Can Commit not to Renegotiate

When contracting parties devise a rigid agreement and pledge that they will not renegotiate, the profit of the private operator is given by:

$$\pi_c = P_0 - C_0 + \underline{f}R(i) - i \quad (12)$$

The private operator only receives a part of the surplus generated by his investment, which depends on whether the contract matches the states of nature. He chooses a level of investment such that

$$i^r \mid R'(i^r) = \frac{1}{\underline{f}} \quad (13)$$

Consumer surplus is then given by  $CS^r$ , where

$$CS^r = B_0 - P_0 + (1 - \underline{f}) R(i^r) \quad (14)$$

The *ex post* maladaptation of the contract results in the recovery by the consumers of a part of the surplus generated by the private operator's investment. This simply means that if the private operator considers his investments as means of improving the quality or other dimensions of the service provided, he anticipates that, because renegotiation is not an option, he will retain only a part of the generated surplus, depending on whether the initial agreement matches the states of nature. The other part is considered to be a positive externality for consumers.

The total surplus is then given by  $S^r$ , with

$$S^r = B_0 - C_0 + R(i^r) - i^r \quad (15)$$

We note here that, for a given level of investment, a flexible contract leads to a lower total surplus than a rigid one. This is due to the fact that a flexible contract, in contrast to a rigid one, induces renegotiation costs that constitute deadweight losses. However, this does not imply that rigid contracts are always preferable to flexible ones, since the global surplus is also a function of the investments realized by private operators. More precisely, under rigid contracting, private operators may underinvest because they fear contractual maladaptation, leading to a lower surplus compared with the flexible contracting case.

## Appendix 2: Proofs for propositions 1 to 4

In view of Equation (11), we have the following condition for a rigid contract to be preferred to a flexible one:

$$[(1 - \eta) \bar{f} + \eta] \cdot R(i^{rr}) - i^{rr} - \bar{f}R(i^f) + i^f > 0 \quad (16)$$

Let us define  $\rho(\cdot)$  using the following equivalence:

$$y = \rho(x) \Leftrightarrow x = \frac{2}{R'(y)} \quad (17)$$

In other words, for every  $x$  we have  $R'[\rho(x)] = \frac{2}{x}$

We may thus reformulate the investment levels such that:

$$i^f = \rho(\alpha + \bar{f}) \quad (18)$$

$$i^{rr} = \rho(\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \bar{f})) \quad (19)$$

Our problem boils down to an investigation of the mathematical properties of the function  $\phi(\bar{f}, \underline{f}, \alpha, \eta)$  defined as:

$$\begin{aligned} \phi(\bar{f}, \underline{f}, \alpha, \eta) &\equiv [(1 - \eta) \bar{f} + \eta] \cdot R\{\rho[\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \bar{f})]\} \\ &\quad - \rho[\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \bar{f})] - \bar{f} \cdot R\{\rho[\alpha + \bar{f}]\} + \rho[\alpha + \bar{f}] \end{aligned}$$

By studying the partial derivatives of the function  $\phi$ , we obtain:

$$\begin{aligned} \phi'_{\bar{f}} &= (1 - \eta) R(i^{rr}) - R(i^f) + \{[(1 - \eta) \bar{f} + \eta] \cdot R'(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \bar{f}} - \{\bar{f} \cdot R((i^f) - 1)\} \cdot \frac{\partial i^f}{\partial \bar{f}} \\ \phi'_{\underline{f}} &= \{[(1 - \eta) \bar{f} + \eta] \cdot R(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \underline{f}} \\ \phi'_{\eta} &= (1 - \bar{f}) R(i^{rr}) + \{[(1 - \eta) \bar{f} + \eta] \cdot R'(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \eta} \\ \phi'_{\alpha} &= \{[(1 - \eta) \bar{f} + \eta] \cdot R(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \alpha} - \{R'(i^f) - 1\} \cdot \frac{\partial i^f}{\partial \alpha} \end{aligned}$$

The first term of each derivative captures the direct effect, keeping  $i^f$  and  $i^{rr}$  constant. The second term is the indirect effect that originates from the variation of  $i^{rr}$ . The third term is the indirect effect that originates from the variation of  $i^f$ . We note that there is no direct effect for  $\underline{f}$  and  $\alpha$ . There is also no indirect effect via  $i^f$  on  $\underline{f}$ , nor is there one on  $\eta$ .

