

Public-Private Partnerships for Transport Infrastructure: Some Efficiency Risks*

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Abstract

This paper models a Public-Private Partnership (PPP) to construct a highway. It captures some of the key features of the Transmission Gully PPP. The winner of the tender recovers its costs (including capital costs) via an availability payment rather than toll revenue. While the availability payment eliminates demand risk, the winner of the tender faces cost risk: maintenance costs are only learned after construction is complete. The winning firm can make investments during the construction phase that reduce subsequent maintenance costs. As the government faces transaction costs to replace the successful bidder, firms use debt strategically to pass on some of the cost risk to the government. This distorts incentives to invest in maintenance cost reduction. Private financing therefore undermines some of the benefits from bundling construction and maintenance, which is often mentioned as an important advantage of PPPs.

1 Introduction

In late 2012 the NZ Government announced that Transmission Gully would be the first roading project in New Zealand to be undertaken as a PPP. Shortly afterwards, in early 2013, BrisConnections, the private partner in the

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PPP to develop Brisbane’s Airport Link, went into voluntary administration owing more than AU\$3b. Australians are all-too-familiar with failed PPP’s for the provision of transport infrastructure, so one might reasonably ask whether Transmission Gully is likely to fare any better?

An important difference between Transmission Gully and the Australian PPPs is that the latter have typically remunerated the private partner through toll revenue, while Transmission Gully will be tendered as an “availability contract”: the Government will make regular service payments once the highway is operating according to the agreed performance standards. *These payments will be independent of the volume of traffic using the new highway.*

Forecasting traffic volumes on new roads is a notoriously difficult exercise, so toll-based PPPs push significant demand risk onto the private partner; a risk that they are not well-placed to manage.¹ Moreover, PPP traffic forecasts are not merely inaccurate, they tend to be *biased*, and upwards (Bain, 2009). Given that PPP contracts are awarded by competitive tender, this bias could reflect a “winner’s curse” effect (Kagel and Levin, 1986), though some commentators have suggested that strategic misrepresentation may be at work (e.g., Gomez-Ibanez and Meyer, 1993; Estache, 2005; Guasch, 2004; Athias and Nunez, 2006). Whatever the cause, below-forecast toll revenues have been a significant factor in many cases of financial distress amongst private partners in PPP roading projects.

The National Infrastructure Unit (NIU) – a specialised unit within Treasury that manages New Zealand’s PPP programme – has clearly learnt some lessons from the Australian experience. Its 2009 Guidelines (NIU, 2009) emphasise that the private partner should only bear such risks as they are in a position to manage, and only to the extent needed to incentivise optimal performance by the private partner. The Guidelines note in particular that the Government is usually the best repository for demand risk in roading PPPs. This is the rationale for using an availability contract for Transmission Gully.² Such contracts transfer cost-side risks, but not demand risk.

The authors have addressed the hazards of toll-financed PPPs elsewhere (Menezes and Ryan, 2014). An important lesson from our earlier analysis is that, irrespective of the *desirability* of transferring demand risk to the

¹Moreover, in the case of urban highways such as Brisbane’s Airport Link or Sydney’s Cross City tunnel, the alternative roads around the tolled tunnels are toll-free, and owned and operated by the government.

²It is not, however, the only way to insure the private partner against demand risk. A “least present value of revenue” (LPVR) auction allows the private partner to be remunerated through toll revenue, but with a flexible concession period to ensure it collects a pre-determined total revenue (in present value terms) over the life of the contract. See Engel, Fischer and Galetovic (2001).

private partner, the *feasibility* of downside risk transfer is limited. Because construction is privately financed in a typical PPP, the private partner enters the post-construction phase with significant debt servicing costs. If demand turns out to be weaker than expected it may default on its loans. Its bankers will try to renegotiate the contract with the Government. If, as will often be the case, the Government faces significant transaction or political costs from re-assigning the concession, it may be willing to make a transfer payment to keep the concessionaire afloat.³ In other words, private financing exposes the Government to hold-up when the private partner comes under financial pressure. Furthermore, by choosing its debt levels strategically, the private partner can exercise some *ex ante* control over the size of the expected *ex post* transfer.

The present paper extends this analysis to availability contracts of the Transmission Gully variety. Our particular focus here is on efficiency issues, which are absent from the earlier paper. In the model of Menezes and Ryan (2014) the expected hold-up rents to the firm are completely offset by more aggressive bidding in the original tender. Firms anticipate these rents and shade their bids accordingly. The overall expected costs to the Government are therefore unaffected by the hold-up problem. There is also no loss of efficiency in the allocation process – the lowest cost provider still wins the auction⁴ – and the model has no role for cost-reducing effort so it has nothing to say about distortions to incentives for effort.

In the present paper we build a simple model of a PPP with cost risk. The private partner is paid on an availability basis, so the demand side is not modelled explicitly. As in Menezes and Ryan (2014) we study the consequences of hold-up and the strategic choice of debt when the road is privately financed. We examine distortions to cost-reducing investments in some detail, and also briefly discuss (Section 7) potential inefficiencies in the allocation of the contract.

2 The PPP model of procurement

To set the scene, let us briefly rehearse the basic structure of PPPs, and the standard arguments for and against the PPP model of procurement.

³This “transfer” need not be a direct payment, but may take an indirect form, such as an increase in the allowed toll rate or an extension of the concession.

⁴There may, however, be some distortion to the likelihood that the original concessionaire has to be replaced. To the extent that this process involves transaction costs, there may be efficiency consequences. This possibility is obscured in Menezes and Ryan (2014) because the specific stochastic structure of demand risk in that model ensures that performance reliability is not degraded as a result of strategic debt manipulation.

A canonical PPP has two key features:

- It bundles construction and on-going operation and maintenance into a single long-term contract. In the case of Transmission Gully, the contract will run for 25 years beyond the end of the construction phase. This is sometimes called “whole-of-life contracting”.
- PPPs are privately financed: the private partner is required to raise the funds for the construction phase. In the case of an availability contract, for example, the Government makes no payments until the road is complete and meets various pre-specified performance standards.

