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Abstract

How should the different tasks in an infrastructure project be allocated to private and public agents, respectively? Traditionally, building the physical asset is assigned to private partners whereas financing and operation are carried out by the public sector. But even if building, operation, and possibly financing are delegated to the private sector, the question remains whether all these tasks should be accomplished by a single private agent in the form of a Public Private Partnership (PPP) or assigned to independent firms. To analyze this problem we apply an incomplete contracts approach and consider both informational asymmetries and investment incentives. The advantage of bundling tasks within a PPP is shown to depend crucially on how uncontractible investments in the building stage influence operating costs and service quality. The theoretically derived criteria are then applied to a specific PPP–project: The federal motorway A8 between Augsburg and Munich. Here we particularly discuss whether the chosen way of sharing financing tasks and demand risk within this PPP is likely to be appropriate.

Zusammenfassung

An welchen Kriterien sollte sich die Entscheidung über die bestmögliche Aufgabenverteilung zwischen staatlichen Stellen und privaten Akteuren bezüglich Finanzierung, Erstellung und Betrieb öffentlicher Infrastruktureinrichtungen orientieren? Während die unmittelbare Erstellung der Infrastruktur üblicherweise an private Unternehmen vergeben wird, kann sowohl der Betrieb als auch die Finanzierung in öffentlicher Regie oder durch einen privaten Partner erfolgen. Neben dem Aspekt öffentlich vs. privat stellt sich aber auch die Frage, ob im Fall einer privaten Lösung ein einziges Unternehmen im Rahmen eines Public–Private–Partnership (PPP) sowohl Erstellung und Betrieb (und gegebenenfalls auch die Finanzierung) übernehmen soll, oder ob diese Aufgaben durch voneinander unabhängige Unternehmen durchgeführt werden sollen. Diese Frage analysieren wir im Rahmen des Konzepts unvollständiger Verträge unter Berücksichtigung von Informationsasymmetrien und Investitionsanreizen. Es zeigt sich dabei, dass der optimale Umfang der Aufgabenbündelung innerhalb eines PPP entscheidend davon abhängt, wie sich nicht explizit kontrahierbare Investitionen in der Erstellungsphase auf Betriebskosten und Servicequalität auswirken. Die im Rahmen der theoretischen Analyse herausgearbeiteten Kriterien werden zur Veranschaulichung auf ein konkretes PPP–Projekt angewandt: den Ausbau und Betrieb der A8 zwischen München und Augsburg. Hierbei wird insbesondere diskutiert, ob die festgelegte Aufteilung der Finanzierungsaufgaben und die Übernahme eines Teils des Nachfragerisikos durch den privaten Partner im vorliegenden Fall angemessen sind.

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JEL-classification: H4, H54, H57, L33

1 Introduction

All around the world governments are looking for new ways of providing public services and infrastructure. Tasks that have usually been performed by the public sector are now delegated to private agents. One specific form of such kind of delegation is a Public Private Partnership (PPP). While the concept itself dates back to France in the 17th century [1], it was only quite recently that the economic literature started to deal with PPPs. Public interest seems to be triggered by the so called "Private Finance Initiative" that has been launched in the United Kingdom in 1992. Initially PFIs were concentrated in the transportation sector, but recently they are used in a wide range of areas, including hospitals, schools, roads, public housing, waste management, bridges, etc.

From an economic point of view, the bundling of different tasks (building, operating and financing) is one of the core features that distinguishes PPPs from other forms of public procurement. Following Iossa and Martimort (2008) we compare unbundling and different forms of bundling in an incomplete contract framework. In a moral hazard context with a risk averse contractor we discuss how different institutional forms affect investment incentives and risk shifting. We consider two kinds of PPPs: In the base case the PPP is restricted to building and operating. As shown by Iossa and Martimort (2008) a PPP will then be preferable to unbundling if a quality–enhancing investment in the building stage also reduces the operating cost (positive externality). Having in mind our application — the PPP that is in charge to build, operate and (partially) finance the motorway A8 between Augsburg and Munich — we extend the analysis by considering explicitly that the quality–improving investment may also boost demand for the service. If private financing is coupled with repayment via user charges, such a design of the PPP may provide investment incentives even in cases with a negative cost externality. However, as demand risk is shifted from the (risk–neutral) government to the contractor, it is not obvious whether this kind of PPP

[1] See e. g. Grimsey and Lewis (2005) and de Bettignies and Ross (2004).

actually yields higher welfare. We therefore analyze in detail how the impact of the investment on cost and demand as well as the risk parameters determine the optimal institutional design.

