PUBLIC CONTRACTING, RENEGOTIATION AND THE OPTIMAL MIX OF FINANCING SOURCES

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Public contracting, renegotiation, and the optimal mix of financing sources*

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Abstract

A government offers a long-term contract to a private firm for the realization of a public project that involves first constructing a facility (for which a cost is to be sunk) and then operating it to provide a service. At the contracting stage, both parties are uncertain about the operation cost, which the firm learns privately immediately after construction. We show that, under limited commitment, the government is not indifferent as to the financing structure of the project. We characterize the renegotiation-proof contract and pin down the mix of financing sources (namely, public funds, firm's own funds, and credit) that the firm should be instructed to effect at optimum. The government should guarantee the firm's loan only as long as the firm does not attempt to renege on the initial agreement.

Keywords: Public projects, investment, renegotiation, duration, guarantees
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1 Introduction

Governments often resort to private firms for the execution of long-term public projects, such as the realization of infrastructures, schools, hospitals, prisons and city redevelopment. In most cases, private firms are also required to invest. Investments are very high, in general, and largely financed with debt.[1] An important but still under-explored issue is whether and to what extent involving private resources in large public projects is socially desirable, how much of the latter should be drawn from firms' own funds and how much from external sources. Our study investigates this issue, building finance concerns in optimal public-contracting design.

The focus is on environments that display two essential characteristics: first, uncertainty about operating conditions; second, imperfections in contract commitment and/or enforcement, which may lead to renegotiation of the original agreement.

Concerning the first characteristics, we look at situations in which uncertainty pertains to the operating costs of the project. While the latter are unknown (or, more precisely, known only stochastically) to all parties at the contracting stage, their realization is observed by the sole private partner at the operation stage. Situations where operating costs are uncertain when the contract is drawn up are very frequent, in practice. For instance, in tunnel projects, the maintenance costs to be borne during the operation phase are not perfectly predictable, in general, at the time the contract is awarded.[2] Moreover, in procurement/regulation contexts, it is typically the case that the executing party holds private information about some action or relevant aspect of the production environment. Naturally enough, this is the root to the appearance of incentive problems during the realization of the project. Firms can influence the probability of cost realization (see Bennett and Iossa [4], Hart [18], Iossa and Martimort [22], and Martimort and Pouyet [27] about infrastructure projects) and/or observe the realized cost of operation privately (see Laffont [25] about monopoly regulation, Guasch *et alii* [16] - [17] about concession contracts, and Iossa and Martimort [22][3]). In all these situations, optimal prescription is to let the private firm bear some risk to contain the agency cost.

The difficulty with this prescription is that, in practice, contracts between governments and private firms are frequently renegotiated so that either risk transfer is limited or it does not take place (Guasch [15], Engel *et alii* [10], Estache [11], Chong *et alii* [6]). Renegotiation occurs due to problems of limited commitment, meaning that either the firm forces the government to sit

[1] According to a report appeared in *The Economist* in June 2008, "never before has infrastructure spending been so large as a share of world GDP," with $22 trillion allocated to projected investments over a ten-year horizon only in emerging economies. Before the recent economic crisis, projects used to be mainly funded with corporate bonds issued by the private firms running them. At present, they are more often financed with senior debt. See also Flyvbjerg *et alii* [13] on these aspects.

[2] Uncertainty about construction costs and future demand conditions is also considerable.

[3] These authors build a model of moral hazard followed by private observation of cost (cost overrun). As usual, once incentives to exert effort are provided, the problem reduces to one of cost overrun only.

again at the contracting table against its will (limited enforcement), or the government breaks the contract at a later stage even if this disadvantages the private firm (non-commitment).[4] In environments where long-term contractual relationships are plagued by this kind of problems, limited enforcement and non-commitment are likely to be both present. Therefore, considering both kinds of commitment imperfections is key to a proper understanding, on one side, of the reasons that determine such a poor risk transfer and of the ways in which contracts should be designed to be robust to renegotiation.

The framework of our study is similar to that of Laffont [25] and related studies. The government offers to the firm an incentive contract for the construction of an essential facility and the subsequent provision of a service. The contract is designed and agreed upon *ex ante i.e.*, when the cost of providing the service is still unknown to either party, and should induce the firm to reveal this cost *ex post*, after it is learnt privately. With respect to those aforementioned, our model presents, nonetheless, two novel aspects. First, we extend the two-period horizon to an infinite-time horizon. Second, and perhaps more essential, we allow the project to be funded by a combination of private and public funds. The benefit of introducing these elements is twofold. On the one hand, the analytical setting comes closer to reality. On the other, we shed light on a few relevant finance aspects in public contracting and on the way parties' behaviour is affected thereof. In particular, the duration of the contract and, more importantly, the mix of financing sources are endogenized as clauses in the contractual offer that the government addresses to the firm. Once the investment is sunk to build the facility and the operating cost observed, the firm might default, either involuntarily, because it has not enough resources, or strategically, because it anticipates renegotiation. The optimal contract takes, of course, these incentives into account.

1.1 Preliminary results

In this manuscript, only a part of our overall research project concerning public contracting, renegotiation and optimal financing structure is developed. The results that we obtain are partial and, yet, essential for the steps of analysis to come next. We describe them hereafter.

Our first finding concerns the benchmark scenario in which parties fully commit to the original agreement. Under this circumstance, the government induces production of the Ramsey-Boiteux (second-best) output for each possible cost level and extract all surplus from the firm *ex ante*. Because no better outcome could be achieved if the activity were run directly by the

[4] The two labels used in the text are reported in Estache and Wren-Lewis [12], who recall that non-commitment is explored in Chapter 9 of Laffont and Tirole, and limited enforcement in Laffont [25] and, more widely, in Guasch *et alii* [16]. Lack of enforcement is referred to as a cause of pervasive renegotiations in Saussier *et alii* [30] as well. Alternatively, renegotiation occurs because some future contingencies are too costly to specify when the contract is drawn up (see Bajari *et alii* [2] with regards to highways).

government, the latter may well decide to make the contract last infinitely long. Importantly, no specific prescription emerges regarding the financing structure of the project. Once it is ensured that public and private funds are sufficiently large, altogether, to cover the investment cost, the exact combination of sources is not relevant.

In a limited-commitment world, parties may wish to engage in profitable renegotiation once the operation cost is realized together with the associated payoff distribution. In the renegotiation game that we look at, we do not take parties to split the available surplus according to the usual Nash-bargaining approach. Rather, we allow either party to make a contractual proposal to the other, whatever the party that has initiated the renegotiation. Within this context, we characterize the Pareto frontier of implementable payoffs, showing that the set of such payoffs shrinks as the debt guarantee becomes larger.

We then focus on the case in which renegotiation is led by the firm. We assess that only a high-cost firm has an interest in engaging in renegotiation, whereas a low-cost firm does not. Renegotiation thus occurs under complete information. Moreover, renegotiation is initiated as soon as the operation phase starts, provided the reputation loss that the government would bear if the firm were to quit the project decreases quickly enough over time. When we characterize the optimal renegotiation-proof contract, in line with Guasch *et alii* [16], we find that it provides the same incentives as the full-commitment contract. That is, quantities are not distorted away from the second-best levels. The reason for this is that any rent appearing in the operation phase for the firm can be captured at the contractual stage by properly adjusting the sum of public funds and credit to be injected into the project so as to saturate the firm's participation constraint. As a result, the government is still indifferent about the duration of the contract. Under limited enforcement, however, more restrictions are cast on the financing structure of the project. Specifically, while under full commitment it suffices to inject enough public funds to complement the private resources (be they firm's own funds or loans) in the coverage of the initial investment, in the renegotiation-proof contract this is no longer the case because the optimal mix of sources also depends upon the payoffs that the parties could obtain in the renegotiation game.

