The Regulation of Public-Private Partnerships

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Abstract

We study the regulation of Public-Private Partnerships (PPPs), focusing on highways. We describe the specific characteristics of PPP contracts, their strengths and weaknesses, and their efficient regulation. One of the main problems of PPPs is that contracts are often renegotiated, which can negate the benefits of selecting the firm via competitive tender, increasing costs to the public and the possibility of corruption. This chapter analyzes approaches for dealing with these problems. We also discuss how different sources of risk should be allocated and show that it is efficient to assign demand risk to the public. The efficient contracts in this case are availability contracts when there are no user fees, and a present value of revenue contract when tolls are charged. The conclusion is that the lessons from experience with PPPs over the last three decades shows how this organizational form can be regulated to provide an attractive option for providing transport infrastructure such as highways and airports.

1. Introduction

Governments face three challenges in the provision of transport infrastructure: deciding what to build and when, building cost-effectively, and ensuring proper maintenance and service quality once the project is built. This article focuses on highways, since they represent the largest fraction by far of worldwide investment in transport PPPs.[2] Until recently, highways were considered public goods and were built by the State, with funding from budget appropriations, and were managed by ministries or public agencies. In the last few decades, many countries have introduced public-private partnership (PPP) as a new alternative to provide roads, bridges, and tunnels, among other types of infrastructure.

A PPP bundles finance, construction, and operation into one long-term contract between the government and a standalone firm---the special purpose vehicle (SPV; Figure 1, panel a) which we also denote the concessionaire. The SPV builds and operates a legally and

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[2] For low- and middle-income countries, PPIAF records that 47% of the USD 584 Bn in PPP transport infrastructure corresponds to toll roads. In high income countries, highways represent a higher fraction of the value of PPPs: in Europe, they represent 54.8% of all PPP projects (Engel, Fischer and Galetovic 2021). For a more general overview of PPPs, see Hodge, Greve and Boardman (2010).

economically self-contained project for periods lasting up to several decades.

On the funding side, the PPP contract pledges the cash generated by the infrastructure, which can be generated by tolls or by government payments, to pay back equity investors and debt. The SPV's narrow focus leaves no room to divert funds to other businesses, and PPP deals are often highly leveraged. On the production side, the SPV hires firms to build, operate and maintain the facility. When the contract ends, the infrastructure reverts to the government.

PPPs can be contrasted to traditional provision, where the government deals directly with financiers, the builder, and the operator (Figure 1, panel b). Under traditional provision, the project is financed with public debt and budget appropriations; a government agency hires the builder and then the operator. This basic structure has many variations, often influenced and determined by country, regional, and city laws and institutions. Sometimes the whole process is led by a single public institution (for example, a central government ministry or a city authority), or the tasks are split among many agencies, layers of government, or even within branches of one government institution. Indeed, PPPs often inherit many of its shortcomings from existing infrastructure programs.

The promise of PPPs is that private firms will be more efficient than traditional provision. One reason is that the entire process is integrated into a single package. When finance, design, construction, operation and maintenance are bundled, the concessionaire will aim for a design and a construction method that reduces life-cycle costs (Hart, 2003). Moreover, the one-to-one match between infrastructure projects and management teams creates focused firms, which substitute for a governance structure determined by the internal organization of the government. In addition, if the state does not guarantee the private debt, the project will also face a market viability test. Moreover, PPPs can be funded with tolls, which can be used to optimally manage congestion and externalities.[3]

We argue in this chapter that the promise of PPPs cannot be realized without skillful government planning and regulation. PPPs are a means to procure public infrastructure, and thus governments must still plan and decide which projects to build and when. For PPPs to work, governments must impose and enforce contractual quality and performance standards. Finally, competition among roads is not sufficient to prevent private firms from exploiting market power, which governments must therefore regulate. The optimal PPP contract allows the government to toll optimally and to adjust tolls over time, while remunerating the PPP project.

2. The contract

2.1 BOT contracts

[3] An additional claim that is often made is that PPPs free public funds that can be used for other purposes. This argument is incorrect. If funded by availability payments, the PPP creates an obligation for the government, since it will have to make periodic payments to the PPP. This is indistinguishable from debt. If, on the other hand, the PPP is funded by tolls, the government relinquishes the toll revenue, as the government could have issued a bond backed by the toll revenues from the project. See Engel, Fischer and Galetovic (2013 and 2014, ch. 6) for a detailed analysis of the fiscal effects of PPPs.

2.1.1. Public and private contracting

Governments regulate PPPs through their contracts with concessionaires. The standard is a Build, Operate and Transfer (BOT) contract. Under this contract, the concessionaire builds the infrastructure, operates, and maintains it for a limited term (typically between 10 and 30 years). The project then returns to the State. In the case of DBOT contracts, the government asks the concessionaire to design the project.

As shown in Figure 2, in a typical PPP contract the concessionaire forms a Single Purpose Vehicle (SPV), an independent company with its own balance sheet and whose sole purpose is to undertake the project. On the one hand, the SPV contracts with the government under public law, assuming the responsibility of delivering the infrastructure and its services. In the contract, the government imposes a regulatory and incentive scheme that forces the concessionaire to fulfill minimum quality standards. This scheme sometimes includes a conflict resolution mechanism.

On the other hand, the SPV is a private specialized firm whose contracting relations with employees, other firms and financiers are governed by private law. This improves incentives, because during the term of the PPP the concessionaire can manage the infrastructure as a private entity. By contrast, management practices in government are less flexible, and public agencies are constrained by annual budgets. A public manager cannot use the earnings of her organization to reward employee's performance nor freely allocate factors of production. Regulations imposed by the legislature and the administration constrain hiring, purchasing, contracting and organizational structures.[4]

Moreover, by creating a specialized firm, the SPV's scope is clearly defined and bounded, and the project gets a dedicated management team, which answers to the SPV's board. By contrast, public agencies in charge of infrastructure projects (e.g., ministries of public works) tend to have multiple objectives and are accountable to multiple principals. Moreover, a ministry or public agency manages a large number of tasks and projects. Scale and scope are likely to be well beyond what is efficient, which blunts incentives.

Note that PPPs have finite terms---the infrastructure reverts to the government in finite time by design. While finite terms are not necessary for PPPs (for example, privatized utilities can be thought of as a non-ending PPPs), they allow governments to keep control over planning. This is important, because network effects may appear over time and these require government planning and authority to execute the projects. More generally, a PPP is not a privatization but a different way of procuring *public* infrastructure.

2.1.2 Bundling

A PPP bundles financing, construction, operation and maintenance in a single contract. Bundling differentiates PPPs from traditional provision and is a key feature of the PPP model.

As Hart (2003) shows, when building the project, the concessionaire considers the total life cycle costs of the project. Moreover, bundling allows the firm to propose a design with features that increase demand in a cost-efficient way. However, as mentioned by Hart (2003), these advantages can be at the expense of quality.