It is important to note that these two features of PPPs are logically separable; in particular, private financing is not necessitated by bundling. It is possible to tender a bundled contract in which the Government provides up-front funding for construction. However, the NIU defines a PPP as a mode of procurement that involves both of the elements above (NIU, 2009).

The pros and cons of whole-of-life contracting are easily perceived. There may be synergy benefits if (as is the case with roading projects) maintenance costs are affected by choices made during the construction phase. Whole-of-life contracts also expand the scope for innovation. When a road is conventionally procured – the construction and maintenance contracts are tendered separately – the contracts are typically input-based: they set out the specifications of the work (materials, tolerances, methods and so forth). With a PPP contract, contract terms are often output-based: specifying measurable targets for the end-user experience to be delivered. On the other side of the ledger, whole-of-life contracting creates lock-in, which reduces flexibility to respond to changing circumstances (or raises the cost of such adaptation) and involves a high degree of contractual incompleteness.⁵

While there is substantial agreement in the literature about the nature – if not the relative magnitudes – of the costs and benefits of bundling, the pro’s and con’s of private financing are both more elusive and subject to more dispute.

Two traditional arguments for and against private finance – that it eases pressure on strained public sector budgets (for) and that it raises the financing cost of the project (against) – have now largely been dismissed, or at least substantially circumscribed, in the academic debate on PPPs. There is

⁵For example, a construction firm, which may be very good at building large road projects but not necessarily at maintaining or operating a road, will be lock in contractually, usually through a special purpose vehicle (SPV) firm, with other companies throughout the duration of the concession. It is unclear whether managerial effort and oversight is not better directed at their core construction activity.

no free lunch in a PPP arrangement, and while private partners may pay a higher nominal interest rate on debt, once appropriate risk adjustments are properly accounted for, total financing costs may not be appreciably higher. In the model introduced below, for example, the interest rate on private debt is higher than that on Government debt, but the overall cost of the project is the same as if the Government had borrowed the money.⁶

The NIU guidelines dismiss both the “free lunch” and the higher cost of private financing arguments (see NIU, 2009, pp.19-20).⁷ The interested reader is referred to Engel, Fischer and Galetovic (2013), and the references therein, for more detailed discussion of these public finance issues.

Another argument for private financing – and one that the NIU does accept – is that it provides appropriate incentives for the private partner to keep the project on schedule and on budget.⁸ There is no doubt some truth in this. The argument is a natural carry-over from similar arguments in favour of fixed-price contracting in conventional procurement. A fixed-price construction contract, for example, provides high-powered incentives for the contractor to complete on time and on budget. But the argument does not carry over perfectly to the PPP context. In a PPP, the “project” is not a discrete construction task, but a multi-decade arrangement to deliver infrastructure services. The consequences of the private partner entering the post-construction phase with substantial debts have been little explored in the literature. How will this debt affect incentives and performance reliability during the 25-30 years of the typical concession?

This question was the motivation for Menezes and Ryan (2014). The

⁶Our model has frictionless and fully efficient capital markets, but this, in our view, is the right benchmark for thinking about financing cost issues.

⁷Strangely, the New Zealand Transport Agency (NZTA) appears to have a different view: “The expectation, and requirement, is that the private sector will be able to equal or ‘beat’ the [Public Sector Comparator] by providing construction, risk management and operating costs savings to at least offset the difference in financing costs between the public and private sectors.” (NZTA, 2012, p.59). It is not clear why the NZTA believes that there is a higher financing cost under a PPP model. Even if one accepts this premise, it still makes no sense to claim that we should accept such costs if the benefits of bundling offset them. As noted above, one can have bundling without private finance, so no issue of trading off the costs of one against benefits of the other need arise.

⁸Practitioners often cite a fourth benefit as the primary rationale for privatising finance. This is the benefit of improved due diligence. When the banks become involved, it is alleged, there is better planning and better risk assessment *ex ante*, leading to fewer problems *ex post*. However, unless this improved due diligence results in the whole PPP being abandoned, it is not obvious how to quantify the *social* benefit of this factor. It may certainly benefit the bidding firm in developing its bid and avoiding bankruptcy. But is there a social benefit from paying a higher price to the winning bidder in exchange for a lower bankruptcy risk?

same issue motivates the present paper.

3 A simple model

In Menezes and Ryan (2014) we studied a toll-financed PPP roading project with demand risk but no cost risk, since our focus was on understanding the Australian PPP experience. In the present section we develop a model of an arrangement that more closely resembles the Transmission Gully PPP: the contract is of the “availability” variety, and cost risk – rather than demand risk – is the dominant issue.

A contract to construct a highway and maintain it for a fixed (concession) period, normalised to one unit of time, is to be offered by tender. The winning bidder will receive a one-off service payment from the Government at the end of the concession period.⁹ This payment is not contingent on the volume of traffic using the road.¹⁰

Assumption 0. All parties are risk neutral. We ignore discounting for simplicity, and capital markets are assumed to be fully competitive, so the risk-free rate of interest is zero.

There are $n > 1$ bidding firms. A firm’s bid is the amount of the one-off payment that it would like to receive. The lowest bid wins the contract and the winning bidder receives its bid at the completion of the concession (i.e., the tender is a first-price, sealed-bid auction).

This, of course, is a very simplified description of a PPP tender process. There are usually multiple dimensions along which bids are evaluated. However, it is not uncommon to select a short-list based on non-price criteria, with a final winner chosen on price. The NIU Guidelines (NIU, 2009), for example, recommend selecting a short-list of firms that meet some minimal quality standards, and then choosing the lowest priced bid from amongst this

⁹Availability payments are typically made in regular instalments once construction is complete. We assume that payment is made at the end of the concession period, rather than at the beginning, to reflect the fact that the private partner does not recover its construction costs until well into the concession period. Because we have normalised this period to one unit of time, payment at the end better reflects the incentive structure of an availability contract.

¹⁰The availability payment is subject to an incentive scheme where rewards and penalties are related to factors such as customers’ satisfaction, peak travel times and safety. While the incentive scheme may introduce some linkage to demand risk, our focus here is on cost risk and so we do not explicitly model the rewards and penalties.

group.¹¹

Firm i 's total cost to deliver the project is $c_i + m_i$, where c_i is the construction cost and m_i is the maintenance cost over the life of the concession.¹² If firm i wins the contract it will learn the value of m_i only after construction is complete – at the start of the concession period. Firm i learns c_i privately prior to bidding.¹³ We refer to c_i as firm i 's *type*.

