Should we fear Renegotiations in PPPs? Multi-contracting and contractual arrangements in the French car park sector

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Abstract

Using an incomplete contract framework, we model the consequences of non-contractible innovations in public-private partnerships (PPPs) signed in the French car park management sector. We show that the kind of contractual agreement and the number of contracts parties share have an influence on the occurrence and outcome of renegotiations caused by these non-contractible innovations. Consequences are both on the level of incentives to innovate, and their impact on the global ex post surplus, as well as its allocation between parties.

JEL Codes: L14, L22, L24, L33.
Key Words: Renegotiation, Public-private partnership, Contractual Agreement, Efficiency, Innovation, Multi-contract

1 Introduction

Relationships between private companies and public authorities in the management of public services are all but simple. Recent literature on public-private partnerships stresses how difficulties may emerge, whether before, after or during the execution of the contract. In this context, renegotiations often appear as a sign of failure. In this paper, we show how the type of contractual agreement and the number of contracts between a public authority and a private operator determine the occurence of renegotiations and their outcomes for each party. Our focus on renegotiations comes from an apparent contradiction. On the one hand, renegotiations are often described as a "lack of compliance with agreed-upon terms and departure from expected promises"(Guasch [2004]). For such a reason, they would lead to losses of social surplus, hence their image of failures in the public-private relationship.

On the other hand, interviews with both public and private practionners[1] reveal that renegotiations are indeed frequent, but do not systematically lead to a negative outcome. Both private firms and public authorities admit that renegotiations are often a way to adapt the service and are mutually beneficial.

Given this mismatch about the question of renegotiations, we wonder in which conditions renegotiations may be beneficial to both partners or only to one of them at the expense of the other. In this regard, and as a starting point which later justifies the assumptions of our model, we explore a sector where contracting out is widespread, and renegotiations are numerous: the car park management sector in France, where 89% of off-street parkings are managed by a private operator[2], and on average, a contract is renegotiated 2.45 times.[3] We noticed that when a public authority decides to contract out such a service, she has two means to shape a relationship with a private operator: the type of contractual arrangement (i) and the number of contracts she has with the same partner (ii).[4] For this reason, we explore the impacts of these two choices on the occurence and outcomes of renegotiations for each party.

(i) Indeed, public authorities can use different contractual arrangements when they contract out with private firms for the management of car parking services. We focus on the two main types of agreements: public procurement and delegated management. None of these agreements is privatization, nor public provision. They are "hybrid" structures, that allow a private operator to manage a public service for a contractually-defined period. However, both agreements allocate differently the decision and payoff rights during the execution of the contract, and the remuneration schemes are also different. Under public procurement, the private operator is remunerated by a fix payment made by the public authority, while under delegated management, the private operator is paid through the collection of users fees (article L. 1411-1 of *Code général des Collectivités Territoriales*). Thus, he bears the demand risk (World Bank [2009]).

(ii) The other tool we investigate for the public authority to influence the outcome of renegotiations is the number of contracts she has with a same private operator. Indeed, in cities where there are several parkings, public authorities can decide to attribute one or

[1] Pierre-Denis Coux, Head of Urbanism and Construction department, French Ministry of Infrastructure, Septembre 26th, 2008; Mathieu Muzumdar, Head of Public contract evolution department, French Ministry of Sustainable Development, Ecology and Transportation, Septembre 29th, 2008; Jean-Vianney d'Halluin, Head of Concession Contracts department, Cofiroute, September 23rd, 2008; Stéphane de Barros, Head of Legal Department, Vinci Park, January 16th, 2009

[2] theeuropeanparkingassociation2009

[3] Statistics from the French leader company of car parking, collected for the paper, and which will be refered to as the Debrux Database [2010], including 580 car park contracts signed in France between 1965 and 2009.

[4] The French legislation also grants public authorities with some veto power on the decisions of a private partner, when the national interest is at stake. However, such power (called *Fait du Prince*) can only be used in case of a real danger for the general public interest. In practice, it is scarcely used, and never in the car park sector. That's why we focus on the two means public authorities have at disposal: the choice of the contractual agreement and the number of contracts that are shared.

several contracts to a same private operator.[5] We wonder whether this decision has an impact on the outcome of renegotiations. So, here, we call "multi-contracting" a situation where a private operator and a public authority share several contracts related to a similar service.[6]

With such a perspective, our paper attempts to show that the type of contractual agreement defined in the legislation and the number of contracts shared by parties determine the *ex post* efficiency of the transaction. Our focus is then on the formal "contractual" rules of the game and on the environment of the transaction, which puts our contribution in the second level of the social analysis described by Williamson [2000].

To reach our goal, the perspective we adopt is that of the incomplete contracting (Grossman and Hart [1986], Hart and Moore [1990], Hart [1995]). This theoretical framework highlights the role of the allocation of property rights[7] in uncontracted-for circumstances, so as to understand the costs and benefits of contractual choices. The assumption of contractual incompleteness is often used to study contracts signed between public and private partners (Hart et al. [1997], Hart [2003], Bennett and Iossa [2006]), mainly because the quality of service often cannot be fully specified by public authorities. Nor can they anticipate the contingencies which will arise during the execution of the contract. Because of uncontracted-for contingencies, we follow the basic idea of Hart et al. [1997] and assume that, during the execution of the contract, the operator may come up with some ideas to improve the quality of the service or to reduce its costs. Such non-contractible efforts to find innovations may lead to renegotiations, when the service has to be modified.

With such a framework, we first determine the incentives of the private operator to innovate under each type of contractual agreement, and then the total *ex post* surplus reached in each case. Second, we put the emphasis on how this *ex post* surplus is allocated between parties. This leads us to show under which conditions both parties benefit from innovations (*ex post* pareto-efficiency) and under which conditions only one party benefits from them at the expense of the other (Hicks-Kaldor *ex post* efficiency). Last, we show that multicontracting increases both the gains and losses of each party.

Our results can be summed up as follows: We show (1) the occurence of renegotiations and the incentives to innovate of the operator are different under each type of contractual agreement. Public procurement contracts generally lead to under-optimal incentives to innovate, while these incentives under delegated management contracts are mainly driven by the impacts of innovations on the number of users of the service, and then on the revenue of the operator. When this impact is low, incentives to reduce costs are over-optimal, and incentives to reduce quality are under-optimal. (2) Innovations benefit to both part-

[5] The decision to award several contracts to a same operator can be taken simultaneously for all contracts, or sequentially, which has no impact on the results.

[6] So we exclude the question of multi-service, which, contrary to multi-contract, has already been the object of attention in the litterature(Chong et al. [2009], Bernheim and Whinston [1990])

[7] As will be explained in the model, we rather focus here on decision and payoffs rights than property rights per se.

ners under public procurement thanks to renegotiations that allow to share their gains. On the contrary, innovations may be detrimental to the public authority under delegated management, but the features of the contract do not allow to limit them. (3) Under some conditions, multicontracting allows to increase the global *ex post* surplus, but makes the losses of the public authority larger. This third result allows us to highlight an "efficiency dilemma": if the public authority chooses delegated management, she maximizes the total surplus, but accepts some losses when innovations are implemented, because her losses are outweighted by the gains made by the private operator. If she prefers public procurement, the global surplus is lower, but she does not suffer from some losses because of the implementation of innovations.

To relate our paper to the previous literature, many papers have explored the *make-or-buy* question in the management of public services (Williamson [1999], Hart [2003], Levin and Tadelis [2009]). In our paper, we do not clear-cut the debate between public *vs.* private provision, but we account for the diversity of hybrid forms in the car park sector and we show that the efficiency of a contractual agreement also depends on the environment of this transaction, *i.e.* the type of contractual agreements and the number of contracts parties share.

Our paper is also mainly related to that of Hart et al. [1997], but we depart from this paper in two different ways. First, we only focus on contracting-out and compare two types of contractual agreements with some private involvement, while Hart et al. [1997] compare privatization to public provision. Thus, we emphasize the role of the allocation of payoff and decision rights, instead of property rights. Second, while Hart et al. [1997] focus on the question of whether it is optimal or not to privatize public services, our goal is to determine *how* to contract-out temporarily public services, *i.e.* what kind of hybrid forms to use and how many transactions to have with a same private partner. The recent contribution of Hoppe and Schmitz [2010] also propose to analyze the different contractual arrangements observed in the management of public goods, beyond the bipolar case of privatization and public provision. However, they focus on the impact of the initial *ex ante* specified quantity of the good on the incentives to innovate. On the contrary, we rather focus on the consequences of those innovations on the payoffs of public and private parties.

Our paper also contributes to the literature on renegotiations. Many papers (Guasch [2004], Guasch et al. [2008]) highlight the main determinants of renegotiations, while we focus on their results and on the driving forces of the sharing of the *ex post* gains during renegotiations. Moreover, renegotiations have been generally analysed through the lens of opportunism, from the private operator (Williamson [1976], Guasch et al. [2000], Bajari and Tadelis [2001], Estache and Quesada [2001]) or from the public authority(Engel et al. [2006], Guasch et al. [2006], Levy and Spiller [1994]). This literature emphasizes opportunistic renegotiations that are the results of hold-ups. On the contrary, our paper allows to distinguish some cases where renegotiations lead to enhance the *ex post* payoffs of one or

both partner(s). We suggest that the type of contractual agreement and the number of contracts between parties should be considered as two full-fledged elements for successful public-private partnerships.

The paper is organized as follows: Next section describes the French car park management sector. Section 3 presents a model derived from the description of the sector given in section 2. In section 4, we define the levels of ex post efficiency that can be reached under each contractual agreement, and analyse under which conditions they are reached. We also show the various effects of multicontracting on the global surplus and the payoffs of each party. Finally, we conclude with some possible extensions and some public policy recommendations.