Our paper is closely related to some other contributions to the economic theory of PPPs. The first to mention is the seminal article by Hart (2003). Using an incomplete contract approach, he analyzes the conditions under which bundling of building and operating is preferable. Ignoring the choice between public and private ownership, he concentrates on the bundling decision in a setting with two kinds of investment in the building stage. Both investments decrease operating cost, but only the first one is productive in the sense of improving the quality of the service while the second one is unproductive, i. e. reduces service quality. It is shown that bundling is preferable if the quality of the service can be well specified (and therefore contracted upon) while the quality in the building stage is less easily observable. Bennett and Iossa (2006) also analyze the choice between traditional service provision (unbundling) and PPP (bundling). However, they differ from Hart (2003) by considering different ownership structures and by assuming that there is only one kind of investment in the building stage. Depending on an externality parameter this investment either has a positive or a negative impact on operational cost. It is shown that the bundling of tasks within a PPP is optimal in the case of a positive externality, whereas with a negative externality one should choose the traditional way of service provision. The same result is obtained in Martimort and Puoyet (2008) in a agency setting with complete contracts. Beyond that the paper by Martimort and Puoyet also considers different ownership structures and addresses some aspects of the political economy of PPPs.

The remainder of the paper is organized as follows: In section 2 we present an extended version of the base model from Iossa and Martimort (2008) that allows us to consider the (partial) shifting of demand risk. In order to obtain a reference point for the further analysis, we replicate the results from Iossa and Martimort (2008) concerning bundling vs. unbundling of building and operating in our setting. In section 3 we explicitly analyze how the possibility to shift part of the demand risk to the PPP affects the preferability of this kind of institutional setting. In section 4 we demonstrate the usefulness of our approach by applying the criteria that have been derived in the theoretical model to a specific PPP–project, the motorway A8 between Augsburg and Munich. Section 5 concludes.

2 Bundling of construction and operation

Iossa and Martimort (2008) attempt to provide a general theoretical framework to analyze the incentive issues regarding PPPs. Building on a unified model they identify circumstances under which a PPP is likely to be preferable to traditional forms of public service provision. They define three key characteristics of public private partnerships that are also central to our analysis:

- The first defining feature of a PPP is the bundling of different tasks like designing, building, operating and financing. These tasks may be contracted out to a single private agent or, more commonly, to a consortium of private firms. Such a consortium usually comprises at least a construction firm and a management company that operates the facility after it has been built. The consortium is responsible for all aspects of the service that have been contracted out. In any case at least the building and the operating stage is bundled within a PPP. We analyze reasons for extending the tasks of PPPs to incorporate responsibilities for financing and for letting payments to the PPP to be dependent on realized demand.

- The second main characteristic relates to the degree of risk transfer to the private sector. Compared to traditional provision of public services, a PPP contract involves a greater transfer of risk and responsibility to the private partner. In a PPP the government usually specifies the basic services to be provided and the standards to be met while the consortium controls how to deliver the required services. Thus the private contractor usually bears a substantial amount of design risk, construction risk and operational risk. The aspect of risk transfer plays a crucial role in our analysis as we consider both the transfer of operational risk and of demand risk to the private partner.

- The final key property of PPPs relates to the long–term relationship between the public and the private sector. In general contracts last about 25 to 30 years. During the contract period payments to the private contractor are either made by the government (in the case of PFIs) or by the users of the facility (in the case of more standard concession contracts). To limit complexity we refrain from applying an explicitly dynamic structure in our analysis. However, we discuss how contract length interacts with the transfer of demand risk and we compare the impact of different repayment forms on incentives.

In this section we develop a simple procurement model with moral hazard that incorporates an investment opportunity in the building stage that affects both cost and demand in the operation stage. In a second step we replicate the results from Iossa and Martimort (2008) in our extended setting. These results will then serve as a reference point for the analysis in section 3, where we consider the possibility of giving additional investment incentives by transferring demand risk to the private partner.

2.1 The basic model

In our analysis we compare three institutional designs — unbundling and two different forms of PPPs — in a procurement model. In the first type of PPP only building and operation tasks will be bundled (BO–PPP). The second type also includes aspects of private financing and the transfer of demand risk to the private agent (BOF–PPP).

To provide a public service the government (G) may either close a contract with two private firms, a construction company (F1) and a facility–management company (F2), or with a consortium (F). The eventual provision of the public service requires that an infrastructure of appropriate quality has been designed and built in the first instance. As effort must be exerted in both stages, we have to model delegation in a multi–task framework. In this setting the defining characteristic of a PPP is the bundling of tasks in the different stages of the project.

The construction company (F1) may exert a quality–enhancing effort a. In other words the firm can invest in an improvement of the infrastructure which in turn increases the quality of the service in the operation stage. In a similar way the facility management company (F2) can exert an operating cost–reducing effort e. Both the quality–enhancing and the operating cost–reducing effort causes a monetary cost for the respective agent. To keep things simple, we assume that these costs may be described by two quadratic disutility functions, $\varphi(a) = \frac{a^2}{2}$ and $\psi(e) = \frac{e^2}{2}$.[2] The government is supposed to be risk–neutral whereas private agents are considered to be risk–averse with a constant degree of risk–aversion $r > 0$.