Assumption 1. Types are (commonly known to be) independent random draws from the differentiable distribution F with support $[\underline{c}, \bar{c}] \subseteq \mathbb{R}_{++}$.

During construction, the firm may make investments that reduce subsequent maintenance costs. This captures the potential synergy benefits from whole-of-life contracting. In particular:

Assumption 2. Firm i 's maintenance cost m_i is drawn randomly (and independently of c_i) from the distribution $H(\cdot \mid \theta_i)$ supported on

$$[m_0(\theta_i), m_1(\theta_i)] \subseteq [\underline{m}, \bar{m}] \subseteq \mathbb{R}_{++}$$

The parameter $\theta_i \in \mathbb{R}_+$ is chosen by the firm during the construction phase. Higher θ_i values correspond to higher levels of investment in maintenance cost reduction, in the sense that $H(\cdot \mid \theta)$ FOSD $H(\cdot \mid \theta')$ whenever $\theta' > \theta$. In particular,

$$\mathbb{E}[m \mid \theta] = \int_0^\infty z dH(z \mid \theta)$$

is non-increasing in θ . We further assume that $\mathbb{E}[m \mid \theta]$ is differentiable in θ . The firm chooses θ_i by paying an investment cost $C(\theta_i)$, where $C(0) = C'(0) = 0$, $C'(\theta_i) > 0$ and $C''(\theta_i) > 0$ for all $\theta_i > 0$. (It follows that $C(\theta_i) \rightarrow \infty$ as $\theta_i \rightarrow \infty$.)

Importantly, we assume that investment in cost reduction is not contractible. One of the main rationales for PPP arrangements is precisely the

¹¹In December 2013, the NZTA announced a shortlist of two bidding consortiums: the Wellington Gateway Partnership and Positive Connections. (See their announcement at www.nzta.govt.nz/projects/transmission-gully/ppp.html).

¹²We assume that m_i is independent of traffic volumes so as not to introduce demand risk complications.

¹³In practice, capital costs are not fully known at the time of bidding. For example, the longest maturity for a New Zealand Government Bond is considerably less than the duration of the concession contract. While it may be possible for firms to hedge interest rate risk, we conjecture that this will be too costly. In this paper we abstract from such risk but point out that this may be another avenue for bankruptcy risks to materialise.

assumption that private partners know more than the Government about how to deliver infrastructure services at least cost. The PPP structure is intended to provide the private partner with financial incentives to find these economies.

Note that firms face *common* uncertainty about maintenance costs – the distribution $H(\cdot | \theta)$ is the same for all firms. This assumption greatly simplifies the analysis. The implications of relaxing it are discussed in Section 7.

4 Cash finance

The winning bidder is required to raise the finance necessary to meet its construction costs.¹⁴ Typically, much of this finance will be in the form of debt. However, it is useful to solve a benchmark version of the model in which all bidders are required (and able) to be 100% equity financed. Firms therefore face unlimited liability. Since construction costs are typically much larger than maintenance costs, we assume that bids cover maintenance costs with probability one (i.e., that all bids exceed $\bar{m}$). It follows that cash financed firms always perform their contractual obligations.

Our task is to calculate the equilibrium bidding strategies and the equilibrium level of investment in cost reduction.

The latter question is easily settled. Maintenance costs are independent of the winning firm's type, so θ will be chosen to solve

$$\min_{\theta \geq 0} \mathbb{E}[m | \theta] + C(\theta).$$

Assumption 2 guarantees that the optimal θ value satisfies

$$C'(\theta) = \left| \frac{d}{d\theta} \mathbb{E}[m | \theta] \right| \quad (1)$$

This is also the optimal choice of θ from a Social Planner perspective. Let $\hat{\theta}$ denote the solution to (1).

Next, consider the equilibrium bidding strategy. We seek a symmetric, differentiable bidding function $b(c_i)$ that is strictly increasing in the firm's type. It will be convenient to define

$$G(b_i) = b_i - \mathbb{E}[m | \hat{\theta}] - C(\hat{\theta}).$$

¹⁴We assume that firms do not require financing to pay maintenance costs. It is reasonable to suppose that Government service payments are received before maintenance invoices fall due for payment.

to be the winning bidder's revenue net of all costs except c_i . Let $g(c_i) = G(b(c_i))$ and note that g is a strictly increasing and differentiable function.

By our assumption that b is a strictly increasing equilibrium bidding function, it follows that $c = c_i$ solves

$$\max_c [g(c) - c_i] (1 - F)^{n-1}(c)$$

Using this fact, we can determine the function g by standard methods (Menezes and Monteiro, 2005, Chapter 3). Let X denote the random variable corresponding to the lowest of $n - 1$ random draws from F . Then familiar arguments imply that $g(\bar{c}) = \bar{c}$ and

$$g(c) = \mathbb{E}[X \mid X > c]$$

for any $c < \bar{c}$. In other words, each firm bids an amount equal to the expected total cost of the next highest type, assuming that their own type is the lowest of all the firms.

It follows that the equilibrium bidding function is

$$b(c) = G^{-1}(g(c)) = \mathbb{E}[X \mid X > c] + \mathbb{E}[m \mid \hat{\theta}] + C(\hat{\theta}) \quad (2)$$

Since the function (2) is strictly increasing and differentiable (as we had assumed above), it constitutes a symmetric equilibrium bidding strategy.

Notice that the equilibrium is fully efficient: the firm with the lowest construction cost wins the contract and this firm makes an efficient level of investment in maintenance cost reduction. This is a PPP on its best behaviour.

