

THE BASIC PUBLIC FINANCE  
OF PUBLIC-PRIVATE PARTNERSHIPS

Eduardo Engel      Ronald Fischer      Alexander Galetovic  
Yale and NBER      U. de Chile      U. de los Andes

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**Abstract**

Public-private partnerships (PPPs) have been justified because they release public funds or save on distortionary taxes. However, the resources saved by a government that does not finance the upfront investment are offset by giving up future revenue flows to the concessionaire. If a PPP can be justified on efficiency grounds, the PPP contract that optimally balances demand risk, user-fee distortions and the opportunity cost of public funds has a minimum revenue guarantee and a revenue cap. The optimal contract can be implemented via a competitive auction with reasonable informational requirements. The optimal revenue guarantees, revenue sharing agreements and auction mechanisms are different from those observed in the real world. In particular, the optimal contract duration is shorter in demand states where the revenue cap binds. These results also have implications for budgetary accounting of PPPs, as they show that their fiscal impact resembles that of public provision, rather than privatization.

**Keywords:** Bundling, cost of public funds, Demsetz auction, minimum revenue guarantees, privatization, revenue and profit caps, scope of government, subsidies.

**JEL classification:** H21, H54, L51, R42.

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<sup>1</sup>Engel: Department of Economics, Yale University, 28 Hillhouse Ave., New Haven, CT 06511. Fischer: Center for Applied Economics (CEA), Department of Industrial Engineering, University of Chile, Av. República 701, Santiago, Chile. Galetovic: Facultad de Ciencias Económicas y Empresariales, Universidad de Los Andes, Av. San Carlos de Apoquindo 2200, Santiago, Chile. E-mails: eduardo.engel@yale.edu, rfischer@dii.uchile.cl, alexander@galetovic.cl. We thank Maham Mela for research assistance, and Raj Chetty, Peter Diamond, Hadi Esfahani, Antonio Estache, John Friedman, Aldo González, James Hines, Mervyn Lewis, Guillermo Perry, Eduardo Saavedra, John Shoven, the editor, three anonymous referees, and participants at various conferences and workshops for insightful comments on an earlier version of this paper. We also thank the Corporación Andina de Fomento (CAF), the World Bank and the Instituto Milenio de Sistemas Complejos en Ingeniería (Chile) for financial support, and the Stanford Center for International Development for its hospitality. The views are our own and do not represent those of any of the above mentioned institutions.

# 1 Introduction and motivation

The use of Public-Private Partnerships (PPPs) to replace the public provision of infrastructure services has become increasingly common. Projects that require large up-front investments, such as highways, water and sewage, bridges, seaports and airports, hospitals, jails and schools are being provided via PPPs. The average annual value of €22,900 million for PPP projects signed in Europe between 2002 and 2006 was three times the annual average over the preceding decade. Similarly, investment in PPPs in developing countries grew at an average annual rate of 28.3% between 1990 and 1997, followed by a slowdown after the East-Asian crisis, and a new growth spurt beginning in 2003, reaching 154,400 million dollars during 2008.<sup>2</sup>

The main characteristic of a PPP, compared with conventional provision, is that it bundles investment and service provision in a single long term contract. For the duration of the contract, which typically lasts several decades, the concessionaire manages and controls the assets, usually in exchange for user fees and government transfers, which compensate for investment and other costs. At the end of the concession, the assets revert to government ownership.<sup>3</sup>

As the economics of PPPs is still imperfectly understood, practice has run ahead of theory. Many practitioners and governments claim that PPPs relieve strained budgets and release public funds,<sup>4</sup> while others suggest that PPPs are appealing because finance, investment and management is delegated to private firms, which are more efficient. Despite these seemingly reasonable arguments, the experience with PPPs has been mixed. In some cases expectations have been met, but in many more cases contracts have been renegotiated in favor of the concessionaire, and sometimes firms have been affected by regulatory takings (Guasch, 2004).<sup>5</sup> The reason seems to be that the profitability of PPP projects is subject to large exogenous demand uncertainty, which is often not considered properly when designing the contracts. This explains why renegotiations take place when demand is lower than expected, as well as the array of risk sharing agreements that are observed.

The purpose of this paper is to contribute to the normative analysis of PPPs by answering two public finance questions. First, what is the structure of the optimal risk-sharing contract between a government and a private firm when there is substantial exogenous demand risk? Second, what is the impact of PPP's on the government budget? In order to answer these questions we use a styl-

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<sup>2</sup>See Tables 3 and 4 in the appendix for details on PPP investments in Europe and developing countries.

<sup>3</sup>There are several definitions for "Public-Private Partnership". In this paper we mean an infrastructure project such that (i) assets are controlled by a private firm for a (possibly infinite) term; (ii) during the duration of the contract, the firm is the residual claimant, while the government is the residual claimant at the end of the concession, and (iii) there is considerable amount of public planning in the design of the project. Note that the claims in (ii) are ambiguous. We use the term "concession" as synonymous to PPP.

<sup>4</sup>"The boom is good news for governments with overstretched public finances: many local and national authorities have found themselves sitting on toll roads, ports and airports that they can sell for billions of dollars to fund other public services." *Financial Times*, July 5, 2007.

<sup>5</sup>This does not mean that the traditional approach to infrastructure provision, with the government contracting a private firm to build the project, would have done better. For an early evaluation of infrastructure PPPs, see Economic Planning Advisory Commission (EPAC) (1995), *Final Report of the Private Infrastructure Task Force*, Australian Government Publishing Service, Canberra. For more recent evaluations, see Engel et al. (2003) and Grimsey and Lewis (2007).

ized model in which the government contracts a risk averse firm to build, operate and maintain an infrastructure project.<sup>6,7</sup> The investment is upfront, there are no further costs and the demand for the project is perfectly inelastic, exogenous and stochastic. The concessionaire receives a combination of state dependent user fees and subsidies (i.e., direct transfers) as compensation for its efforts. Thus our model encompasses the range from conventional provision of infrastructure, in which the government pays for the project and the firm collects no user fees, to the case of a traditional concession, in which the firm's only source of income is user fees.

In standard fashion, we assume that there is a cost of raising public funds, so that a dollar in government revenues costs more than one dollar to society. This leads to our first result, namely that contrary to common wisdom, PPPs do not release public funds even when totally financed by user fees. The reason is that while private financing reduces the need for current taxes, this is followed by a period where the government foregoes user fee revenues that are cashed in by the concessionaire. These revenues could have been received by the government and used to reduce distortionary taxes, so there is no net gain to the government in discounted value.

Having shown that private financing cannot justify a PPP raises the question of whether there exist other reasons to prefer them. Hart (2003) argued that the main characteristic of PPPs is that they bundle investment expenditure with life-cycle operation costs.<sup>8</sup> A PPP achieves the most efficient mix of these costs and is therefore superior to conventional provision when the benefits of cost cutting investments during the building phase are not undone by the cost to users of lower service quality.<sup>9</sup>

In this paper we focus on an alternative efficiency justification for PPPs, by considering the financial aspect of bundling in PPPs. We note that in a PPP the firm can be compensated with a combination of user fees and subsidies, and assume that user fees are a more efficient way of putting money in the hands of the concessionaire, because the private sector pays lower overhead and has better incentives to control corruption. Agency problems faced by the budgetary authority when monitoring the government agency in charge of the resource transfer justify this assumption.

In the presence of this second wedge, the optimal contract is characterized by two thresholds: a revenue cap and a minimum income guarantee. If discounted income is above the revenue cap, the contract ends when this cap is attained. On the other hand, if revenue never reaches the minimum income guarantee, the firm is compensated with the difference. Last, in states with revenues between both thresholds, the concession has an infinite duration but the firm does not receive a

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<sup>6</sup>Martimort and Pouyet (2008) also assume a risk-averse concessionaire, see also Dewatripont and Legros [2005] and Hart [2003]. Others are skeptical, and point out that private firms can use the capital market to diversify risks at least as well as the government (Hemmings [2006] and Klein (1997)). For a discussion of the controversy in economics see Brealey et al. (1997). Finally, note that similar results to the ones we derive are obtained by assuming a risk neutral firm subject to expropriation risk (Engel and Fischer [2008]).

<sup>7</sup>Note also that firms routinely ask for minimum revenues guarantees as part of PPP contracts because they consider demand risks to be excessive. Apparently, the same reason underlies the move in some European countries away from shadow toll contracts towards availability payments.

<sup>8</sup>Bennet and Iossa (2006), Bentz et al. (2005), Martimort and Pouyet (2008) and Iossa and Martimort (2008).

<sup>9</sup>See also Grout (1997).

subsidy.