Iossa and Martimort (2012) show that if the design and operating efforts of an

[4]See Wilson (1987, ch. 7).

infrastructure PPP are both contractible, and all shocks are perfectly insurable, then bundling or unbundling is immaterial. However, when there is incomplete contracting there is a difference: if productivity (say traffic demand or O&M costs) is observed *ex post*, bundling is preferable so long as uncertainty is limited. Iossa and Martimort (2015a) show that when service or infrastructure quality and operating costs are contractible and project externalities are positive, the preference for bundling continues to hold.[5]

Highways (and tunnels and bridges) have the advantage that quality standards can be contracted and verified easily. This leads to one of the main advantages of highway PPPs: the fact that continuous maintenance is ensured, in contrast to the costlier stop-and-go maintenance of road infrastructure in most countries.[6] Another advantage is that user fees (tolls) can reduce the congestion externality while collecting revenue that pays for all or part of the project. The fact that many European countries highways have availability payments is a political compromise in response to opposition to tolls, rather than an efficient choice.

2.1.3 Funding

Just like traditional projects, PPPs can be funded with budget appropriations or tolls. The standard budget-funded PPP is an availability contract where the government pays the SPV for capital (CAPEX) and operating expenses (OPEX) for a fixed number of years, subject to the SPV meeting the contractual quality standards and keeping the infrastructure available. For example, availability contracts have been used to procure roads in the United Kingdom (see Villalba, Romero and Liyanage, 2016) and the United States (see Poole, 2017).

Some governments have used shadow tolls, a per-vehicle piece rate that emulates standard tolls, but which are paid by the government, not by drivers. Shadow tolls were used in many roads in the UK (see Villalba, Romero, and Liyanage, 2016) and in Portugal (see Sarmento and Reneboog, 2020).

Note that while both availability payments and shadow tolls are funded from the budget, shadow tolls create demand risk both for the concessionaire *and* the budget (see Engel, Fischer and Galetovic, 2014, Table 5.1). By contrast, an availability contract creates a fixed and largely riskless stream of government disbursements for the concessionaire.

Many PPPs are funded with tolls collected by the concessionaire. In most cases, toll-funded concessions are fixed term, which implies that the concessionaire bears substantial exogenous demand risk. An alternative are present-value-of-revenue (PVR) contracts. In a PVR-type PPP, the concessionaire asks for a predefined revenue in present value terms, and the contract lasts until the amount is collected. The term is shorter when demand is high and longer when demand is low, which transfers demand risk to the government/user.[7] PVR contracts were first used in the mid 1980's in the United Kingdom to concession the

[5] Externality in this sense corresponds to the impact of effort in the construction stage on future O&M costs. If positive, more effort in construction reduces costs, and bundling incorporates this effect. Conversely, if effort on quality increases costs, separation is best.

[6] TRIP (2013) estimates a 150% increase in maintenance costs in the US. The higher estimate is from the World Development Report (1994), for developing countries. This cost does not include the costs to users of driving on roads without maintenance.

[7] The residual claimant is the user or the government, depending on whether the toll is kept forever (to collect revenue for the government), or is eliminated at the end of the contract.

Second Severn Crossing and the Queen Elizabeth II bridges. More recently, Chile has auctioned PVR contracts worth several billion dollars (Engel et al., 2021).[8]

2.1.4 Risk allocation

The basic principle of risk allocation is to assign each risk factor to the party best able to manage it. Irwin (2007) applies this principle to infrastructure projects and focuses ohn three dimensions of "risk management":

i. Influencing the risk factor.
ii. Reducing the sensitivity of the project's value to the risk.
iii. Bearing the risk.

This means that in general, construction cost risk should be assigned to the private party, except in those cases, such as tunnels, in which the costs risks are too high and uncontrollable (because of geology). In those cases, the government usually bears the excess risk. The private party also is assigned operating and maintenance cost risk, and availability and performance risks.

Regarding policy risks, the distinction between general policies and those aimed specifically at the project is important. In the first case, which includes interest rate and currency devaluations, the risk should be borne by concessionaires as is the case for firms in other sectors. In contrast, specific policy measures that affect the costs of the project, such as an increase in safety standards or new environmental requirements, should be borne by the public. Similarly, regulatory takings risk should also fall on the public.

In the case of demand risk in tolled PPPs, the risk is usually large and exogenous (given by macro or regional economic factors). It should be assigned to the public, as tolls represent a small proportion of national income, in contrast to its proportion of the revenues for the SPV. Finally, the finance risk should fall on the private party.

2.1.5 Awarding the contract

PPPs are awarded in competitive auctions or direct assignment, perhaps after a negotiated procedure. In general, direct awards are associated to a higher frequency of contract renegotiation and corruption. Knack, Biletska, and Kacker (2017), using data from 88 countries show that open auctions reduce the size of bribes and increase participation. Tran (2009) analyzes internal information from a bribe-paying firm and finds that there is less corruption when biding is competitive, and contracts are awarded following transparent criteria such as the lowest price. Huang (2019) shows that subjective scoring functions, which sometimes include subjective measures of quality, foster corruption.

These results are consistent with Bosio, Djankov, Glaeser, and Shleifer (2020), who show that in well-governed countries, discretion in procurement is to be preferred. In contrast, in countries with weaker governance, less discretion reduces corruption and leads to more efficient outcomes in procurement. Thus, in countries with little corruption,

[8] In some cases, governments fund the PPP with toll revenues, but keep the tolls and use a fixed-term availability contract with the concessionaire. In the United States transit authorities have used this variant to reduce the demand risk borne by the concessionaire (Poole, 2017).

contracts can be awarded on the basis of subjective measures of quality. For example, in New Zealand the government decides the amount of funding for a PPP availability project and an expert panel chooses the best design.

Auctions must be tailored to the type of contract. In the case of availability contracts, the government sets the service standards that the infrastructure must meet, and firms compete on the lowest annual payment. When the PPP is funded with tolls, and the term is fixed, the government sets service standards and firms may bid the toll schedule or the length of the contract term. As a final option, firms bid on the present value of revenues (PVR) and the contract lasts until the winning bid is collected.

2.1.6 Renegotiations

It is well known that PPPs tend to be routinely renegotiated. Many renegotiations occur while projects are under construction or even just after signing. An early influential book by Guasch (2004) studied almost 1,000 PPP projects in Latin America. He showed that more than half (54.4%) of the projects in the transport sector had been renegotiated at least once.

More recently, Engel Fischer and Galetovic (2019) examined 59 PPP highways in Chile, Peru and Colombia. There had been 535 contract renegotiations, leading to yearly increases over the initial planned investment of 9.5% in Colombia, 3.6% in Peru and 1.3% in Chile.[9] This resulted in accumulated renegotiations of 85.1% of initial investments in Colombia, 13.7% in Peru and 16.5% in Chile. Renegotiations generate incentives for bidders to lowball their offers in the expectation of profits in future renegotiations. In turn, this leads to an "adverse selection" problem, as it provides an advantage at the auction to firms that have a comparative advantage in renegotiation vis-a-vis firms that are relatively better in technical aspects.