Our benchmark model eliminates scope for any of the “cons” of the PPP model to play a role. First, since firms face common uncertainty about maintenance costs, there are no lock-in problems. Second, cash financing eliminates any of the issues that come with private debt: default, bankruptcy and renegotiation. In the benchmark model, if firm i wins the contract and its realised maintenance costs m_i satisfy

$$m_i - \mathbb{E}[m \mid \hat{\theta}] > g(c_i) - c_i,$$

it will still deliver on its contractual obligations (since we assumed that $b_i > \bar{m}$ in equilibrium) but it will make a loss.¹⁵ This downside risk is necessary to provide optimal incentives for the firm to manage maintenance costs. However, if firms are (partially) debt financed then this possibility

¹⁵Recall that $g(c_i) - c_i$ is the winning firm's expected profit margin on the contract.

of loss becomes a possibility of bankruptcy and default. The central lesson of the present paper is that limited liability may interfere with investment incentives: the benefits of whole-of-life contracting are not separable from the mode of financing of the PPP. The following sections explain this link.

5 Debt and default

In practice, bidders for PPP contracts are substantially debt financed. The winning bidder may choose to default on its debt repayments if it receives a sufficiently high m_i draw. In such circumstances, the firm's financiers will enter into negotiation with the Government. The firm may be bailed out by the taxpayer, or another auction may be held to re-assign the contract and pay off creditors.

Anticipated Government bail-outs provide firms with additional insurance against high maintenance cost contingencies. Firms bear this in mind when choosing how much debt to take on and how much to bid in the tender. We therefore need to model the impact of *ex post* renegotiation on *ex ante* decisions about financial structure, investment in cost reduction and optimal bids.

In the remainder of this section (and its subsections) we describe a general model that incorporates all of these factors, and outline its solution. This will expose the efficiency tensions inherent in the PPP arrangement. The following section obtains explicit solutions for a special case of the model.

As usual, we solve our model “backwards”: we first consider the post-auction decisions (the level of debt and the investment in cost reduction), and then the equilibrium bidding function.

5.1 The post-auction phase

Suppose that firm i has won the auction with a bid of b_i . It now has two decisions to make:

- It must choose θ_i by determining its investment in maintenance cost reduction.
- It must also choose the combination of equity K_i and debt $D_i = c_i + C(\theta_i) - K_i$ with which to fund the construction phase. We shall suppose that firms face no cash constraints, though we will discuss the implications of relaxing this assumption later (see Section 7). Therefore, firm i can choose any $D_i \in [0, c_i + C(\theta_i)]$.

The firm's choice of debt will depend on the interest rate charged by the bank, which we denote r_i . This interest rate in turn depends on D_i through the associated default risk – higher levels of debt may carry higher risks of default and therefore require higher interest to be charged.

It is clear that the equilibrium values of θ_i , D_i and r_i are jointly determined.¹⁶ In order to determine them, we must first consider what happens in the post-construction phase of the partnership.

At the completion of construction, the winning firm i learns its maintenance costs m_i . Let

$$\lambda_i = b_i - (1 + r_i) D_i$$

denote its future revenue net of debt repayment obligations. This is the amount available to pay maintenance costs, since its equity contribution K_i has already been expended on construction. The firm is therefore insolvent at this point if

$$m_i > \lambda_i \tag{3}$$

In this event, the firm will inform its bankers that it must default on its obligations. The parties will either renegotiate their contracts, or the firm will be allowed to go bankrupt and the concession will be re-auctioned.

As in Menezes and Ryan (2014), we assume it is common knowledge that the Government places value $V^* > 0$ on keeping firm i in place. This reflects the cost of re-auctioning the contract, the cost of disruption to road users, plus any other financial or political costs of replacing the original concessionaire. If

$$V^* \geq m_i - \lambda_i > 0 \tag{4}$$

the private partner is insolvent but there is scope for renegotiation. The firm will be bailed out by the Government. To keep things simple, we assign all the bargaining power to the Government in this renegotiation, so the firm receives a transfer equal to $m_i - \lambda_i$ when condition (4) is obtained: just enough to clear its outstanding debts.¹⁷

If

$$m_i - \lambda_i > V^* \tag{5}$$

the Government allows the concessionaire to fail. The banks will attempt to recover as much of their money as possible through competitive re-tendering

¹⁶As we will see, the equilibrium values depend on firm i 's unobserved type (c_i) only indirectly – through the observed bid (b_i). This is due to the assumption of no cash constraint and greatly improves the tractability of the model.

¹⁷In Menezes and Ryan (2014) we allow the firm to have some bargaining power in the negotiation. The added generality plays an interesting role in that analysis, but it would not do so here.

of the contract. Since the residual value of the concession contract ($b_i - m_i$) is public information, that will be the price obtained.¹⁸ This money will go to the banks to partially settle the original contractor's debts. The Government will therefore pay b_i to the new contractor, which would complete the maintenance on the highway, and the banks would lose $m_i - \lambda_i$.

Figure 1 illustrates the various post-construction scenarios.

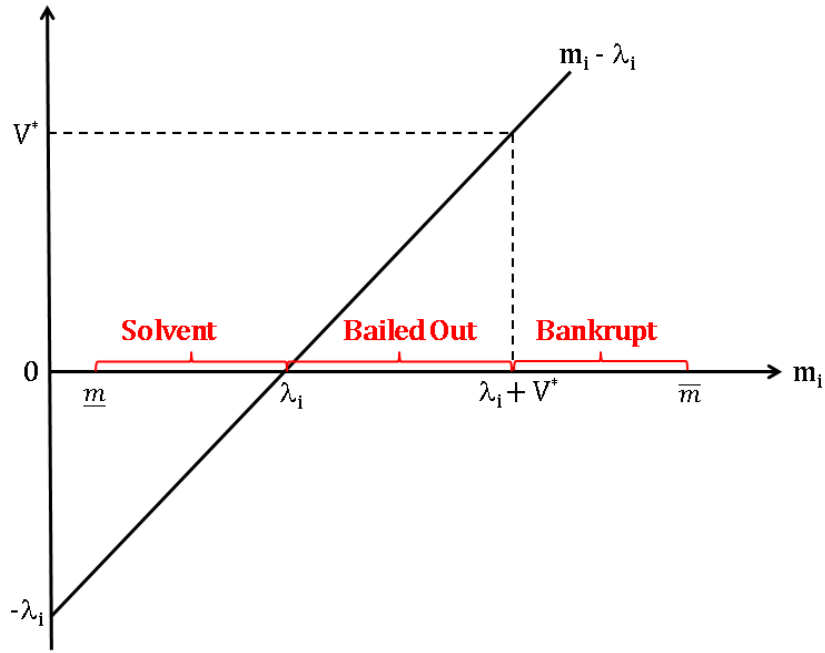


Figure 1: Post-construction scenarios

Note that the banks do not incur any transaction costs from the bankruptcy process in our model – any such costs are borne by the Government (though we do not model them explicitly).¹⁹ This is obviously unrealistic, but it ensures that debt financing is no more costly than equity financing, which allows us to concentrate on the *strategic* role of debt. The private partner has a *strict* preference for $D_i > 0$ in our model because this will allow it to “hold up” the Government, as we now explain.