1.2 Related literature

To begin with, our work is related to the literature about reliance on private resources for the realization of public projects. Among recent studies, Engel *et alii* [9] argue that requiring the private firm to fund the initial investment entirely and recover costs directly from user-fees, is a desirable option in situations where the budgetary authority that monitors the governmental agency in charge of shifting funds from the public budget to the firm faces agency problems. Our results suggest that another motivation for private financing resides in the need to provide incentives to the private partner itself, rather than to avoid that incentive issues between different tiers of the governmental hierarchy plague the project performance. In turn, de Bettignies and Ross [8] argue that private investment is beneficial because private firms credibly commit to early termination of socially inefficient projects, when the latter generate low cash flows. By contrast, a public authority would not do so for political reasons. Indeed, the termination of any project (whether it generates high or low cash flow) provides a bad signal to society about the activity of the government. While de Bettignies and Ross [8] focus on projects for which early termination is socially desirable, we explore situations in which this is not the case. From this standpoint, our analysis is related to that of Dewatripont and Maskin [7]. They show that, under decentralized financing, taking credit from a (small) financier provides the firm with good incentives to avoid default. In our model, in which the firm runs a public (rather than a private) project, incentives are provided by the government (rather than by the creditor) also by instructing the firm on the amount of credit to take.

Our study is also related to the literature about capital structure in agency problems. Spiegel and Spulber [33] - [34] and Spiegel [32] investigate the effects of the capital structure chosen by the agent/firm on the contractual relationship with the principal/regulator. They assume that the regulated firm exercises discretion in its choice of a capital structure as this accords with what they observe to occur, in practice, for the U.S. regulated utilities. By contrast, we are interested in identifying the capital structure that the government should optimally set for the project, to be decentralized through the contract offered to the firm.[5] From this standpoint, our approach is closer to that of Lewis and Sappington [26]. However, in the latter's framework, renegotiation issues are ruled out as parties are taken to fully commit to the initial agreement.

Lastly, the paper is related to the literature about contract renegotiation after a sunk investment is made. Hart and Moore [19] consider a credit contract for a project the outcome of which is observable by the parties but not verifiable. Based on the observed cash-flow, the firm and the creditor either renegotiate or break down the agreement. In the latter situation, the firm does not share the cash-flow with the creditor and the creditor liquidates the project, obtaining some benefit from liquidation. In our model, the cash-flow of the firm is endogenous and thus verifiable, at least in part. Indeed, the firm receives transfers from the government. However, under limited enforcement, the firm does not commit to pay the debt. Moreover, the creditor is not in a position to liquidate assets, which belong to the government and have no other potential use than the public project for which they were created. Under these circumstances, a credit contract can be drawn up not because the creditor can exercise residual control rights on the assets, as in Hart and Moore [19]. Rather, it exists because the government pledges a guarantee in favour of the private firm, for it to be able to raise funds from external sources.

[5] This seems to be in line with the attitude displayed by U.S. regulators before the Eighties, to control utility company debt, as detected in Taggart [35].

1.3 Outline

The remainder of the paper is organized as follows. In section 2, we describe the model. In section 3, we present the benchmark situation in which parties fully commit and characterize the optimal contract. In section 4, we introduce limited commitment into the picture and describe how we approach this issue formally. In section 5, we present the renegotiation game. In section 6, we focus on the situation where the firm wishes to renegotiate (limited enforcement) and characterize the optimal renegotiation-proof contract. Some of the mathematical details are relegated to an appendix.

2 The model

We consider a long-term contract between a government (denoted G) and a private firm (denoted F) for the provision of a service of general interest. The project unfolds over two stages. The first stage, which takes place at time $\tau = 0$, represents the *construction phase*, during which the facility that is needed to provide the service, is financed and built. The second stage, which begins as soon as the facility is available and lasts till time T, represents the *operation phase*, during which the service is provided to the collectivity. As frequent in recent decades, the private party F is delegated both stages of the project. At time T, when the contract ends, the infrastructure is transferred to G, which manages the activity thereafter.

2.1 Technology, consumer surplus and demand

At time $\tau = 0$, F sinks a cost $I > 0$ to build the infrastructure. At each instant $\tau \in [0, T]$, it bears a cost $\theta q + K$ to provide the service, with $\theta > 0$ the marginal cost, $q \geq 0$ the production quantity, and $K > 0$ the fixed cost. Consumption of q units of the service yields the instantaneous gross surplus $S(q)$, with $S(0) = 0$, $S'(q) > 0$ and $S''(q) < 0$. Consumers cannot store the service and transfer consumption to future periods. Hence, the output produced at some given τ is entirely consumed at that same time and sold on the market at the equilibrium price $p(q) \equiv S'(q)$. This defines the inverse demand function. Once the investment is made, both technology and demand parameters remain constant for the whole duration of the project, including the period in which the activity is run by G (say, through a public firm).

2.2 Information structure

The contract between G and F is signed and the investment I is made *ex ante i.e.*, when the unit variable cost θ is still unknown to either contractual party. However, at the contracting stage, it is commonly known that θ will be either low ($\theta_l > 0$) or high ($\theta_h > \theta_l$) with probabilities

ν and $(1-\nu)$, respectively. After the investment is made and before production takes place, F observes privately the realized state of nature *i.e.*, whether the marginal cost is θ_l or θ_h. Hence, F enjoys an information advantage *vis-à-vis* the contractual partner, as it is typically the case in delegation settings. The degree of uncertainty that G faces about operating costs is denoted $\Delta\theta = \theta_h - \theta_l$.

2.3 Project financing

F has a resource endowment $E \geq 0$. Through the contract, G recommends how much of this endowment F should invest in the project, namely an amount $M \in [0, E]$, as well as the amount of funds that it should borrow on the competitive credit market, namely $C \geq 0$. Moreover, G makes an up-front payment t_0 to F such that the total amount of funds that is injected into the project at the outset of the construction phase, is equal to the cost of investment:

$$t_0 + M + C = I. \tag{1}$$

The transfer t_0 is positive when the project is partially financed with public funds. It is negative when the project is financed only with private funds and F makes a payment $[I-(M+C)]$ to G to be awarded the contract. Given (1) and because $C \geq 0$, F ultimately borrows

$$C = \max\{0; I-(M+t_0)\}. \tag{2}$$

In the operation phase, F receives a transfer t from G and obtains the market revenues $p(q)q$. Observe that allowing the private firm to receive a combination of subsidies and fees warrants that a variety of real-world situations be encompassed, ranging from conventional infrastructure provision, in which the government pays for the activity and the firm earns no money from consumers, to traditional concession, in which the firm only relies upon market revenues.[6]

2.4 Payoffs under complete information

We now present the payoffs that contractual parties obtain for some given cost realization θ. We begin with the firm and then turn to the government.

[6]In the E.U. context, this is the case of BOT (build, operate and transfer) concession contracts. It is indeed required that concession holders recover the cost of investment through market sales only, in order to ensure that they bear operation and demand risks entirely (as an illustration, Auriol and Picard [1] mention the Channel Tunnel project).