Using the new formulation for  $i^f$  and  $i^{rr}$  (see equations 18 and 19), we obtain:

$$\begin{aligned} \frac{\partial i^f}{\partial \bar{f}} &= \rho'[\alpha + \bar{f}] > 0 \\ \frac{\partial i^{rr}}{\partial \bar{f}} &= (1 - \eta) \cdot \rho'[\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \bar{f})] > 0 \\ \frac{\partial i^f}{\partial \underline{f}} &= 0 \\ \frac{\partial i^{rr}}{\partial \underline{f}} &= 2\eta \cdot \rho'[\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \bar{f})] > 0 \\ \frac{\partial i^f}{\partial \eta} &= 0 \\ \frac{\partial i^{rr}}{\partial \eta} &= (2\underline{f} - \alpha - \bar{f}) \cdot \rho'[\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \bar{f})] > 0 \\ \frac{\partial i^f}{\partial \alpha} &= \rho'[\alpha + \bar{f}] > 0 \\ \frac{\partial i^{rr}}{\partial \alpha} &= (1 - \eta) \cdot \rho'[\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \bar{f})] > 0 \end{aligned}$$

We also note that because

$$R'(i^f) = \frac{2}{\alpha + \bar{f}} \quad R'(i^{rr}) = \frac{2}{(1 - \eta)(\alpha + \bar{f}) + 2 \cdot \eta \cdot \underline{f}}$$

we have

$$\bar{f} \cdot R'(i^f) - 1 = \frac{\bar{f} - \alpha}{\alpha + \bar{f}}$$

and similarly

$$[(1-\eta)\bar{f} + \eta] \cdot R'(i^{rr}) - 1 = \frac{(1-\eta)(\bar{f}-\alpha)+2\eta \cdot (1-\underline{f})}{(1-\eta)(\alpha+\bar{f})+2\eta \cdot \underline{f}}$$

In order to prove our propositions, we must first prove that we can find some values of our parameters for our inequality (11) to hold. To show this, we note that  $\phi(\bar{f}, \underline{f}, \alpha, 0) \equiv 0$ . Suppose that  $\underline{f} > \frac{\bar{f}+\alpha}{2}$ , which is implied by  $i^{rr} > i^f$  (a condition that is present in all our cases) and if we choose values for  $\bar{f}, \underline{f}, \alpha$  such that this condition is met, then:

$$\phi(\bar{f}, \underline{f}, \alpha, \eta) = \phi(\bar{f}, \underline{f}, \alpha, 0) + \int_0^\eta \phi'(\bar{f}, \underline{f}, \alpha, x) dx$$

$$\text{Indeed, if } \underline{f} > \frac{\bar{f}+\alpha}{2} \text{ we have } \phi'(\bar{f}, \underline{f}, \alpha, \eta) > 0 \text{ so } \phi(\bar{f}, \underline{f}, \alpha, \eta) > 0$$

We must also prove that  $\phi'_f > 0$ ,  $\phi'_\eta > 0$ ,  $\phi'_\alpha < 0$  and  $\phi'_f < 0$ . The proofs are given below.

### ***Proof of Proposition 1.***

*Proposition 1: The higher the maladaptation costs (i.e. the lower  $\underline{f}$ ), the more efficient a flexible contract is compared to a rigid one*

If we assume that condition (1) holds, that is  $\bar{f} > \alpha$ , we know that  $\bar{f} \cdot R'(i^f) - 1 = \frac{\bar{f}-\alpha}{\alpha+\bar{f}} > 0$

$$\text{and that } [(1-\eta)\bar{f} + \eta] \cdot R'(i^{rr}) - 1 = \frac{(1-\eta)(\bar{f}-\alpha)+2\eta \cdot (1-\underline{f})}{(1-\eta)(\alpha+\bar{f})+2\eta \cdot \underline{f}} > 0.$$

It is then obvious that

$$\phi'_f = \{[(1-\eta)\bar{f} + \eta] \cdot R'(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \underline{f}} > 0$$

### ***Proof of Proposition 2.***

*Proposition 2: The higher the probability of renegotiating a rigid contract, the more efficient a flexible contract is compared to a rigid one*

If we assume that the following conditions hold:

$$\bar{f} > \alpha$$

$$\eta > \frac{R(i^{rr}) - R(i^f)}{R(i^{rr})}$$

$$i^{rr} > i^f$$

Given that:

$$\frac{\partial i^{rr}}{\partial \eta} = (2\underline{f} - \alpha - \bar{f}) \cdot \rho' [\alpha + \bar{f} + \eta(2\underline{f} - \alpha - \bar{f})] > 0,$$

it is then obvious that

$$\phi'_\eta = (1 - \bar{f}) R(i^{rr}) + \{[(1-\eta)\bar{f} + \eta] \cdot R'(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \eta} > 0$$