Moreover, renegotiations of construction contracts (including PPPs) are intimately linked to bribes and corruption, as shown by the Odebrecht corruption case in Campos et al. (2021). Renegotiations of Odebrecht contracts where there was no evidence of bribe payments amounted to 5.9% of initial costs, compared with 70.8% for contracts where there was evidence of bribe payments.

An additional driver is that incumbents use renegotiations to elude spending limits, burdening future administrations and enhancing their reelection probabilities, as shown in Engel, Fischer, and Galetovic (2019). Aguirre et al., (2015) found that Peruvian transport PPPs are renegotiated with higher frequency during election years.

There are two types of contract renegotiations, in the terminology of Laffont and Martimort (2002). There is renegotiation, when both parties agree to renegotiate; and breach of contract, when either party breaks the rules of the contract to its advantage. In the case of PPPs, this distinction is often not clear. The reason is that the government may respond to political aims that diverge from the welfare of society, as analyzed in Engel, Fischer and Galetovic (2019). The government may break the contract either to expropriate the concessionaire or to benefit it at the expense of the public.

Alternatively, renegotiation can improve the profitability of projects for the

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[9]See also Guasch et al. (2007) and Bitrán et al. (2013) who quantify the determinants of government-led renegotiations in Latin America. Also, Guasch et al. (2008) empirically studied renegotiations in transport and water in Latin America

concessionaire ex post (see Menezes and Ryan 2015, Beuve et al., 2018). Renegotiations are possible during the construction phase of a traditional project, but a PPP contract adds the possibility of renegotiation at later stages. The firm may pressure the government to change the terms of the contract to its benefit when demand is lower than predicted or when O&M costs are high. If the concessionaire can pressure the government to renegotiate contracts, the advantages of PPPs may disappear. A firm need not design a project to reduce life cycle costs or be careful about construction costs nor in the estimation of the profitability of the project if it can renegotiate away its mistakes. Indeed, Valero (2015) shows that the ability of governments to pre-commit to a long-term contract is necessary to ensure the realization of the efficiency gains that PPPs promise (see also Spiller 2013). Thus, renegotiations are at odds with the efficient regulation of PPPs.

2.1.7 Unsolicited proposals

Unsolicited proposals are schemes for new PPP projects brought to the attention of the Public Works Authority (PWA). Since they involve a measure of Intellectual Property (IP), the proponents of successful proposals should be rewarded. Often it is firms specialized in PPPs that make these proposals, which need to be assessed, while subject to lobbying by the firm. It is necessary to have a system to filter unsolicited proposals so that only projects that are novel, useful, and non-obvious are accepted. The rewards usually take the form of an advantage in the bidding scores for awarding the project, and this can dissuade competition. A better alternative (see Engel et al (2014)) is to have a periodic competition for projects, in which the PWA chooses the proposals it wants to include in its plans and rewards the proponents with a fixed prize. The PWA becomes the owner of the project, eliminating the IP problems of unsolicited proposals.

2.2. Financing of PPPs

2.2.1 Project finance

As shown in Figure 2, a key component of a PPP is the relation between the SPV and financiers. Project sponsors invest equity and debt holders lend to the SPV. Because the infrastructure has no alternative use, both provide finance against the cash flows of the project, rather than against the assets of the SPV---a financing technique known as *project finance*. Lending against cash flows is feasible because the SPV's focus is narrow, and funds cannot be diverted towards other uses (see Yescombe 2007, and Engel et al., 2014, ch. 5). In their evaluation, financiers focus on the riskiness and the potential profitability of the project.

A PPP project normally involves a large initial investment and a payback period of decades. The initial investment requires management capabilities to subcontract and supervise the contracts with building companies (see Figure 2).[10] Once the project has been built, the SPV contracts with firms that operate and maintain the infrastructure and ensures that the service contract with the government is fulfilled. Once the facility is built, the PPP is often sold to institutional investors, or the short-term construction loans are converted to

[10]Often the sponsor of a project is a building company.

long term bonds and loans.

2.2.2 Leverage

An interesting issue with PPPs is the leverage that is feasible, which depends on how much risk the SPV bears. In the case of an availability contract with annual Capex and O&M payments, the only risks are construction risks, O&M risks and availability risk, i.e., that the project delivers services complying with the standards of the PPP contract. The SPV can subcontract construction and O&M with firms that provide full guarantees. The periodic payments from the State pay for construction debt, O&M and the profits of the SPV. Since construction and O&M costs are guaranteed there is no risk, except for contractual risk. This means that the SPV can obtain financing with little equity. If the PPP contract is a PVR contract, the reduction in demand risk also allows for high leverage. In fact, the Queen Elizabeth II and Second Severn bridges were fully financed with debt and no equity (ITF, 2013).

On the other hand, loading risks on the PPP reduces the leverage attainable by the SPV, but can provide incentives for effort. For example, in a sample of 124 transport PPPs in Latin America, Moore, Straub and Dethier (2014) find that leverage depends on the power of the incentive contract---strong incentives are associated with lower leverage.

2.2.3 Risk and guarantees

When remuneration is based on availability payments there is no demand risk, though there is a residual risk associated with failing to comply with the agreed service quality. When the PPP is funded by toll revenue and the term is fixed, the government often provides a minimum income guarantee to make the project bankable. Otherwise, demand risk may make it impossible for the concessionaire to obtain loans at a reasonable cost.

2.2.4 Valuation of PPPs

As a private investment, prospective investors and lenders need a means of valuing PPP projects. Given that PPP projects confront several risks, including construction cost risk, political risk and demand risk, a straightforward net present value (NPV) approach is inappropriate. Two approaches have been used: calculating the PPP's Value at Risk (VaR) and a real options approach.

A VaR calculates the distribution of the NPV of the project through Montecarlo simulations of the distributions of the key variables. The VaR is the lowest NPV that occurs with a frequency higher than the given confidence level, for instance 95%. This approach was used to value PPPs used in the 90's and early 00's (see Ye and Tiong, 2000), but has become less common since the financial crisis of 2008, since it ignores outcomes deemed as unlikely.

Real options were pioneered by Brennan and Schwartz (1985). In general, this approach consists of adding the real options value component associated to different characteristics of the PPP contract, see Trigeorgis (2005). The literature has concentrated on the valuation of aspects such as management options, minimum traffic guarantees (Galera and Sánchez Soliño 2010, Brandao and Saraiva 2008), exchange rate guarantees, concession extensions, toll adjustments, contract renegotiation, road expansion (Kruger 2012), competition restrictions (Liu et al, 2014) and others (Buyukyoran and Gundes, 2017, Power at al 2016, Lu et al, 2017).

2.3 PPP or traditional provision?

A precondition for successful PPPs, as with infrastructure provision in general, is proper government planning, skilled project design, and efficient project procurement. It is important to note that planning and project design are government tasks under both PPPs and traditional provision. Therefore, a key decision is whether to procure a project as a PPP or with traditional provision.