When $m_i \in (\lambda_i, \lambda_i + V^*]$ the firm receives a transfer payment from the Government. As noted previously, construction costs tend to be much larger

¹⁸Since m_i is a common shock, it is reasonable to suppose it is publicly observed. Otherwise, it will certainly be revealed through the bankruptcy process.

¹⁹Bankruptcy costs are implicitly bundled into V^* .

than maintenance costs, so it is likely that $b_i > \bar{m}$, which means renegotiation never occurs when $D_i = 0$. The firm holds debt to ensure that it receives a positive expected transfer. This expected transfer is equal to

$$T(\lambda_i, \theta_i) = \int_{\lambda_i}^{\lambda_i + V^*} (m - \lambda_i) dH(m | \theta_i) \quad (6)$$

The firm can affect the size of this expected transfer through its choice of debt – since D_i affects the location of the solvency threshold λ_i – and also through its choice of θ_i , which affects the distribution of maintenance costs.

Before determining the optimal values for D_i and θ_i we first need to consider how the bank chooses r_i .

If the bank lends D_i to firm i at an interest rate of r_i , its expected gross repayment is:

$$H(\lambda_i + V^* | \theta_i) (1 + r_i) D_i + \int_{\lambda_i + V^*}^{\bar{m}} (b_i - m) dH(m | \theta_i) \quad (7)$$

The first term reflects the fact that the bank is paid in full when $m_i \in [\underline{m}, \lambda_i + V^*]$ since the firm is either solvent ($m_i \leq \lambda_i$) or bailed out by the Government ($\lambda_i < m_i \leq \lambda_i + V^*$). The second term represents the bank's receipts in states where the firm is bankrupt and the concession re-assigned.

The bank can directly observe V^* , b_i and D_i . We claim – and will shortly verify – that θ_i is a function of b_i , which is also observable to the bank, so r_i will be chosen by equating (7) to D_i . (Recall that capital markets are competitive and the riskless rate of interest is zero – Assumption 0.)

Because the bank therefore receives D_i in expectation – made up of payments from the firm, renegotiation transfers from the Government and proceeds from the sale of the concession in the event of bankruptcy – we can write the winning firm's *ex ante* (i.e., at the conclusion of the auction but prior to the start of construction) expected payoff as follows:

$$b_i + T(\lambda_i, \theta_i) - [c_i + C(\theta_i)] - \mathbb{E}[m | \theta_i] \quad (8)$$

To see how we obtained this expression, note that $b_i + T(\lambda_i, \theta_i) - \mathbb{E}[m | \theta_i]$ is total expected revenue, including revenue from the sale of the concession in bankruptcy states, net of maintenance costs. The bank receives D_i of this expected net revenue and equity-holders contribute

$$K_i = [c_i + C(\theta_i)] - D_i$$

towards construction. It follows that (8) is the profit earned by the owners of the firm.

The firm will therefore choose λ_i (via D_i) and θ_i to maximise (8), which is equivalent to maximising

$$T(\lambda_i, \theta_i) - C(\theta_i) - \mathbb{E}[m \mid \theta_i] \quad (9)$$

By observation of (6) and (9), the optimal values for D_i and θ_i are jointly determined functions of b_i (i.e., neither depends directly on c_i). Denote these optimal solutions by $D^*(b_i)$ and $\theta^*(b_i)$. This implies, in particular, that the bank can infer θ_i from observable quantities, so r_i is determined by equating (7) to D_i . This interest rate will therefore also be a function of b_i , which we denote $r^*(b_i)$. It is also convenient to define

$$\lambda^*(b_i) = b_i - [1 + r^*(b_i)] D^*(b_i).$$

In Section 6 we obtain explicit forms for these functions when $H(\cdot \mid \theta)$ is Uniform for each θ .

Note that it will generally be the case that $r^*(b_i) > 0$ when b_i is the winning bid. The private firm receives finance on more expensive terms than the Government would be able to obtain. Nevertheless, the *total financing cost* is the same. The banks receive exactly D_i in expectation. This observation sheds some useful light on the alleged higher cost of private financing in PPP arrangements. The higher rate of interest on private debt simply reflects the risk of default, which requires the bank to receive higher payments in states in which the firm is solvent (or bailed out). In terms of overall financing costs, the only difference between private and public funding is the higher transaction cost from the higher risk of bankruptcy under the former.²⁰

5.2 The auction

Having solved for the post-auction variables, we can determine the equilibrium bidding strategies. If firm i were to win the auction with a bid of b_i its payoff (conditional on winning) would be

$$b_i + T(\lambda^*(b_i), \theta^*(b_i)) - c_i - C(\theta^*(b_i)) - \mathbb{E}[m \mid \theta^*(b_i)].$$

We may write this expression as

$$\Gamma(b_i) - c_i \quad (10)$$

²⁰Ultimately, in our view, all debates about how best to finance a PPP boil down to a proper evaluation of the social costs of bankruptcy. Bankruptcy imposes transaction costs, and the possibility to renegotiate in the event of financial distress causes debt to be used strategically, which distorts investment incentives. As noted above, even the practitioners' argument – that debt is beneficial because it improves due diligence – boils down to evaluating the social cost of bankruptcy.

by defining

$$\Gamma(b_i) = b_i + T(\lambda^*(b_i), \theta^*(b_i)) - C(\theta^*(b_i)) - \mathbb{E}[m \mid \theta^*(b_i)] \quad (11)$$