2.4.1 The payoff of F

During the operation phase, F redeems the debt taken at the outset of the construction phase. At each instant $\tau \in [0, T]$, F has to pay a fixed amount g to the creditor. At a later stage, we will see that the amount g that is due by F to the creditor in each period τ, will be guaranteed with public funds. Overall, at any instant $\tau \in [0, T]$, F receives a transfer t from G, makes the market profit $p(q)q - (\theta q + K)$, pays g to the creditor, and remains with the net operating profit

$$\pi = t + p(q)q - (\theta q + K) - g. \tag{3}$$

Denoting r the discount factor, the present value of the future stream of operating profits that F will obtain under the contract, evaluated at time τ, is written

$$\Pi_\tau = \int_\tau^T \pi e^{-r(x-\tau)} dx. \tag{4}$$

At time 0, the payoff of F from the project in state θ includes Π_0, together with the initial financing sources used in the project, namely t_0, M and C, net of the cost of investment I and of the amount injected by the firm itself into the project *i.e.*, $\Pi_0 + (t_0 + M + C - I) - M$. Relying on the financing condition (1), the payoff of F is further expressed as

$$\widetilde{\Pi} = \Pi_0 - M \tag{5}$$

and is thus equal to the difference between the discounted net operating profit and the own resources invested into the project.

2.4.2 The payoff of G

G is a benevolent government, aiming at maximizing the discounted consumer surplus, net of the market expenditures and the social cost of transferring resources from taxpayers to producers, over the *whole* time horizon. This includes not only the surplus generated under the contract, while the activity is run by F, but also the surplus generated after the end of the contract, under public management. Whatever the regime, to finance the transfers, G needs to raise distortionary taxes. Each transferred euro requires that $(1 + \lambda)$ euros be collected from taxpayers, with $\lambda > 0$.[7] The imperfections of the taxation system are taken not to vary over time so that λ remains constant for all $\tau \in [0, +\infty)$.

[7] According to Snow and Warren [31], the shadow cost of public funds is around 0.3 in developed economies. The World Bank [36] provides a figure of 0.9 with regards to developing countries.

Under the contract, the discounted net consumer surplus is given by

$$U_0 \equiv \int_0^T [S(q) - p(q)\, q - (1+\lambda)\, t]\, e^{-rx} dx - (1+\lambda)\, t_0. \tag{6}$$

Under public management, letting $(\widehat{q}, \widehat{t})$ denote the quantity-transfer pair, the discounted surplus at time $z \geq T$ is written

$$\widehat{U}_z = \int_z^\infty \left[S(\widehat{q}) - p(\widehat{q})\, \widehat{q} - (1+\lambda)\, \widehat{t}\right] e^{-r(z-y)} dy.$$

Hence, the payoff of G at time 0 is given by

$$\widehat{V}_0 = U_0 + e^{-rT} \widehat{U}_T.$$

It is straightforward to see that, in the period after the contract, the transfers will only need to warrant exact break-even. This requires that

$$\int_T^\infty \widehat{t} e^{-ry} dy = \int_T^\infty (K - (p(\widehat{q}) - \theta)\, \widehat{q})\, e^{-ry} dy. \tag{7}$$

Furthermore, the optimal output to be delivered after the end of the contract in state θ is pinned down according to the formula

$$\frac{p(q^{sb}) - \theta}{p(q^{sb})} = \frac{\lambda}{1+\lambda} \frac{1}{\varepsilon(q^{sb})}, \tag{8}$$

where the superscript *sb* denotes *s*econd-*b*est values. Actually, this is the familiar Ramsey-Boiteux condition, which determines by how much price should be raised above marginal cost for production costs to be recovered through the most efficient mix of market revenues and transfers, given the price elasticity of demand and the shadow cost of public funds.

Taking (7) and (8) into account and defining

$$w(q) \equiv S(q) + \lambda p(q)\, q - (1+\lambda)(\theta q + K)$$

for the generic quantity q, the payoff of G, optimized over the interval $[T, \infty)$ is written

$$V_0 = U_0 + \int_T^\infty w(q^{sb}) e^{-ry} dy. \tag{9}$$

3 Full commitment

For the time being, we suppose that both parties fully commit to the initial agreement and do not wish to engage in renegotiation. As a benchmark for the subsequent analysis, we characterize the optimal contract in this scenario.

G designs an incentive scheme that induces F to participate in the activity and to release information about the operating cost once this is realized and observed privately. The scheme includes the three components described hereafter.

First, the scheme specifies how much private and public resources (the triplet (M, C, t_0)) should be devoted to fund the investment in the construction phase. Second, as the Revelation Principle applies and attention can be restricted to direct revelation mechanisms in which F reports the true cost value, the scheme includes the allocation $(t_i, q_i)_{i=l,h}$, with q_i the quantity to be produced and t_i the transfer to be made during the operation phase, in the event that the realized cost is θ_i.[8] Third, the contract stipulates for how long F should run the project *i.e.*, the overall duration T.

All these elements are to be set so as to satisfy the incentive-compatibility constraints

$$\Pi_{l,0} \geq \Pi_{h,0} + \frac{1-e^{-rT}}{r}\Delta\theta q_h \tag{10}$$

$$\Pi_{h,0} \geq \Pi_{l,0} - \frac{1-e^{-rT}}{r}\Delta\theta q_l, \tag{11}$$

together with the *ex ante* participation constraint of F

$$E\left[\Pi_{i,0}\right] \geq M, \tag{12}$$

which requires that the expected discounted flow of net operating profits accruing to F be sufficiently large to compensate for the own resources injected into the project.

The value of the debt at any τ is given by

$$D_\tau = \int_\tau^T \left[\nu g_h + (1-\nu) g_l\right] e^{-r(x-\tau)} dx = E(g)\frac{1-e^{-r(T-\tau)}}{r},$$

where g_i, $i = l, h$, is the the debt payment that F makes to the creditor in each period during the operation phase. To rule out any arbitrage possibility across the three financing sources in (1), we make the (reasonable) assumption that any alternative investment available in the economy yields the same return. For simplicity, each unit of funds invested in any alternative

[8] With a usual change of variable, in the sequel of the analysis, we will mainly work with the instantaneous operating profit rather than directly with the transfer. The subscript i will be appended to all variables that depend upon the specific cost realization θ_i.

undertaking, whether it is drawn from own funds, public funds or market sources, yields a return of one euro. One implication of this is that the project can be funded with fairly priced debt, meaning that $D_0 = C$ and

$$E(g) = \frac{rC}{1 - e^{-rT}}. \tag{13}$$

The optimal contract that G designs for F is the one that yields the largest level of expected surplus under the financing conditions (1), (2) and (13), and to the constraints (10) to (12). At optimum, constraint (10) and (12) are binding. Using (4), (3) and (13), we can thus write the latter as

$$\int_0^T E[t_i]\, e^{-rx} dx = M + C - \int_0^T E[p(q_i)q_i - (\theta_i q_i + K)]\, e^{-rx} dx,$$

which enables us to express the expected surplus of the project as

$$\begin{aligned} W &= E[V_{i,0}] \\ &= \int_0^T E[w(q_i)]\, e^{-rx} dx + \int_T^\infty E\left[w(q_i^{sb})\right] e^{-ry} dy - (1+\lambda) I, \end{aligned} \tag{14}$$

Optimization of (14) with respect to the contracting variables yields the following result. In stating it, the superscript fc is appended to indicate the *full-commitment* regime.