The optimal contract does not provide full insurance to the concessionaire, even though the government could eliminate all risk for the firm by remunerating it with any combination of user fees and transfers that add up to investment costs. The planner can improve on this contract, however, by trading off increased risk for the concessionaire against lower subsidies. It can lengthen the term of the concession in high demand states, so that user fee revenues exceed investment costs, thus lowering the need for subsidies in low demand states. This is an improvement on full insurance because user fees foregone by the planner in high demand states are less valuable at the margin than subsidies required in low demand states; this wedge drives our results.

Even though the optimal contract would appear to be difficult to implement, we show that it can be attained in a competitive auction. The government announces the probability density of the different states, and the wedge between the shadow cost of public funds and subsidies. Firms bid both a minimum income guarantee and a revenue cap. The government scores the bids according to a weighted average of expected payments to the firm via user fees and subsidies, and chooses the one with the lowest score. Assuming firms with identical costs and competition, the auction reproduces the optimal revenues caps and guarantees. The auction neither requires the government to know investment costs nor the degree of risk aversion of firms.

The simplicity of our results —both for the optimal contract and the auction that implements it—relies on the assumption that quality of service is contractible, which allows us to ignore moral hazard. That quality of service can be defined and enforced is arguably the case for the main types of PPP infrastructure in the transportation sector, a sector that accounts for 84% of PPP investments in continental Europe, 67% of which are roads.<sup>10</sup> For example, in the case of roads and highways the quality of service provided can be ascertained by independent third parties using equipments such as laser/inertial Profilometers, to measure roughness, unevenness, texture, surface skid resistance and rutting problems. Measures of the time needed to remove a broken down car are also easy to implement (see Engel et al. (2009) for details). And when seaports are contracted as a PPP, service standards, such as the time ships need to wait before obtaining a berth and the speed with which cargo is unloaded, can be specified and enforced.

The optimal contract we derive in this paper has implications for the ongoing debate on whether PPPs should add to public debt or not.<sup>11</sup> We show that if demand risk is allocated optimally, the impact of a PPP on the intertemporal government budget is usually the same as under conventional provision of infrastructure. Most, or even all, risk is borne by the government and the concessionaire recovers the upfront investment in most states. By contrast, under privatization, assets and cash flows are transferred forever to a private firm in exchange for a one time payment. This means

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<sup>10</sup>See Blanc-Brude et al. (2007). Also, in the case of the United States, where until recently PPPs played a smaller role than in many European countries, financing of transportation infrastructure via PPPs increased almost tenfold, on an annual basis, between 2006-2008 and the preceding decade (1996-2005). 24,698 million dollars of investment were financed in this sector via PPPs during the 1996-2008 period.

<sup>11</sup>See, for example, Daniels and Trebilcock (1996, 2000), Gerrard (2001), Savas (2000), and Starr (1988)

that the link between the project and the public budget is permanently severed. Under a PPP this link continues to exist, even when the compensation to the concessionaire is derived solely from user fees. It follows that from a public finance perspective PPPs are much closer to conventional provision, and therefore should be accounted for in the same way.

There is a growing literature on PPPs related to this paper.<sup>12</sup> Risk sharing between the government and the concessionaire has always been a concern among practitioners and policy makers. The standard prescription is that each risk should be allocated to the party best able to manage it.<sup>13</sup> Martimort and Pouyet (2008) study this problem in a moral hazard model where effort during investment affects both the quality of the infrastructure and its operating cost, and their analysis is extended in various directions by Iossa and Martimort (2008). Bentz et al. (2005), on the other hand, study a model with moral hazard in building and adverse selection in operation.

Our paper, by contrast, studies the implications of the optimal allocation of demand risk, when subsidy finance is less efficient than user-fee finance. We show that variable, state-contingent concession lengths are a key component of the optimal risk-sharing contract. In addition, we provide a rigorous foundation for minimum income guarantees and revenue caps and show that the optimal guarantees and caps bear little relation to observed guarantees and revenue sharing agreements.

This paper is also related to the literature on franchise bidding pioneered by Chadwick (1859) and Demsetz (1968), according to which competition for a monopoly infrastructure project replicates the competitive outcome (see Stigler [1968], Posner [1972], Riordan and Sappington [1987], Spulber [1989, ch. 9], Laffont and Tirole [1993, chs. 7 and 8], Harstad and Crew [1999] and Engel et al. [2001] for papers within this tradition, and Williamson [1976, 1985] for a criticism). We contribute to this literature by considering projects that require subsidies to make them feasible.

Finally, in Engel et al. (2001), we studied the optimal private provision of infrastructure projects by solving a Ramsey problem with variable concession lengths. In that paper we assumed a “self-financing constraint,” which ruled out government transfers to the concessionaire. In the present paper, demand-contingent government subsidies play a central role, thus providing a framework to study the public finance of PPPs.

The remainder of the paper is organized as follows. Section 2 describes the model and presents the basic irrelevance result as well as the optimal contract. This section also contains extensions of the model to the case of price responsive demand, when there are operational and maintenance costs, as well as to the moral hazard case in which effort in the investment stage increases the likelihood of higher demand. Section 3 shows that the optimal contract can be implemented with an auction with reasonable information requirements. Section 4 discusses the practical relevance of the results derived in the preceding sections. We document the increasing popularity of flexible term contracts similar to those suggested by the optimal contract we derive. We also examine the

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<sup>12</sup>See Grimsey and Lewis (2004) for a survey, and Grimsey and Lewis (2005) for a collection of articles on PPPs. Vaillancourt-Rosenau (2000) and Akintoye et al. (2003) include useful collections of essays.

<sup>13</sup>Irwin (2007, p. 14) is more precise: each risk should be allocated to maximize project value, taking account of moral hazard, adverse selection and risk-bearing preferences. See also the discussion in Dewatripont and Legros (2005).

implications of our results for the fiscal accounting of PPPs. Section 5 concludes and is followed by an appendix.

## 2 Model and optimal contract

A risk-neutral benevolent social planner must hire a concessionaire to finance, build and operate an infrastructure project with exogenous technical characteristics. There are no maintenance nor operation costs, the up-front investment does not depreciate, and the concessionaire is selected among many firms that can build the project at cost  $I > 0$ .<sup>14</sup> All firms are identical, risk-averse expected utility maximizers, with preferences represented by the strictly concave utility function  $u$ .

Demand uncertainty is summarized by a probability density over the present value of user fee revenue that the infrastructure can generate over its entire lifetime,  $f(v)$ , with c.d.f.  $F(v)$ .<sup>15</sup> This density is common knowledge to firms and the planner, and is bounded from below by  $v_{\min}$  and from above by  $v_{\max}$ . Also, for simplicity we assume that  $v$  equals the discounted private willingness to pay for the project's services.<sup>16</sup>

### 2.1 Planner's problem

Let  $PS(v)$  denote producer surplus in state  $v$ ,  $CS(v)$  denote consumer surplus in state  $v$  and  $\alpha \in [0, 1]$  be the weight that the planner gives to producer surplus in the social welfare function.<sup>17</sup> The planner's objective is to maximize

$$\int [CS(v) + \alpha PS(v)] f(v) dv, \quad (1)$$

subject to the concessionaire's participation constraint

$$\int u(PS(v)) f(v) dv \geq u(0), \quad (2)$$

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<sup>14</sup>That is, we ignore construction cost uncertainty and focus instead on demand uncertainty, which is considerably larger for many PPP projects.

<sup>15</sup>We assume that the instantaneous user fee revenue process is "well behaved", in the sense that the expected time for a  $v_1$ -income trajectory —i.e., a revenue trajectory with discounted value equal to  $v_1$ — to reach a given threshold  $M$  is larger than for a  $v_2$ -trajectory when  $M < v_1 < v_2$ . This will be the case, for example, if all demand trajectories grow at the same rate and differ only in their initial values. It also holds for more general instantaneous revenue processes such as a Brownian motion. This assumption is used only when associating higher values of  $v$  with shorter contract terms when the optimal contract term is finite.

<sup>16</sup>In Appendix A of Engel et al. (2008) we show that this simplification does not affect the structure of the optimal PPP contract.

<sup>17</sup>In many countries foreign firms are important investors in PPPs, which implies  $\alpha < 1$ .

where  $u(0)$  is the concessionaire's outside option.<sup>18</sup> Assuming that the firm's utility is concave in discounted profits simplifies the dynamic problems facing firms and government. From a public finance perspective, this is all we need to determine the long run fiscal impact of PPPs and the optimal contract.