Many countries use value-for-money tests to make this decision. These tests compare costs under both types of procurement. Ideally, the analyst would estimate the costs of the project under each option and choose the least-cost solution. In practice, governments issue guidelines which are often ---as in the case of the UK--- politically motivated.[11] This implies that, whether a project is procured in the traditional way or as a PPP will often depend on the policy cycle.[12] An additional shortcoming of value-for-money tests is that they eschew quantification of the benefits wrought by the project, which may vary with the type of procurement. For example, if PPPs provide better incentives for highway maintenance than public provision, but these incentives are not incorporated in the comparison, a value-for-money approach will be biased against the PPP option.

An alternative to value-for-money tests is to classify infrastructure into broad classes--- e.g., airports, seaports, highways--- taking into account the incentives created by the different types of infrastructure contracts. Next, one can examine whether the benefits of bundling dominate the costs of PPPs for a particular class of infrastructure assets. Ideally, the best organizational form for providing a specific infrastructure should be determined by the project's physical and economic characteristics.[13] Whether a PPP or traditional procurement is better may depend on the institutional capabilities of a country, so different types of infrastructure may be preferred as PPPs in different countries.[14] This has been the approach, for example, in Chile, where airports, seaports and toll roads are routinely procured as PPPs.

That said, the case for highway PPPs seems particularly compelling. First and as mentioned above, incentives to maintain are inadequate under traditional provision, since it may take years for the effects of insufficient maintenance to emerge. Moreover, repairing a very deteriorated road has political visibility, providing another incentive to lower the allocation of resources to routine maintenance. This leads to a stop-and-go approach to highway maintenance in most developing and some developed countries, which raises

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[11]See Grout (2005) and Ball et al. (2007) for critical appraisals of the Value for Money approach in the UK.

[12]See for example, the so-called optimism uplift bias and other limitations of PFI in paragraphs §36-40 of page 14 of the *Private Finance Projects and off-balance sheet debt Report*, Volume I, House of Lords, Select Committee on Economic Affairs, 17 March 2010, UK.

[13]See EFG (2014, chapter 4).

[14]For example, in some countries, hospital concessions involve only finance, design, construction and maintenance, while in others they may also involve medical services. In the second case there are more opportunities for efficiency gains, which must be weighed against the higher cost of these more complex PPPs due to lack of flexibility in a complex contract and higher risk.

maintenance costs (as mentioned before, it can triple the cost of timely maintenance, according to some estimates) and lowers average quality.[15] On the other hand, if the PPP contract specifies quality standards, the concessionaire has strong incentives to maintain the road because routine maintenance is so much less costly than recovering a deteriorated road. Bundling also provides incentives for the concessionaire to design the project to minimize life-cycle costs.

3. Optimal contracting

PPPs are regulated via contract, and theory offers guidance about appropriate contractual structures. The following approach to the characteristics of the optimal PPP contract is derived from Engel, Fischer and Galetovic (2001 and 2013). Our model assumes that the main driver of risk is exogenous demand for the project (see Trujillo, Quinet and Estache 2002), and that construction, operational and maintenance cost risks, while important, are under the control of the private party and should be assigned to the private party.

3.1 A simple model

Assume that a risk-neutral benevolent social planner hires a concessionaire to finance, build and operate a road that costs $I > 0$. For simplicity we ignore maintenance and operation costs and assume that the up-front investment does not depreciate. The concessionaire is a risk-averse expected utility maximizer, with preferences represented by the increasing, strictly concave utility function u.

Demand uncertainty is summarized by a probability density over the present value of toll revenue that the infrastructure can generate over its entire lifetime, $f(v)$. This density is common knowledge and is bounded from below by v_{min} and from above by v_{max}. For simplicity we assume that demand can finance the road in all demand scenarios, that is, that $v_{min} \geq I$.[16] We assume that v is equal to the discounted private willingness to pay for the project's services (independent of toll and congestion in this section but see section 3.2 for other cases).

The PPP can be funded with tolls and subsidies. Let $R(v)$ be the present value of toll revenues received by the concessionaire during the term of the PPP in state v, and let $S(v)$ be the present values of subsidies paid by the government in state v. Further, let $\text{PS}(v)$ be producer surplus in state v and $\text{CS}(v)$ be consumer surplus in state v. The planner then chooses $R(v)$ and $S(v)$ to solve the following program:

$$max\left\{\int [\text{CS}(v) + \text{PS}(v)]f(v)dv\right\}$$

Subject to the participation constraint

[15]See World Bank (1994, p.4).

[16]See Engel, Fischer and Galetovic (2008 and 2013) for the remaining cases.

$$\int u[\mathrm{PS}(v)]f(v)dv \geq u(0) \qquad (1.1)$$

with

$$\mathrm{PS}(v) = R(v) + S(v) - I$$

$$0 \leq v \leq R(v)$$

Moreover, when choosing $R(v)$ and $S(v)$, the planner has two concerns. One is that subsidies must be funded with distortionary taxation. Thus, we let $1 + \lambda > 1$ be the cost of public funds. Second, subsidy funding is affected by red tape, so we assume that achieving \$1 of useful spending costs \$1 if funded with tolls collected directly by the concessionaire, but $1 + \zeta$ dollars if funded with a subsidy. If subsidies are monetary transfers from the government to the concessionaire, then $\zeta > 0$ means resources are wasted in the process, perhaps because of agency problems facing the budgetary authority when monitoring the government agency in charge of spending. The concessionaire receives $R(v) \leq v$, so the government can use $v - R(v)$ to reduce distortionary taxation. Then:

$$\begin{aligned}\mathrm{CS}(v) &= [v - R(v) - (1+\lambda)(1+\zeta)S(v)] + \lambda[v - R(v)] \\ &= (1+\lambda)[v - R(v) - (1+\zeta)S(v)]\end{aligned}$$

Replacing these last two equations into the planner's objective function is:

$$(1+\lambda)\int [v - R(v) - (1+\zeta)S(v)]\,f(v)dv \qquad (1.12)$$

Thus the planner chooses functions $R(v)$ and $S(v)$ to minimize (1.2) subject to the constraints

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

,

$$0 \leq R(v) \leq v,$$
$$S(v) \geq 0.$$

It is apparent that the optimal contract is independent from λ, the cost of public funds. This might be surprising, but it follows from the fact that toll revenue can substitute for distortionary taxes in the government's budget. That is, at the margin any dollar transferred to the concessionaire, be it via tolls or funded by taxes, costs $1 + \lambda$.

It is also apparent that if $\zeta > 0$, tolls are a more efficient means of compensating the concessionaire than subsidies, hence $S(v) = 0$ for all v. The reason is that the cost to society of one dollar in tolls is $1 + \lambda$, while a subsidy costs $(1+\lambda)(1+\zeta)$.[17] Hence the

[17] $\zeta > 0$ is not a sufficient argument against subsidizing projects, for the project's social value may exceed I, and toll revenue may be insufficient to compensate the concessionaire in low-demand

optimal contract is funded with tolls.

Last, note that $R(v) = I$ for all v is feasible, satisfies the participation constraint with equality, and because u is concave, minimizes the expected cost of meeting constraint (PC). Thus, the optimal contract provides full insurance to the concessionaire.