Lemma 1 *Under full commitment:*

- *any triplet* (M, C, t_0) *satisfying the financing conditions* (1) *and* (2) *together with* (10) – (12) *is optimal;*

- *the optimal quantity is characterized by condition* (8), *with* q^{sb} *replaced by* q_i^{sb} $\forall i \in \{l, h\}$;

- *at any time* $\tau \in [0, T]$, *the optimal net operating profits are given by*

$$\pi_l^{fc} = \frac{rM}{1 - e^{-rT}} + (1 - \nu)\, \Delta\theta q_h^{sb} \tag{15}$$

$$\pi_h^{fc} = \frac{rM}{1 - e^{-rT}} - \nu \Delta\theta q_h^{sb}; \tag{16}$$

- *any* $T \in [0, +\infty)$ *is optimal.*

Proof. See Appendix A. ■

In the full-commitment scenario, G achieves the same outcome whether the initial investment is financed with public funds only (t_0) or with private funds only (M and C). This can be viewed as an application of the Irrelevance Theorem due to Sappington and Stiglitz [29]. That is, provided the government faces a private firm that is risk-neutral and has (or can raise) enough funds not to be financially constrained, public and private financing are equivalent. With both public and private financing involved, once the amount of private resources $M + C$ is fixed, G can always find a transfer t_0 such that all relevant constraints are satisfied.

The optimal full-commitment contract implements the second-best output levels without cost from the viewpoint of G,[9] by introducing some risk in the distribution of information rents

$$\widetilde{\Pi}_l^{fc} = (1-\nu)\,\Delta\theta q_h^{sb}\frac{1-e^{-rT}}{r} > 0 \quad \text{and} \quad \widetilde{\Pi}_h^{fc} = -\nu\Delta\theta q_h^{sb}\frac{1-e^{-rT}}{r} < 0.$$

In particular, the agent is rewarded if efficient and punished if inefficient, as typical of adverse selection problems with *ex ante* participation constraint under risk-neutrality. Although the rents do not depend upon how much funds are invested from the various sources, the expressions in (15) and (16) show that the instantaneous net profits do reflect the amount of own funds that F uses to construct the facility. Even a high-cost firm receives a positive payoff during the operation phase, if it has injected a sufficiently large amount of money at the construction phase.

The full-commitment contract yields the same outcome as public management will after the end of the contract: the second-best quantities are provided and no surplus is given up to the producer *ex ante*. Under these circumstances, it is not surprising that G has no specific preference as to the determination of the contract duration, and may well decide to offer an everlasting contract.

4 Limited commitment

So far we have supposed that G and F fully commit to the contract for its whole duration. We have shown that any stopping time T is optimal, in that case. We now turn to explore a framework in which commitment is limited and the contract between G and F may end earlier than originally agreed upon. Two scenarios are possible. First, F induces G to come back to the contracting table, despite that this is not the latter's will. According to the terminology adopted in previous works, this is the case of *limited enforcement*. Second, G breaks the initial agreement during the contract execution, despite that this may disadvantage F. This is the case of *non-commitment*. We hereafter describe these scenarios. In either case, we specify the consequences for the execution of the contract between F and the creditor.

[9]This occurs because the second-best output is monotonic with respect to types $\left(q_l^{sb} > q_h^{sb}\right)$.

4.1 Limited enforcement

Once it is informed about the realized value of θ, either before or after reporting $\widetilde{\theta}_i \in \{\theta_l, \theta_h\}$, F may credibly threat G to default on the project (*i.e.*, either not to start or to stop operating and quit the activity), unless the contract is revised. F takes this initiative in two cases. First, whatever its incentive to report information, F would like to renege on the initial agreement if, under the latter, it bears a loss *ex post*. For instance, this may happen when F is of type θ_h and has no incentive to lie (π_h^{fc} in (16) can be negative). Second, F may threat default as a deliberate strategy to retain more surplus in the relationship with G, when it is aware that replacement with another firm would be costly to G. Examples of limited enforcement and firm-led renegotiation are pervasive in public contracting. In institutionally weak contexts (developing countries, in general), strong rules of law seldom exist and renegotiation likely takes place. For instance, Estache and Wren-Lewis [12] recall that, in Ghana, the incumbent monopoly for fixed telephony entered the mobile business despite the explicit interdiction. In Tanzania, the regulator failed to enforce regional mobile license and the dominant operator began to expand at the national level. Guasch [15] and Guasch *et alii* [16] - [17] provide further examples in Latin America and in the Caribbean regions. Although less often, firms initiate renegotiation also in frameworks where institutions are solid (typically, developed countries) and contracts should be, in principle, more easily enforced, say, by fining firms that are reluctant to produce. For instance, Gagnepain *et alii* [14] detect a progressive increase in the subsidies paid to French urban transport operators all over the concession contract duration, suggesting that governments are weak and/or not prone to engage in costly and time-consuming litigations to enforce contracts.

4.1.1 The credit contract

In a limited-enforcement framework, not only the execution of the contract between G and F is problematic. It is also that of the credit contract, provided F cannot be compelled to return money to the creditor. Unless F cares about reputation sufficiently, repayment is at risk, which involves that F may be unable to borrow on the credit market in the first place. Anticipating this, G can induce creditors' participation by stipulating that, as long as the contract with F is in place, it will pay some guaranteed amount g directly to the creditor abating the instantaneous transfer to F to $(t - g)$. However, in the event that F quits the project and is replaced, G is not responsible for the residual debt, which is to be entirely redeemed by F. In practice, it is often the case that, while firms are responsible for their debts as long as they earn profits from the concerned project, governments bail out the activity and debt responsibilities are passed onto taxpayers as difficulties arise. This occurred, for instance, with the 2002-03 London Underground maintaining-and-upgrading project. The public sector was uncertain over whether Metronet, the consortium in charge of the project, could borrow enough funds on the credit market. To boost the banks' appetite, during the bidding stage, Transport for London guaranteed 95% of Metronet's debt obligations. Eventually, Metronet failed and the Department for Transport had to make a £1.7 billion payment to help Transport for London meet the guarantee (House of Lords [20] - [21]). According to the National Audit Office [28], taxpayers incurred a direct loss of between £170 million and £410 million. This epilogue clearly suggests that public guarantees for debt repayment in the event of failure blunt private finance incentives and should thus not be agreed upon at the contracting stage. Resting on this, in our model, we take G to guarantee the debt only as long as F remains in the project, whether the original contract is maintained or renegotiated.

4.2 Non-commitment

As we previously mentioned, non-commitment means that G can break the initial agreement during the contract execution, despite that this may be detrimental to F. Specifically, once the investment has been sunk and G has received the report $\widetilde{\theta}$ from F, it may wish to modify the allocation initially designed for a $\widetilde{\theta}-$firm, in case it proves inefficient *ex post*. In developing countries, government failure to honor contractual terms is even bigger a concern than limited enforcement, because large-scale investments, which are there desperately needed, especially in utilities, may not take place if governments cannot warrant that investors obtain sufficiently high returns. That this may occur is suggested by the result, which Banarjee *et alii* [3] draw from a cross-country analysis (see also Estache and Wren-Lewis [12]), that governments' opportunistic behaviour does not propitiate private investment. It would also be in line with the observation that political risk has challenged public contracting in Central and Eastern Europe in various occasions over the last decades.[10]

4.2.1 The credit contract

As under limited enforcement, execution of the credit contract is problematic also in a framework where G may not comply with the contractual obligation to make transfers. The debt may remain unpaid. To avoid this, at the time that the contract is signed, a guarantee g is pledged for the transfer to be made to the creditor as a per-period debt repayment thereafter. One can think of G as depositing resources with a third party, which should then be released to the creditor, in the event that it would not receive money directly from G. In practice, strategies of the kind just described are followed when governments mandate an Investment Insurance Agency (IIA) to act as an intermediary, providing insurance and/or direct cover in the event of

[10] Brench *et alii* [5] evidence that repeated changes in political attitude towards partnerships with private firms have slowed down the development of transportation projects in Hungary.

any default in payment by a borrower (or its guarantor) under some loan agreement. Originally created as government entities to promote, facilitate and support the exports of goods and services, starting from the Nineties, IIAs have began to operate in project financing as well and are now widely spread across countries.[11]

4.2.2 The payment to F

Of course, under non-commitment, G may not honor the contractual obligation to make transfers to F either. Applying the same logic as for the credit contract, F is guaranteed the due amount of money in the event that G would not pay.