Provided Γ is strictly increasing and differentiable – which, of course, is not at all clear but let us suppose it to be the case – the equilibrium bidding function may be determined using standard methods. Assume there is a strictly increasing and differentiable equilibrium bidding function $\beta(c_i)$, and define $\gamma(c_i) = \Gamma(\beta(c_i))$. Note that γ is also strictly increasing and differentiable, given our assumptions. Then $c = c_i$ solves

$$\max_c [\gamma(c) - c_i] (1 - F)^{n-1}(c)$$

As we know – recall Section 4 – this means that

$$\gamma(c) = \mathbb{E}[X \mid X > c]$$

and hence

$$\beta(c) = \Gamma^{-1}(\mathbb{E}[X \mid X > c]) \quad (12)$$

is the equilibrium bidding function. Thus, as in Menezes and Ryan (2014), bidders shade their bids by the amount of the expected transfer and, therefore, the auction outcome is still efficient as it allocates the contract to the lowest cost firm. However, as we discuss next, the winning bidder will have an incentive to deviate from the optimal investment in maintenance cost reduction.

5.3 Recap and review

As in Menezes and Ryan (2014), the winning bidder chooses its level of debt to maximise the expected renegotiation transfer $T(\lambda_i, \theta^*(b_i))$. This is the strategic use of debt to “hold up” the Government. However, the competitive pressure of the auction returns this money to the taxpayer *ex ante*. The equilibrium bidding function (12) implies that firms reduce their bids by the amount of the expected transfer $T(\lambda^*(b_i), \theta^*(b_i))$. Fixing $\theta = \theta^*(b_i)$, the firm’s expected revenue is the same as if $V^* = 0$ (i.e., as if the Government could commit not to bail-out the firm in any contingency).²¹

²¹This result is a variation on the well-known theme of Spulber (1990). Competitive pressure ensures a “race to the bottom” in performance reliability. In order to make a competitive bid, firms must plan to use debt to extort *ex post* transfers from Government in high costs states. Equilibrium bids appear very attractive unless one appreciates the associated high probability of insolvency.

However, $\theta^*(b_i)$ will not generally be independent of V^* (see equation (17) below). In particular, the winning bidder's investment in maintenance cost reduction will typically be distorted away from the first-best level $\hat{\theta}$. The equilibrium investment $\theta^*(b_i)$ is chosen to maximise

$$T(\lambda^*(b_i), \theta_i) - C(\theta_i) - \mathbb{E}[m \mid \theta_i]$$

so $\theta = \theta^*(b_i)$ satisfies

$$C'(\theta) = \left| \frac{d}{d\theta} \mathbb{E}[m \mid \theta] \right| + \frac{\partial}{\partial \theta} T(\lambda^*(b_i), \theta_i)$$

(assuming an interior solution). Comparing with the first-best condition (1) – and recalling Assumption 2 – we see that $\theta^*(b_i)$ is greater (respectively, less) than $\hat{\theta}$ if $T(\lambda, \theta)$ is increasing (respectively, decreasing) in θ . As we show in the following section, both scenarios are possible.

In other words, the benefits of whole-of-life contracting are not entirely separable from the costs and benefits of private financing. By imposing cost risks on the private partner, the Government must be wary of inviting the strategic use of debt, which in turn distorts incentives to manage maintenance costs efficiently. *This efficiency loss should be counted as a cost of privatising finance. The strategic use of debt by privately financed concessionaires will undermine some of the efficiency gains from whole-of-life contracting.*

The public should also be mindful that the up-front tender price for the contract may not reflect the true lifetime cost to the taxpayer. If the deal looks too good to be true, it probably is!

6 Risk management with private finance: the Uniform case

To provide an explicit solution to our model, let us make the following:

Assumption 3. The distribution $H(\cdot \mid \theta)$ is Uniform on $[m_0(\theta), m_1(\theta)]$ for each θ . That is

$$H(m \mid \theta) = \frac{m - m_0(\theta)}{m_1(\theta) - m_0(\theta)}.$$

Furthermore, m_0 and m_1 are non-increasing functions, and

$$m_1(\theta) - m_0(\theta) \geq V^* \tag{13}$$

for all θ .

The requirement that m_0 and m_1 be non-increasing ensures $H(\cdot | \theta)$ FOSD $H(\cdot | \theta')$ when $\theta' > \theta$. Restriction (13) is convenient but could be relaxed at the expense of complicating the mathematics in uninformative ways.

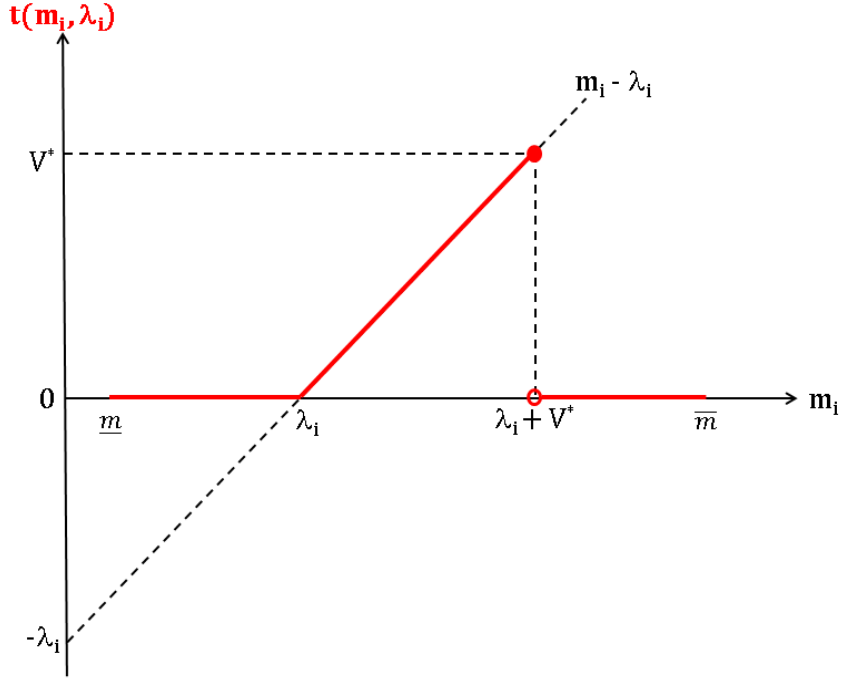


Figure 2: Government transfer to firm

Figure 2 depicts the Government's transfer to the firm as a function of m_i for given λ_i , denoted $t(m_i; \lambda_i)$. By Assumption 3, the quantity $T(\lambda_i, \theta_i)$ is the expected value of this function with respect to $H(\cdot | \theta_i)$. That is:

$$T(\lambda_i, \theta_i) = \int_{m_0(\theta_i)}^{m_1(\theta_i)} \frac{t(z; \lambda_i)}{[m_1(\theta_i) - m_0(\theta_i)]} dz \quad (14)$$