To maximize (1) subject to (2), the planner chooses how much user fee revenue and subsidy the concessionaire should receive in each state  $v$ . Denote by  $R(v)$  the present value of user fee revenue collected by the concessionaire in state  $v$ , and by  $S(v)$  the present value of the subsidy it receives. Hence

$$PS(v) = R(v) + S(v) - I \quad (3)$$

Note that by "subsidy" we mean any cash transfer from the government to the private concessionaire. It may be the up-front payment made by the government with conventional unbundled provision (in which case  $S(v)$  is the same for all  $v$ ), but it could also be a cash transfer made over time, contingent on  $v$ , to supplement revenue from the project under a Build-Operate-and-Transfer (BOT) contract (a so-called 'minimum revenue' or 'minimum income' guarantee).

Since the concessionaire receives  $R(v)$  in state  $v$ , the government receives  $v - R(v)$ , hence  $0 \leq R(v) \leq v$ . If the term of the concession is finite and  $v - R(v) > 0$ , these funds can be used to reduce distortionary taxation elsewhere in the economy. Moreover, assuming that the willingness to pay is positive at all points in time,  $R(v) = v$  only if the concession lasts forever. Letting  $1 + \lambda > 1$  denote the marginal costs of public funds (see, e.g., Dahlby, 2008) we then have

$$CS(v) = [v - R(v) - (1 + \lambda)S(v)] + \lambda[v - R(v)] = (1 + \lambda)[v - R(v) - S(v)]. \quad (4)$$

The first term in the expression between equal signs,  $v - R(v) - (1 + \lambda)S(v)$ , is the difference between users' willingness to pay in state  $v$  and the amount transferred to the concessionaire, where the cost of the subsidy is augmented by the cost of the tax distortion required to finance it. The second term,  $\lambda[v - R(v)]$ , is the value of the reduction in distortionary taxes when the government collects  $v - R(v)$  in user fee revenue after the concession ends.

As is traditional in economics, the expression for consumer surplus in (4) includes the social costs caused by tax collection. Nevertheless, it ignores the inefficiencies associated with disbursing those revenues, which are relevant when comparing PPPs with conventional provision. We present a simple model which goes beyond the standard costs of collecting taxes and adds administrative and agency costs incurred when disbursing money.<sup>19</sup> These include standard overhead costs which are present in any organization as well as the additional inefficiencies of government agencies: overstaffing, the lack of a board to pressure management to control overhead, the need to follow and comply with rigid administrative procedures and controls imposed by the budget and

<sup>18</sup>This objective function assumes that the income of users is uncorrelated with the benefit of using the project, so that if users spend a small fraction of their incomes on the services of the project they will value the benefits produced by the project as if they were risk neutral. See Arrow and Lind (1970).

<sup>19</sup>See Appendix C in Engel et al. (2008) for additional details.

the comptroller's offices, or even the diversion of public funds and outright corruption.<sup>20</sup> Our point is that the government has to disburse more than \$1 when it provides \$1 to the recipient.<sup>21</sup>

We assume that the social planner can allocate spending across  $n$  government agencies indexed by  $i = 1, 2, \dots, n$ . The surplus created when agency  $i$  spends  $G_i$  on its best projects is  $\mathcal{S}_i(G_i)$ , with  $\mathcal{S}_i(0) = 0$ ,  $\mathcal{S}'_i \geq 0$  and  $\mathcal{S}''_i < 0$ . Nevertheless, to achieve  $G_i$  dollars spent on projects the government agency  $i$  disburses  $G_i + Z_i(G_i)$  in total, with  $Z_i(0) = 0$ ,  $\zeta_i \equiv Z'_i \geq 0$  and  $Z''_i < 0$ . Let  $T$  be the total amount of taxes raised and  $\Lambda(T)$  the costs of the distortions caused by taxes, with  $\lambda \equiv \Lambda' \geq 0$  and  $\Lambda'' > 0$ . The planner chooses  $(G_i)_{i=1}^n$  and  $T$  to maximize

$$\sum_{i=1}^n \mathcal{S}_i(G_i) - T - \Lambda(T)$$

subject to the budget constraint  $T = \sum_{i=1}^n [G_i + Z_i(G_i)]$ . Solving the planner's allocation problem leads to:

$$\frac{\mathcal{S}'_i(G_i)}{1 + \zeta_i} = 1 + \lambda; \quad i = 1, 2, \dots, n.$$

This is a standard result, which can be traced back to Atkinson and Stern (1974).<sup>22</sup> Government should expand until the marginal benefit of spending an additional dollar equals the marginal cost of public funds,  $1 + \lambda$ , and the marginal benefit of spending should be the same across agencies. But in addition, the marginal benefit of projects undertaken by agency  $i$  must be adjusted by the agency's relative inefficiency,  $(1 + \zeta_i)^{-1}$  to account for the fact that resources are spent and wasted when disbursing funds to projects. Agencies that use up more resources to disburse \$1 should spend less, *ceteris paribus*.

We can now insert a PPP into this framework. In what follows, a PPP is assumed to be undertaken by one agency within the government. The project is small relative to the overall budget, so that  $\lambda$  and  $\zeta$  are evaluated at the optimal resource allocation and can be assumed constant for the PPP agency.

Substituting (3) and (4) in (1) shows that maximizing the planner's objective function is equivalent to maximizing

$$-[(1 + \lambda) - \alpha] \int R(v) f(v) dv - [(1 + \lambda)(1 + \zeta) - \alpha] \int S(v) f(v) dv,$$

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<sup>20</sup>As an example of excess overhead, consider the National Flood Insurance Program of the United States, which hands "[...] one-third of its collected premiums –equivalent to a 50 percent loading cost– to financial intermediaries who do not bear any risk." In comparison, private insurance, with typical loading costs of 20-30%, must pay for rate-making, product development and must hold capital against risk (see Michel-Kerjan [2010]).

Also note that even though a diversion of public funds might be a transfer, it usually involves wasteful activities and expenditures to conceal it. Furthermore, a diversion of \$1 costs more than \$1, because it is financed with distortionary taxation at the margin.

<sup>21</sup>We assume there is no cost of collecting user fees. The results go through, with minor amendments, if the concessionaire's cost of collecting user fees is less than or equal to both the government's cost of collecting user fees and to the shadow cost of public funds.

<sup>22</sup>See Dahlby (2008, Chapter 2.2) for a recent exposition.

and therefore to minimizing

$$\int \{[(1 + \lambda) - \alpha]R(v) + [(1 + \lambda)(1 + \zeta) - \alpha]S(v)\} f(v)dv, \quad (5)$$

where we have dropped  $\alpha I$  and  $(1 + \lambda) \int v f(v)dv$  from the objective function because they do not depend on the planner's choice variables,  $R$  and  $S$ .

In (5) the marginal cost of funds is scaled up by  $1 + \zeta$  when the concessionaire receives subsidies, but not when it receives toll revenue. This captures the fact that toll revenues go directly into the concessionaire's pocket. Thus, by remunerating the concessionaire with toll revenue, society avoids the costs incurred when disbursing subsidies.<sup>23,24</sup>

Defining  $\bar{\zeta} \geq 0$  via:<sup>25</sup>

$$1 + \bar{\zeta} = \frac{(1 + \lambda)(1 + \zeta) - \alpha}{1 + \lambda - \alpha},$$

we have that the planner's program can be written as

$$\min_{\{R(v), S(v)\}} \int \{R(v) + (1 + \bar{\zeta})S(v)\} f(v)dv. \quad (6a)$$

$$\text{s.t. } \int u(R(v) + S(v) - I) f(v)dv \geq u(0), \quad (6b)$$

$$0 \leq R(v) \leq v, \quad (6c)$$

$$S(v) \geq 0. \quad (6d)$$

## 2.2 Irrelevance result

It is often claimed that PPPs relieve the public budget by substituting private finance for distortionary tax finance. Does this argument make the case for PPPs?

If we only consider the distortions associated with taxation, so that  $\zeta = 0$ , the planner's objective described in (6a) is equivalent to minimizing

$$\int R(v) f(v)dv + \int S(v) f(v)dv.$$

The per-dollar cost of paying the concessionaire with either user fee revenues or subsidies is the same, so social welfare only depends on *total* transfers  $\mathcal{T}(v) = R(v) + S(v)$  to the concessionaire, not on the division of payment between subsidies and user fee revenue. This is the insight behind the following result:

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<sup>23</sup>One might argue that the government has to incur in costs to monitor truthful reporting of toll revenues by the concessionaire. Nevertheless, these costs are likely to be negligible, for the concessionaire is monitored by investors and tax authorities.

<sup>24</sup>For simplicity we have assumed that each dollar collected by the concessionaire (net of toll collection costs) ends in its pocket. Of course, private firm pays some overhead. But the parameter  $\zeta$  is to be understood as capturing a relative difference between a private and a public bureaucracy.

<sup>25</sup>From the definition of  $\bar{\zeta}$ ,  $\bar{\zeta} > 0 \iff \zeta > 0$  and  $\bar{\zeta} < 0 \iff \zeta < 0$ . Furthermore,  $\zeta = \bar{\zeta}$  when  $\alpha = 0$ .