Considering the demand side, the social benefit from the project is divided in two parts: One part that depends on the demand D of consumers and the other part that incorporates any additional benefit B for the society. We assume that demand for the service is inelastic up to some price level p_0:

$$D(p) = \begin{cases} d_0 + a + \eta & \text{if} \quad p \leq p_0 \\ 0 & \text{if} \quad p > p_0 \end{cases} . \tag{1}$$

The random variable η describes the demand risk and is normally distributed with zero mean and variance σ_η^2. d_0 denotes the expected basic level of demand. The quality–enhancing effort a positively affects the demand in the operation stage: the higher the effort, the better the quality of the infrastructure and a better infrastructure in turn implies higher demand for the service.

Taking into account the demand risk and assuming that the government is able to extract all profits from the consortium, the function of social benefit can be written as follows:

$$B = b_0 + b\,a + p_0(d_0 + a) + \eta, \tag{2}$$

[2]Note that this formulation also implies that there are no (dis–)economies of scope between efforts.

where b_0 is the basic level of benefits that occurs even without exerting any effort, and b is the marginal benefit from the agent's effort a ($b > 0$). p_0 is the consumers' maximal willingness to pay. Furthermore it is assumed that the social benefit is not verifiable.

The service provision cost for the private agent that operates the infrastructure can be described by

$$C = \theta_0 - e - \delta a + \epsilon, \tag{3}$$

where θ_0 represents the innate costs of the service, e the effort in cost–cutting activities exerted by the operator, and a the quality–improving effort of the constructor. The latter effort is exerted in the building stage but has an impact on operation costs. There are two possible cases depending on the sign of parameter δ which represents the external effect of effort a on the costs of operation. $\delta > 0$ corresponds to a positive externality, i. e. effort a not only improves the quality of the infrastructure but also reduces operational costs. On the other hand $\delta < 0$ stands for a negative externality, i. e. the quality improving effort raises operational costs. Finally, the operational risk ϵ is a random variable that is normally distributed with zero mean and variance σ_ϵ^2.

It is assumed that a and e are both non–verifiable. Therefore the services are delegated to the private agents in a moral hazard environment. While social benefits are also hardly contractible, demand D and operating costs C can be observed ex post and may therefore be used ex ante when the government and the agent sign the contract.[3]

The timing of the game is as follows: In the first stage the government decides about the organizational structure (unbundling, BO or BOF) and designs an appropriate incomplete contract in order to induce (second–best) efficient effort levels in the following stages. In the second stage, the building stage, the private agent chooses the non–verifiable effort level a. In the last stage, the operating stage, the operator determines his cost–reducing operating effort e. Operating costs C and social benefits B

[3]To abstract from adverse selection issues, it is assumed that the principal and the agent face the same degree of demand and cost uncertainty.

are then determined based on the values of this strategic variables and the realization of the stochastic parameters.

We start our analysis by describing the benchmark case under symmetric information because the results obtained may be helpful when comparing the different types of institutional design later on. First–best levels (a^{FB} and e^{FB}) are achievable when both efforts are observable and contractible. Here the risk–neutral government can fully insure the risk–averse agent through a cost–plus contract. According to this contract after having completed the task assigned to him, the contractor receives a compensation equal to his expenses plus a profit. As the government may run a competitive auction to attract potential service providers, it is assumed that it has all bargaining power ex ante and may therefore choose a fee that exactly equals the outside option of the private agent, which is normalized to zero for simplicity. The private firm is then just indifferent between providing the service or not. Additionally, the contract is constructed so as to force the private agent to choose the first–best effort levels that maximize social benefits:

$$\left(a^{FB}, e^{FB}\right) = \arg\max_{(a,e)} b_0 + p_0(d_0 + a) - \theta_0 + (b + \delta)a + e - \frac{a^2}{2} - \frac{e^2}{2} = \qquad (4)$$

$$= (b + p_0 + \delta, 1). \qquad (5)$$

The first–best quality–enhancing effort a^{FB} trades–off the marginal cost of this effort with its marginal social value that includes the external effect on the operating costs and the impact on the social value of the service as well as on the consumers' maximal willingness to pay. The operating effort e^{FB} on the other hand trades–off the marginal benefit of reducing the operating costs with its marginal monetary disutility. In this complete information context the organizational structure is irrelevant.

2.2 Unbundling vs. bundling of construction and operation

We turn now to the more realistic setting under moral hazard and compare unbundling with a PPP where the consortium is responsible for both building and operation. However, we still assume that the financing task is performed by the public sector and that the private partner does not bear any demand risk. Under both organizational settings the government is assumed to propose a linear contract that imposes the private operator to some operational risk in order to induce appropriate incentives.