5 The renegotiation game

We now come back to the formal analysis and consider the possibility that, at some time $\tau \in [0, T]$, either F or G wishes to renege on their initial agreement and proposes the other party to renegotiate.

In the event that renegotiation is refused or fails, G replaces F with another firm (denoted F'). Replacement yields a loss of reputation R_τ to G. Under limited enforcement, this loss reflects the negative consequences for G of not being sufficiently strong to implement the contract originally signed with F (compare Guasch *et alii* [16]). Under non-commitment, it mirrors the reputation penalty that G bears, by not keeping its promises, *vis-à-vis* the concerned firm, other potential investors, and customers (see Irwin [24]). The reputation loss depends upon the time τ at which replacement occurs. It is larger the earlier the replacement and diminishes as the replacement time approaches the natural end of the contract T. Formally, $R'_\tau < 0$ and $R_T = 0$.

Because renegotiation occurs when the investment is sunk, the creditor has no bargaining power in the renegotiation process and can take no action affecting the payoffs of F and G. It means that, at each instant, it receives (no more than) the guaranteed amount g and the players, in the renegotiation game, are F and G only.

Let us begin by considering the situation in which one party proposes the other to renegotiate, without specifying which party takes the initiative. For the time being, we take this to

[11] Most European governments have set up IIAs for the purposes described in the text. All countries that have official IIAs (alternatively labelled Export Credit Agencies) are now party to the "Arrangement on Guidelines for Officially Supported Export Credits," which provides specific rules for project finance, derogating from the usual Consensus Rules to allow, among other things, for a longer repayment term (of up to 14 years). Examples of European IIAs are Compagnie Française d'Assurance pour le Commerce Extérieur (Coface), Euler Hermes Kreditversicherungs (Hermes), Istituto per i Servizi Assicurativi del Credito all'Esportazione (SACE), Office National du Ducroire (ONDD), to mention only a few.

occur in the generic state θ, which is commonly known at this stage of the relationship.[12] At a later stage, we will identify the conditions under which either party initiates renegotiation and the state in which it does so, at equilibrium.

5.1 Replacement payoffs

Consider first the case in which the contract is not renegotiated and G replaces F.

5.1.1 The payoff of F

Once the contract is broken down, F no longer produces. Hence, it obtains no compensation and no longer repays the debt. Its operating profit over the whole period $[\tau, T]$ clearly becomes $\pi^{rp} = 0$, where the script rp is appended to denote the *rep*lacement scenario. Hence, the payoff of F under replacement is simply given by

$$\Pi_{\tau}^{rp} = \int_{\tau}^{T} \pi^{rp} e^{-r(x-\tau)} dx = 0.$$

5.1.2 The payoff of G

The production technology being related to the inner characteristics of the facility, it remains the same, whatever the operating firm, once the facility is in place. Therefore, G is aware that the marginal operating cost of F' is θ. G gives to F' the quantity-transfer pair (q^{rp}, t^{rp}) that maximizes its own payoff. Specifically, G chooses the transfer that makes the instantaneous profit of F' equal to zero over the whole period $[\tau, T]$ *i.e.*, $t^{rp} = K - (p(q^{rp}) - \theta) q^{rp}$. Recall that, once the payments that G owes to F are placed under the aegis of an external institution, this transfer is guaranteed and thus necessarily made to F. Using the definition of $w(q)$, the discounted payoff of G at time τ is written as

$$V_{\tau}^{rp} = \int_{\tau}^{T} w(q^{rp}) e^{-r(x-\tau)} dx - R_{\tau} = \int_{\tau}^{T} \left(w(q^{rp}) - \frac{rR_{\tau}}{1 - e^{-r(T-\tau)}} \right) e^{-r(x-\tau)} dx.$$

Optimization with respect to quantity yields $q^{rp} = q^{sb}$ *i.e.*, F' produces the (second-best) full-commitment output and sells it on the market at the full-commitment price. Moreover, it receives the transfer $t^{rp} = K - (p(q^{sb}) - \theta) q^{sb}$ from G. The replacement payoff of G is thus given by

$$V_{\tau}^{rp} = \int_{\tau}^{T} \left(w(q^{sb}) - \frac{rR_{\tau}}{1 - e^{-r(T-\tau)}} \right) e^{-r(x-\tau)} dx,$$

with $w(q^{sb}) - \frac{rR_{\tau}}{1-e^{-r(T-\tau)}}$ the instantaneous return over the residual contractual period.

[12] For this reason, the subscript i will be dropped in all relevant variables.

5.2 Renegotiation payoffs

Suppose next that G and F do renegotiate the contract at some time $\tau \in (0, T]$. As previously mentioned, renegotiation occurs under symmetric information about the type of F, which is known to be θ, in one of the ways that we describe hereafter.

5.2.1 F makes the offer

With probability $(1-\alpha)$, $\alpha \in [0,1]$, F makes a take-it-or-leave-it offer to G, which includes producing the quantity q^F to be sold at the market price $p\left(q^F\right)$ and receiving the payment t^F, the superscript F being appended to indicate that F makes the offer.

Both here and elsewhere in the renegotiation game, one can think of the transfer from G to F as either including g, the instantaneous debt repayment guaranteed by G, if F is available to pass it to the creditor, or excluding it, in which case G gives g directly to the creditor. In formal terms, the two situations are equivalent and we can innocuously refer to the former.

The payoff of G At any $x \in [\tau, T]$, the instantaneous return of G from the offer of F in state θ is calculated as

$$v^F = S(q^F) - p\left(q^F\right) q^F - (1+\lambda)\, t^F.$$

F chooses the payment that makes G just indifferent between renegotiating and replacing F. This requires setting t^F and q^F such that

$$v^F = w(q^{sb}) - \frac{rR_\tau}{1-e^{-r(T-\tau)}},$$

which yields a transfer equal to

$$t^F = \frac{1}{1+\lambda}\left[S(q^F) - p\left(q^F\right) q^F - \left(w(q^{sb}) - \frac{rR_\tau}{1-e^{-r(T-\tau)}}\right)\right]$$

Notice that the payment is deflated by one plus the shadow cost of public funds. This evidences that, all else equal, the larger the cost of collecting resources from taxpayers and/or distorting production from the efficient level, the smaller the surplus that F can extract from G at the renegotiation stage.