One implication is that the optimum can be implemented with a present value of revenue contract in an auction. Under such a contract, the term is variable and adjusts to demand realizations---with higher demand the term is shorter. Firms bid the present value of revenue and the lowest bid wins the PPP. The term of the PPP ends when the concessionaire collects the present value of revenues that it bid in the auction.

Another implication is that a standard fixed term contract is inefficient. The problem is that the concessionaire is made to bear risk (or too much or too little revenue, depending on the realization of v) and that does not satisfy the conditions for efficient risk sharing. These conditions are that risk should be transferred to those that can manage it or best bear it. This inefficient transfer of risk creates a cost that, for the case of roads in high demand, is shown in Engel, Fischer and Galetovic (2001) to be:

$$\left(\frac{\mathrm{CV}\sqrt{A/2}}{1-\mathrm{CV}\sqrt{A/2}}\right)\cdot I$$

,
where CV is the coefficient of variation of $f(v)$ and A is the coefficient of relative risk aversion of the concessionaire.

3.2 Tolling and the optimal contract

Thus far we have assumed that v is a fixed quantity in each state. In practice, revenues, usage of the highway, and congestion vary with the toll. Moreover, as is well known, tolls play a key allocative role by managing congestion. The remarkable result is that under the optimal contract the government always charges the optimal toll, both during the PPP and after it ends. Moreover, at the margin, tolling substitutes for distortionary taxation, and the optimal toll is adjusted accordingly. Under the optimal contract, tolling is separable from funding---there is no tension between funding and tolling. It follows that governments can choose their tolling policy independently of whether the highway is procured under traditional provision or with a PPP.

This can be seen in a simple model based on Engel, Fischer and Galetovic (2007). If the level of tolls is a choice variable, the present value of toll revenue depends on the toll being charged. Thus, assume that the toll p is charged both during and after the PPP. We denote by $q(p,\theta)$ the demand for the highway in state θ when the toll is p, by g the probability density of θ, and by $k(q)$ the private cost of using the highway when q vehicles are using it.

Let r be the discount rate and assume that the term of the PPP is $T(\theta)$. Then the present value of toll revenue generated during the PPP is

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states. See Engel, Fischer and Galetovic (2013).

$$\int_0^{T(\theta)} p \cdot q(p,\theta) \cdot e^{-rt} dt = (1 - e^{-rT(\theta)}) \frac{p \cdot q(p,\theta)}{r}$$
$$\equiv (1 - L(r,\theta)) \Pi(p,\theta)$$

where $L \equiv \left(1 - e^{-r\tau(\theta)}\right)$ and $\Pi \equiv p \cdot \frac{q(p,\theta)}{r}$.

Next, let $\mathrm{CS}(p,\theta)$ denote the *discounted* consumer surplus if the toll is p in state θ. and assume that the planner gives weight $\eta < 1$ to the concessionaire's discounted cash flow (for example, because it is a foreign firm). Then the planner's discounted welfare during the PPP is:

$$(1 - L(r,\theta)) \cdot H(p,\eta,\theta) \equiv (1 - L(r,\theta)) \cdot (\mathrm{CS}(p,\theta) + \eta \Pi(p,\theta)),$$

where $H \equiv CS(p,\theta) + \eta \Pi(p,\theta)$. Similarly, after the PPP ends, the planner's discounted welfare is:

$$L(r,\theta) \cdot H(p, 1+\lambda, \theta) \equiv L(r,\theta) \cdot (\mathrm{CS}(p,\theta) + (1+\lambda)\Pi(p,\theta)) \ .$$

Where the parameter λ measures the taxation distortion avoided by toll revenue from the project. Now, for every demand state θ, the planner chooses two prices, the toll paid during the PPP, $p^C(\theta)$, and the toll collected by the government after the PPP ends, $p^G(\theta)$. The planner also sets the PPP term $T(\theta)$. Therefore, the planner chooses functions $P^c(\theta), p^G(\theta), L(\theta)$ and a subsidy $S(\theta)$ that solve the following program:

$$\int [(1 - L(r,\theta)) \cdot H(p^C(\theta), \eta, \theta) + L(r,\theta) \cdot H(p^G(\theta), 1+\lambda, \theta) +$$
$$+ (1 + \zeta)(1 + \zeta) S(\theta)] g(\theta) d\theta$$

subject to the constraints

$$\int u[(1 - L(\theta)) H(p^C(\theta), \theta) + S(\theta) - I] \, f(v) dv \geq u(0)$$

,

$$0 \leq L(r,\theta) \leq 1,$$
$$S(\theta) \geq 0.$$

It can be easily seen that the planner will set $S(\theta) = 0$, because it is less expensive to transfer resources directly to the concessionaire, as toll revenue. There are two important results about optimal tolling that follow from this program. To see the first one, consider first $p^G(\theta)$, the toll charged after the PPP ends. At that stage, the planner maximizes $H(p^G(\theta), 1 + \lambda, \theta)$ and it can be shown that the optimal toll is determined by solving:

$$\frac{p^* - q(p^*,\theta)\cdot k'\big(q(p^*,\theta)\big)}{p^*} = \lambda\cdot\frac{1-\varepsilon}{\varepsilon},$$

where ε is the elasticity of the demand for the highway. The economic intuition is that when demand is responsive to tolls there is an additional margin. The cash flow generated by tolls in each state increases with the toll p. Thus, it is optimal to depart from marginal cost pricing as long as the marginal distortion is smaller than the marginal cost of resources for the government, λ. Note that the particular case where $\lambda = 0$ leads to the standard result in the economics of congestion:

$$p^* = q(p^*)\cdot k'(q(p^*)) \ .$$

The second result is that for all states θ, $p^C(\theta) = p^G(\theta) = p^*(\theta, 1+\lambda)$, that is, the optimal toll charged during the PPP is the same as the optimal toll after the PPP ends. This might seem surprising, because the planner values a dollar in the concessionaire's pocket less than a dollar of additional tax revenues. Nevertheless, as the constraint in program (19a)-(19b) shows, the planner can recover the extra cash flow that the concessionaire receives aa a result of a higher p^C by shortening the term of the PPP. Thus, at the margin the higher revenue generated by raising the toll during the PPP substitutes for distortionary taxation *after* the PPP ends. Thus, the optimal toll is independent of the funding of the PPP.

3.3. Extensions

3.3.1 Further advantages of PVR contracts

There are other advantages to PVR contracts that are important in practice. Note that the PVR contract also provides efficient incentives to invest in innovations that reduce life cycle costs, assuming that welfare reducing cost savings are not allowed, a la Hart (2003), which is also a problem with fixed term contracts. This assumption requires that quality of service be contractible.

Another property of the PVR contract that is valuable for congested roads is that if the congestion reducing efficient toll finances the project, then it is efficient in reducing the congestion distortion. In fact, tolls can be made dynamic and adapted to changing traffic conditions, which is a major advantage of the procedure vis-a-vis fixed term concessions, in which setting the optimal toll may provide rents or losses to the concessionaire, increasing risk even more.