Unbundling Under traditional provision (unbundling) the government G contracts separately with the builder F1 and the operator F2, respectively. As in Iossa and Martimort (2008) we assume for simplicity that F1 receives a fixed fee and therefore bears no risk.[4] The fixed payment means that F1 will not be rewarded for effort a which implies that he will in turn not exert any effort at all:

$$a^U = 0. \tag{6}$$

F2 obtains an incentive payment that depends on realized cost C. Given the CARA–utility function of the private agent, we restrict attention to linear contracts of the form $t(C) = \alpha - \beta C$. Here the parameter β determines the power of the incentive scheme. If $\beta = 0$ we get a cost–plus contract that does not provide any incentives for cost reduction whereas $\beta = 1$ yields a fixed–price contract. As the operator has to bear the operational risk, he must receive a risk premium $\frac{r\sigma_\epsilon^2\beta^2}{2}$. Facing this contract, F2 is assumed to maximize the certainty equivalent of his expected utility. His incentive constraint is then given by

$$(e) = \arg\max_{\tilde{e}} \alpha - \beta(\theta_0 - \tilde{e}) - \frac{\tilde{e}^2}{2} - \frac{r\sigma_\epsilon^2\beta^2}{2} = (\beta). \tag{7}$$

The interpretation of the maximization problem is straightforward: An increase in β leads to an increase in the cost–reducing effort e, but as more operational risk is transferred to the operator, the risk premium has to be increased as well. As G is assumed to have all bargaining power ex ante, he will choose a fee α that just leaves the operator indifferent between providing the service or not. Note, however, that the

[4] Iossa and Martimort (2008) show that their basic result concerning the preferability of bundling in the case of a positive externality is not affected by this simplifying assumption.

total expected payment to the operator must cover the risk premium. Providing higher incentives for the operator is therefore costly.

Government G maximizes social welfare taking into account the incentive constraints of the builder and operator, the total benefit and cost of effort including the risk premium:

$$\max b_0 + p_0 d_0 - \theta_0 + e - \frac{(1 + r\sigma_\epsilon^2)}{2} e^2. \tag{8}$$

The second–best level of the operating effort under unbundling is then

$$e^U = \frac{1}{1 + r\sigma_\epsilon^2} < 1 = e^{FB}. \tag{9}$$

By inserting e^U in G's function the social welfare level equals:

$$W^U = b_0 + p_0 d_0 - \theta_0 + \frac{1}{2(1 + r\sigma_\epsilon^2)}. \tag{10}$$

Compared to the first–best both quality–enhancing and operating efforts are lower in the second–best situation under unbundling. The builder does not exert any quality–enhancing effort a, as the fixed payment he receives does not give him any incentives to do so. The operator on the other hand exerts some effort e, but since he has to bear operational risk which is socially costly, the government will not give him enough incentives to obtain the benchmark effort level.[5]

Bundling of construction and operation Under bundling the government signs a single contract with a consortium of private firms (F). With this type of institutional design both building and operation of the infrastructure are accomplished by the same entity. In this case the expected payoff of the consortium is maximized when the effort

[5]This result is standard with the applied linear–CARA model.

levels are jointly chosen to solve:

$$(e, a) = \arg\max_{\tilde{e},\tilde{a}} \alpha - \beta(\theta_0 - \tilde{e} - \delta\tilde{a}) - \frac{\tilde{a}^2}{2} - \frac{\tilde{e}^2}{2} - \frac{r\sigma_\epsilon^2\beta^2}{2}. \tag{11}$$

Taking into account that the non–negativity constraint $a \geq 0$ holds, the incentive constraints can be written follows:

$$e = \beta \quad \text{and} \quad a = \begin{cases} \beta\delta & \text{if} \quad \delta > 0 \\ 0 & \text{if} \quad \delta \leq 0 \end{cases}. \tag{12}$$

For the analysis we have to consider two cases depending on the sign of the externality (δ).

Negative externality, $\delta \leq 0$

Proposition 2.1 *With a negative externality ($\delta \leq 0$), bundling and unbundling yield the same effort levels and in turn the same social welfare.*

Proof Under a negative externality F does not exert any quality–enhancing effort a, since the firm does not receive a direct reward and higher quality would increase future operating costs. The level of e corresponds to the second–best effort level under unbundling:

$$a^{BO} = a^U = 0 \quad \text{and} \quad e^{BO} = e^U < e^{FB}. \tag{13}$$

The social benefits are in turn equivalent in both cases:

$$W^{BO} = W^U. \tag{14}$$

■

Positive externality, $\delta > 0$ With a positive externality the situation is slightly different. The consortium maximizes its expected payoff by jointly choosing appropriate positive values for the quality–enhancing and the operational effort. Here the consortium F partially internalizes the positive impact of the quality–improving effort a on operational costs. Increasing the power of the incentive scheme β — or in other words moving closer to a fixed–price contract — now raises a. Since quality is not contractible this objective could not be directly achieved by the government. As risk transfer is more effective on incentives under these conditions the operating cost–reducing effort e will be higher than in the previous cases.