Given $\theta_i = \theta^*(b_i)$, the firm chooses λ_i to maximise (14). Using (13), we see that any

$$\lambda_i \in [m_0(\theta_i), m_1(\theta_i) - V^*] \quad (15)$$

will do, since this ensures that $t(z; \lambda_i) = 0$ at all $z \notin [m_0(\theta), m_1(\theta)]$. In other words, λ_i is chosen so that

$$[\lambda_i, \lambda_i + V^*] \subseteq [m_0(\theta), m_1(\theta)].$$

In particular,

$$\max_{\lambda_i} T(\lambda_i, \theta_i) = \frac{(V^*)^2}{2[m_1(\theta_i) - m_0(\theta_i)]} \quad (16)$$

for any θ_i .

For this version of our model, one easily sees that investment incentives may be distorted in either direction. Suppose, for example, that $m_0(\theta)$ is constant in θ and m_1 is strictly decreasing. Then (16) is increasing in θ_i so $\theta^*(b_i) > \hat{\theta}$: the winning bidder will over-invest in maintenance cost reduction to increase the expected transfer from Government. On the other hand, if $m'_0 < 0$ and $m'_1 = 0$, then (16) is decreasing in θ_i so $\theta^*(b_i) < \hat{\theta}$. Since both scenarios are consistent with our model, we may observe over- or under-investment in equilibrium.

Using (16), and assuming an interior solution, the optimal θ will be determined by the following equation:

$$C'(\theta) = \left| \frac{d}{d\theta} \mathbb{E}[m | \theta] \right| + \frac{d}{d\theta} \left[\frac{(V^*)^2}{2[m_1(\theta) - m_0(\theta)]} \right]$$

Since

$$\mathbb{E}[m | \theta] = \frac{m_0(\theta) + m_1(\theta)}{2}$$

by Assumption 3, this may be written:

$$C'(\theta) = \frac{(V^*)^2 [m'_0(\theta) - m'_1(\theta)]}{2[m_1(\theta) - m_0(\theta)]^2} - \left[\frac{m'_0(\theta) + m'_1(\theta)}{2} \right] \quad (17)$$

Given explicit functional forms for C , m_0 and m_1 , equation (17) may be solved for $\theta^*(b_i)$. This solution will clearly be independent of the bid, so we denote it θ^* .²² The expected transfer

$$\max_{\lambda_i} T(\lambda_i, \theta^*) = \frac{(V^*)^2}{2[m_1(\theta^*) - m_0(\theta^*)]}$$

²²Suppose, for example, that

$$C(\theta) = \frac{1}{4}\theta^2$$

so $C'(\theta) = \theta/2$. We also set $V^* = 1$. (Note that condition (13) is satisfied in each of the following cases.)

Case I. Let $m_0(\theta) = \underline{m}$ for all θ and let $m_1(\theta) = \underline{m} + 3 - \theta$ for $\theta \in [0, 2]$ and $m_1(\theta) = \underline{m} + 1$ for $\theta > 2$. Then

$$\left| \frac{d}{d\theta} \mathbb{E}[m | \theta] \right| = \begin{cases} \frac{1}{2} & \text{if } \theta \in [0, 2] \\ 0 & \text{if } \theta > 2 \end{cases}$$

is therefore likewise independent of the winning bid. It follows that the function (11) is

$$\Gamma(b_i) = b_i + \Lambda^*$$

where

$$\Lambda^* = \frac{(V^*)^2}{2[m_1(\theta^*) - m_0(\theta^*)]} - C(\theta^*) - \mathbb{E}[m | \theta^*]$$

is a constant. It is obvious that Γ is strictly increasing and differentiable. Hence, we deduce the equilibrium bidding function

$$\beta(c) = \mathbb{E}[X | X > c] - \Lambda^* \quad (18)$$

6.1 Recap and review

Under Assumption 3, the winning bidder's optimal investment in cost reduction θ^* is independent of the winning bid and is given by the solution to equation (17). This solution may be higher or lower than $\hat{\theta}$.

The winning firm's optimal choice of debt – and hence the interest it pays – is indeterminate under Assumption 3. Any λ_i satisfying

$$[\lambda_i, \lambda_i + V^*] \subseteq [m_0(\theta^*), m_1(\theta^*)]$$

and hence $\hat{\theta} = 1$. But

$$\frac{d}{d\theta} \left[\frac{(V^*)^2}{2[m_1(\theta) - m_0(\theta)]} \right] = \frac{1}{2} \left[\frac{1}{(3 - \theta)^2} \right] > 0$$

for all $\theta \in (0, 2)$. It is easy to verify that the winning firm will choose

$$\theta^* = 2 > \hat{\theta}$$

in this case.

Case II. Let $m_1(\theta) = \bar{m}$ for all θ and let $m_0(\theta) = \bar{m} - 1 - \theta$ for $\theta \in [0, 2]$ and $m_0(\theta) = \bar{m} - 3$ for $\theta > 2$. Then $d\mathbb{E}[m | \theta] / d\theta$ is the same as for Case I, and hence $\hat{\theta} = 1$ in this case also. Now

$$\frac{d}{d\theta} \left[\frac{(V^*)^2}{2[m_1(\theta) - m_0(\theta)]} \right] = \frac{1}{2} \left[\frac{-1}{(1 + \theta)^2} \right] < 0$$

for all $\theta \in (0, 2)$. One may easily check that

$$\theta^* = 0 < \hat{\theta}$$

in this case.

is optimal, so

$$\lambda^*(b_i) \in [m_0(\theta^*), m_1(\theta^*) - V^*]$$

(which is also independent of b_i).