2 The contractual management of car parks in France: An overview

The distribution of public space and the management of parking areas is one of the public services under the responsability of the municipalities in France. Many public authorities are today convinced that better parking has positive externalities and that some social benefits can be derived from an efficient management. For instance, recent environmental concerns raise many issues in the urban development, such as the connection between car park and new transport services.[8] During these last years, many innovations have been introduced to increase such social benefits. For instance, modern car park may foresee the offer of shuttle bus services for downtown workers.[9] Because of these social benefits, public authorities have to organize carefully the management of car parking. In practice, municipalities can decide to operate the car park service by themselves (possibly in association with other local communities), or to contract them out to a private firm.[10] Only 11% of off-street parkings are provided in-house ("public provision") in France (The European Parking Association [2009]). On the contrary, when the municipality decides to entrust a private firm with the provision of the service, she can choose between two procedures: public procurement or delegated management. On all the contracts signed since 1965 in the French leader company of car parks[11], 53,62% are delegated management contracts,

[8]We can also think to benefits such as a better access to many public buildings such as hospitals, railways, or airports, more appealing streetscapes, healthier cities and better business.

[9]Other examples of services are the sale of public transport tickets with direct access to metro, car rental, car-sharing, or bike loans. Journey time, distance and travel costs encourage this combination of transport methods.

[10]Let us note that contrary to the U.S., there is no contracting-out towards public agencies. The municipality either provides the service itself or contract it out to a private firm.

[11]Since there is no regulation authority in the car park sector in France, data are not centralised, and hard to bring together. So, the access to the contracts of the French leader company for car park services was an opportunity for us to improve our knowledge about outsourcing in this sector, and to derive some stylized facts. The database, refered to as "Debrux database" in the following tables and graphs, is made of all the car park contracts outsourced to that firm. On the whole, 580 contracts were read and identified in the base. The first one was signed in 1965, and the latest, in December 2008, since the building of

and 46,38% are public procurement contracts. This repartition is different if we focus on the on-going contracts in January 2009, with 29,66% of delegated management contracts and 70,34% of public procurement contracts.

2.1 Contractual agreements in the car park sector

2.1.1 Public procurement

Under public procurement, a service is contracted out to a private firm, with the government keeping ownership (and decision) rights during the contract period and when the contract ends. The recent European legislation defines public procurement as contracts that "cover supplies, services and works purchased by the public sector".[12] The value of the car park contracts generally exceeds the threshold of 20 000 euros, which implies that the local public authority is not exempted from a call for tenders.[13] The selected bidder is generally the one that has the better weighting of the three following award criteria: the tecnhical value of the bid, the quality proposed for the service and the amount of the fix payment required for the execution of the service. This fix payment is the unique source of revenue of the operator, and is paid by the public authority. In this way, the operator does not bear the demand risk.

2.1.2 Delegated management

In France, delegated management refers to two main contractual agreements: lease contracts (or *affermage*) and concession contracts.

Under lease contracts, the operator manages the service of an existing facility, and is paid thanks to the users' fees.[14] However, there is generally a contractual clause stating that, above a certain threshold of sales, the operator must pay the authority a percentage of this additional revenue. This percentage is generally high (above 60%, and sometimes up to 80%), which introduces a kind of limit to the revenue an operator can get from the service. Concession contracts are close from lease contracts, but enable in addition the construction of a new asset or its modernization, upgrade, or expansion by the private operator. In the parking sector, we notice that the number of concession contracts is

the database started in January 2009. During this period, it appears that some of the contracts of the database ended. Some of these were renewed, while others stopped. Some contracts are on-going. All the contracts of the database were awarded by public authorities. Since this firm represents between 40% and 50% of the total market share in the car park sector, and only 11% of car parks are provided in-house, the information we get is not complete but gives us useful indications about the practices in the sector.

[12] *http : //europa.eu/scadplus/glossary/publicprocurementen.htm*

[13] Decree of December 20th, 2006, modifying the *Code Des Marchés Publics* of 2006.

[14] The tarif per user is negotiated with the public authority before the beginning of the contract, but the total revenue of the private operator depends on the frequency of the users.

declining through time[15], so that most of the contracts signed under delegated management are lease contracts, and we will mainly focus on them in our model.

The main feature of both lease and concession contracts is that profits "depend on the utility's sales and costs, which typically gives the operator incentive to improve operating efficiency and increase sales" (World Bank [2006]). Thus, under such types of agreements, commercial risk is transferred to the private partner, as his ability to derive a profit is linked with its ability to reduce operating costs, while still meeting designated service levels (European Commission [2003]). Moreover, unlike public procurement contracts, the public party relinquishes its control on important phases of the life-cycle of the assets (European Parliament [2006]). As a result, the private operator holds the residual rights of control, for the contingencies that arise during the contract period or that had not been specified *ex ante* in the contract.

2.1.3 The problem of contractual incompleteness

Whether public procurement or delegated management is chosen, public authorities can specify many aspects of the service in the contract, such as the types of monitoring they want (electronic monitoring or employees hired to monitor), the number of cleaning per day, the type of lighting, the opening hours of the service, or the total capacity of each parking, etc.

However, in the last few years, renegotiations have been frequent to add some unforeseen investments. For instance, because of the recent political willingness to spread better environmental practices, some municipalities asked for environmental reporting systems that were not foreseen when contracts were signed. New equipments allowing to control for electricity, fuel consumptions, and air quality were added to that purpose. In the same way, the growing popularity of bicycles, scooters and motorbikes calls for new parking services, such as loans of bicycles.[16] Last, many innovations were introduced to make the payment of the fees easier. New electronic systems allow to to pay fees once a month through the same electronic pass than used for motorway tolls. All these examples illustrate that innovations may be regularly introduced in this sector. They allow to increase the quality of the service or to reduce its costs.

All the efforts to improve the service beyond what is foreseen in the contract, are not contractible *ex ante*, because parties cannot know whether technological progress will make updating of the existing material possible or not, and when. Thus, during the execution of the contract, the operator may decide to make such efforts or not.

[15] This is not surprising since those contracts are mostly used when the infrastructure has to be built. Now that cities are well equiped with car parks, they are more prone to contract-out management and maintenance tasks.

[16] For 10 years, 8,000 motorbike parking spaces and 5,000 bicycle parking spaces for the public have been added in France. More details on http://www.vincipark.com/

2.2 Multi-contracting in the car park management sector

Another important feature of contracting-out in the car park management sector is multi-contracting. When public authorities decide to outsource their car park service (through public procurement or delegated management), they launch a call for tenders. In spite of an increasing competition for the field[17] in the past years (there are on average 4 to 6 bidders per call for tenders [18]), in big cities, some operators are likely to have several contracts of car parking with the same public authority. This is what we call multi-contracting[19].
This phenomenon is more and more observed in the car park sector, as shown in Figure 1. In 2005, among all the municipalities with which the French leader company had contracts, almost one out of two had awarded several contracts to this firm, *i.e.* have chosen multi-contracting.[20]

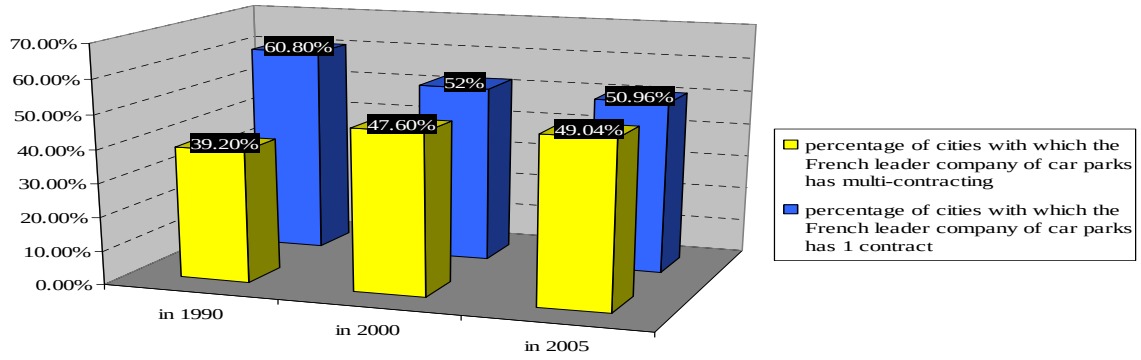

Figure 1: The evolution of multi-contracting in the French leader company of the car park sector

Source: Debrux database, January 2009

Whatever its initial justification[21], this multi-contracting strategy raises the question of its impact over the life-cycle of the contract. In the model, we investigate whether the deci-

[17] The main operators are VINCI Park, Q-Park, Epolia, Efia, Interparking, Parking de France, UrbisPark, AutoCité and SAGS. However, some of them are established in some regions only, others are specialised, for car parking in train stations for instance.

[18] interview led with the Head of Legal Department of Vinci Park, May 2011???

[19] Let us also note that multi-contracting generally applies to the same type of contractual agreement: when a public authority awards several contracts to the same operator, she tends to award mostly public procurement contracts or mostly delegated management contracts to the operator. In the contracts of the French leader company, we observe that when two contracts are signed, they are always of the same type. When more than two contracts are signed with a same private operator, there are few cases where the types of these contracts are different. We can note that the multicontracting effect persists for the dominant contractual type.

[20] Moreover, this proportion is certainly underestimated, since the municipalities that give only one contract may have only one parking to manage, and are then not able to practice multi-contracting.

[21] The multi-contracting strategy may give rise to some economies of scale, that are taken into account in our model. However, this phenomenon does not prevent an analysis of the consequences of multicontracting on *ex post* renegotiations.

sion of awarding several contracts to one operator influences the occurrence and outcomes of renegotiations. Next subsection focuses on the importance of renegotiations, and on why these renegotiations do not seem to represent a failure of a public-private partnership, contrary to what has been generally considered in the recent economic literature.