The payoff of F Assuming that renegotiation takes place at one single instant τ and not again at a subsequent stage, the present value of the payoff of F when G accepts the offer

$\left(t^F, q^F\right)$ is given by

$$\begin{aligned}
\Pi_\tau^F &= \int_\tau^T \left[t^F + \left(p(q^F) - \theta\right) q^F - K - g\right] e^{-r(x-\tau)} dx \\
&= \frac{1}{1+\lambda} \left[\int_\tau^T \left(S(q^F) - p\left(q^F\right) q^F\right) e^{-r(x-\tau)} dx - \left(\int_\tau^T w(q^{sb}) e^{-r(x-\tau)} dx - R_\tau\right)\right] \\
&\quad + \int_\tau^T \left[p(q^F) q^F - \theta q^F - K - g\right] e^{-r(x-\tau)} dx.
\end{aligned}$$

In this expression, g is the instantaneous payment guaranteed to the creditor. Π_τ^F is maximized when $q^F = q^{sb}$ so that it is finally written as

$$\Pi_\tau^F = \frac{R_\tau}{1+\lambda} - \int_\tau^T g e^{-r(x-\tau)} dx.$$

5.2.2 G makes the offer

With probability α, G makes the following take-it-or-leave-it-offer to F. At each $x \in [\tau, T]$, F produces the quantity q^G to be sold at the market price $p\left(q^G\right)$ and G makes the payment t^G, the superscript G being appended to indicate that G puts forward a proposal.

The payoff of F G proposes the quantity-transfer pair (q^G, t^G) that makes F just indifferent between renegotiating and abandoning the project. This requires setting $t^G = K - (p(q^G) - \theta) q^G + g$. It follows that the surplus of F from renegotiation is $\Pi_\tau^G = 0$.

The payoff of G G proposes the quantity that maximizes its payoff

$$V_\tau^G = \int_\tau^T \left(w(q^G) - (1+\lambda) g\right) e^{-r(x-\tau)} dx.$$

This quantity being $q^G = q^{sb}$, its payoff is ultimately given by

$$V_\tau^G = \int_\tau^T \left(w(q^{sb}) - (1+\lambda) g\right) e^{-r(x-\tau)} dx.$$

5.2.3 Expected payoffs from renegotiation and renegotiation frontier

Appending the script rn to indicate the *ren*egotiation framework, the expected payoffs of F and G at time τ are respectively given by

$$\begin{aligned}\Pi_\tau^{rn} &= \frac{1-\alpha}{1+\lambda}R_\tau - (1-\alpha)\int_\tau^T ge^{-rx}dx \\ V_\tau^{rn} &= \int_\tau^T w(q^{sb})e^{-r(x-\tau)}dx - (1-\alpha)\,R_\tau - \alpha\,(1+\lambda)\int_\tau^T ge^{-r(x-\tau)}dx.\end{aligned}$$

Noticeably, while a larger reputation loss benefits F, it penalizes G in the renegotiation process. By contrast, a larger debt guarantee reduces the expected payoff for either party.

To characterize the Pareto frontier of the payoffs that can be effected through renegotiation, we first rewrite

$$(1-\alpha)\,R_\tau = (1+\lambda)\,\Pi_\tau^{rn} + (1-\alpha)\,(1+\lambda)\int_\tau^T ge^{-rx}dx$$

and then replace into the expression of V_τ^{rn} to obtain the equation

$$V_\tau^{rn} = \int_\tau^T \left(w(q^{sb}) - (1+\lambda)\,g\right)e^{-r(x-\tau)}dx - (1+\lambda)\,\Pi_\tau^{rn}. \tag{17}$$

Two observations are in order. First, if taxation were not distortionary, the frontier would have slope -1. Here, because taxation is distortionary, the frontier is steeper, having slope $-(1+\lambda) < -1$. This means that a unit raise in the payoff of F requires imposing a more-than-unit sacrifice on G. Second (and expectably), as the debt guarantee that G pledges is increased, the frontier shifts downwards and the set of implementable payoffs facing contractual parties shrinks.

6 F-led renegotiation and renegotiation-proof contract

Having found the set of implementable payoffs as delimited by the Pareto frontier in (17), we now put forward the analysis focusing on the situation in which the firm proposes renegotiation to the government (F-led renegotiation).

6.1 Implementability of the full-commitment contract

Suppose that F initiates renegotiation at some time $\tau < T$. Then, the present value of the stream of profits during the remaining period is given by

$$\Pi_{\tau}^{rn} = \int_{\tau}^{T} \pi^{rn} e^{-r(x-\tau)} dx = \frac{1-\alpha}{1+\lambda} R_{\tau}, \tag{18}$$

the operating profit at any time $x \in [\tau, T]$ being

$$\pi_{\tau}^{rn} = \frac{1-\alpha}{1+\lambda} \frac{rR_{\tau}}{1-e^{-r(T-\tau)}}.[13]$$

On the other hand, letting π the instantaneous profit under the original contract, the present value of the future stream of profits that this contract yields is written

$$\Pi_{\tau} = \int_{\tau}^{T} \pi e^{-r(x-\tau)} dx = \pi \frac{1-e^{-r(T-\tau)}}{r}, \tag{19}$$

provided that it remains in place till time T. F has no interest in renegotiating the initial contract at time τ as long as $\Pi_{\tau} \geq \Pi_{\tau}^{F}$ or, equivalently,

$$\pi \geq \frac{1-\alpha}{1+\lambda} \frac{rR_{\tau}}{1-e^{-r(T-\tau)}}. \tag{20}$$

Suppose that the initial contract is the full-commitment contract and recall that the latter assigns to type θ_l and θ_h the instantaneous operating profits reported in (15) and (16), respectively. As $\pi_l^{fc} > \pi_h^{fc}$, the full-commitment contract is effected till time T (hence, it is robust to renegotiation) if and only if π_h^{fc} satisfies (20) for all τ *i.e.*:

$$\frac{rM}{1-e^{-rT}} - \nu \Delta\theta q_h^{sb} \geq \frac{1-\alpha}{1+\lambda} \frac{rR_{\tau}}{1-e^{-r(T-\tau)}}, \ \forall \tau \in [0, T]. \tag{21}$$

Lemma 2 *Under limited enforcement, the full-commitment contract is implementable if and only if condition* (21) *is satisfied.*

As long as (21) holds, neither type θ_h nor, *a fortiori*, type θ_l has an interest in reneging the full-commitment contract.

[13] The subscript τ is here appended to stress that this is the instantaneous profit that F obtains if renegotiation takes place at time τ.

6.2 Which type wishes to renegotiate and when?

Having (21) violated means that there exists some time $\tau \in [0, T]$ at which (at least) type θ_h would like to renegotiate the full-commitment contract. We investigate this issue focusing on the situation in which, for all τ, $\frac{d}{d\tau}\left(\frac{R_\tau}{1-e^{-r(T-\tau)}}\right) \leq 0$. This occurs if and only if

$$R'_\tau \leq -R_\tau \frac{re^{-r(T-\tau)}}{1-e^{-r(T-\tau)}}, \tag{22}$$

requiring that the reputation loss associated with replacement of F decreases sufficiently fast over time. Condition (22) involves that (20) is most stringent at $\tau = 0$. This allows us to distinguish two cases. First, (20) is slack at $\tau = 0$. Then, condition (21) is strictly satisfied and the full-commitment contract is renegotiation-proof. Second, (20) is binding already at $\tau = 0$, meaning that the θ_h-firm begins renegotiation as soon as the operation phase starts.

Lemma 3 *Suppose that* (22) *holds. Then, there is no* $\tau \in [0, T]$ *at which the* θ_h-*firm has an incentive to renegotiate as long as* (20) *is slack for all* $\tau \in [0, T]$. *Otherwise, it has an incentive to initiate renegotiation at* $\tau = 0$.