A final property of the PVR approach is that it allows the government to cancel the contract --for instance in response to unforeseen circumstances that dictate an increase in the size of the project, or its joint control as part of an efficiently managed road network, and pay a fair price, acceptable to the concessionaire. This fair compensation is approximately equal to the difference between the winning bid and revenues collected at the time of termination This flexibility can be very valuable in contracts that last for decades and can solve the real risk of unforeseen events.

Chile has been successful in using the PVR contract since the early 2000's. About 55% of its transport PPP contracts by value are variable term contracts (more than $6 bn, with more projects being auctioned at present). Renegotiations during construction and the first eight years of operation under PVR amount to 6.1% of initial costs, compared with 57.2% under fixed term contracts.[18]

3.3.2 Endogenous demand

Thus far we have mostly considered exogenous demand. In many cases, demand for trips at an airport is exogenous, but a large source or revenues is derived from commercial operations, which respond to effort by the PPP. A PVR contract where the bidding variable includes only aeronautical revenues, possibly combined with a risk-sharing arrangement for non-aeronautical revenues, provides optimal risk allocation and incentives to attract demand for ancillary services (Engel et al., 2018). This is a special case, since demand for non-aeronautical services is determined by the demand for aeronautical services, which often (when airports do not compete) may be viewed as exogenous.

In general, when the demand for the infrastructure responds to the concessionaire's effort, as is the case for example in seaports, where fast and diligent service provides a competitive advantage, a PVR contract is no longer appropriate for regulating a PPP. By eliminating demand risk, the PVR contract eliminates the incentives to provide effort to increase demand. In this case a fixed term contract, perhaps allocated to the lowest tariff, provides strong incentives to increase demand, since revenues will increase by taking cost efficient actions.[19] Nevertheless, even though it provides strong incentives, it is not necessarily the optimal contract, because it may assign too much risk to the concessionaire.

Engel, Fischer and Galetovic (2007) examines in detail the case where demand responds to the efforts of the concessionaire. The paper examines the case when costly effort increases the probability of higher realizations of demand, i.e., when the likelihood ratio property holds. In that case, there will be two endogenous bounds. If revenues are below the lower bound, the government provides a partial subsidy; if revenues exceed the upper bound, the government charges a tax. Thus, risk is reduced, but not eliminated, and in particular, in the range between these two endogenous constants, the concessionaire bears the full risk of demand. The contract has the property that the term of the PPP is demand-contingent, being longer when demand is lower. However, now revenues increase with higher demand realizations. Figure 3 shows the revenues of the firm against demand realizations in the optimal contract.

3.3.3 Untolled roads

The optimal contract when the PWA does not charge user fees is the availability contract. In this case the firms compete on the minimum Capex for building, operating and maintaining the infrastructure, given the O&M payments. This is an appropriate contract for infrastructure projects where tolls cannot be charged efficiently, such as rural and

[18]This comparison considers all highway PPPs with at least eight years of operation, see Engel et al. (2021). The numbers remain similar if airport PPPs are also included.

[19]However, it is not clear if this is the optimal risk assignment. Sharing some risk between the government and the concessionaire may well be a more efficient allocation, though difficult to implement in practice.

secondary roads, and when there is no congestion. If service quality can be specified and enforced, this is an optimal arrangement because it eliminates demand risk for the firm, while preserving the incentives to reduce life cycle costs by bundling. Contrast this with the case of a road financed by shadow tolls, where there are no charges on users so there is no congestion reduction, while still assigning the demand risk to the private partner.[20] Clearly, availability contracts are preferable, assuming that the project passes a social cost-benefit assessment.

4. Can private road competition substitute for regulation?

Mohring and Harwitz (1962) show that under constant returns to scale in construction (the cost per unit of capacity is independent of total capacity) and in congestion technology (equiproportional changes in traffic flows and capacity leave the average user cost unaffected), an efficiently tolled road is self-financing and maximizes social welfare.[21] As Verhoef and Mohring (2009) point out, the theorem also extends to dynamic models (Arnott, De Palma and Lindsey 1993); in present-value terms when allowing for adjustment costs and depreciation (Arnott and Kraus,1998); when maintenance and durability are considered (Newbery, 1989); and when input markets are not competitive (Small, 1999). Moreover, Small and Winston (1991) argue that the production function of highways exhibits roughly constant returns to scale. Can toll competition substitute for regulation in a PPP?

De Vany and Saving (1980) show that under constant returns to scale, price-taking private roads set optimal tolls and optimally expand capacity. Nevertheless, this begs the question of whether private roads in a network will behave as price-taking firms. Engel, Fischer and Galetovic (2004) show that the set of Nash equilibrium tolls in a network of private congestible roads is similar to Cournot competition. The equilibrium is inefficient, in the sense that congestion is less than optimal, i.e., tolls are set too high. Only when the road system is replicated many times does the equilibrium tend to the efficient, price-taking solution. Xiao, Yang, and Han (2007) confirm this result in a multi road network with endogenous investment. Assuming constant returns to scale in construction, they show that the volume to capacity ratio in the Nash equilibrium is equal to that in the social optimum. Total traffic flow is lower than the optimum under Nash competition, however, but converges to the social optimum as the number of parallel toll roads increases without bounds. While these results show that there are conditions under which competition among private roads implement the social optimum, these are unlikely to hold in practice, as most networks will not be large because roads are lumpy.

One may conclude, therefore, that toll regulation must be a feature of PPPs, just as price regulation is a feature of natural monopolies.

Conclusions

[20]As mentioned above, a shadow toll contract is one in which the Public Authority pays a specified amount per user of the PPP project.

[21]See Verhoef and Mohring (2009) for a restatement of the result and a synthesis and a review of the literature.

This chapter shows that important policy questions required for the efficient regulation of PPPs have been solved through observation and theoretical analysis. This understanding should bring about better PPP programs. There are many remaining areas of research. There is a need for cross-country studies and data on the interaction between legal and contractual settings and the outcomes from PPP programs in terms of renegotiation, effectiveness of the programs, cost to the government, among others. There is the need for analysis of the political economy of PPPs, both in theoretical as well as empirical aspects. In terms of perceptions, PPPs are often believed to be a close relative of privatization, whereas in various dimensions they are similar to public provision of infrastructure.[22] Would a change in these perceptions improve public support for PPPs?

References

Aguirre, J., 2015. "Electoral cycles and renegotiations of transport infrastructure in concession contracts". In: Arnold Picot, M.F., Grove, N. (Eds.), *The Economics of Infrastructure Provision*. CES-Ifo Seminar Series. MIT Press.

Arnott R, de Palma A, Lindsey R. "A structural model of peak-period congestion: A traffic bottleneck with elastic demand", *American Economic Review* 83 (1): 161 – 179, 1993.

Arnott R, Kraus M . "When are anonymous congestion charges consistent with marginal cost pricing?! *Journal of Public Economics* 67 (1): 45 – 64, 1998.