2.3 The issue of renegotiations in the car park sector

The French leader company renegotiates its contracts on average 2.45 times during the execution of each contract. Distinguishing between lease and public procurement contracts shows that, on average, lease contracts are renegotiated 0.203 times per year, *i.e.* once every 5 years, and public procurement contracts, 0.288 times per year, *i.e.* once every 3.5 years. [22]

In many cases, renegotiations are a direct consequence of the contractual incompleteness. Among a more restrictive sample of 146 contracts where the causes of the renegotiations were detailed, 123 contracts have been modified to allow the implementation of investments that had not been foreseen *ex ante*.

As mentioned earlier, the common view in the literature on public-private partnerships is to consider renegotiations as a proof of inefficiencies, because they represent opportunism, or because of their costs (Crocker and Reynolds [1993], Bajari et al. [2007], Estache and Quesada [2001]).

Yet, an interesting fact in our data is that the numerous renegotiations do not prevent municipalities from still outsourcing their services. If renegotiations were the proof of the inefficiency of contracts, or of the difficulties to align the interests of the parties, it seems difficult to understand why municipalities are still willing to contract-out their services, while organizing the provision of car parking is not a complex task, and could be easily provided in-house.

Another surprising stylized fact is that contracts which give rise to contract renewals, once they have expired, are renegotiated more than the average, as shown in table 1.

[22] On average, lease contracts are renegotiated 3.418 times, and their average duration is of 16.828 years, whereas public procurement contracts are renegotiated on average 0.723 times, ad their duration is of 2.511 years

Table 1: Average annual number of renegotiations of contracts in the French leader company of car parks between 1965 and 2008.

	Delegated management contracts	**Public procurement contracts**
Average number of renegotiations per year, all contracts taken together	0.203	0.288
Average number of renegotiations per year, for contracts that give rise to contract renewal	0.274	0.471

Source: Debrux database, January 2009

Our model attempts to analyse these stylized facts, by showing how the type of contractual agreement and the choice of multicontracting impacts on the global level of *ex post* efficiency, and on the payoffs of each partner.

3 The model

In this section we use an incomplete contract framework to determine the incentives of the operator to make non-contractible efforts to innovate. Our focus is on the impact of the type of contractual agreement on the *ex post* social surplus. We assume in this section that the public authority awards all her car park contracts to the same operator. We will relax this restrictive assumption in section 4, in order to analyse the impact of the number of contracts awarded to the same operator ("the multicontracting strategy" compared to a situation where different operators are chosen for different contracts). As a consequence, in this section, our goals are to determine:

- the occurence of renegotiations under each type of contractual agreement
- the levels of incentives the private operator gets to make non-contractible efforts under each type of agreement (which is partly determined by the presence or not of renegotiations)
- the levels of *ex post* global surplus reached under each type of agreement compared to the optimal *ex post* global surplus

3.1 General framework

Let us note G, the benevolent public authority (whom we refer to as "she"), in charge of the management of car parks in a municipality. G represents all the citizens of the municipality, i.e. the users of the service, and the non-users. In this article, we focus on the case where G chooses to outsource the provision of one or several ($N \geq 1$) car park(s) to

a private operator, M (whom we refer to as "he").[23] The perspective we adopt is that of the incomplete contracts (Grossman and Hart [1986], Hart [1995]).
More precisely, we assume that the public authority and the chosen operator are able to write contracts, specifying some aspects of each service to be provided. For simplicity, each contract is relative to one parking.[24] We call the service thus described in the contract "the basic service". We denote N the number of contracts that G has in charge.
Our assumption is that there are so many possible contingencies arising *ex post*, that it is impossible to anticipate them all, and contract on how to deal with them in advance. Instead, the parties revise the contract *ex post*, once it is clear what the relevant contingencies are. We refer to the basic service modified to allow for possible contingencies as the "modified service".

The modified service $j \in [1; N]$ yields a benefit B_j to the society, and costs the operator C_j to produce. For example, B_j may represent the satisfaction to pollute less when direct access between the car park and the tube encourages to use public transports. The operator can manipulate B_j and C_j through prior effort choices. He can devote efforts to two types of innovations relative to a basic service: quality innovations and cost innovations that reduce the cost of provision but may create an adverse effect on quality. We denote the effort devoted to quality innovation i, and that devoted to cost reduction e. Those efforts leading to innovations are observable, but not verifiable. Then, the ex-post cost (C_j) and benefit (B_j) functions derived from the provision of the service j are the following:

$$B_j = B_j^0 - b(e) + \beta(i)$$
$$C_j = C_j^0 - c(e) + i + e$$

B_j^0 and C_j^0 are the (contractible) social benefit and cost of the service j as described in the basic contract; $c(e) \geq 0$ represents the cost decrease implied by an innovation in cost reduction e and $b(e) \geq 0$ corresponds to the adverse effect on quality due to an investment in cost reduction. Such investments can be efficient ($c'(e) - b'(e) > 0$) or inefficient ($c'(e) - b'(e) < 0$). As for $\beta(i)$, it is the quality increase of the service for the whole society, following an investment i. This investment is assumed to net of cost, and then always efficient. The quality increase may benefit to all citizens, users or non-users of the service: for instance, a reduction in pollution benefits to all the citizens.
Moreover, as we suppose that the private operator has several car parks under his own responsability, we allow for some possible economies of scale between all the services he manages. In this case, investments e and i can be implemented on several contracts. Since N is the number of existing contracts awarded to the private manager, we denote $\gamma \in [0; 1]$ the proportion of the (N-1) other contracts (than j) on which the innovations can be

[23] The contracts can be awarded simultaneously or not, which has no impact on our results, since we develop a static analysis.

[24] But the results can be generalized on the case where several parkings are outsourced in one contract.

applied. For simplicity, we assume that the impact of innovations is the same for all the contracts on which they are applied.

As a consequence, the total *ex post* cost and benefit functions for the management of N contracts become:

$$\sum_{j=1}^{n} B_j = (\sum_{j=1}^{n}(B_j^0)) + [1+\gamma(N-1)][-b(e)+\beta(i)]$$
$$\sum_{j=1}^{n} C_j = (\sum_{j=1}^{n}(C_j^0)) - [1+\gamma(N-1)]c(e) + i + e$$

We make the following standard assumptions concerning c and b: $b(0)=0$, $b'(e)\geq 0$, $b''(e)\geq 0$; $c(0)=0$, $c'(0)=\infty$, $c'(e)\succ 0$, $c''(e)\prec 0$, $c'(\infty)=0$; $\beta(0)=0$, $\beta'(0)=\infty$, $\beta'(i)\succ 0$, $\beta''(i)\prec 0$, $\beta'(\infty)=0$.

In accordance with our previous section, we explore two types of contracts between public and private partners, that differ about the allocation of payoff and decision rights.[25]

- The *delegated management* where the operator holds the residual control rights during the contract period in uncontracted-for contingencies. Since the private operator holds these rights, he can implement e and i without the approval of the government. However, as the operator holds the demand risk, his revenue depends on user fees. As a consequence, depending on the sensitivity of his revenue to users' behaviour, the private operator takes into account the impacts of innovations on the satisfaction of users.

- On the contrary, under *public procurement*, the public authority holds the control rights so that the implementation of any innovation requires its approval. The public authority pays the private operator a fix price for the service, and thus bears the demand risk.

The timing of the model is as follows:

- In $t=0$, $N(\geq 1)$ contract(s) have been signed between the parties
- In $t=1/2$, M makes the efforts e and i on a contract $j\in[1;N]$
- In $t=1$, renegotiations and innovations are implemented on all the contracts on which they can be applied, i.e. $(1+\gamma(N-1))$.

[25]The literature developed by Grossman, Hart, and Moore focus on the role of the allocation of property rights, and not "decision rights" and "payoff rights", simply because they consider that these rights are included in property rights. When studying public-private partnerships, it seems important to us to distinguish property, decision and payoff rights. Indeed, property rights are genereally hold by the public party, while the right to decide about management tasks, and to keep the revenues from the service (payoff rights) can be temporarily allocated to the private partner during the contract period. For a more general discussion about these differences, see Desrieux [2009].

3.2 The First-best Solution

First, let us determine the optimal levels of investment in case of contractual completeness. The first-best incentives are those maximising social benefits minus social costs on all the contracts:

$$max_{e,i}(\sum_{j=1}^{N}(B_j^0 - C_j^0)) + [1 + \gamma(N-1)][c(e) - b(e) + \beta(i)] - e - i$$

Thus, the optimal levels of effort to find innovations in cost reduction e_N^{FB} and in quality increase i_N^{FB}, are the followings:

$$(1 + \gamma(N-1))[c'(e_N^{FB}) - b'(e_N^{FB})] = 1$$
$$(1 + \gamma(N-1))\beta'(i_N^{FB}) = 1$$

Let us note that:

- $i_N^{FB} \geq 0$
- When the innovation e is socially efficient ($c'(e) - b'(e) > 0$), then $e_N^{FB} \geq 0$.
- On the contrary, when the investment e is inefficient ($c'(e) - b'(e) \leq 0$), $e_N^{FB} = 0$.

Pursuant to Hart et al. [1997], the first-best total surplus is :

$$S_N^{FB} = (\sum_{j=1}^{N}(B_j^0 - C_j^0)) + (1 + \gamma(N-1))[\beta(i_N^{FB}) + c(e_N^{FB}) - b(e_N^{FB})] - e_N^{FB} - i_N^{FB}$$

3.3 Public procurement

In this section, we explore the contractual arrangements where the public authority holds the residual control rights, and pays a fix price to the private operator for the service. We denote this price P_j^0 (for each contract $j \in [1; N]$). Then, P_j^0 is the price that the operator receives for providing the basic service j, and it results from the *ex ante* bargaining power of the parties.[26] It is paid thanks to the taxes collected by the public authority on all the citizens.