**Proposition 1 (Irrelevance of the cost-of-funds argument)** *Assume  $\zeta = 0$ . Then any combination of user fee and subsidy schedules that satisfies constraints (6c) and (6d) and such that  $\mathcal{F}(v) = I$  for all  $v$  solves the planner's program (6a)–(6d).*

**Proof** See Appendix A.1. ■

What is the economics of this result? The standard reasoning in favor of PPPs points out that subsidies are an expensive source of finance, because they are financed with distortionary taxes. Yet the multiplicity of optimal subsidy-revenue combinations indicates that distortionary taxation ( $\lambda > 0$ ) is not a sufficient reason to prefer private provision. One solution is  $R(v) \equiv 0$  and  $S(v) \equiv I$ , which in our framework corresponds to public provision. Another solution is that the concessionaire invests  $I$ , collects user-fee revenues equal to  $I$  in present value, and no subsidies are paid.<sup>26</sup> In addition, there is a continuum of combinations where the government provides a partial subsidy.

The intuition for this result is that if the user fee revenue collected by the concessionaire increases by \$1 (and thus government revenue decreases by \$1), the government has to levy \$1 in additional taxes, which costs society  $1 + \lambda$ . This is the same cost that society bears when paying \$1 in additional subsidies. Hence, at the margin the opportunity cost of paying with user fee revenue or subsidizing the concessionaire is exactly the same. The rich set of optimal combinations of state-contingent subsidies and concession terms reflects that user fees and subsidies are perfect substitutes in the planner's objective function.

A similar argument shows that the planner will satisfy the concessionaire's participation constraint with equality. An additional dollar for the concessionaires increases social welfare by  $\alpha$ , but costs  $1 + \lambda$  to users. Since  $1 + \lambda > \alpha$ , the planner extracts all rents from the concessionaire. Finally, note that the optimal contract provides full insurance to the concessionaire.

The irrelevance result implies that the case for PPPs cannot rest on the claim that they relieve strained budgets. When are PPPs warranted? As mentioned in the introduction, one justification of PPPs is that bundling may enhance productive efficiency. An additional advantage of PPPs, stressed in this paper, is that they reduce the sums flowing through the public budget, reducing the inefficiencies associated with subsidy transfers. This corresponds to the case where  $\zeta > 0$  in our model. The remainder of this section (and paper) is devoted to deriving (and implementing) the optimal contract for this case.

### 2.3 Optimal risk-sharing contract: high and low demand projects

To derive the optimal contract when  $\zeta > 0$ , note that (6a) implies that the planner will pay subsidies in state  $v$  only after exhausting user fees—otherwise she could slightly reduce subsidy payments, which would save  $(1 + \lambda)(1 + \zeta) - \alpha$ ; and increase  $R(v)$ , which would cost only  $1 + \lambda - \alpha$ . This rules out the possibility that  $R(v) < v$  and  $S(v) > 0$  simultaneously, and it follows that if the firm receives

<sup>26</sup>This is only possible if  $v_{\min} \geq I$ , for otherwise the project cannot be financed with user fees in all states.

subsidies in state  $v$ , it must be the case that user fees revenues are exhausted in this state. This insight motivates classifying demand states into high, intermediate and low demand states as follows. In a high demand state, the contract length is finite and no subsidies are paid out, that is,  $R(v) < v$  and  $S(v) = 0$ . By contrast, in low demand states the contract lasts indefinitely and the firm is remunerated with subsidies:  $R(v) = v$  and  $S(v) > 0$ . There remain the intermediate demand states, where the contract lasts indefinitely, as in low demand states, but no subsidies are paid out, as in high demand states.

The planner faces the following tradeoff: On the one hand, she would like to utilize user fee revenues as far as possible to compensate the concessionaire, in order to avoid paying subsidies. On the other hand, using only user fees may expose the concessionaire to excessive risk, and an efficient contract would insure against low demand states through subsidies.

The planner can avoid the subsidy-risk tradeoff when user fees alone always pay for the project, that is, when  $v_{\min} \geq I$ . The optimal contract then fully insures the firm, financing it solely out of user fee revenues, while providing no rents. This contract sets  $R(v) = I \leq v$  and  $S(v) = 0$  for all  $v$ —all states are high demand states when  $v_{\min} \geq I$ .

Consider next the case where user fees are always insufficient to pay for the project, that is,  $v_{\max} < I$ . Then  $R(v) = v$  combined with  $S(v) = I - v > 0$  for all  $v$  also defines the optimal contract, since this contract exhausts user fees in all states of demand before resorting to subsidies, while avoiding a risk premium, and without giving rents to the firm. As in the previous case, there is no tradeoff between minimizing subsidy payments and reducing risk exposure for the firm.

Table 1: Taxonomy of demand states and taxonomy of projects

	Demand state	Project
High:	$R(v) < v, S(v) = 0$	$v_{\min} > I$
Intermediate:	$R(v) = v, S(v) = 0$	$v_{\min} < I < v_{\max}$
Low:	$R(v) = v, S(v) > 0$	$v_{\max} < I$

We refer to a project with  $v_{\min} \geq I$  as a high demand *project*, while one with  $v_{\max} < I$  is a low demand project; intermediate demand projects satisfy  $v_{\min} < I \leq v_{\max}$ . Table 1 summarizes our taxonomies for states and projects. We summarize the optimal contract for high and low demand projects in the following Proposition.

**Proposition 2 (Optimal contract for high and low demand projects)** *The optimal contract for high and low demand projects requires that  $R(v) + S(v) = I$  for all  $v$ . Given demand realization  $v$ , the government collects  $v - I$  in each state if the project is high demand, while it pays a subsidy of  $I - v$  in each state if the project is low demand. ■*

## 2.4 Optimal risk-sharing contract: intermediate demand project

The subsidy-risk tradeoff becomes relevant when designing the optimal contract for an intermediate demand project, that is, a project with  $v_{\min} < I < v_{\max}$ . In this case full insurance does not implement the optimal program.

To see that even at the lowest cost, full insurance ( $R(v) + S(v) = I$ ) in all states is suboptimal, we argue below that a minor modification of this contract—referred to as the “full insurance contract” in what follows—improves welfare. Consider lowering insurance from  $I$  to  $I - \Delta I$  for states with  $v$  below  $I$ , and use the resources that are freed up to raise the revenue cap for states with  $v$  above  $I$  by an amount proportional to  $\Delta I$ .<sup>27</sup> Since user fee revenue is substituting for subsidy financing, every dollar saved in low demand scenarios has a social value that is  $(1 + \bar{\zeta})$  times that of every additional dollar transferred to the firm in high demand scenarios. It follows that for small  $\Delta I$  this leads to a welfare gain proportional to  $\Delta I$ . It is true that the firm bears risk under the modified contract, yet the compensation needed to satisfy its participation constraint is only of order  $(\Delta I)^2$ , since we are starting from a situation where it bears no risk. Thus there exists a contract with minimum revenue guarantee  $I - \Delta I$  and revenue cap  $I + c\Delta I$  that is feasible and improves welfare.<sup>28</sup>

For intermediate demand projects, the optimal contract is characterized by two thresholds, a minimum revenue guarantee  $m$  and a revenue cap  $M$ . In *low demand* states  $v < m$ ,  $R(v) = v$  and  $S(v) = m - v$ . By contrast, in *high demand* states  $v > M$  and  $R(v) = M$ . The remaining states, with  $m \leq v \leq M$ , are intermediate demand states, with  $R(v) = v$  and  $S(v) = 0$ . This contract cuts off the tails of the distribution and is the most efficient means of reducing the variance of revenues using subsidies in bad states and caps on revenue in good states in order to satisfy the participation constraint (see appendix). The optimal contracts of Proposition 2 may be viewed as particular cases of two-threshold contracts, where either the minimum income guarantee or the revenue cap are not binding.

Figure 1 shows how the subsidy-risk trade off is resolved optimally when  $v_{\min} < I < v_{\max}$ . The horizontal axis plots the support of  $v$  while the vertical axis shows the total revenue received by the concessionaire in each state,  $R(v) + S(v)$ . Implicit is the assumption that subsidies are used in a particular state only once user fees are exhausted.

In any state with a finite concession term, the social opportunity cost of the last dollar received by the concessionaire is  $1 + \lambda - \alpha$ ; this justifies equalizing the concessionaire’s revenue across high demand states by fixing a revenue cap  $M$ . On the other hand, in any low demand state the last dollar paid to the concessionaire comes from a subsidy and costs society  $(1 + \lambda)(1 + \zeta) - \alpha$ . Again, this justifies equalizing revenue across low demand states at the minimum revenue guarantee  $m < M$ .