In appendix we check whether type θ_l may have an incentive, in turn, to renegotiate the contract that assigns the renegotiation-proof instantaneous payoff $\pi_{h,0}^{rn}$ to type θ_h. We draw the following conclusion.

Lemma 4 *Suppose that* (22) *holds. Then, there is no* $\tau \in [0, T]$ *at which the* θ_l-*firm has an incentive to renegotiate the contract that assigns the renegotiation-proof payoff to the* θ_h-*firm.*

Proof. See Appendix B. ■

Putting together our previous findings, we can now state the following overall result.

Lemma 5 *Private information is revealed at the subgame perfect equilibrium described by (the second part of) Lemma 3 and Lemma 4. Suppose that* (22) *holds, whereas* (21) *does not. Then, the equilibrium is supported by the following beliefs:*

1. If F wants to renegotiate at $\tau = 0$, *then G believes that the type is* θ_h; *otherwise, it believes that the type is* θ_l.

2. If F wants to renegotiate at $\tau > 0$, *then G maintains the initial believes.*

The lemma says that only the initial action of F is relevant for G to deduce the type. Scenario 2 is an out of equilibrium situation.

6.3 The optimal renegotiation-proof contract

Let π_l^{rn} and q_l^{rn} be, respectively, the instantaneous profit and the quantity that type θ_l is assigned when type θ_h receives $\frac{1-\alpha}{1+\lambda}\frac{rR_\tau}{1-e^{-r(T-\tau)}}$. In Appendix C.1 we show that, in this setting, renegotiation taking place at $\tau = 0$, (10) and (11) respectively become

$$\begin{aligned}\Pi_{l,0}^{rn} &\geq \frac{1-\alpha}{1+\lambda}R_0 + \int_0^T \Delta\theta q_h^{rn} e^{-rx}dx \\ \frac{1-\alpha}{1+\lambda}R_0 &\geq \Pi_{l,0}^{rn} - \int_0^T \Delta\theta q_l^{rn} e^{-rx}dx,\end{aligned}$$

whereas (12) is reformulated as

$$\nu\Pi_{l,0}^{rn} + (1-\nu)\frac{1-\alpha}{1+\lambda}R_0 \geq M.$$

As usual, giving up a rent to F is costly to G. Hence, the incentive constraint of the efficient type is binding and the participation constraint further becomes

$$\nu\int_0^T \Delta\theta q_h^{rn} e^{-rx}dx + \frac{1-\alpha}{1+\lambda}R_0 \geq M. \tag{23}$$

The relevant (binding) constraints are thus (20) and (23). Taking the latter into account, the objective function of G is now written as (see Appendix C.2)

$$\begin{aligned}W &= \int_0^T \left[\nu w\left(q_l^{rn}\right) + (1-\nu)\, w(q_h^{rn})\right] e^{-rx}dx \\ &\quad + \int_T^\infty \left[vw(q_l^{sb}) + (1-\nu)\, w(q_h^{sb})\right] e^{-ry}dy - (1+\lambda)\, I.\end{aligned} \tag{24}$$

Optimization of (24) with respect to the contracting variables yields the following result.

Proposition 1 *In the contract that prevents renegotiation led by the θ_h−firm at time $\tau = 0$:*

- *the optimal amount of firm's own funds is given by*

$$M^{rn} = \nu\int_0^T \Delta\theta q_h^{rn} e^{-rx}dx + \frac{1-\alpha}{1+\lambda}R_0;$$

- *any pair (t_0, C) such that $t_0 + C = I - M^{rn}$ is optimal;*

- *the optimal quantity is $q_i^{rn} = q_i^{sb}$ $\forall i \in \{l, h\}$;*

- *at any time* $\tau \in [0,T]$ *, the optimal net operating profits are given by*

$$\begin{aligned}\pi_l^{rn} &= \frac{1-\alpha}{1+\lambda}\frac{rR_0}{1-e^{-rT}} + \Delta\theta q_h^{sb} \\ \pi_h^{rn} &= \frac{1-\alpha}{1+\lambda}\frac{rR_0}{1-e^{-rT}};\end{aligned}$$

- *any* $T \in [0,+\infty)$ *is optimal.*

In line with Guasch *et alii* [16], this result means that the renegotiation-proof contract provides the same incentives as the full-commitment contract. Quantities are not distorted away from the second-best levels. This occurs because any rent appearing in the operation phase for F (*ex post*) is captured at the contractual stage by properly adjusting the sum $t_0 + C$ so as to saturate the participation constraint. Moreover, as under full commitment, only the expected value of the guarantee is relevant. Once it is made sure that $\int_0^T E(g_i)e^{-rx} = C$, the amount specifically guaranteed in each possible state does not matter. And, of course, as long as G can avoid to give up any rent to F *ex ante* without distorting quantities, it is also indifferent about the duration of the renegotiation-proof contract.

Despite that the achievements of the renegotiation-proof contract are similar to those of the full-commitment contract, a relevant difference does arise. In the limited-enforcement framework, more restrictions are cast on the financing structure of the project. Specifically, under full commitment, it suffices that the up-front transfer be adjusted to the magnitude of the sum $M + C$, given the investment to be made. In the renegotiation-proof contract, this is no longer the case because the payoffs that the parties would obtain in the renegotiation game must also be accounted for.

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A Proof of Lemma 1

The optimal full-commitment quantity is obtained by optimizing (14) with respect to q_i, $i = l, h$. This yields

$$p(q_i) - \theta_i + \lambda [p'(q_i) q_i + p(q_i) - \theta_i] = 0,$$

from which (8) is obtained. The incentive constraint of type θ_l is binding and given by

$$\Pi_{l,0} = \Pi_{h,0} + \Delta\theta q_h \frac{1 - e^{-rT}}{r}. \tag{25}$$

Hence, we can write

$$\begin{aligned} \int_0^T E\left[t_i + p(q_i)q_i - (\theta_i q_i + K + g)\right] e^{-rx} dx &= \nu \Pi_{l,0} + (1-\nu)\Pi_{h,0} \\ &= \nu \left(\Pi_{h,0} + \Delta\theta q_h \frac{1 - e^{-rT}}{r} \right) + (1-\nu)\Pi_{h,0} \\ &= \Pi_{h,0} + \nu \Delta\theta q_h \frac{1 - e^{-rT}}{r} \\ &= (\pi_h + \nu \Delta\theta q_h) \frac{1 - e^{-rT}}{r}. \end{aligned} \tag{26}$$

The participation constraint of F is binding and given by

$$\nu \Pi_{l,0} + (1-\nu)\Pi_{h,0} + (t_0 + M + C - I) - M = 0,$$

which reduces to

$$\nu \Pi_{l,0} + (1-\nu)\Pi_{h,0} = M. \tag{27}$$

Replacing (26) into (27), we derive

$$\pi_h = \frac{rM}{1 - e^{-rT}} - \nu \Delta\theta q_h.$$

We can then compute

$$\Pi_{h,0} = \pi_h \frac{1 - e^{-rT}}{r} = M - \nu \Delta\theta q_h \frac{1 - e^{-rT}}{r}$$

and then, using (25),

$$\Pi_{l,0} = M + (1-\nu)\Delta\theta q_h \frac{1 - e^{-rT}}{r},$$

from which we ultimately derive

$$\pi_l = \frac{rM}{1-e^{-rT}} + (1-\nu)\,\Delta\theta q_h.$$

B Proof of Lemma 4

When the contract assigns the renegotiation-proof instantaneous payoff $\pi_{h,0}^{rn}$ to type θ_h, type θ_l truthtells if and only if

$$\Pi_{l,0} \geq \Pi_{h,0}^{rn} + \int_0^T \Delta\theta q_h^{rn} e^{-rx} dx.$$

This constraint is binding and thus requires that type θ_l be assigned the operating profit

$$\pi_{h,0}^{rn} + \Delta\theta q_h^{rn} = \frac{1-\alpha}{1+\lambda} R_0 + \Delta\theta q_h^{rn}.$$