As a consequence, under public procurement, the private manager cannot implement any innovation without the approval of the public authority. Indeed, the private manager does not hold the decision rights, and implementing an innovation without renegotiation would not change the price P_j^0 he receives to provide the service. So, renegotiation applies to the global surplus of all innovations, and aims at sharing the gains between parties. We

[26] If we compare "public provision" described in Hart et al. [1997] and "public procurement" in our paper; in both cases, the public authority holds decision and payoff rights. However, under public provision, she can replace the public manager by another one, while she cannot do it under public procurement. She is committed for the contractual period. The consequence is that under public provision, the bargaining about the gains of new investments only bears on the part of the investment that cannot be implemented without the public manager, because of his personal skills. The public authority can replace him for the other part of the investment. This implies that the public manager has no bargaining power on this last part of the investment.

assume a Nash bargaining process, and we denote $\sigma \in [0;1]$ the *ex post* bargaining power of the operator.
The payoffs of the operator and of the public authority become respectively:

$$UM_N^P = (\sum_{j=1}^{n}(P_j^0 - C_j^0)) + \sigma(1+\gamma(N-1))[c(e_N^P) - b(e_N^P) + \beta(i_N^P)] - e_N^P - i_N^P$$
$$UG_N^P = (\sum_{j=1}^{n}(-P_j^0 + B_j^0)) + (1-\sigma)(1+\gamma(N-1))[\beta(i_N^P) + c(e_N^P) - b(e_N^P)]$$

Consequently, we find the following incentives to invest e_N^P and i_N^P:

$$\begin{aligned} e_N^P &= \arg\max_e UM_N^P \\ i_N^P &= \arg\max_i UM_N^P \end{aligned}$$

The first-order condition gives us the investment level e_N^P and i_N^P such as:

$$\begin{aligned} (1+\gamma(N-1))\sigma[c'(e_N^P) - b'(e_N^P)] &= 1 \\ (1+\gamma(N-1))\sigma\beta'(i_N^P) &= 1 \end{aligned}$$

From the first-order conditions, and the concavity of the functions c(.) and $\beta(.)$, we can deduce that $\forall N \geq 1, e_N^P \leq e_N^{FB}$ and $i_N^P \leq i_N^{FB}$, since $\sigma \in [0;1]$. First-best is achieved only if $\sigma = 1$, *i.e.* all the *ex post* bargaining power is to the private operator.

Result 1. *Under public procurement, when $0 \leq \sigma < 1$, both incentives to reduce costs and to increase quality are under-optimal, so that $e_N^P \leq e_N^{FB}$ and $i_N^P \leq i_N^{FB}$. Incentives to invest increase in σ and are optimal when $\sigma = 1$.*

Under public procurement, the total surplus is:

$$S_N^P = (\sum_{j=1}^{n}(B_j^0 - C_j^0)) + (1+\gamma(N-1))(c(e_N^P) - b(e_N^P) + \beta(i_N^P)) - e_N^P - i_N^P$$

3.4 Delegated management

In this section, we explore the contractual arrangements where the private operator holds the residual decision rights, which means that he can implement innovations without the approval of the public authority. Moreover, as described in section 2, the private operator bears the demand risk: he is not paid through a fix payment made by the public authority, but by the fees collected on the users of the service. Let us first detail the consequences of theses features.

3.4.1 The revenue function

Under delegated management, the global revenue of the private operator depends on the frequency of the use of the service. Such a frequency is determined by some exogenous parameters such as the geographical location, or the economic activity of the local area, and also depends on some endogenous parameters, *i.e.* the quality of the service. Indeed, we assume that efforts to create a better quality, or efforts leading to quality damages, are not neutral on the frequenting of the service. When users have to choose between alternative provisions, we can reasonably think that the quality of the service (a better security for their car, or a better connection to other transportation means) may influence their decision. This means that innovations to create a better quality or innovations that create a damage on quality also influence the number of users of the service, and then the number of fees that remunerate the private operator.[27] As a consequence, for each service j, we model the revenue R_j that the operator gets from the service as:

$$R_j = \tilde{R_j} + R^+(\beta(i)) - R^-(b(e))$$

where:

- $\tilde{R_j}$ represents the stochastic revenue of the basic service ($\tilde{R_j} \in [R_{min}; R_{max}]$, with $0 \leq R_{min} < R_{max}$), that depends on exogenous criteria such as the economic activity of the local area and/or the geographical location.[28] Traffic forecasts mainly bear on $\tilde{R_j}$, and we can assume that in the car park sector, such forecasts are rather easy to do. Last, this stochastic part of the revenue is specific to each service j, since it depends partly on local criteria relative to each service.

- $R^+(\beta(i))$ represents the additional revenue due to an increase in the number of users, caused by a better quality ($\beta(i)$), with $R^+(0) = 0; R^{+'} \geq 0; R^{+''} \leq 0$. The higher the quality increase of the service, the more numerous users are, and the higher the additional revenue is. We add two other assumptions. First, $0 \leq R^+(\beta(i)) \leq \beta(i)$: remember that $\beta(i)$ is the quality increase of the service for the public authority representing the whole society (existing users, new users, and non-users of the service). The additional revenue $R^+(\beta(i))$ is the increase of revenue caused by the new users of the service, but does not necessarily cover the global quality increase for all the society ($\beta(i)$). For instance, a better protection of the environment is valued by all the citizens, but does not always induce more using of the service, hence the additional

[27] To simplify, we model the additional revenue as caused by an additional frequentation of the service. It could also be an adiditonal per unit price increase accepted by the users, since the total additional revenue is the per unit price multiplied by the number of users.

[28] More formally, $\tilde{R}$ is drawn from $[R_{min}; R_{max}]$ by a distribution function F(.). This function is known by both parties. We introduce R_{max}, because above some treshold of revenue, the private operator has to give a large part of this additional revenue to the public authority, as explained in section 2. We assume that trade is always efficient, i.e. $R_{min} > c$.

revenue may be lower than the value of the quality increase for the whole society. The second assumption we introduce is that $0 \leq R^{+'}(\beta(i)) \leq 1$, the marginal revenue increase is not higher than the marginal quality increase. In other words, the operator does not overestimate the quality increase, which would be the case if a small quality increase would lead to a huge increase of his revenue.[29] If $R^{+'}(\beta(i)) \to 1$, we say that the pressure exerted by the consumers is high, because all marginal quality increase leads to a similar marginal increase of revenue, so that the incentive to innovate will be high for the operator. On the contrary, if $R^{+'}(\beta(i)) \to 0$, we say that the pressure exerted by the consumers is low, because their behavior does not allow to create incentives for the private operator.

- $R^{-}(b(e))$ represents the amount of revenue that can be lost because of a quality damage that induces less using of the service. The higher the damage on quality, the higher the loss of revenue is, so that $R^{-}(0) = 0$; $R^{-'} > 0; R^{-''} > 0$.[30] As in the previous case, we assume that this loss can be as high as the total damage, $\forall b(e) \in \mathbf{R}^{+}$, $0 \leq R^{-}(b(e)) \leq b(e)$. If it is inferior to the quality damage, this means that the loss of revenue caused by fewer users (among the existing ones) does not reflect the quality damage for the whole society. For instance, investing to find cheap light bulbs may lead to bad results in terms of sustainable development, but it is unlikely that it really reduces the frequentation of the parking. Hence, $R^{-}(b(e)) \leq b(e)$. Moreover, we assume that $0 \leq R^{-'}(b(e)) \leq 1$, which means that the marginal loss of revenue is not disproportioned to the marginal loss in quality, i.e. there is no over-reaction due to the quality damage. Last, if $R^{-'}(b(e)) \to 1$, the pressure exerted by the consumers is high because all marginal quality damage leads to a similar marginal loss of revenue, while if $R^{-'}(b(e)) \to 0$, the pressure is low because the marginal quality damage has no influence on the marginal revenue the operator may get.

3.4.2 The implementation of new innovations

Let us now analyse the conditions of the implementation of *ex ante* unforeseen investments:

- **Cost-reducing innovations:**
  Since the private operator holds the decision rights under delegated management, he

[29] In the parking sector, it seems reasonable to think that the number of new users and/or their using of the service do not increase exponentially, and a small quality increase does not lead to a huge increase in revenue.

[30] While $\tilde{R}_j$ is specific to each service j, R^{+} and R^{-} represents the variations of revenue due to the implementations of new innovations i or e. Since these innovations create the same effects $(\beta(i), b(e), c(e))$ on the services in which they are implemented, we assume that they also create the same effects on the revenue of each service: $R^{+}(.)$ and $R^{-}(.)$ have the same values for all services in which innovations are applied. We could also assume that the variations of revenue are specific to each contract j, and $R^{+}(.)$ and $R^{-}(.)$ represent the average consequence on each contract, which does not change the demonstration.

does not need the approval of the public authority to implement new innovations. His main motivation to implement innovation e is the gain from cost reduction (c(e)) on each service in which the innovation can be applied.[31] However, the private operator also supports a loss of revenue caused by the quality damages, $R^-(b(e))$, when a cost-reducing investment is implemented. As a consequence, the total net gain from innovation e for the private operator is $(1+\gamma(N-1))[c(e)-R^-(b(e))]-e$.
Since $0 \leq R^{-'}(b(e)) \leq 1$, some inefficient investments can be implemented, because the public operator does not internalize the whole marginal value of the adverse effect, but only the negative impact on his revenue, i.e. $R^{-'}(b(e))$.
As for the public authority, she represents all the citizens that suffer a quality damage ($b(e)$), among which the users of the service that will use it less frequently[32], *i.e.* economize $R^-(b(e))$. The consequence of the implementation of the cost-reducing innovation for the public authority is then $(1+\gamma(N-1))[R^-(b(e))-b(e)]$, which is a loss, since $R^-(b(e)) \leq b(e)$.