As can be seen from figure 1, the wedge between  $1 + \lambda - \alpha$  and  $(1 + \lambda)(1 + \zeta) - \alpha$  creates an in-

<sup>27</sup>More precisely, this modification of the full insurance contract frees up resources  $F(I)\Delta I$  in expected value, that can be used to finance a new revenue cap  $I + c\Delta I$  with  $c = F(I)/(1 - F(I))$ , where  $1 - F(I) > 0$  since this is an intermediate demand project.

<sup>28</sup>The constant  $c$  will be slightly lower than the original  $F(I)/(1 - F(I))$ , by an amount on the order of  $\Delta I$  to compensate for the added risk.

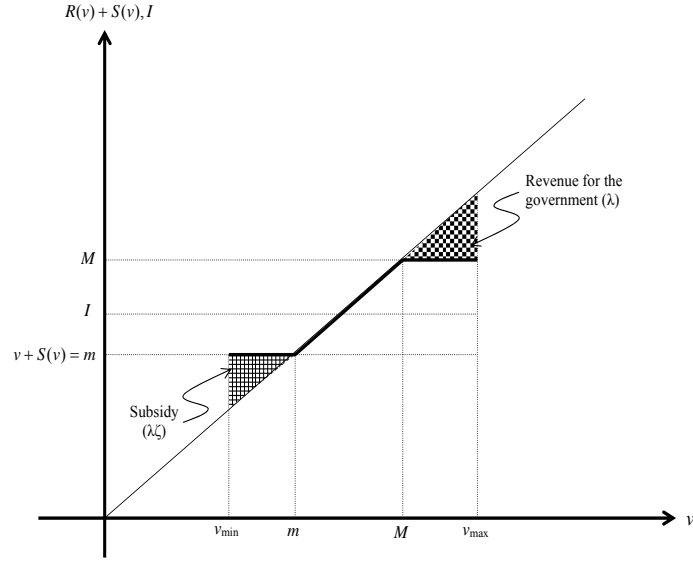


Figure 1: Optimal contract, intermediate demand project

terval  $M - m$  of intermediate demand states. To see the intuition, consider one such state,  $\tilde{v}$ . It is straightforward to obtain the following inequalities

$$\frac{1}{1 + \bar{\zeta}} < \frac{u'(\tilde{v} - I)}{u'(m - I)} < 1 < \frac{u'(\tilde{v} - I)}{u'(M - I)} < 1 + \bar{\zeta}.$$

These inequalities imply that the concessionaire's marginal utility evaluated at  $\tilde{v} - I$  is lower than the marginal utility at  $m$ , but higher than the marginal utility at  $M$ . In other words, the shadow value of the last dollar received by the concessionaire in state  $\tilde{v}$  is too low to warrant a subsidy, as well as too high to warrant a revenue cap. Consequently, the concession lasts forever, but no subsidies are paid. The following proposition characterizes the optimal values of both thresholds:

**Proposition 3 (Optimal contract for intermediate demand projects)** *Consider a project with  $v_{\min} \leq I < v_{\max}$  (intermediate demand project). Assume  $u'(v_{\min} - I) > (1 + \bar{\zeta})u'(v_{\max} - I)$ .<sup>29</sup> Then the optimal*

<sup>29</sup>This condition ensures that  $m > v_{\min}$  and  $M < v_{\max}$ , so that condition (8) below holds with equality. Two possibilities arise if  $u'(v_{\min} - I) < (1 + \bar{\zeta})u'(v_{\max} - I)$ . First, if  $\int u(v - I)f(v)dv > u(0)$ , the optimal contract involves no subsidies ( $m < v_{\min}$ ) and  $M$  is determined from

$$\int_{v_{\min}}^M u(v - I)f(v)dv + (1 - F(M))u(M - I) = u(0).$$

When the inequality is reversed:  $\int u(v - I)f(v)dv < u(0)$ , the optimal contract involves no revenue cap and the minimum income guarantee is determined from

$$F(m)u(m - I) + \int_m^{v_{\max}} u(v - I)f(v)dv = u(0).$$

contract is characterized by thresholds  $m$  and  $M$ , with  $v_{\min} < m < I < M < v_{\max}$ , such that states with  $v > M$  are high demand, states with  $m \leq v \leq M$  are intermediate demand and states with  $v < m$  are low demand.<sup>30</sup>  $M$  and  $m$  are determined from the concessionaire's participation constraint

$$F(m)u(m - I) + \int_m^M u(v - I)f(v)dv + (1 - F(M))u(M - I) = u(0) \quad (7)$$

and the condition

$$u'(m - I) = (1 + \bar{\zeta})u'(M - I). \quad (8)$$

**Proof** See Appendix A.2. ■

## 2.5 Extensions

The results derived above can be extended in several directions. Here we briefly discuss the intuition underlying two extensions of the model, and refer the reader to Engel et al. (2008) for a formal treatment. First, we consider the case where demand responds to price changes and the concessionaire faces a standard convex short-run cost curve. Second, we incorporate moral hazard, by assuming that demand responds to the concessionaire's unobservable effort.

### Price-responsive demand

Assuming a totally inelastic demand simplifies the derivations, but is not realistic. Nevertheless, the insights obtained above carry through to the case with a price-responsive demand. Once tolls are set appropriately, the optimal contract continues to be characterized by a minimum guarantee and a cap on revenues.

In Engel et al. (2008) we consider a continuum of verifiable demand states where, for tractability, we assume that the demand curve becomes known immediately after the project is built and remains constant over time.<sup>31</sup> This means that for every demand state, the planner chooses two prices, the user fee paid during the concession, and the user fee collected by the government after the concession ends. The planner also sets a demand-contingent concession length.

While the determination of optimal user fees is no longer trivial, the structure of the optimal contract remains identical to the case of perfectly inelastic demand. Thus, the present value of the cash flow received by the concessionaire is equal to  $M$  across all high demand states, and  $m$  across low demand states, with  $m < M$ . As before, the cash flow received by the concessionaire in intermediate demand states lies between  $m$  and  $M$ . Moreover, high, intermediate and low demand projects are defined as before.

<sup>30</sup>See Table 1 for the definition of high, intermediate and low demand states.

<sup>31</sup>The results that follow extend easily to the case where the demand schedule grows at an exogenous rate that may vary over time and with the demand state, since the price-elasticities of demand do not vary over time in this case. We can also introduce production costs that are increasing and convex in quantity demanded. The problem becomes considerably harder when demand is allowed to evolve arbitrarily.

User fees are set taking into account the relevant margin of fiscal revenue which they substitute. For example, user fees after the concession ends are set so as to create a distortion commensurate with the cost of public funds, since these fees substitute for this source of government revenue. It follows that there will be marginal cost pricing after the concession ends only when  $\lambda = 0$ .

The same principle applies, *mutatis mutandis*, to the different types of demand states during the life of the concession. Somewhat surprisingly, in a high demand state the relevant margin also is the shadow cost of public funds, despite the fact that the planner values a dollar in the concessionaire's pocket at  $\alpha < 1 + \lambda$ . The reason for this is that the planner can recoup the extra cash flow that the concessionaire receives per period in a high demand state as a result of a higher user fee during the concession because the concession duration is shorter. This implies that at the margin the higher revenue generated by raising the user fee during the concession substitutes for distortionary taxation *after* the concession ends. Similarly, the user fee during the concession in a low demand state is set commensurate with the cost of subsidy financing,  $(1 + \lambda)(1 + \zeta)$ . In low demand states the planner can recover any extra dollar of user fee revenue received by the concessionaire by lowering the subsidy.<sup>32</sup>

### **Moral hazard**

Another extension is to allow for demand that depends on unobservable and costly effort by the concessionaire. An additional motive to have the firm bear risk emerges in this case, as risk induces optimal levels of effort by the concessionaire. As before, two thresholds,  $m$  and  $M$ , suffice to partition states into high, intermediate and low demand states. Even though in the optimal solution the total revenue collected by the concessionaire now always increases with the demand realization  $v$ , subsidies are still paid out only in low demand states ( $v < m$ ), while the government still receives user-fees only in high demand states ( $v > M$ ).

Figure 2 shows that for an intermediate demand project with  $\zeta > 0$  we have a range of values of  $v$  where the contract lasts indefinitely and there are no subsidies. This range of intermediate demand states (and intermediate demand projects) emerges only when  $\zeta > 0$ , leading to an increase in risk borne by the concessionaire beyond the level predicted by the standard principal-agent model for the case  $\zeta = 0$ . Contrary to the optimal contract for the case with no moral hazard depicted in figure 1, the concessionaire's revenue is not equal across all high demand states or all low demand states. But the gap between  $m$  and  $M$  emerges, as before, because subsidy finance is more expensive than user fee revenue, at the margin. Again as in the case with no moral hazard, the optimal contract also involves a state-contingent concession term, with shorter terms in high demand states.