Beuve, Jean, Aude Le Lannier, and Zoé Le Squeren, "Renegotiating PPP Contracts: Opportunities and Pitfalls," in Julie de Brux and Stéphane Saussier, eds., *The Economics of Public-Private Partnerships: Theoretical and Empirical Developments*, Springer, 2018, pp. 135–162.

Ball, Rob; Maryanne Heafey & Dave King, "The Private Finance Initiative in the UK", *Public Management Review*, 9:2, 289-310, 2007.

Bitran, Eduardo, Sebastián Nieto-Parra, and Juan Sebastián Robledo, "Opening the Black Box Of Contract Renegotiations: An Analysis Of Road Concessions In Chile, Colombia And Peru," Working Paper 317, OCDE April 2013.

Bosio, Erica, Simon Djankov, Edward L. Glaeser, and Andrei Shleifer, "Public Procurement in Law and Practice," Working Paper 27188, NBER 2020.

[22] The UK provides an example of program that lost public support because of a combination of excessive promises and some very public failures, such as the underground PPPs (NAO 2018).

Brandao, Luiz Eduardo T. and Eduardo Saraiva, “The option value of government guarantees in infrastructure projects,” *Construction Management and Economics*, 2008, 26 (11), 1171–1180.

Brennan, Michael and Eduardo S. Schwartz, “Evaluating Natural Resource Investments,” *The Journal of Business*, 1985, 58 (2), 135–157.

Buyukyoran, Faruk and Selin Gundes, “Optimized real options-based approach for government guarantees in PPP toll road projects,” *Construction Management and Economics*, 2017, 3 6 (4), 203–216.

Campos, Nicolás, Eduardo Engel, Ronald Fischer, and Alexander Galetovic, “Renegotiations and Corruption in Infrastructure: The Odebrecht Case,” *Journal of Economic Perspectives*, 2021.

Arthur De Vany and Thomas R. Saving, “Competition and Highway Pricing for Stochastic Traffic”, *The Journal of Business, 53(1)*. 45-60, 1980.

Engel, Eduardo, Ronald Fischer, and Alexander Galetovic, “Least-Present-Value-of Revenue Auctions and Highway Franchising,” Journal of Political Economy, 2001, 109 (5), 993–1020.

Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic, “The Basic Public Finance of Public-Private Partnerships,” *Journal of the European Economic Association*, February 2013, 11 (1), 83–111.

Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic : “The Basic Public Finance of Public-Private Partnerships,” Working paper 13284, NBER, July 2007

Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic, *Public-Private Partnerships: A Basic Guide*, Cambridge University Press, 2014.

Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic “Soft Budgets and Renegotiation in Public-Private Partnerships,” *Economics of Transportation*, August 2019, 17, 40–50.

Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic, “When and How to Use Public-Private Partnerships in Infrastructure: Lessons from the International Experience,” in Edward L. Glaeser and James M. Poterba, eds., *Economics of Infrastructure Investment,* University of Chicago Press, 2021.
.

Guasch, José Luis, *Granting and Renegotiating Infrastructure Concessions: Doing it Right*, Washington: The World Bank, 2004.

Guasch, Jose Luis, Laffont, Jean Jacques and Straub, Stephane, “Concessions of

Infrastructure in Latin America: Government-led Renegotiations", *Journal of Applied Econometrics*, Vol. 22, No. 10. 1267-1294, 2007.

Guasch, Jose Luis, Laffont, Jean Jacques and Straub, Stephane, "Renegotiation of Concession Contracts in Latin America", *International Journal of Industrial Organization*, Vol. 26 p. 421-442, 2008.

Grout , Paul: "Value-for-money measurements in Public Private Partnerships" EIB Papers , European Investment Bank (EIB), Luxembourg, 10(2), pp. 33-56, 2005.

Hart, Oliver, "Incomplete Contracts and Public Ownership: Remarks and an Application to Public-Private Partnerships," *Economic Journal*, 2003, 113 , C69–C76.

Hodge, Graeme A., Carsten Grve and Anthony E. Boardman (2010): *International Handbook on Public-Private Partnerships,* Edward Elgar, UK.

Huang, Yangguang and Jijun Xia, "Procurement auctions under quality manipulation corruption," *European Economic Review*, 2019, 111, 380–399.

Krüger, Niclas A. "To kill a real option – Incomplete contracts, real options and PPP", 2012 *Transportation Research Part A*, Vol. 46 p. 1359-1371.

International Transport Forum, "Better Regulation of Public-Private Partnerships for Transport Infrastructure," 2013.

Iossa, Elisabetta and David Martimort, "Risk Allocation and the Costs and Benefits of Public-Private Partnerships," *RAND Journal of Economics*, 2012, 43 (442-474).

Iossa, Elisabetta and David Martimort: "The Simple Microeconomics of Public-Private Partnerships," *Journal of Public Economic Theory*, February 2015, 17 (1), 4–48.

Irwin, Timothy C. (2007): *Government Guarantees: Allocating and Valuing Risk in Privately Financed Infrastructure Projects.* The World Bank, Direction is Development 39497.

Knack, Stephen, Nataliya Biletska, and Kanishka Kacker, "Deterring Kickbacks and Encouraging Entry in Public Procurement Markets: Evidence from Firm Surveys in 88 Developing Countries," Policy Research Working Paper 8078, The World Bank, Washington, DC 2017.

Laffont, Jean-Jaques and David Martimort, *The Theory of Incentives: The Principal Agent Model*, Princeton University Press, 2002.

Lara Galera, Antonio L. and Antonio Sánchez Soliño, "A Real Options Approach for the Valuation of Highway Concessions," Transportation Science, 2010, 44 (3), 416–427.

Liu, Jicai, Xibing Yu, Charles Yuen, and Jen Cheah, "Evaluation of restrictive competition in PPP projects using real option approach," *International Journal of Project Management*, 2014, 3 2 (473-481).

Lu, Zhaoyang and Qiang Meng, "Analysis of optimal BOT highway capacity and economic toll adjustment provisions under traffic demand uncertainty," *Transportation Research Part E: Logistics and Transportation Review*, 2017.

Menezes, F. and M. Ryan, "Default and Renegotiation in Public-Private Partnership Auctions," *Journal of Public Economic Theory*, 2015, 17, 49–77.

Mohring, Herbert and Mitchell Harwitz, *Highway benefits: An analytical framework*, Evanston, IL: Northwestern University Press, 1962.

Moore, Alexander, Stéphane Straub, and Jean-Jacques Dethier, "Regulation, renegotiation and capital structure: theory and evidence from Latin American transport concessions," *Journal of Regulatory Economics*, 2014, 45, 209–232.

National Audit Office, UK (2018). "PF1 and PF2." Report by the Comptroller and Auditor General. Ordered by the House of Commons to be printed on 17 January 2018.

Newbery D.M.: "Cost recovery from optimally designed roads", *Economica* 56 : 165 – 185, 1989.