- **Quality-increasing innovations:**
  Whenever the private operator implements such innovations, his gain is the additional revenue $R^+(\beta(i))$ caused by a higher frequency due to the higher quality. On the contrary, for the public authority, the gain from such innovation is $\beta(i) - R^+(\beta(i))$, *i.e.* the satisfaction of a better quality ($\beta(i)$) for the whole society minus the revenue spent to use the service more frequently by the new users.
  However, if the pressure exerted by the consumers is low, so that $\forall\beta(.)$, $R^+(\beta(i)) \to 0$, quality innovations are unlilely to be implemented since the private operator would have no gain from such innovations.[33] In such a situation, a renegotiation may still occur as in public procurement, because the public authority represents the whole society and wants such innovations to be implemented, even if it does not increase the number of new users. This renegotiation leads to a gain $\sigma\beta(i)$ per contract for the private operator. Consequently:

  - Whenever $R^+(\beta(i)) \geq \sigma\beta(i)$, no renegotiation occurs. The private operator receives some gains from the implementation of quality innovations through the higher revenue caused by the higher frequency of service using, and renegotiations would not give him more payoffs, i.e. more incentives.
  - Whenever $R^+(\beta(i)) \leq \sigma\beta(i)$, the gains obtained under a renegotiation are higher than those derived from a higher frequenting of the park. Then, the public au-

[31] There is no repercussion of costs savings c(e) by the private operator on prices for users. Otherwise, users would also benefit from innovation e. The absence of amendments dealing with cost decrease in the Debrux Database consolidates this assumption.

[32] We can imagine several alternatives: The users can choose to park freely in the street or to use public transport. We assume that the choice of the alternative has no impact on the global surplus.

[33] When $\tilde{R}_j = R_{max}$, this also implies that $R^+(\beta(i)) \to 0$, since the private operator cannot get any additional revenue above R_{max}.

thority gives the private operator a share z of the benefits of the implementation of the innovation, in order to complement the low revenue increase $R^+(\beta(i))$. Adding up the revenue increase and the share z of the gain, the private operator finally has a gain $\sigma(1+\gamma(N-1))\beta(i)$ corresponding to his bargaining power σ:

$$\begin{aligned} z\beta(i) + R^+(\beta(i)) &= \sigma\beta(i) \\ z &= \sigma - \frac{R^+(\beta(i))}{\beta(i)} \end{aligned}$$

Proof n°1 shows that $z \in [0;1]$.

As a consequence:

- $z = \sigma - \frac{R^+(\beta(i))}{\beta(i)}$ if $(1+\gamma(N-1))R^+(\beta(i)) \leq \sigma(1+\gamma(N-1))\beta(i)$
- $z = 0$ if $(1+\gamma(N-1))R^+(\beta(i)) \geq \sigma(1+\gamma(N-1))\beta(i)$

Since z depends on $\beta(.)$ and $R^+(.)$, we note $z = z(\beta, R^+)$. This is the proportion of the gain $\beta(i)$ that the public authority accepts to give to the private operator, so that his total gain becomes $R^+(\beta(i)) + z\beta(i) = \sigma\beta(i)$. With such a gain, the private operator has incentives to implement quality innovations, and to be more precise, the same incentives than under public procurement.

3.4.3 Incentives and global surplus

From the previous paragraphs, we can deduce that:

$$\begin{aligned} UM_N^D = (\sum_{j=1}^{n}(\tilde{R}_j &- C_j^0)) + (1+\gamma(N-1))[R^+(\beta(i_N^D)) - R^-(b(e_N^D)) + z(\beta,R^+)\beta(i_N^D) + c(e_N^D)] \\ &- e_N^D - i_N^D \end{aligned}$$

$$UG_N^D = (\sum_{j=1}^{n}(-\tilde{R}_j + B_j^0)) + (1+\gamma(N-1))[-b(e_N^D) + (1-z(\beta,R^+))\beta(i_N^D) - R^+(\beta(i_N^D)) + R^-(b(e_N^D))]$$

The investment levels are characterized by the maximization of the utility function of the operator, UM_N^D.

The incentives to reduce costs:

$$\begin{aligned} e_N^D &= \arg\max_e \{(\sum_{j=1}^{n}(\tilde{R}_j - C_j^0)) \\ &+ (1+\gamma(N-1))[R^+(\beta(i_N^D)) - R^-(b(e_N^D)) + z(\beta,R^+)\beta(i_N^D) + c(e_N^D)] - e_N^D - i_N^D\} \end{aligned}$$

The first-order condition gives us the investment level e_N^D such as

$$(1+\gamma(N-1))[c'(e_N^D) - R^{-'}(b(e_N^D))(b'(e_N^D))] = 1$$

Let us denote $r_b^{'} = R^{-'}(b(e_N^D))$, then we have:

$$(1+\gamma(N-1))[c'(e_N^D) - r_b^{'}(b'(e_N^D))] = 1$$

Since $0 \leq r_b^{'} \leq 1$, we have to separate two cases:

- First, if $r_b^{'} = 1$, then the optimal incentives are reached under delegated management.[34]

- Second, if $0 \leq r_b^{'} < 1$, because of the first-order conditions and the concavity of the functions c(.), then $c'(e) - r_b' b'(e) > 0$, i.e. incentives to invest e under delegated management are over-optimal. This can be explained as follows: the operator does not internalize the adverse effect on the quality of service when he invests e, but only internalizes the share $r_b^{'}$ corresponding to his marginal loss of revenue caused by a lower quality ($c'(e) - r_b' b'(e) \geq c'(e) - b'(e) \geq 0$).

- Moreover, inefficient cost-reducing investments can be implemented since the total adverse effect is not internalized by the private operator. He only takes into account the loss of revenue caused by the adverse effect, i.e. $R^-(b(e)) \leq b(e)$. When $c'(e) - b'(e) \leq 0$ but $c'(e) - r_b' b'(e) \geq 0$, then $e_N^D > 0$ and the operator implements cost-reducing innovations that generate a gain for him, even if they are socially inefficient.

Given the previous first-order conditions, we can rank the incentives to invest as follows $e_N^D \geq e_N^{FB} \geq e_N^P$.

The incentives to invest in quality:

$$\begin{aligned} i_N^D &= \arg\max_i \{(\sum_{j=1}^{n}(\tilde{R}_j - C_j^0)) \\ &+ (1+\gamma(N-1))[R^+(\beta(i_N^D)) - R^-(b(e_N^D)) + c(e_N^D) + z(\beta, R^+)\beta(i_N^D)] - e_N^D - i_N^D\} \end{aligned}$$

- When $R^+(\beta(i)) > \sigma\beta(i)$, then $z = 0$ and the first-order condition gives us:

$$(1+\gamma(N-1))[R^{+'}(\beta(i_N^D))\beta'(i_N^D)] = 1$$

[34] Contrary to Hart et al. [1997], our model shows that holding decision rights to a private operator is not necessarily inefficient when adverse effects are high. We can reach the optimal incentive to reduce cost when the pressure of the users is very high.

Let us denote $r_{\beta}^{'} = R^{+'}(\beta(i_N^D))$, since $0 \leq r'_{\beta} \leq 1$, we have:

$$(1+\gamma(N-1))(r_{\beta}^{'})\beta'(i_N^D) = 1$$

- When $R^+(\beta(i)) \leq \sigma\beta(i)$, then $R^+(\beta(i_N^D))+z(R^+,\beta)\beta(i_N^D) = \sigma\beta(i)$ and the first-order condition becomes:

$$(1+\gamma(N-1))[\sigma\beta'(i_N^D)] = 1$$

As a consequence:

$$(1+\gamma(N-1))[Max\{\sigma, r'_{\beta}\}\beta'(i_N^D)] = 1$$

- From the previous equality, the first-order conditions, and the concavity of $\beta(.)$, i_N^D is always under-optimal, except when $r'_{\beta} = 1$ or $\sigma = 1$, i.e. when the private operator has all the bargaining power, or the pressure exerted by the users is high.

- Because of concavity of function $\beta(.)$, and given the previous first-order conditions, we can now rank the incentives to invest:

$$i_N^{FB} \geq i_N^D \geq i_N^P$$

Last, under delegated management, the total surplus is:

$$S_N^D = \sum_{j=1}^{n}(B_j^0 - C_j^0) + (1+\gamma(N-1))[c(e_N^D) - b(e_N^D) + \beta(i_N^D)] - e_N^D - i_N^D$$

Result 2: *Under delegated management, the private operator has over-incentives to reduce costs (with adverse effects on quality), but has under-optimal incentives to increase quality. Incentives to invest are all the more likely to become close from their optimal level than the pressure exerted by users is high.*

3.5 Summary of section 3

The goals of this section were to determine the occurence of renegotiations, the levels of incentives of the private operator, and the levels of *ex post* surplus under each type of agreement. Table 3 summarizes our answers to these questions.

	Public procurement		Delegated management	
	$0 \leq \sigma \leq 1$	$\sigma = 1$	$0 \leq r'_b; r'_\beta < 1$	$r'_b = r'_\beta = 1$
Need of renegotiations	Yes	Yes	If r'_β is too low	No
Levels of the incentives e	Underoptimal	Optimal	Overoptimal	Optimal
Levels of the incentives i	Underoptimal	Optimal	Underoptimal	Optimal
Level of ex post surplus	Underoptimal	Optimal	Over/under optimal	Optimal

Table 2: Impacts of the contractual agreement on the incentives to innovate and on the global surplus

Proposition 1. *The occurence of renegotiations, the incentives to make non-contractible efforts, and the global ex post surplus are different under public procurement and delegated management.*

Let us also note that in each case, the incentives of the private operator are determined by the share of the new surplus he gets, *i.e.* by the allocation of this new surplus between him and the public authority. However, the determinants of this allocation are different in each case. Under public procurement, it depends on the bargaining powers of the parties, while under delegated management, it is also determined by the level of pressure exerted by users. As a consequence, to determine whether public procurement is preferable to delegated management, we have to take into account (1) the type of innovations, (2) the bargaining power of the private operator, and (3) the level of pressure the users may exert. The higher the bargaining power of the private operator or the pressure of the users are, the more likely the incentives are to become close from their optimal level. However, in such situations, the public authority also gets a low share of the net gains. While this section 3 stresses the impact of the type of the contractual agreement on the total surplus, the following section proposes to detail the consequences of these different contracts on the payoffs of each party. This will lead us to show why in some circumstances the public authority may be reluctant to choose a contractual agreement that yet leads to implement efficient innovations. We will also show how multicontracting may help to reach optimal incentives to invest, but be detrimental to the public authority.