Proposition 2.2 *Under a positive externality ($\delta > 0$) bundling strictly dominates unbundling.*

Proof The maximization problem of F yields the following effort levels:

$$\tilde{e} = \beta \quad \text{and} \quad \tilde{a} = \beta\delta. \tag{15}$$

Turning to social welfare the government's maximization problem is as follows:

$$\max b_0 + p_0(d_0 + a) - \theta_0 + (b + \delta)a + e - \frac{a^2}{2} - \frac{(1 + r\sigma_\epsilon^2)}{2}e^2 \tag{16}$$

subject to $a = \delta e$ according to (15). The first–order conditions yield

$$e^{BO} = \frac{1 + \delta(b + p_0 + \delta)}{1 + \delta^2 + r\sigma_\epsilon^2} \quad \text{and} \quad a^{BO} = \delta e. \tag{17}$$

Based on these effort levels we can calculate expected welfare for the case with a positive externality. Comparing social welfare and effort under unbundling and bundling, respectively, we obtain

$$W^{BO} > W^U \quad \text{and} \quad a^{BO} > a^U = 0 \quad \text{and} \quad e^{BO} > e^U. \tag{18}$$

$\blacksquare$

Note that in the case of a positive externality bundling not only strictly dominates unbundling but that the welfare gain increases in the magnitude of the externality δ. Furthermore, both quality–enhancing and operational efforts are higher than in the other second–best cases. Thus PPP projects with a positive externality are associated with higher powered incentives and with more operational risk transferred to the private agent. It seems important to mention that in reality moving from traditional service provision to a PPP is also likely to change the cost–reimbursement rule. Bundling and fixed–price contracts are common under PPPs, whereas unbundling and cost–plus contracts usually occur under the traditional way of procurement. As shown in Iossa and Martimort (2008) the outcome of the analysis would not be changed if a complete contract environment with a noisy signal about asset quality is assumed. While the agency problem under unbundling would be eased, it still holds that bundling is preferable in the case with a positive externality.

3 Financing and sharing of demand risk

In the last section we showed that it may be advantageous to bundle building and operation within a PPP if a non–contractible quality enhancing effort a at the building stage exerts a positive externality on costs in the operation stage. Hereby we assumed that the incentive payment to the contractor only depends on operating costs and thus the firm ignores the impact of a on demand. Looking at PPPs in reality, we find that the private partner quite often has to bear at least part of the demand risk. As another departure from the model in section 2 it is also common that the consortium is involved in the financing of the project. Note that these two aspects are closely related as the firm may be allowed to collect user charges to cover the cost of the privately financed initial investment in the building stage. If the consortium is not responsible for financing, it might be necessary to write a contract that stipulates negative payments for low realizations of demand. Such a contract, however, may not be enforceable ex post due to liquidity constraints. A PPP that is also responsible for financing would ease this problem as sufficient funds must be provided ex ante.

We try to incorporate the basic aspects of financing and bearing of demand risk in our model in a way that avoids the complexity of an explicitly dynamic structure. Therefore we do not directly deal with financing but just assume that financing by the consortium makes it feasible for the government to induce demand dependent incentives via user charges. In our setting with inelastic demand this can be done straightforwardly by allowing the firm to charge an amount $p \in [0, p_0]$ from users. By fixing p appropriately the government is able to adjust the incentive scheme optimally to the extent of externalities and the degree of risk aversion. Based on (1) expected revenue is given by

$$E_\eta(R) = pE_\eta(\max d_0 + a + \eta, 0) \approx p(d_0 + a). \tag{19}$$

Note that the approximation holds when σ_η is small enough compared to the base level of demand d_0 which seems to be reasonable in our setting and therefore will be assumed in the following analysis.

According to these assumptions the contractor maximizes the uncertainty equivalent of his expected utility and his incentive constraint can be written as follows:

$$(a, e) = \arg\max_{\tilde{a},\tilde{e}} p(d_0 + \tilde{a}) - \beta(\theta_0 - \tilde{e} - \delta\tilde{a}) - \frac{\tilde{a}^2}{2} - \frac{\tilde{e}^2}{2} - \frac{r\sigma_\epsilon^2}{2}\beta^2 - \frac{r\sigma_\eta^2}{2}p^2$$
$$= (p + \beta\delta, \beta). \tag{20}$$

Using the above incentive constraints of the contractor by eliminating the slope of the cost incentive scheme β and substituting the user charge p by the consumer valuation p_0 yields the following maximization problem for the government:

$$\max b_0 + ba + p_0(d_0 + a) - \theta_0 + e + \delta a - \frac{a^2}{2} - \frac{e^2}{2} - \frac{r\sigma_\epsilon^2}{2}e^2 - \frac{r\sigma_\eta^2}{2}(a - \delta e)^2$$
$$\text{subject to} \quad a = p + \delta e \tag{21}$$

Optimization results in the following second–best effort levels:[6]

$$a^{BOF} = \frac{(b + p_0 + \delta)(1 + r\sigma_\epsilon^2) + r\sigma_\eta^2\delta(1 + \delta(b + p_0 + \delta))}{1 + r\sigma_\epsilon^2 + r\sigma_\eta^2(1 + \delta^2 + r\sigma_\epsilon^2)} \quad \text{and}$$

$$e^{BOF} = \frac{1 + r\sigma_\eta^2(1 + \delta(b + p_0 + \delta))}{1 + r\sigma_\epsilon^2 + r\sigma_\eta^2(1 + \delta^2 + r\sigma_\epsilon^2)} \quad (22)$$