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<sup>32</sup>For intermediate demand states the user fee is set so that the resulting distortion lies between that associated with financing from general taxes and that associate to subsidies. See Engel et al. (2008).

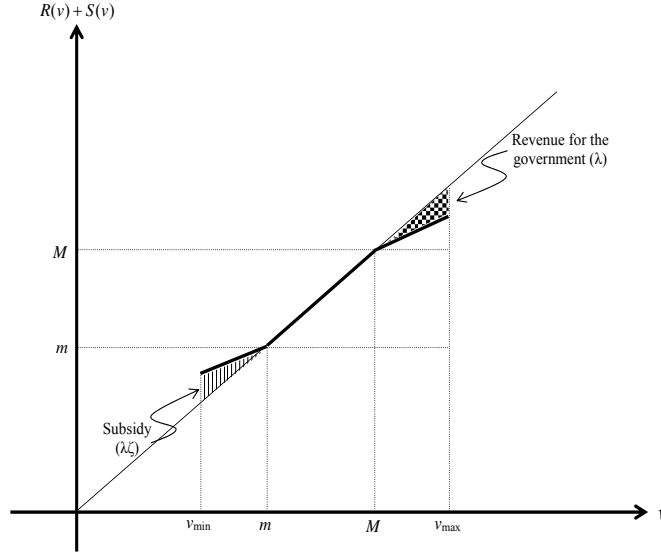


Figure 2: Optimal contract with moral hazard and  $\zeta > 0$

### 3 Implementation

The informational requirements needed to implement the optimal contract might seem formidable, but somewhat surprisingly, this is not the case. We show next how to implement the optimal contract with a competitive auction when the planner knows neither  $I$  nor the risk aversion of firms.

#### 3.1 High and low demand projects

Consider first a high demand project. Then an auction where the bidding variable  $\beta$  is the total present value of user fee revenues (PVR) collected by the concessionaire implements the optimal contract. This follows from observing that rents will be dissipated in a competitive auction, so that  $\beta$  will satisfy:

$$\int u(\beta - I) f(v) dv = u(0). \quad (9)$$

Hence the winning bid will be  $\beta = I$ , which corresponds to the optimal contract derived in proposition 2. Denote by  $T(v)$  the time it takes for user fee revenue accumulated in state  $v$  to attain  $I$ . The concession term is shorter when demand is high, that is, when  $T(v)$  is small.<sup>33</sup> The concessionaire bears no risk because users pay him the same amount in all states of nature.<sup>34</sup> Furthermore, the planner can implement the optimal contract using a PVR auction even if she does not know  $I$ , the density  $f(v)$  or the concessionaire's degree of risk aversion. All that the planner needs to know is

<sup>33</sup>This requires that the instantaneous user fee revenue process be well behaved, see footnote 15.

<sup>34</sup>Uncertainty in  $I$ , which may be important in some projects, cannot be eliminated with a variable (or fixed) term contract.

that the project can finance itself in all states of demand, that is, that  $v_{\min} \geq I$ . Furthermore, moving from a fixed term contract to the optimal contract can lead to substantial welfare gains.<sup>35</sup>

Consider next a low demand project. A PVR auction will implement the optimal contract in this case as well, as long as the government subsidizes the difference between the winning bid and the present value of user fees collected. In this case firms end up bidding on a minimum income guarantee and the winning bid ensures a total revenue of  $I$ . Informational requirements are modest again, since the planner only needs to know that  $v_{\max} < I$ , and be able to verify revenue in each state. Note that the concession lasts forever in this case. We summarize both cases reviewed so far as follows:

**Proposition 4 (High and low demand projects)** *The optimal contract can be implemented with a PVR auction, or by a simple extension, for both high and low demand projects. Furthermore, bidders reveal  $I$  in the auction and there is no need to know  $f$  or  $u$ . ■*

### 3.2 The general case

Next we consider the case where the planner does not know if the project is high, intermediate or low demand. We also assume that the planner does not know the firms' degree of risk aversion, but does know the probability density  $f(v)$ .<sup>36</sup> We show next how to implement the optimal contract with an auction where firms bid on the minimum revenue guarantee and on the revenue cap they desire.<sup>37</sup>

**Proposition 5 (Optimality of the two-threshold auction)** *The following two-threshold, scoring auction implements the optimal contract:*

- *The government announces the probability density of expected discounted user fee revenue flow from the project,  $f(v)$ , and the parameter  $\bar{\zeta}$  that summarizes the wedge between the shadow cost of public funds and subsidies.*
- *Firms bid on the minimum revenue guarantee,  $m$ , and on the cap on user fee revenue,  $M$ .*
- *The firm that bids the lowest value of the scoring function*

$$W(M, m) = M(1 - F(M)) + \int_0^M v f(v) dv + (1 + \bar{\zeta}) \int_0^m (m - v) f(v) dv \quad (10)$$

*wins the concession.*

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<sup>35</sup>Depending on the degree of risk aversion and revenue uncertainty, Engel et al. (2001) find welfare gains between 16 and 64% of the upfront investment.

<sup>36</sup>The government should have as much information on demand as third parties, because it either provides the service or it must compare the PPP with conventional provision. Furthermore, substantial public planning is needed to design most PPP projects, and this requires an assessment of demand.

<sup>37</sup>See Engel et al. (2008) for an extension of the results to the case with price-responsive demand.

**Proof** See Appendix A.3. ■

What is the intuition underlying this result? Note first that the planner's objective function does not require knowledge of  $I$ . The objective function only depends on the probability distribution of the present value of revenue that the project can generate and the distortions associated with government expenditures, as summarized by  $\bar{\zeta}$ . By awarding the PPP to the bidder that maximizes this objective function, and assuming competitive bidding, the planner induces the concessionaire to solve society's problem without knowing the cost of the project or the firms' degree of risk aversion.

In the case of a high demand project, the two-threshold auction is equivalent to a PVR auction. If all states have high demand, any bid with  $M = I$  and  $m \leq I$  will win the auction. No subsidies are paid out and the concession term is shorter if demand is higher.<sup>38</sup> Similarly, in the case of a low demand project, a bid with  $m = I$  and  $M \geq I$  wins the concession, since this time the upper threshold is irrelevant. In this case the two-threshold auction reduces to the extension of the PVR auction described in proposition 4. However, the two-threshold auction is more general than a PVR auction, as it can be used for intermediate demand projects or, more importantly, for projects where the planner does not know whether the project is low, intermediate or high demand.

## 4 Practical relevance

For the duration of a typical PPP contract, which can be thirty years or more, the concessionaire will build, manage, maintain and control the assets, in exchange for some combination of user fees and government transfers, which are its compensation for its investment and other costs. For example, the main source of compensation for European PPP contracts for roads, bridges and tunnels are user tolls (61.1% of all projects), followed by shadow tolls (32.6%).<sup>39</sup>

Usually PPP contracts are conferred via competitive (Demsetz) auctions, the most common bidding variables being user fees, length of the contract, government subsidies and payments to the government. Minimum income guarantees, which ensure that revenue reaches a predetermined sum are common, and so are revenue sharing arrangements when revenues exceed a predetermined thresholds. At the end of the contract, the asset reverts to the government.

In this section we discuss the practical relevance of the optimal contract and the implementation derived in Sections 2 and 3. Even though most observed contracts have a fixed duration, which is suboptimal, flexible term contracts have become increasingly common. These non-standard contracts share characteristics with those of the optimal contract derived in this paper.

We begin by describing the experience with flexible term contracts. Next we compare minimum income guarantees and revenue sharing agreements observed in practice with those suggested by our results. Finally, we use our model to contribute to the debate on whether investment in PPPs should add to the public debt.

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<sup>38</sup>This assumes the instantaneous revenue process is well behaved, see footnote 15.

<sup>39</sup>See Table 5 for details.

## 4.1 Experience with flexible term contracts

The United Kingdom was probably the first country to use a contract similar to the optimal contract derived in Section 2.3. In 1987 the British government concessioned the construction and operation of the Queen Elizabeth II Bridge in Essex county. While demand for bridge crossings was uncertain, there was little doubt that the project was financially sound provided that the concession term was long enough. In our terms, it was a high demand project. The contract specified that the concession would end after 20 years or when toll revenue was sufficient to repay principal and interest, whichever happened first. The £190 million project relied 100% on debt financing, with no equity. The bridge was inaugurated in October 1991 and the concession ended in March of 2002. This contract is identical to the optimal contract we derived for high demand projects, except for the upper bound on the concession duration.