### ***Proof of Proposition 3.***

*Proposition 3: The higher the level of asset specificity (i.e. the lower  $\alpha$ ), the less efficient a flexible contract is compared to a rigid one*

If we assume that

$$\bar{f} > \alpha$$

$$\eta > \frac{R(i^{rr}) - R(i^f)}{R(i^{rr})}$$

$$i^{rr} > i^f$$

Given that:

$$\phi'_\alpha = \{[(1-\eta)\bar{f} + \eta] \cdot R(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \alpha} - \{R'(i^f) - 1\} \cdot \frac{\partial i^f}{\partial \alpha}$$

Because of our assumptions concerning function  $R(\cdot)$  and our parameters  $\eta$  and  $\bar{f}$ , we know that

$$R'(i^f) > R'(i^{rr}) \text{ and } (1-\eta)\bar{f} + \eta \leq 1$$

then

$$[(1-\eta)\bar{f} + \eta] \cdot R(i^{rr}) - 1 < R'(i^f) - 1 \text{ and } \frac{\partial i^{rr}}{\partial \alpha} < \frac{\partial i^f}{\partial \alpha}$$

We thus have

$$\phi'_\alpha = \{[(1-\eta)\bar{f} + \eta] \cdot R(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \alpha} - \{R'(i^f) - 1\} \cdot \frac{\partial i^f}{\partial \alpha} < 0$$

### ***Proof of Proposition 4.***

*Proposition 4: The lower the renegotiation costs, the more efficient a flexible contract is compared to a rigid one.*

If we assume that:

$$\bar{f} > \alpha$$

$$i^{rr} > i^f$$

$$\eta > \frac{R(i^{rr}) - R(i^f)}{R(i^{rr})}$$

We have

$$(1-\eta)R(i^{rr}) - R(i^f) < 0$$

Following the same reasoning as in the proof of Proposition 3, we obtain

$$\phi'_\bar{f} = (1-\eta)R(i^{rr}) - R(i^f) + \{[(1-\eta)\bar{f} + \eta] \cdot R'(i^{rr}) - 1\} \cdot \frac{\partial i^{rr}}{\partial \bar{f}} - \{\bar{f} \cdot R'(i^f) - 1\} \cdot \frac{\partial i^f}{\partial \bar{f}} < 0$$

## Appendix 3: Data Collection on the Uncertainty of Traffic Flow data

Some of the data used in this paper (TRAFFIC and NUMBER OF BIDDERS) were collected during interviews with three different employees of a French private concessionaire, namely the CEO and two other senior colleagues. The interviews were conducted separately, and the respondents had no idea of the purpose of the project. Most of the projects were negotiated or renegotiated in the last ten years, and the interviewees each had more than 15 years of experience in the firm. They therefore had no difficulty answering any of the questions. For very old contracts, at least one of the three interviewees was able to answer on each of the contracts, because the firm had kept adequate records. Thus, the cross-checking of information was not always possible for every old contract even though the data were available.

For each contract, respondents were asked to rate (between 1 and 5) the uncertainty in the forecast of traffic flow that was likely to be experienced during the course of the exploitation phase as expected at the time of contract negotiation (a rating of 1 corresponded to a contract in which the uncertainty was very low, *i.e.* the respondents had a good idea of future traffic flows, and a rating of 5 signified the opposite case). In order to facilitate the interviews and obtain comparable answers from each respondent we used a structured questionnaire to remind the respondent about the general background of each project. This questionnaire (not exhaustive) was as follows:

1. Regarding the tolling culture of the country in question: are toll roads well established or are there no toll roads in the country? (to estimate uncertainty in toll acceptance)
2. Regarding toll-facility details:
  - (a) Is the infrastructure in question an extension of existing roads or to be built on a Green-field site?
  - (b) Is the infrastructure in question a stand-alone facility or does it rely on other, proposed improvements?
  - (c) Are there few competing roads or many alternative ones? - Is there only road competition or multimodal competition?
3. Regarding the users:
  - (a) Are there few, key origins and destinations or multiple origins and destinations?
  - (b) Is the demand profile flat or highly seasonal and/or “peaky”?
  - (c) Is the income time-sensitive to market highs or lows?
4. Is the local/national economy strong or weak?

Once the respondent had answered these questions, he was better able to give an accurate rating of the uncertainty of the traffic flow forecasts of the project in question, on a scale between 1 and 5.

Furthermore, when we did not obtain comparable answers between interviewees, we probed until we reached agreement (which was usually easily achieved).

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