Poole, Robert. "Availability Payment or Revenue-Risk PPP Concessions? Pros and Cons for Highway Infrastructure." Reason Foundation, 2017. https://reason.org/policy-study/availability-paymentor-revenue-risk-public-private-partnership-concessions-pros-and-cons-for-highwayinfrastructure/

Power, Gabriel J., Mark Burris, Sharada Vadali, and Dmitry Vedenov, "Valuation of strategic options in public-private partnerships," *Transportation Research Part A,* 2016, 90, 50–68.

Sarmento, Joaquim Miranda and Luc Renneboog, "Portugal's Experience with Public-PrivatePartnerships," in Akintola Akintoye, Matthias Beck, and Mohan Kumaraswamy, eds., *Public Private Partnership s: A Global Review*, Routledge, UK., 2015.

Small K.A.: "Economies of scale and self-financing rules with noncompetitive factor markets", *Journal of Public Economics* 74 : 431 – 450, 1999.

Small K,A., Winston C.M. and Evans C.A.: *Road Work: A New Highway Pricing and Investment Policy* . Washington , D.C. Brookings 1989.

Spiller, Pablo T., "Transaction cost regulation," *Journal of Economic Behavior & Organization*, 2013, 89, 232–242.

Tran, Anh, “Can procurement auctions reduce corruption? Evidence from the internal records of a bribe-paying firm„” Job-market paper, Kennedy School, Harvard 2008.

Trigeorgis, Lenos, “Making use of real options simple: An overview and applications in fexible/modular decision making,” *The Engineering Economist*, 2005, 50 (1), 25–53.

Trujillo, Lourdes, Emile Quinet, and Antonio Estache. "Dealing with demand forecasting games in transport privatization." Transport Policy 9.4 (2002): 325-334.

Valero, V.. Government opportunism in public private partnerships. *Journal of Public Economic Theory* (17), 111–135, 2015.

Verhoef, E. and H. Mohring, Self-Financing Roads, *International Journal of Sustainable Transportation* **3**, 293-311, 2007.

Villalba-Romero, Felix and Champika Lasanthi Liyanage, “Implications of the use of different payment models: The context of PPP Road Projects in the UK,” *International Journal of Managing Projects in Business*, 2016, 9 (1), 11–32.

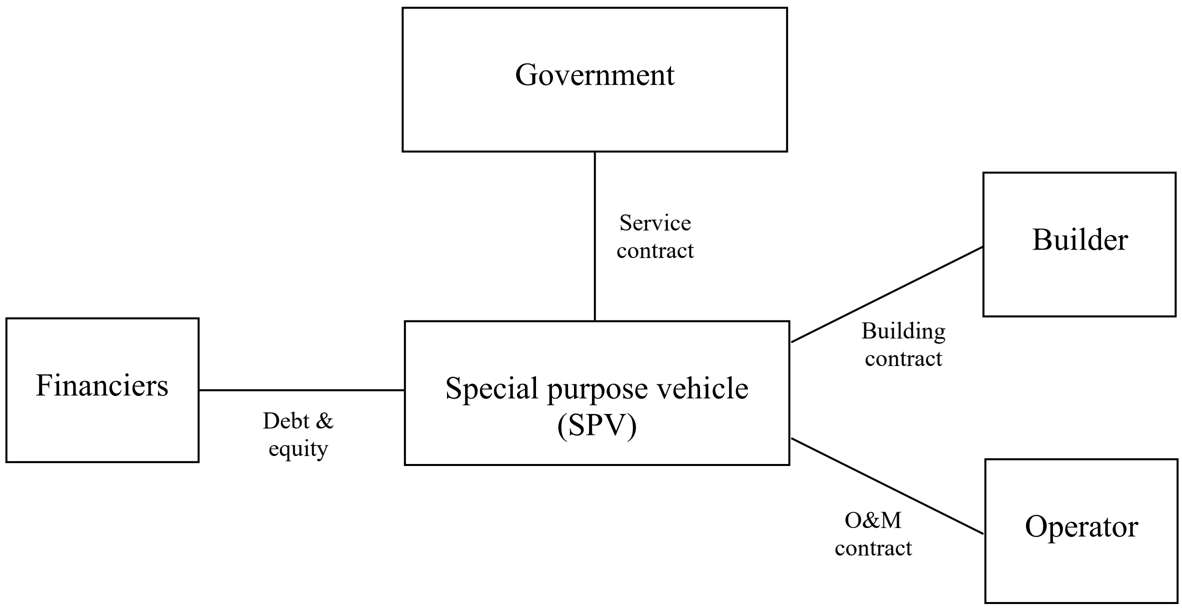
James Q. Wilson, Bureaucracy: What government agencies do and why they do it. New York, Basic Books, 1987.

Ye, Sudong and Robert L. K. Tiong, “NPV-at-Risk Method in Infrastructure Project Investment Evaluation,” *Journal of Construction Engineering and Management*, 2000, 126 (3), 227–233

Yescombe, Edward R., *Public-Private Partnership s: Principles of Policy and Finance*, Butterworth-Heinemaan, 2007.

Figure 1
Contracting under PPPs and conventional provision

(a) PPPs



(b) Conventional provision

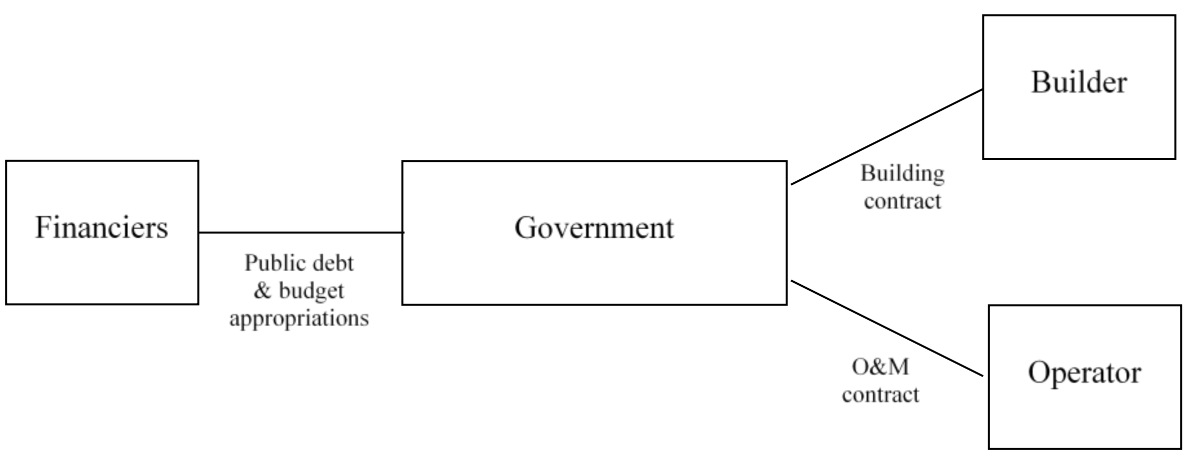


Figure 2

PPPs as a web of contracts (from: Engel et al 2014, op.cit.)