4 Allocation of surplus, multicontracting and *ex post* efficiency

4.1 The allocation of the *ex post* surplus

In this subsection, we propose to go one step further than in section 3. We will focus not only on the global surplus reached under each type of contractual agreement, but also on its allocation between parties. To reach this goal, we first define what we mean by "*ex post* efficiency" of a contractual agreement (subsection 4.1.1), and then apply such a notion to public procurement (subsection 4.1.2) and delegated management (subsection 4.1.3).

4.1.1 Ex post efficiency of a contractual agreement

We consider that a contract is *ex post* efficient if it allows to implement efficient unforeseen innovations (i.e. quality innovations, and cost-reducing innovations for which $c'(e) - b'(e) \geq 0$). In this case, the *ex post* surplus is higher than the (contractible) surplus defined *ex ante*.
On the opposite, a contract is *ex post* inefficient if the *ex post* surplus is lower than the surplus that would be achieved without innovations. The features of the contractual agreement do not always allow to prevent the implementation of inefficient investments that are detrimental to the global surplus.

In case of *ex post* efficiency, two situations may be observed:

- The ex post efficiency is considered as **pareto-efficient** if the global *ex post* surplus is higher than expected *ex ante* and both parties are better off *ex post* compared to their payoffs without the implementation of innovations. No party can be better off without creating a damage for the other.
- The *ex post* efficiency is considered as satisfycing **the Hicks-Kaldor criteria** if the global surplus is higher than expected *ex ante* (without the innovations), but only one party benefits from it. The other party suffers a loss compared to her situation without innovations. However, this loss is outweighed by the gains of her partner, so that the final impact on the global surplus remains positive.[35]

4.1.2 Ex post efficiency of public procurement

From subsection 3.3, we know that only efficient innovations are implemented under public procurement, since $e_N^P = 0$ when $c'(e) - b'(e) < 0$. Then, the contract is always efficient (which does not mean that it is the most efficient or optimal).

To determine whether the contract is pareto-efficient or Hicks-Kaldor efficient, we have to focus on the allocation of the new surplus between the parties. The private operator gets a share σ of the net surplus created by innovations, and the public authority gets a share $(1 - \sigma)$, which results from the Nash bargaining between the parties. Given their respective bargaining power, no party can expect a higher gain, and both have a positive share of the new surplus created by innovations.[36] As a consequence, both of their payoffs

[35] The Hicks Kaldor efficiency is widely used in welfare economics. Using Hicks Kaldor efficiency, an outcome is more efficient if the global payoffs of the parties increase, even if some lose and others win. Those that are made better off could in theory compensate those that are made worse off, so that a Pareto improving outcome results. However, Kaldor-Hicks does not require compensation actually be paid, merely that the possibility for compensation exists, and thus does not necessarily make each party better off (or neutral). Thus, under Kaldor-Hicks efficiency, a more efficient outcome can in fact leave some people worse off.

[36] In the special case where $\sigma = 1$, the payoff of the public authority is the same than her payoff without innovation, but she does not suffer a loss.

are higher than those they would get without innovations. The contractual agreement is then *ex post* pareto-efficient, since it allows to implement only efficient innovations and none of the parties can expect a higher gain without being detrimental to the other.

4.1.3 Ex post efficiency of delegated management

From subsection 3.4.:

- Inefficient innovations can be implemented when the pressure exerted by users is so low that $c'(e) - r'_b b'(e) > 0$ but $c'(e) - b'(e) \leq 0$. As a consequence, the contract is *ex post* inefficient, since it does not prevent inefficient non-contractible investments to be implemented.

- However, such a contract also allows for efficient cost-reducing investments and quality investments to be implemented, so that when $(c('e) - b'(e) + \beta'(i) \geq 0)$, the global *ex post* surplus is higher thanks to the innovations, and the contract is *ex post* efficient.
  Let us now have a look at the payoff of the public authority in this situation:

$$UG_N^D = (\sum_{j=1}^{n}(-\tilde{R}_j + B_j^0)) \quad + \\ (1+\gamma(N-1))[-b(e_N^D) \quad + \quad (1 - z(\beta, R^+))\beta(i_N^D) - R^+(\beta(i_N^D)) + R^-(b(e_N^D))]$$

  - When $(-b(e_N^D) + R^-(b(e_N^D) + (1 - z(\beta, R^+))\beta(i_N^D) - R^+(\beta(i_N^D)))) > 0$, the public authority gets a positive share from the innovations. This is the case when quality innovations are high enough, when there are few adverse effects caused by cost reduction, or when the pressure exerted by the users in case of adverse effects is high. Then, the contractual agreement is *ex post* pareto-efficient, since both parties benefit from the innovations.
  - On the contrary, when $(-b(e_N^D) + R^-(b(e_N^D) + (1 - z(\beta, R^+))\beta(i_N^D) - R^+(\beta(i_N^D)))) \leq 0$, then the public authority has a lower gain compared to her situation without innovations. This is the case when the pressure exerted by the consumers and relative to adverse effects is low, or when there are few quality innovations. Since the impact on the global surplus remains positive, then the efficiency that is reached satisfies the Hicks-Kaldor criteria.

As a consequence, the level of pressure exerted by users, and the relative value of $\beta(i)$ and $b(e)$ will determine whether delegated management is *ex post* pareto-efficient or Hicks-Kaldor efficient.

To sum up, public procurement appears as an efficient agreement whatever the circumstances, because when unforeseen innovations arise, only the efficient ones are implemented. However, it is not always the most efficient agreement, nor the optimal one, since the operator has still underoptimal incentives to make efforts, as underlined in section 3. As for delegated management, when the pressure exerted by the consumers is very low and there are few (or no) quality innovations, then this contractual agreement may be inefficient as it does not prevent inefficient (unforeseen) innovations to be implemented. However, when the pressure exerted by the consumers in case of adverse effect is high, then delegated management prevents inefficient investments. According to the value of those parameters, both Hicks-Kaldor or Pareto efficiency can be observed in this situation.[37]

Proposition 2. *Only efficient innovations are implemented under public procurement and both parties benefit from them because of renegotiations. On the contrary, inefficient cost-reducing innovations may be implemented under delegated management, and even efficient innovations may entail some losses for the public authority.*

In the following subsections, we continue to comment the impacts of the contractual agreements on both the global surplus and its allocation, but we try to include the effects created by the number of contracts, as suggested by the observation of the French car park management. To reach this goal, we first analyze how the number of contracts impacts the incentives to invest (subsection 4.2.) and then the global surplus. In subsection 4.3., we focus on the impacts of multicontracting on the payoffs of each party.

4.2 Consequences of multicontracting on the level of incentives to invest

In this subsection, we show that in many circumstances, the incentives of the operator to make non-contractible efforts (*i.e.* to innovate) increase in the number of contracts the parties share. This mainly comes from the possibility to exploit economies of scale on the implementation of innovations. From the first-order conditions determined in section 3., we can establish that:

- When $c'(e) - b'(e) > 0$, then the efforts to reduce costs e_N^{FB} and e_N^P are increasing in N.
- When $c'(e) - b'(e) \leq 0$, then $e_N^P = e_N^{FB} = 0$.
- Under delegated management, the effort to reduce cost e_N^D is increasing in N when $c'(e_N^D) - r'_b b'(e_N^D) > 0$
- On the contrary, when $c'(e) - r'_b b'(e) < 0$, $e_N^D = 0$

[37] Under such circumstances, whether delegated management is more or less globally efficient than public procurement depends on the value of the bargaining power and the pressure exerted by the consumers as explained in section 3.

- The effort to improve quality i_N^{FB}, i_N^P, i_N^D are always increasing in N.

See proof n°2 for the demonstration.

Since multicontracting entails higher incentives to invest, it makes the gains of innovations all the higher. However, it also makes the damages on quality all the stronger. As a consequence, multicontracting may increase the global surplus but also the differences between the payoffs of each party.

4.3 Consequences of multicontracting on *ex post* efficiency

In this subsection, we explore how multicontracting influences the global surplus and its allocation, compared to a situation where contracts are awarded to different operators. To reach this goal, we relax the previous assumption according to which all the contracts were awarded to the same operator. We will assume that (N-1) contracts have been awarded to the manager M among the N existing contracts. We try to determine whether the N^{th} contract has better be awarded to M (multicontracting) or to another manager, having no other contract with the public authority. We do not introduce any *ex ante* difference between the two operators, *i.e.* they are able to manage the "basic" service of the N^{th} contract with the same cost C_N^0 and for the same price (in case of public procurement).[38] Moreover, to stress the effects of multicontracting, we explore the case where there are strong economies of scale, i.e. $\gamma = 1$.
We compare the global surplus when two operators are chosen (denoted as $(S_{N-1} + S_1)$), to the surplus achieved in case of multicontracting, i.e. S_N. In the same way, we compare the global payoff of the public authority when two operators are chosen $(UG_{N-1} + UG_1)$, and compared it to the payoff in case of multicontracting UG_N.

In what follows, we show that multicontracting has:

- an enhancing effect when the contract is *ex post* Pareto-efficient, since it increases the benefits of both parties,
- a controversial effect when the contract is *ex post* Hicks-Kaldor efficient, since multicontracting is socially efficient but creates larger losses for the public authority,
- a damaging effect when the contract is *ex post* inefficient, since multicontracting makes the social surplus all the lower.

[38] Here, we only want to quantify the potential gains of awarding all the contracts to a same manager. Our goal is not to compare *ex post* gains (in case of economies of scale on innovations) to possible *ex ante* losses (due to the choice the incumbent compared to a competitor). Such a comparaison would need to introduce many other variables to model the competitive pressure, and we deserve it for future work.