As these terms are to complicated to allow a direct intuitive economic interpretation, we will first discuss the impact of δ on differences between the second best effort in the BO and the BOF setting, respectively. For $\delta \leq 0$ no investment incentives can be given in a BO–PPP. On the other hand in the case of a BOF-PPP positive levels of a may be induced via appropriately fixed user charges p. Note, however, that decisions on β and p are only independent for $\delta = 0$ as costs are negatively affected by higher levels of a if $\delta < 0$. For determining the optimal level of investment incentives in the case with negative externalities the government has to consider a trade–off between the positive impact on demand and social benefits and the negative impact due to rising costs in the operation stage and the higher risk premium. If $\delta > 0$, however, it depends on the relative importance of operational and demand risk and the exact value of delta whether incentives for a should be given mainly via user charges or via high powered cost incentives.

In a next step we will now ask the central question: Under what circumstances will the government prefer the institutional structure of a BOF–PPP relative to unbundling or a BO–PPP? In answering this question we will first consider the case were β and p may be both freely chosen in the case of the BOF–PPP. As PPP–contracts with private financing and repayments via user charges usually also stipulate that the contractor has to bear the operational risk ($\beta = 1$), we will subsequently discuss implications for this more realistic incomplete contract setting.

Proposition 3.1 *A BOF–PPP where β may be freely chosen between zero and one*

[6]For high negative values of δ it is possible that the term for a^{BOF} gets negative. As negative values of a are not feasible, p should be set to zero in this case and we are back in the BO–case with negative externalities.

strictly dominates a BO–PPP and unbundling if the equilibrium user charge p^* exceeds zero.

Proof The BOF–PPP introduces an additional instrument to influence the level of the quality enhancing investment a. As the government is free to chose $p^* = 0$, it could always replicate the result of a BO–PPP. A value of p^* that exceeds zero will therefore only be chosen if this raises welfare. This proofs that the BOF–PPP with $p^* > 0$ strictly dominates the BO–PPP. The proof is completed by the fact that propositions 2.1 and 2.2 jointly imply that unbundling is weakly dominated by a BO–PPP. ■

We will now simplify the problem by setting the incentive scheme β equal to 1. If this is assumed for all three institutional settings, we can obtain a straightforward condition that ensures that $p^* > 0$. As $e = \beta = 1$ we get the following second–best quality enhancing effort level a^{BOF}:

$$a^{BOF} = \frac{b + p_0 + \delta + r\delta\sigma_\eta^2}{1 + r\sigma_\eta^2}. \tag{23}$$

For positive externalities $a^{BO} = \delta$ if $\beta = 1$. Rearranging the term for a^{BOF} it can easily be seen that $a^{BOF} > a^{BO}$. However, for substantial negative externalities it may be the case that $a^{BOF} \leq 0$ and therefore p^* would be set equal to zero. Therefore we obtain the following result:

Proposition 3.2 *Given that $\beta = 1$ in both institutional settings, a BOF–PPP strictly dominates unbundling if $(b + p_0)/(1 + r\sigma_\eta^2) > -\delta$.*

Proof A BOF–PPP strictly dominates unbundling if it is welfare enhancing to set $p^* > 0$, which in turn induces a positive level of a. It is therefore sufficient to show that the second–best effort a^{BOF} given in equation (23) exceeds zero. Rearranging the resulting expression to get $-\delta$ on the right hand side yields the expression in proposition 3.2. ■

What can we learn from this theoretical analysis for practical applications? In a more realistic incomplete contract setting the government will not allways be able to fine tune the incentives by setting second–best optimal values of β and p. In this case the theoretically derived advantage of the BOF setting is no longer generally assured. If, for example, demand risk is relatively high it will still be optimal to give some incentives for the quality enhancing investment by the way of a demand dependent payment. However, a "full BOF" where the private partner must completely finance the project and gets his initial investment solely repayed via user charges might be inappropriate as it exposes the private firm to too much risk.

In order to decide about the appropriate institutional form, all feasible specifications of contracts have to be considered (for example partial financing by the private partner or making part of the repayments independent of demand). For deciding between these specifications the government must then ascertain the extent of the demand risk and the likely importance of non–contractible quality enhancing investments in the building stage. As a rule of thumb, the "full BOF" described above is quite likely to be inappropriate in situations with substantial demand risk. Limiting the exposure to demand risk will generally be an important issue in BOF-PPPs, especially when considering the high level of uncertainty due to the long term nature of PPPs. However, while restricting the responsibility of the private partner to building and operating in a BO-PPP would completely eliminate the demand risk, this solution has the disadvantage that investment incentives for the building stage will only result in the case of a positive externality on costs in the operation stage.