The Route 68 concession in Chile, linking Santiago with Valparaíso and Viña del Mar was the first flexible term contract assigned via an open auction along the lines suggested by our implementation results in Section 3.1. This concession involved major improvements and extensions of the 130 kilometer highway, and was auctioned in February of 1999. Bidders were given a choice of fixed or flexible inflation adjusted interest rates (plus a 4% risk premium) to use in discounting their annual toll revenue. The winner, which chose the fixed rate, asked for a present value of revenue of US\$373 million, which was lower than the US\$ 379 million construction and maintenance costs estimated by the Ministry of Public Works. A possible explanation is that the risk premium was set too high.

After a first generation of highway concessions using shadow tolls and fixed duration contracts, Portugal began using flexible term concessions.<sup>40</sup> The first flexible term auction was the 98.4km Litoral Centro highway along the Atlantic ocean, with an estimated cost of €795 million euros. The concession duration depends on the net present value (NPV) of toll revenue reaching a limit of €784 million. If the limit is reached before year 22, the concession lasts 22 years; if it is reached between years 22 and 30, the concession ends once the limit is attained; and if it is not reached by year 30, the concession ends. Toll revenue is discounted at a market rate and tolls are indexed to the consumer price index. This is a flexible term contract that limits the up and downside risk for the concessionaire, as does the two-threshold optimal contract discussed in Section 3.2. The project won the Eurofinance prize in 2004 and the Portuguese government has announced that it will use flexible term concessions for all future highway concessions.

Other countries also have used flexible term auctions, yet it is worth speculating on why flexible term contracts have not been adopted more broadly throughout the world. Opposition has come mainly from the concession lobby, which fears that a flexible contract will limit their ability to renegotiate contracts.<sup>41</sup> In most countries, the Public Works Authority tends to support the position of

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<sup>40</sup>What follows is based on *Project Finance*, February 2005.

<sup>41</sup>Guasch (2004) presents evidence on frequent renegotiations of concession projects and argues that they often reflect opportunistic behavior by the concessionaire.

the concession lobby, since its governance structures usually provide incentives for road building rather than supervision and regulation that eventually benefits users. This requires good relations with future bidders for concessions.

By contrast, the Ministry of Finance usually favors flexible term contracts, since they reduce the demand for guarantees given the lower demand side risk. It is not surprising, therefore, that flexible term concessions have been adopted when the budgetary authority has the upper hand over the public works authority. For example, in the case of Portugal, the shadow tolls used to remunerate highway concessions auctioned beginning in 1999 became an increasing burden on the budget. By 2004 it was estimated that the shadow toll obligations would increase to €660 million per year by 2008, which was almost equal to the total annual road budget. Thus, it became necessary to shift towards financing schemes that relied on user charges.

In Chile, the Ministry of Finance was able to push for flexible term contracts after the Ministry of Public Works overspent between 2000 and 2003.<sup>42</sup>

## **4.2 Minimum income guarantees and revenue sharing**

Minimum income guarantees and revenue sharing are common in PPP contracts. However, they differ from the optimal contract because contract lengths are fixed and do not last longer in low demand states, implying that guarantees in those states are excessive. The usual profit and revenue sharing agreements in fixed term contracts split revenues above a threshold in fixed proportions. By contrast, Propositions 2 and 3 suggest assigning all the revenue in excess of a given threshold to the government, so the windfall profits tax rate should be 100%.<sup>43</sup>

More generally, the rationale behind real-world guarantees and revenue sharing schemes is to reduce the risk borne by the concessionaire. By contrast, the rationale behind the optimal contract in Propositions 2 and 3 is to optimally trade off insurance on one hand, and user fees and subsidies on the other. This is why the concession lasts indefinitely when subsidies (i.e., guarantees) are granted and why in high demand states the term is variable and the concessionaire's revenue is higher than in low demand states.

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<sup>42</sup>PVR auctions were used recently in Chile to auction Route 160 (February, 2007), the road accessing Santiago's main airport (December, 2007), the Melipilla-Camino de la Fruta highway (January, 2008), and the Vallenar-Caldera highway (January, 2008).

<sup>43</sup>The optimal contract under moral hazard discussed in Section 2.5 is closer to observed contracts in high demand scenarios, since the firm receives a fraction of marginal revenues in these states as is the case under most observed sharing agreements. Yet the moral hazard contract implies a variable term in high demand states, and that the firm will share in marginal user fee revenue in low demand states, which is not the case under the often used minimum income guarantees. The contract derived in proposition 3 does better than the moral hazard contract in low demand states. More importantly, as argued in the Introduction, in the case of transport infrastructure, the moral hazard problem is not relevant, as service quality is contractible and thus there is no way to increase demand significantly.

### 4.3 Are PPPs private or public?

It has often been argued that the main reason why governments find PPPs an attractive option is that investments financed this way do not contribute to the public debt.<sup>44</sup> We use this paper's results to argue that, as far as the risk profile of the government's budget is concerned, PPPs are much closer to public provision than to privatization.

Our starting point is that when thinking about the risk allocation implied by PPPs, what matters is the risk profile of discounted cash flows, not the year-to-year risk profile. This has interesting implications: for low and high demand projects, an optimal PPP contract replicates the net cash flow streams of conventional provision, state by state (see Table 2, which assumes an additive risk premium). Essentially, all residual risk is transferred to the government, and the concessionaire recovers  $I$  in all states, as with conventional provision.

This result implies that some of the most influential guidelines on when to classify a PPP asset as government owned may be misguided, since they are based on whether the concessionaire bears risk. For example, Eurostat, the Statistical Office of the European Community, recommends that the assets involved in a public-private partnership be classified as non-government assets, and therefore recorded off balance sheet for government, if both of the following conditions are met: (1) the private partner bears the construction risk, and (2) the private partner bears at least one of either availability or demand risk (Eurostat Press Office, February 11, 2004). When quality is contractible, as we argued is the case for most of PPP investments in the transportation sector, demand risk will be mainly exogenous and therefore this risk does not generate useful incentives. Furthermore, in the case of a high or low demand project, the optimal contract eliminates risk for the firm, with implications for the public budget that are identical to those of public provision.

Table 2: Average discounted budget: public provision vs. PPPs (High and low demand)

	Public provision	PPP	Privatization
Upfront surplus:	$-I$	0	$\int f(v)dv - I - \text{Risk Premium}$
Discounted user fees:	$\int f(v)dv$	$\int f(v)dv - I$	0
Total:	$\int f(v)dv - I$	$\int f(v)dv - I$	$\int f(v)dv - I - \text{Risk Premium}$

For intermediate demand projects, Proposition 3 show that some risk-sharing is optimal. The extent to which the firm bears risk now depends on the extent to which subsidies are a more costly source of financing than user fees, as captured by the parameter  $\bar{\zeta}$ . When subsidy financing is very inefficient, it is too expensive to reduce the firm's risk via subsidies, and it is best to have the firm bear most (sometimes all) of the risk. The efficient PPP contract resembles privatization in this case. On the other hand, if subsidy financing is only slightly less efficient than user-fee financing,

<sup>44</sup>"Cynics suspect that the government remains keen on PFI not because of the efficiencies it allegedly offers but because it allows ministers to perform a useful accounting trick." *The Economist*, July 2nd 2009.

the minimum income guarantee and the cap on user fee revenues that characterize the optimal contract are very similar, and the government bears most of the risk. As with high and low demand projects, risk sharing arrangements resemble public provision in this case.

Under privatization, the project is sold for a one-time payment and all risk is transferred to the firm. Moreover, the link between the project and the public budget is permanently severed. This is not the case with a PPP, where at the margin cash flows from the project always substitute for either taxes or subsidies. The conclusion, then, is that from a public finance perspective there is a strong presumption that PPPs are analogous to conventional provision—in essence, they remain public projects, and should be treated as such.

#### **4.4 Least subsidy auctions**

Low demand projects are sometimes awarded to the firm that bids the lowest subsidy required to build, operate and maintain the project. However these are fixed duration concessions. For that reason, and even under a competitive auction, the winning bid includes a risk premium, because the concessionaire is forced to bear the risk of varying revenue in different states of demand. This implies that the winning bid will be higher than the difference between the cost of the project and expected revenues. On the other hand, a PVR auction for a low demand project provides complete insurance to the concessionaire, so the winning bid in a competitive auction does not require a risk premium. This leads to the somewhat counterintuitive result that the average subsidy paid out with a PVR auction is lower than the winning bid in a lowest-subsidy auction.<sup>45</sup>

## **5 Conclusion**

The insights of this paper have implications for the question of whether PPPs are closer to private or public provision of infrastructure. The existing literature focusses on the incentives wrought by PPPs and concludes that they have several attributes typically associated to privatization. For example, in a PPP the concessionaire owns assets (Hart, 2003);<sup>46</sup> retains control over how to produce the service and may unilaterally implement any cost-saving innovation (Bennet and Iossa, 2006); and directly collects user fees (Grout and Stevens, 2003).<sup>47</sup>

We use a different approach, which derives the optimal PPP contract from a public finance perspective. In this case the optimal contract provides full insurance for high and low demand projects, and is characterized by a minimum income guarantee and revenue cap for intermediate demand projects. The impact on the intertemporal budget is similar to that of public provision, suggesting that PPPs should be counted as public projects in the budget.