4.3.1 The enhancing effect of multi-contracting

When the contract is *ex post* pareto-efficient, then the innovations create benefits for both parties. Since multicontracting increases the incentives to innovate, then it is beneficial for both parties and for the global surplus.

In subsections 4.1.3 and 4.1.2, we show that *ex post* pareto-efficiency is always observed in public procurement, and is observed in delegated management when $(-b(e)+R^-(b(e)+(1-z(\beta,R^+))\beta(i)-R^+(\beta(i)))) \geq 0$. Proofs 3.a. and 4.a. show that multicontracting enhances the global surplus in these cases, since $S_N \geq S_{N-1}+S_1$. Proofs 3.b. and 4.b.1. show that it also enhances the payoff of the public authority, since $UG_N \geq UG_{N-1}+UG_1$. Since the total surplus and the payoff of the global authority increase in the number of shared contracts, multicontracting appears as a socially efficient strategy.[39] Let us note that when the pressure exerted by users is at its highest level ($-b(e) = R^-(b(e)$ and $R^+(\beta(i) = \beta(i))$), multicontracting allows to reach the optimal incentives to invest, since $e_N^D = e_N^{FB}$ and $i_N^D = i_N^{FB}$.[40]

4.3.2 The controversial effect of multi-contracting

When the contract is *ex post* Hicks-Kaldor efficient, then the innovations allow to increase the total surplus, but only benefit to the manager. The public authority suffers from losses, even if they are lower than the gains of the private operator. Since multicontracting allows to increase the incentives to innovate, it is socially efficient to award all the contracts to a same operator, however, it also makes the losses of the public authority all the larger.

Such a situation occurs in delegated management, when $(-b(e) + R^-(b(e) + (1 - z(\beta,R^+))\beta(i) - R^+(\beta(i)))) < 0$, i.e. when the quality innovations and the users are very sensitive to the quality of the service. Proof 4.b.2. shows that the public authority has a lower payoff in case of multicontracting, since $UG_N \leq (UG_{N-1} + UG_1)$.[41] However, multicontracting still allows to increase the global surplus, as shown in proof 4.a.

[39] We do not mention the effect for the manager for two reasons. First, a manager always increases his benefits by being awarded more contracts. Second, if the total surplus increases, and the payoff of the public authority increases, it is straightforward that the payoff of the manager also increases (or at least remains constant). Yet, let us note that "the payoff of the manager" has here to be considered as the payoff of the whole industry, since multicontracting implies that the alternative manager has no more contracts. Then, our result implies here that it is more efficient to have a single operator in the industry under such circumstances, so as to exploit all the economies of scope of the efficient innovations.

[40] We could show that in such a case, $e_N^D > e_{N-1}^D$ and $i_N^D > i_{N-1}^D$.

[41] Let us also notice that under delegated management, if the pressure exerted by the consumers is very high so that $r'_b = 1$ and $r'_\beta = 1$, multicontracting allows to reach the optimal incentives since $e_N^D = e_N^{FB}$ and $i_N^D = i_N^{FB}$, but this does not imply that all the parties benefit from these optimal incentives in the same way. If $b'(e) > 0$, then the public authority may still suffer a loss. This is not the case when innovations are inefficient ($c'(e) - b'(e) < 0$), since the manager has then no incentive to implement cost-reducing innovations.

This situation raises an “efficiency dilemma" for the public authority. Since she represents the interests of the citizens, her role is to defend their interests. Then, she should not use delegated management, and even less multicontracting in such a case, because it creates losses for her payoff that represent the benefits of the citizens. Yet, this choice is less efficient as regard to its effects on the global surplus.
On the contrary, if we consider that her role is to represent the whole society, and if she cares for the benefits of the citizens as well as for the benefits of the firms, then she should accept the losses of the citizens that are overweighted by the benefits made by the firm.[42] In other words, the public authority has to choose between global efficiency and equity in the sharing of the gains. This choice determines the best contractual agreement to implement, and the number of contracts to share with the private firm. In the French car park management sector, this dilemma is all the more important as public authorities generally have to manage several contracts. As shown in section 2., they face the problem of multicontracting.[43] The distribution of delegated management and public procurement contracts (29.66% of delegated management contracts and 70.34% of public procurement) in 2009 in the French leader company of car parks, seems to indicate that public authorities are rather willing to favor the interests of their citizens instead of maximising the total surplus.

4.3.3 The damaging effect of multicontracting

Last, under delegated management, when the pressure is low ($r_b^{'} < 1$), inefficient investments may be implemented when they create benefits for the manager (*i.e.* when $c'(e) - r_b^{'}b'(e) > 0$). By increasing the incentives to invest (as shown in subsection 4.2.), multicontracting leads to more inefficient cost-reducing investments with large adverse effects on quality ($b'(e) > c'(e)$). Then, $S_N^D \leq S_{N-1}^D + S_1^D$ (See *proof 5.a.*).
Since the public authority suffers from the adverse effects, her payoff is lower in case of multicontracting: $UG_N^D \leq UG_{N-1}^D + UG_1^D$ (See *proof 5.b.*)

The following proposition summarizes our results of subsection 4.2. and 4.3.:

Proposition 3. *Multicontracting increases the incentives of the private operator to make non-contractible efforts, but under some circumstances, it may both increases the global surplus and be detrimental to the public authority.*

[42] A complete analysis of such a situation would require to wonder to what extent the benefits of the firms can be transformed into social benefits through the level of employment or taxes for instance. However, our analysis is not led at a macroeconomic level, and our goal is simply to show that the most efficient solution is not necessarily the solution that the public authority rationally chooses.

[43] The assumptions according to which innovations are efficient($c('e) - b'(e) \geq 0$) in this sector seems quite realistic. Moreover, according to the respective bargaining powers of the parties, public authorities may had better choose delegated management than public procurement, which justifies why they face such a problem.

5 Conclusion

In the French car park management sector, public authorities have two main tools to shape their relationships with private firms: the type of contractual agreement (public procurement versus delegated management) and the number of contracts to award. We show that these choices have different implications as regards to renegotiations caused by contractual incompleteness.

Our results first show that the *ex post* global surplus reached under each type of contractual agreement is different, because those contractual agreements entail different occurrences of renegotiations, and different incentives to make non-contractible efforts for the manager. Moreover, we also stress how these contractual agreements share differently the gains for the parties, and why, under some circumstances, delegated management may entail a higher global surplus but be detrimental for the public authority. Last, our results also stress how the strategy of multicontracting makes the problem all the more difficult for public authorities under such circumstances: the more contracts they award to the same private operator, the higher the global surplus is, but the larger their own losses are. Then, in practice, public authorities have to face an "efficiency dilemma": either they choose the contractual type that gives them the highest payoff but creates a lower global surplus; or they prefer a contract that maximizes the total surplus but creates some damages for their own interests. In this regard, our analysis is both normative and positive, and shows the difficulties to make policy recommendations in the contracting-out of public services.

More broadly, our paper highlights the fact that the environment of the relationship - and especially the legal environment allowing the choice of the contractual agreements- is not neutral on the *ex post* efficiency of public-private partnerships.

Our analysis also includes some important features of the relationship between public and private parties that have been analyzed separately up to now, such as the precise allocation of decision and payoff rights, the number of contracts about the same service, and the role of the third party (*i.e.* the users). This may have some consequences for the emerging literature on participative management, including users as a regulating force in public-private contracts (Pezon [2002]).

Besides, although our paper is applied to the car park management sector, it could also apply to other public services where there are the same types of outsourcing, and where there is multi-contracting. Indeed, in large cities, instead of giving one contract for the monopoly of a public service to one operator, some public authorities have decided to split the public service into different geographical areas. This is the case of water distribution in Nantes, France: the public authority decided to divide the territory into seven zones. At the final stage, three operators are present in the city to operate the seven contracts.[44]

[44] In the same way, the city of London also chose to cut up her bus service: each line of bus is subject to a call for tenders and a contract. In this way, there are several operators operating the London bus network, but some operators have several bus contracts (Amaral et al. [2010]). They are in a position of multi-contracting.

However, our analysis is a first step to better understand the consequences of contractual incompleteness in the public-private relationships. For a complete analysis of renegotiations under incomplete contracts, a more detailed vision of the factors of renegotiations would be required. Introducing external shocks as an origin for renegotiations should be the purpose of a future research. In the same way, a full understanding of the choice of the contractual agreement would introduce the role of budget constraints for public authorities, which is not neutral on their choice to contract out, as suggested by Engel et al. [2010]. We defer such analysis for future work.

Appendix

Proof n°1

By definition, $z = \sigma - \frac{R^+(\beta(i))}{\beta(i)}$ when $R^+(\beta(i)) \leq \sigma\beta(i)$ so that $z \geq 0$, and $z = 0$ when $R^+(\beta(i)) \geq \sigma\beta(i)$.
Moreover, since $R^+(.) > 0, \beta(.) > 0$, and $\sigma \in [0;1]$, then

$$\begin{aligned} \sigma \leq 1 + \frac{R^+(\beta(i))}{\beta(i)} &\Leftrightarrow \sigma\beta(i) \leq \beta(i) + R^+(\beta(i)) \\ &\Leftrightarrow \sigma\beta(i) - R^+(\beta(i)) \leq \beta(i) \Leftrightarrow \sigma - \frac{R^+(\beta(i))}{\beta(i)} \leq 1 \Leftrightarrow z \leq 1 \end{aligned}$$

We show that $z \in [0;1]$.