4 Application: Extension of motorway A8 in Bavaria

Since the introduction of Public–Private Partnerships as an institutional setting for public procurement, road construction and -maintenance have been one of the areas where PPPs are used quite frequently. Especially in the last two decades a lot of experiences have been made with such kind of PPPs and these projects predominantly turned out to be successful. Despite this fact, the number of projects in Germany is relatively small. Actually, the first PPP–project for building and operating a German federal motorway ("Autobahn") relates to our example — the A8 between Munich and Augsburg in Southern Bavaria.

The A8 is an important corridor in Southern Germany belonging to the Trans-European Network (TEN). Most parts of the motorway are still in prewar condition and the number of users per day accounts for 60 to 100 thousands, thus it is of particular importance that the quality of the road will be improved as quickly as possible. The motorway currently has two lanes in each direction with soft shoulders. When reconstruction is complete, there will be three lanes open for traffic in each direction with hard shoulders.

The A8–project was initiated years ago, but construction did not start before last year. In May 2007 the consortium "Autobahnplus ("a+") began its work on the approximately 37 km segment of the motorway between Augsburg/West and Palsweis. "Autobahnplus" is a consortium formed by BAM PPP, Trapp Infra Wesel (VolkerWessels), Fluor Infrastructure, Berger Bau and Egis Projects. The client is the Motorway Authority for Southern Bavaria (Autobahndirektion Südbayern) on behalf of the Federal Ministry of Transport. The value of construction activities is approximately 250 million Euros. The extension of the motorway by the consortium partners and Wayss & Freytag Ingenieurbau (BAM) is planned to be finished in December 2010. During the 30 years concession period the consortium will be also responsible for the operation and maintenance of an additional 15 km long stretch of the motorway near Munich, implying a total concession length of 52 km. The outside capital needed for financing has been provided by the Defpa Bank (headquarters Ireland) and the Spanish Banco Santander Central Hispano, S.A. During the concession period the consortium receives the revenues from freight vehicle tolls collected on the concerned motorway. There has been also a start–up financing from the federal budget, which allowed for a lower level of initial investment by the private partner.

In the following we will apply the criteria developed in the theoretical model to evaluate the A8 project from an economic perspective. The theoretical model states that the choice between bundling and unbundling depends primarily on the impact of a non–contracitble quality enhancing investment in the building stage on operating costs. If a positive externality on operating costs between stages can be observed, bundling of tasks always dominates traditional service provision. Things are less clearcut in the case of a negative externality. Here bundling and unbundling yield identical results as long as the contract only stipulates cost–based incentive payments. As shown, appropriate incentives may be given by demand based payments like the freight vehicle tolls that will be received by Autobahnplus. However, that means that the private partner has to bear at least part of the demand risk, which will be only appropriate if this risk is not to high. Demand risk may be limited by obtaining reliable demand forecasts and by shifting only part of total risk.

Let us first deal with the reliability of forecasts. The risk associated with traffic demand belongs to the wider group of commercial risks which usually arise due to uncertainty in the marketplace. Regarding the transfer of demand risk in the transportation sector very different experiences have been made so far. Historically demand forecasts tended to overestimate actual demand by 20 to 30%.[7] This may be partially due to an winner's curse problem as projects with overestimated demand are more likely to be carried out. Demand forecasting techniques have improved markedly in the last years, particularly due to intensified economic research in this field which generated more reliable methods. The practical importance of demand forecasting has sharply increased with the growth of privatization in the transportation sector. Traffic studies recently tend to be done by private firms in preparation for their bids to operate a service. Government–provided traffic studies are viewed as unreliable by private operators since the government has an incentive to "overestimate" the potential future demand in order to extract the highest possible fiscal gains from privatization efforts.[8]

Considering the amount of demand risk transferred to the private sector the chosen methods of financing and repayment are crucial. Three forms may be distinguished.

[7]See Medda (2007)p.214.

[8]See Trujillo et al. (2002)

Under an availability payment scheme the private contractor is compensated by a periodic payment based on lane availability, level of service or similar demand independent indicators. This resembles the BO–PPP discussed in section 2. Another possibility is the application of a shadow toll, i. e. a payments provided by the government based on the number of vehicles using the road. The third method is a real toll scheme where users of the road have to pay user charges. In the latter case, which is comparable to the BOF–PPP from section 3, usually a relatively large part of the whole demand risk is transfered to the private sector.

In our example, the A8 motorway, the so–called A–model has been used in the concession contract between the consortium and the Bavarian federal state. The A–model is the designated financing scheme for PPPs dealing with the extension of federal motorways in Germany. Similar modes are used in road projects in other countries such as the Netherlands. In this setting the private partner receives a concession contract for the design, construction, maintenance, operation and financing of a predefined section of a motorway. The funding of the project occurs through user charges for heavy vehicles (> 12 tonnes). Note that these charges are determined by the government in a pre–specified legislative process. Furthermore, the concession partner receives a one–time start–up financing as compensation for traffic by passenger cars and other smaller vehicles that are exempted from the toll–payment.