For example, if the firm chooses $\lambda^* = m_1(\theta^*) - V^*$ the bank is exposed to zero default risk – the firm is solvent or bailed out with probability 1 – so $r^*(b_i) = 0$ (Assumption 0) and

$$D^*(b_i) = b_i - \lambda^* = b_i - m_1(\theta^*) + V^*.$$

On the other hand, if the firm chooses $\lambda^* < m_1(\theta^*) - V^*$ there is a positive probability of default and hence $r^*(b_i) > 0$.

Using the fact that

$$D^*(b_i) = \frac{b_i - \lambda^*}{1 + r^*(b_i)} \quad (19)$$

we obtain $r^*(b_i)$ as the solution (in r) to the following equation:

$$H(\lambda^* + V^* | \theta^*)(b_i - \lambda^*) + \int_{\lambda^* + V^*}^{m_1(\theta^*)} \frac{(b_i - z)}{m_1(\theta^*) - m_0(\theta^*)} dz = \frac{b_i - \lambda^*}{1 + r} \quad (20)$$

The left-hand-side of (20) is the expected value, with respect to $H(m | \theta^*)$, of the function depicted in Figure 3. This is the area under the graph divided by $[m_1(\theta^*) - m_0(\theta^*)]$. If $A^*(b_i)$ denotes this quantity, then²³

$$r^*(b_i) = \left[\frac{b_i - \lambda^*}{A^*(b_i)} \right] - 1$$

and $D^*(b_i)$ is calculated from (19).

²³If $\lambda^* = m_1(\theta^*) - V^*$ then

$$A^*(b_i) = b_i - \lambda^*$$

and hence $r^*(b_i) = 0$ as we already observed. If $\lambda^* < m_1(\theta^*) - V^*$ then

$$A^*(b_i) < b_i - \lambda^*$$

and $r^*(b_i) > 0$.

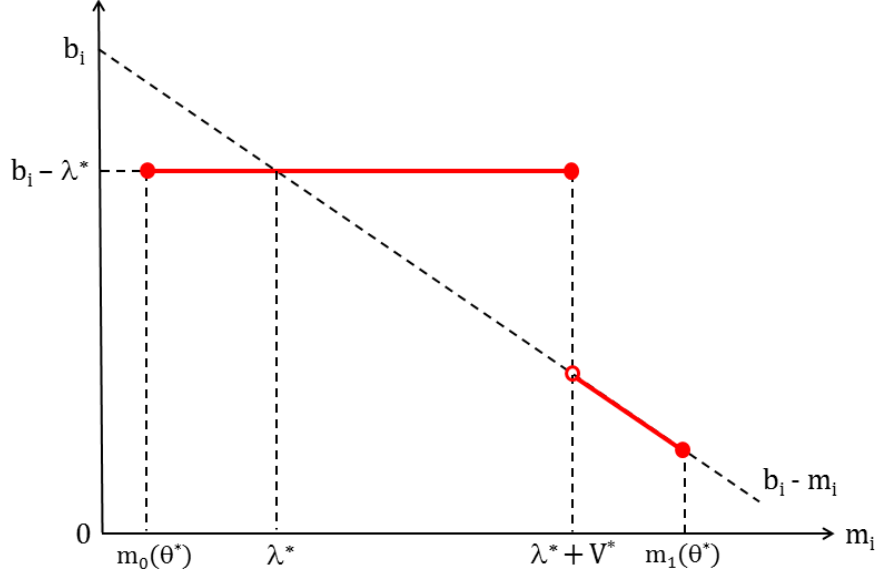


Figure 3: Total payment to bank

Finally, the optimal bidding function is given by (18).

7 Discussion

An “availability contract”, of the sort proposed for Transmission Gully, avoids the inappropriate transfer of demand risk to the private partner. Nevertheless, whenever the private partner provides up-front finance for a PPP project, limited liability considerations impact on the efficiency gains from whole-of-life contracting. The Government is exposed to ex post hold-up, and this affects the winning firm’s investment incentives in complex ways. Efficiency losses are to be expected.

Public financing would be one means of neutralising this distortion. The winning bid would determine the total (discounted) payment from Government. All construction costs could be invoiced to Government for payment. The balance of the bid amount would then be disbursed in the form of regular service payments over the life of the concession. This would remove the need for the private partner to undertake any significant borrowing.

Of course, a private SPV with negligible equity could still run into financial difficulties if realised maintenance costs are high enough. However, small

surety bonds or modest equity participation requirements could easily eliminate hold-up risk. The large debt requirements to meet up-front construction costs create real potential for strategic manipulation of default probabilities. Much larger sureties or minimum equity requirements would be needed to address this problem, which might harm participation in the tender.

More generally, the relative merits of public versus private financing of PPP projects needs closer scrutiny. As our analysis shows, there are hidden efficiency issues that are not fully recognised in the extant literature.

The model presented here provides a framework for systematic consideration of these issues. Needless to say, it could be usefully elaborated in a number of ways. At least two generalisations seem important to consider: (i) the introduction of firm-specific uncertainty about maintenance costs, and (ii) the introduction of firm-specific cash constraints.

The first elaboration would allow us to explore the costs of lock-in through whole-of-life contracting. If firms differed in their return on investment in maintenance cost reduction, then the winning firm would be the one with the lowest overall (construction plus optimal expected maintenance) costs. It need not have the lowest construction cost, nor the lowest ex post realised maintenance cost. If the Government contracted separately for construction and maintenance it could minimise on both cost dimensions separately, though foregoing any synergy benefits.

The second elaboration would expose yet another source of inefficiency in the tendering process. Firms with access to greater levels of equity have more flexibility in their strategic choice of debt, which gives them an advantage in the bidding phase – they can reduce their bids in anticipation of greater ex post transfers. This raises the possibility that the contract may be allocated to a high-cost firm with deep pockets, rather than a more efficient, but cash-strapped, rival. This effect is a version of the phenomenon first described by Spulber (1990).

The challenge in pursuing either of these generalisations is that firm types become (at least) two-dimensional. This substantially complicates the computation of optimal bidding functions. Nevertheless, both are important avenues for future research.

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