With this profit, type θ_l has no interest in mimicking type θ_h and proposing renegotiation at $\tau = 0$. However, type θ_l may still prefer to renegotiate after reporting truthfully and we need to check whether this is the case. When θ_l is reported, G deduces that F is efficient. Hence, the renegotiation game is unchanged, except that type θ_l is concerned instead of type θ_h. This means that the discounted payoff of the θ_l-firm from renegotiating at some time τ is $\frac{1-\alpha}{1+\lambda} R_\tau$ and the instantaneous operating profit $\frac{1-\alpha}{1+\lambda} \frac{rR_\tau}{1-e^{-r(T-\tau)}}$. Under (22), also type θ_l might want to renegotiate only at $\tau = 0$. It is not willing to renegotiate even at $\tau = 0$ as long as it obtains a larger payoff by truthtelling and not renegotiating. This requires that

$$\frac{1-\alpha}{1+\lambda} \frac{rR_0}{1-e^{-rT}} + \Delta\theta q_h^{sb} \geq \frac{1-\alpha}{1+\lambda} \frac{rR_0}{1-e^{-rT}},$$

which is evidently true.

C The renegotiation-proof contract

C.1 Incentive and participation constraints

Recall that π_l^{rn} and q_l^{rn} denote, respectively, the instantaneous profit and the quantity that type θ_l is assigned when type θ_h receives Π_τ^{rn}. With renegotiation at time τ, the initial incentives constraints (10) and (11) are rewritten as

$$\begin{aligned}
\Pi_{l,\tau} + e^{-r\tau}\Pi_{l,\tau}^{rn} &\geq \Pi_{h,\tau} + \int_0^\tau \Delta\theta q_h e^{-rx} dx + e^{-r\tau}\Pi_{h,\tau}^{rn} + \int_\tau^T \Delta\theta q_h^{rn} e^{-rx} dx \\
\Pi_{h,\tau} + e^{-r\tau}\Pi_{h,\tau}^{rn} &\geq \Pi_{l,\tau} - \int_0^\tau \Delta\theta q_l e^{-rx} dx + e^{-r\tau}\Pi_{l,\tau}^{rn} - \int_\tau^T \Delta\theta q_l^{rn} e^{-rx} dx.
\end{aligned}$$

Substituting $\Pi_{h,\tau}^{rn}$ from (18) and recalling that renegotiation occurs at $\tau = 0$, they further becomes

$$\begin{aligned}
\Pi_{l,0}^{rn} &\geq \frac{1-\alpha}{1+\lambda} R_0 + \int_0^T \Delta\theta q_h^{rn} e^{-rx} dx \\
\frac{1-\alpha}{1+\lambda} R_0 &\geq \Pi_{l,0}^{rn} - \int_0^T \Delta\theta q_l^{rn} e^{-rx} dx
\end{aligned}$$

Moreover, (12) becomes

$$\nu \Pi_{l,0}^{rn} + (1-\nu) \frac{1-\alpha}{1+\lambda} R_0 \geq M.$$

As the incentive constraint of type θ_l is binding, at optimum, this is further reformulated as (23) in the text.

C.2 Derivation of W

Recall (9) , the expression of discounted social value from the project, in some given state i:

$$V_{i,0} = U_{i,0} + \int_T^\infty w(q_i^{sb}) e^{-ry} dy.$$

Substituting q_i^{rn}, t_i^{rn} and g_i in the formula (6) of $U_{i,0}$, we can write the expected discounted social value as

$$\begin{aligned}
W &= \int_0^T E\left[S(q_i^{rn}) - p\left(q_i^{rn}\right) q_i^{rn} - (1+\lambda) t_i^{rn}\right] e^{-rx} dx - (1+\lambda) t_0 \\
&\quad + \int_T^\infty E\left[w(q_i^{sb})\right] e^{-ry} dy.
\end{aligned}$$

Recalling that $t_i^{rn} = \pi_i^{rn} - p\left(q_i^{rn}\right) q_i^{rn} + (\theta_i q_i^{rn} + K) + g_i$, this further becomes

$$\begin{aligned}
W &= \int_0^T E\left[w\left(q_i\right) - (1+\lambda)\left(\pi_i^{rn} + g_i\right)\right] e^{-rx} dx - (1+\lambda) t_0 \\
&\quad + \int_T^\infty E\left[w(q_i^{sb})\right] e^{-ry} dy.
\end{aligned}$$

Substituting the expression of π_l^{rn} from the binding IC of type l, the expression of W is rewritten

$$\begin{aligned}
W &= \int_0^T \left[\nu w\left(q_l^{rn}\right) + (1-\nu) w(q_h^{rn})\right] e^{-rx} dx \\
&\quad + \int_T^\infty \left[v w(q_l^{sb}) + (1-\nu) w(q_h^{sb})\right] e^{-ry} dy \\
&\quad - (1+\lambda) \int_0^T \left(\pi_h^{rn} + \nu \Delta\theta q_h^{rn} + E(g_i)\right) e^{-rx} dx - (1+\lambda) t_0.
\end{aligned}$$

Further using $\int_0^T \pi_h^{rn} e^{-rx} = \Pi_{h,0}^{rn}$ and substituting the expression $\Pi_{h,0}^{rn} = \frac{1-\alpha}{1+\lambda} R_0$, together with $\int_0^T E(g_i) e^{-rx} = C$, W becomes

$$
\begin{aligned}
W &= \int_0^T \left[\nu w\left(q_l^{rn}\right) + (1-\nu)\, w(q_h^{rn})\right] e^{-rx} dx \\
&\quad + \int_T^{\infty} \left[v w(q_l^{sb}) + (1-\nu)\, w(q_h^{sb})\right] e^{-ry} dy \\
&\quad - (1+\lambda) \int_0^T \nu \Delta\theta q_h^{rn} e^{-rx} dx - (1+\lambda) \frac{1-\alpha}{1+\lambda} R_0 - (1+\lambda)\left(t_0 + C\right).
\end{aligned}
$$

This evidences that W decreases with $t_0 + C$.

Now replace $M = I - C - t_0$ into (23). It becomes

$$t_0 + C \geq I - \left(\nu \int_0^T \Delta\theta q_h^{rn} e^{-rx} dx + \frac{1-\alpha}{1+\lambda} R_0\right).$$

While in the left-hand side we find the up-front transfer and the credit, the right-hand side contains I but is independent on the financing structure of the project. Therefore, because W decreases in $t_0 + C$, as we said, this sum must be set just as large as it is necessary to have (23) exactly satisfied *i.e.:*

$$t_0 + C = I - \left(\nu \int_0^T \Delta\theta q_h^{rn} e^{-rx} dx + \frac{1-\alpha}{1+\lambda} R_0\right).$$

Replacing this expression into W yields (24) in the text.