As passenger cars do not underlie user charges, part of the demand risk is already eliminated. Most importantly, the risk that traffic is switching to alternative toll–free roads is reduced substantially as this option is much less viable for heavy vehicles. In the case of the A8 motorway the consortium "a+" receives revenues directly through toll payments from heavy vehicles. Transferring demand risk to the contractor raises his incentives to boost demand and increase consumer surplus. However, the government has to compensate the private partner by paying a higher risk–premium. Since demand levels are likely to be affected substantially by the private partner's actions and since the quality of the infrastructure has a strong impact on the value of the service, it should nevertheless be desirable that at least part of the demand risk is borne by the contractor.

Until now we based our appraisal of the institutional setting solely on the criteria developed in our model. As there are other important aspects as well, we want to highlight at least two of them.

- One point relates to the contract length which is specifically interesting with respect to the allocation of construction risk and to private financing. One of the most important reasons to increase contract length lie in the fact that financially free–standing projects bring additional costs. To allow the firm to recoup his initial investments, the contract has to be longer. Regarding the A8 between Munich and Augsburg the concession period takes 30 years, including the period of the extension of the motorway. Since the contract period includes the construction period as well, it follows that the endogenous risk associated with the length of the construction period is also transferred to the contractor. This gives the private partner a higher incentive to complete the extension as soon as possible.[9] Furthermore, as the private partner is also (at least partly) responsible for the financing of the project, he suffers the consequences of a delay in construction even more. This strengthens his incentives to finish on time and on budget.

- Another point we would like to mention is the aspect of external finance. In the case of the A8 motorway external capital has been provided by two banks, by the Defpa Bank (headquarters Ireland) and the Spanish Banco Santander Central Hispano, S.A. External finance of PPP–projects has often been criticized by experts for damping the consortium's incentives since the firm has to share its profits with external investors and so the advantages from bundling of tasks diminish. On the other hand proponents argue that especially in the case of very complex projects specialized outside financiers can lead to more effective monitoring as economies of scale in monitoring may be realized. However, in our

[9] See also Sadka (2008).

example it is not only external capital that is being used for the project. The federal government also provides a one–time start–up financing for the consortium, implying that the initial capital investment is reduced, which in turn decreases the amount of investment required from the consortium and thus mitigates potential problems caused by external finance [10].

To sum up, it seems to be quite likely that the government has chosen a sensible institutional structure for the A8–project. The transfer of demand risk should give enough incentives for quality enhancing investments in the building stage. On the other hand demand risk is limited as only heavy vehicles are considered as toll-payers. This reduces the risk premium that has to be paid to the private partner. While initial financing requirements are relatively high, the public start–up financing partially mitigates this problem and the length of the contract period ensures that investments of the private partner can be recouped. As has been argued, contract length and private financing also provide incentives to complete the construction on time and on budget. Furthermore, while the necessity of external finance might have a negative impact on the incentives of the private contractor, this negative effect may be offset by better monitoring capabilities of specialized outside investors. Thus we can conclude that the efficiency gains from the chosen institutional setting are likely to be large enough to compensate for any frictions caused by the agency problems in the partnership between the consortium and the Bavarian federal state. Beyond that it may be noticed that although so far little experience is available relating to PPPs in the German motorway sector, existing projects in other countries show relatively strong evidence that partnerships work well in this field.

5 Conclusion

Public Private Partnerhips are becoming a more and more common form for the provision of public services or infrastructure. From an economic point of view, the core

[10] See also Dewatripont and Legros (2005)

characteristic of PPPs is the bundling of some or all of the different tasks of a project, namely design, building, operation and finance. A closely linked second aspect is the transfer of a greater degree of risk and responsibility to the private partner. It has been shown that bundling may be preferable if non–contractible investments in one stage influence costs or benefits in another stage of the project. To provide appropriate investment incentives, the contractor's compensation must depend on cost, output and/or service quality. In turn, the private partner in a PPP has to face a greater degree of cost and demand risk than under traditional procurement.

In our theoretical analysis we discussed how the form of externalities between the building and the operation stage as well as risk parameters affect the desirability of two specific forms of PPPs. The first one is the standard form of a PPP that bundles building and operating. Here the private partner has only to face operational risk, but incentives for quality improving non–contractible investments may be insufficient. The second form includes (partial) responsibility for financing on behalf of the private partner and lets the repayment of this investment depend on the revenues in the operating stage. While this may yield more appropriate investment incentives in the building stage, it will also expose the private actor to demand risk. We showed that the latter institutional design is likely to be preferable if (i) quality enhancing investments in the building stage negatively affect operating costs, (ii) higher quality raises demand, and (iii) demand risk is relatively low. To demonstrate the usefulness of our approach, we applied our results to a specific project — the six-lane development of the A8 motorway between Augsburg and Munich. We argued that the chosen institutional design is likely to be appropriate given the specific circumstances of this project.

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