Proof n°2

We can note that all incentives (e_N^{FB}, i_N^{FB}, e_N^D, i_N^D, e_N^P, i_N^P) are increasing in N:

By the implicit function theorem,

$$\begin{aligned} \frac{d(e_N^{FB})}{dN} &= -\frac{\gamma(c'(e_N^{FB}) - b'(e_N^{FB})}{(1+\gamma(N-1))(c''(e_N^{FB}) - b''(e_N^{FB}))} > 0 \\ \frac{d(i_N^{FB})}{dN} &= -\frac{\gamma(\beta'(i_N^{FB}))}{(1+\gamma(N-1))(\beta''(i_N^{FB}))} > 0 \\ \frac{d(e_N^P)}{dN} &= -\frac{\gamma(c'(e_N^P) - b'(e_N^P)}{(1+\gamma(N-1))(c''(e_N^P) - b''(e_N^P))} > 0 \\ \frac{d(i_N^P)}{dN} &= -\frac{\gamma(\beta'(i_N^P))}{(1+\gamma(N-1))(\beta''(i_N^P))} > 0 \\ \frac{d(e_N^D)}{dN} &= -\frac{\gamma(c'(e_N^D) - R^-(b(e_N^D))b'(e_N^D)}{(1+\gamma(N-1))(c''(e_N^D) - (R^{-''}(b(e_N^D))b'(e_N^D)^2 + R^{-'}(b(e_N^D))b''(e_N^D))} > 0 \end{aligned}$$

When $R^+(\beta(i)) > \sigma\beta(i)$:

$$\frac{d(i_N^D)}{dN} = -\frac{\gamma R^+(\beta(i_N^D))(\beta'(i_N^D))}{(1+\gamma(N-1))((R^{+'}(\beta(i_N^D))\beta''(i_N^D)) + R^{+''}(\beta(i_N^D))(\beta''(i_N^D))^2} > 0$$

else:

$$\frac{d(i_N^D)}{dN} = -\frac{\gamma(\beta'(i_N^D))}{(1+\gamma(N-1))(\beta''(i_N^D))} > 0$$

Proof n°3

Proof. 3.a.

$\forall N \geq 2$ let us compare S_N^P and $S_{N-1}^P + S_1^P$:

$$\begin{aligned} S_N^P &= \sum_{j=1}^{N}[B_j^0 - C_j^0] + N[c(e_N^P) - b(e_N^P) + \beta(i_N^P)] - e_N^P - i_N^P \\ S_1^P + S_{N-1}^P &= \sum_{j=1}^{N}[B_j^0 - C_j^0] + (N-1)[c(e_{N-1}^P) - b(e_{N-1}^P) + \beta(i_{N-1}^P)] - e_{N-1}^P - i_{N-1}^P \\ &+ [c(e_1^P) - b(e_1^P) + \beta(i_1^P)] - e_1^P - i_1^P \end{aligned}$$

From section 3., when innovations are socially efficient, $e_N^P, i_N^P \geq 0$ and e_N^P, i_N^P are increasing in N. Then, $\forall N \geq 2, N \geq N-1 \geq 1$ and:

$$N[c(e_N^P) - b(e_N^P) + \beta(i_N^P)] \geq N[c(e_{N-1}^P) - b(e_{N-1}^P) + \beta(i_{N-1}^P)] \quad (1)$$

Moreover,

$$c(e_{N-1}^P) - b(e_{N-1}^P) + \beta(i_{N-1}^P) - e_{N-1}^P - i_{N-1}^P \geq c(e_1^P) - b(e_1^P) + \beta(i_1^P) - e_1^P - i_1^P$$

and $$-[c(e_{N-1}^P) - b(e_{N-1}^P) + \beta(i_{N-1}^P) - e_{N-1}^P - i_{N-1}^P] + c(e_1^P) - b(e_1^P) + \beta(i_1^P) - e_1^P - i_1^P \leq 0$$

Then, by adding this negative term on the right side of (1):

$$\begin{aligned} N[c(e_N^P) - b(e_N^P) + \beta(i_N^P)] - e_N^P - i_N^P \geq [(N-1)(c(e_{N-1}^P) - b(e_{N-1}^P) + \beta(i_{N-1}^P)) - e_{N-1}^P - i_{N-1}^P \\ + c(e_1^P) - b(e_1^P) + \beta(i_1^P) - e_1^P - i_1^P] \end{aligned}$$

As a consequence, $S_N^P \geq S_{N-1}^P + S_1^P$

Proof 3.b.: Let us compare:

$$UG_N^P = \sum_{j=1}^{N}[B_j^0 - P_j^0] + (1-\sigma)N[c(e_N^P) - b(e_N^P) + \beta(i_N^P)]$$

$$\begin{aligned} UG_1^P + UG_{N-1}^P &= \sum_{j=1}^{N}[B_j^0 - P_j^0] + (1-\sigma)(N-1)[c(e_{N-1}^P) - b(e_{N-1}^P) + \beta(i_{N-1}^P)] \\ &+ (1-\sigma)[c(e_1^P) - b(e_1^P) + \beta(i_1^P)] \end{aligned}$$

Symmetrically to proof 3.a., we can establish:

$$N(1-\sigma)[c(e_N^P) - b(e_N^P) + \beta(i_1^N)] \geq N(1-\sigma)[c(e_{N-1}^P) - b(e_{N-1}^P) + \beta(i_{N-1}^P)]$$

and $$(1-\sigma)(c(e_1^P) - b(e_1^P) + \beta(i_1^P)) - (1-\sigma)(c(e_{N-1}^P) - b(e_{N-1}^P) + \beta(i_{N-1}^P)) \leq 0$$

leading to $$UG_N^P \geq UG_{N-1}^P + UG_1^P$$

Proof n°4

Proof. 4.a.: We compare:

$$\begin{aligned} S_N^D &= \sum_{j=1}^{N}(B_j^0 - C_j^0) + N[c(e_N^D) - b(e_N^D) + \beta(i_N^D)] - e_N^D - i_N^D \\ S_{N-1}^D + S_1^D &= \sum_{j=1}^{N}(B_j^0 - C_j^0) + (N-1)[c(e_{N-1}^D) - b(e_{N-1}^D) + \beta(i_{N-1}^D)] - e_{N-1}^D - i_{N-1}^D \\ &+ c(e_1^D) - b(e_1^D) + \beta(i_1^D) - e_1^D - i_1^D \end{aligned}$$

Since the incentives increase in N, the demonstration is similar to proof 3.a, and $S_N^D \geq S_{N-1}^D + S_1^D$.

Proof 4.b.: Let us compare:

$$\begin{aligned} UG_N^D &= (\sum_{j=1}^{n}(-\tilde{R}_j + B_j^0)) + N[-b(e_N^D) + (1 - z(\beta, R^+))\beta(i_N^D) - R^+(\beta(i_N^D)) + R^-(b(e_N^D))] \\ UG_N^D + UG_1^D &= (\sum_{j=1}^{n}(-\tilde{R}_j + B_j^0)) + (N-1)[-b(e_{N-1}^D) + (1 - z(\beta, R^+))\beta(i_{N-1}^D) - R^+(\beta(i_{N-1}^D)) \\ &+ R^-(b(e_{N-1}^D))] + [-b(e_1^D) + (1 - z(\beta, R^+))\beta(i_1^D) - R^+(\beta(i_1^D)) + R^-(b(e_1^D))] \end{aligned}$$

4.b.1

When investments are socially efficient, and quality innovations are large enough, or the adverse effect is low enough, so that $(-b(e) + R^-(b(e_N^D) + (1 - z(\beta, R^+))\beta(i) - R^+(\beta(i)))) \geq 0$, the demonstration is similar to that of proof 4.c., since the innovations create a global positive surplus.

4.b.2

On the contrary, when $(-b(e) + R^-(b(e_N^D) + (1 - z(\beta, R^+))\beta(i) - R^+(\beta(i)))) \leq 0$, the

global effect of the innovations is negative, and the proof is similar to proof 4.b.: $UG_N^D \leq UG_{N-1}^D + UG_1^D$.

Proof n°5

Proof 5.a. From subsection 3.3, e_N is increasing in N, so that:

$$\begin{aligned}
& N(c(e_N^D) - b(e_N^D)) \leq N(c(e_{N-1}^D) - b(e_{N-1}^D))(\leq 0) \\
\text{and} \quad & 0 \leq c(e_1^D) - b(e_1^D) - c(e_{N-1}^D) + b(e_{N-1}^D) \\
\text{which leads to} \quad & N(c(e_N^D) - b(e_N^D)) \leq (N-1)(c(e_{N-1}^D) - b(e_{N-1}^D)) + c(e_1^D) - b(e_1^D) \\
\text{and} \quad & S_N^D \leq S_{N-1}^D + S_1^D
\end{aligned}$$

Proof 5.b. We compare:

$$\begin{aligned}
UG_N^D &= (\sum_{j=1}^{n}(-\tilde{R}_j + B_j^0)) + N[-b(e_N^D) + R^-(b(e_N^D))] \\
UG_{N-1}^D + UG_1^D &= (\sum_{j=1}^{N}(-\tilde{R}_j + B_j^0)) + (N-1))[-b(e_{N-1}^D) + R^-(b(e_{N-1}^D))] - b(e_1^D) + R^-(b(e_1^D))
\end{aligned}$$

$$\begin{aligned}
\text{Since} \quad & N(-b(e_N^D) + R^-(b(e_N^D))) \leq N(-b(e_{N-1}^D) + R^-(b(e_{N-1}^D))) \\
\text{and} \quad & -b(e_1^D) + R^-(b(e_1^D)) + b(e_{N-1}^D) - R^-(b(e_{N-1}^D)) \geq 0 \\
\text{Then,} \quad & N(-b(e_N^D) + R^-(b(e_N^D))) \leq \\
& N(-b(e_{N-1}^D) + R^-(b(e_{N-1}^D))) - b(e_1^D) + R^-(b(e_1^D)) + b(e_{N-1}^D) - R^-(b(e_{N-1}^D))
\end{aligned}$$

This implies that $UG_N^D \leq UG_{N-1}^D + UG_1^D$: the public authority has a higher loss because of multicontracting that enhances the amount of adverse effects.

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