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<sup>45</sup>For more details and a formal statement, see Engel et al. (2008).

<sup>46</sup>Though usually it needs authorization to sell assets that are comprised in the concession.

<sup>47</sup>In a different vein, Besley and Ghatak (2001) show that when contracts are incomplete, transferring the ownership of the assets needed to produce a public good to a private party is efficient, when that party values the benefits created by the public good relatively more.

Our framework stresses the importance of risk allocation in the face of large demand uncertainty present in many PPP projects. We emphasize that the temporary nature of PPP contracts can be used to improve welfare by allowing state-contingent contract terms, making feasible risk allocations that are not available under privatization or public provision.

The crisis that started in 2008 has left many countries with large budget deficits. Hence, these countries may find PPPs an attractive solution to finance infrastructure projects without increasing their apparent debt burden. We have shown that this should not be a basis for choosing PPPs over conventional provision. PPPs should be favored only when they lead to efficiency gains. To ensure this happens, PPPs should be given the same treatment in budgetary accounting than publicly provided infrastructure.

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## A Appendix: Proofs of Propositions

### A.1 Proposition 1

We solve the program (6a)–(6d) for the case where  $\bar{\zeta} = 0$  (which is equivalent to  $\zeta = 0$ , see footnote 25).

Since  $u$  is concave, applying Jensen's inequality to the concessionaire's participation constraint leads to

$$u\left(\int [R(v) + S(v)]f(v)dv - I\right) \geq \int u(R(v) + S(v) - I)f(v)dv = u(0),$$

where we used that the planner leaves no rents to the firm (see the main text). And since  $u$  is strictly increasing, the above inequality implies that

$$E[R] + E[S] \geq I,$$

where  $E[R] = \int R(v)f(v)dv$  denotes the expected revenue before demand is realized and  $E[S]$  denotes expected government expenditure on subsidies.

It follows that if the solution to

$$\begin{aligned} \min_{R \geq 0, S \geq 0} E[R] + (1 + \bar{\zeta})E[S] \\ \text{s.t. } E[R] + E[S] \geq I, \end{aligned} \tag{11a}$$

satisfies (6c)–(6d), then it solves program (6a)–(6d) as well.

Hence, if  $\zeta = 0$ , any combination of revenue and subsidy schedules that satisfies (6c), (6d), and  $R(v) + S(v) = I$  for all  $v$ , solves the planner's problem. ■

### A.2 Proposition 3

Let  $\mu > 0$  denote the multiplier of the concessionaire's participation constraint (6b).<sup>48</sup> The FOC with respect to  $R(v)$  for a state  $v$  such that the term of the concession is finite leads to

$$u'(R(v) - I) = \frac{1 + \lambda - \alpha}{\mu}. \tag{12}$$

While the FOC with respect to  $S(v)$  for a state where subsidies are paid leads to

$$u'(v + S(v) - I) = \frac{(1 + \lambda)(1 + \zeta) - \alpha}{\mu}, \tag{13}$$

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<sup>48</sup>Note that the participation constraint will hold with equality because  $1 + \lambda > \alpha$ , hence  $\mu > 0$ .

where in both cases we have used that revenue financing dominates subsidy financing. Define  $m$  and  $M$  via

$$u'(m - I) = \frac{(1 + \lambda)(1 + \zeta) - \alpha}{\mu}, \quad (14)$$

$$u'(M - I) = \frac{1 + \lambda - \alpha}{\mu}. \quad (15)$$

Since  $\zeta > 0$  we have  $m < M$  and

$$u'(m - I) = (1 + \bar{\zeta})u'(M - I),$$

It follows from (12) and (15) that in states with  $v > M$  no subsidies are paid out and the concession lasts until the concessionaire collects  $M$  in present value. The government, on the other hand, collects  $v - M$  after the concession ends. Thus, in high demand states the concessionaire's revenue is capped by  $M$  and the term of the concession is variable.<sup>49</sup>

Similarly, from (13) and (14) we have that a subsidy equal to  $m - v$  is paid in states with  $v < m$ . Therefore, in low demand states the concession lasts indefinitely and the concessionaire receives a minimum revenue guarantee.

Finally, there is a third class of states of demand such that  $m \leq v \leq M$ . In these states the concession lasts indefinitely, for otherwise they would be high demand states. But no subsidies are paid out by the government, for otherwise they would be low demand states. It follows that  $R(v) = v$  and  $S(v) = 0$  in this class.

Having established that the optimal contract is a two-threshold contract, the planner's problem is equivalent to finding  $m$  and  $M$  that minimize

$$M(1 - F(M)) + \int_0^M v f(v) dv + (1 + \bar{\zeta})F(m) \int_0^m (m - v) f(v) dv, \quad (16)$$

subject to the concessionaire's participation constraint (7). Noting that (7) implicitly defines  $M$  as a function of  $m$ , we have that:

$$M'(m) = -\frac{F(m)u'(m - I)}{(1 - F(M))u'(M - I)}. \quad (17)$$

A similar calculation shows that the rate at which  $M$  and  $m$  have to change to keep the objective function (16) unchanged is given by

$$M'(m) = -\frac{(1 + \bar{\zeta})F(m)}{1 - F(M)}. \quad (18)$$

Equating (17) and (18) for  $M'(m)$  leads to (8) and completes the proof.<sup>50</sup> ■

<sup>49</sup>Under the assumption that the user fee revenue process is well behaved, this implies that higher values of  $v$  correspond, on average, to shorter concession terms.

<sup>50</sup>The above proof assumes that  $F(m) > 0$  and  $F(M) < 1$ . Footnote 29 outlines the proof when this is not the case.

### **A.3 Proposition 5**

Since all firms are identical, the winning bid of the competitive auction minimizes the scoring function subject to firms' participation constraints. And since the scoring function is equal to the planner's objective function, where we use the fact that the optimal contract is characterized by thresholds  $m$  and  $M$ , it follows that the winning bid maximizes the planner's objective function subject to the firm's participation constraint, thereby solving the planner's problem. ■

## B Appendix: PPP Statistics

Table 3: PPP Investment in Europe\*

Country	Total Investment (1990–2006, MM EUR)	Fraction of public investment (2001–2006, %)
Belgium	2,112	3.5
France	7,670	1.3
Germany	5,658	1.5
Greece	7,600	5.9
Hungary	5,294	7.3
Italy	7,269	2.5
Netherlands	3,339	2.2
Portugal	11,254	22.8
Spain	24,886	6.9
UK	112,429	32.5**

\*Source: Blanc-Brude et al. (2007). 10 countries with most investment.

\*\* If the London Underground is excluded, this becomes 20%.

Table 4: PPP Investment in Developing Countries (1990-2008, MM USD)\*

Country	Energy**	Telecom**	Transport	Water-sewage	Total
Argentina	29,540	29,328	14,094	8,176	81,137
Brazil	75,993	107,554	32,142	4,576	220,265
China	37,339	14,518	47,449	8,427	107,732
India	45,868	52,898	24,766	331	123,864
Indonesia	15,492	24,972	3,743	1,020	45,228
Malaysia	14,313	9,596	16,552	10,144	50,605
Mexico	10,753	54,068	25,374	1,675	91,869
Philippines	19,268	14,280	3,478	8,071	45,096
Russia	30,484	48,813	706	2,225	82,228
Turkey	12,678	24,293	8,170	942	46,082

\*Source: World Bank-PPIAF PPI Database. 10 countries with most investment.

\*\* It is debatable to what an extent projects in this sector fit what we consider a PPP in this paper, since they correspond to infrastructure that is privatized (thereby severing any link with the public budget) and regulated as a natural monopoly.

Table 5: Toll Types for PPP Roads, Bridges and Tunnels Europe\*

Country	Availability	Real Toll	Shadow Toll	Total
Austria	0	2	0	2
Finland	2	0	0	2
France	0	8	0	8
Germany	0	8	0	8
Greece	0	6	0	6
Hungary	0	5	0	5
Ireland	0	8	0	8
Italy	0	7	0	7
Latvia	1	0	0	1
Netherlands	2	0	1	3
Norway	0	3	0	3
Poland	0	1	1	2
Portugal	0	6	11	17
Spain	0	31	14	45
UK	4	3	20	27
<b>Total</b>	<b>9</b>	<b>88</b>	<b>47</b>	<b>144</b>

\* Source: Timo Valila at the European Investment Bank.