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Effect of internal conflicts among private sponsors on bundling and risk sharing in PPP projects

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Abstract: Public-private partnership (PPP) projects are characterized by the bundling of construction and operation phases and risk sharing, which motivate private sponsors to enhance project efficiency throughout its life-cycle. However, internal conflicts of interest among sponsors can potentially distort these incentives. Building on agency theory, this study presents a game model to examine the effect of internal conflicts among private sponsors on bundling and risk sharing. The results show that the degree of the bundling and risk transfer from the government to private sponsors depend on the sponsors' shareholding and capabilities. This study contributes to the PPP knowledge body by introducing the internal conflicts among sponsors into the incentive mechanism of risk-sharing between the government and private sponsors. The findings also provide support for the government to formulate risk-sharing strategies and shed light on the sponsor selection of PPP projects.

Key words: PPP projects, operational sponsors, bundling, risk sharing

1. INTRODUCTION

A public-private partnership (PPP) is defined as a long-term contractual agreement between public and private sector partners, which allows private sector partners to provide some or all financing, design, construction, operation, and maintenance of infrastructure facilities and ancillary services [1]. The main motivation of governments for embarking on PPPs for the delivery of public infrastructure is that the private sector is believed to be better at performing complex technical tasks, stimulating innovation, and adapting to rapid changes, compared to the public sector [2]. The financial and technical strength of the private sector would be highly helpful for implementing the projects more cost-effectively and efficiently [3] Thus, an active participation of the private sector in all phases of the project life cycle may help to secure better value for money (VFM) in the PPP project than the traditional procurement model, where the private sector's role is mainly limited to the construction phase.

The bundling of construction and operation phases into a single contract is one of the key characteristics of the PPP project [4]. If the design, construction, and operational tasks are entrusted to a private consortium, the bundling of project phases encourages the consortium to evaluate the implications of its actions at different stages of the project, thus favouring a whole-life costing approach [5]. Bundling is usually done by transferring risks from the government to the private partners. The more the risk the government transfers to the private consortium, the greater intensity of incentives provided to the private consortium [6].

Thus, PPPs are characterized by a bundling of building and operating tasks and risk sharing between the government and private partners. However, a simplifying assumption made in prior research was that the formation of a consortium created a single contractor. In fact, the transaction of PPPs is constructed by using a special purpose vehicle (SPV) which acts as the management and operating company for the projects and a subject that signs project contract with the government. Typical sponsors for PPP projects including "operational" investors and "financial" investors would form the SPV. The former usually are building firms and service operating firms for whom investment is part of a strategy for securing other business as subcontractors to the SPV, while the latter includes banks, life-insurance companies, pension funds or infrastructure-investment companies or funds [7]

Recent studies have mainly focused on the conflicts of interest between governments and private partners and analysed how to align the interests of two parties via a proper incentive mechanism, e.g., revenue sharing [8], government supervision [9], and government guarantee [10]. However, the conflicts of interest between the private partners receive limited attention. It is widely believed that placing these risks (i.e., conflicts among the private partners) squarely on the SPV's owners will insulate the government and public from harm due to any conflicts of interest internal to the SPV [11]. However, as Martimort and Pouyet [12] indicated, "the benefit of a coordinated choice of efforts might be somewhat dissipated by internal agency problems". This means the relationship among private partners may weaken the effects of incentive mechanisms designed to align the interests between the government and private partners.

Consequently, this study aims to address the following research questions: (1) How does the conflicts of interest between the private partners (e.g., building firm and operating firm) affect their motivations to invest in the project? (2) How to design the risk sharing between the government and the SPV based on conflicts of interest between the private partners?

2. MODEL ANALYSIS

2.1. Model description

A government (G) relies on a private consortium consisting of a building firm (B) and an operating firm (O) to implement a PPP project and provide public services. At the beginning of the project, the B and O set up an SPV and determine the equity shareholdings (profit sharing) of the B and O (η and $1-\eta$, respectively). $\eta=0$ or $\eta=1$ means the SPV is not an equity alliance, where the O or the B is the sole owner of the SPV, and enjoys the dividend exclusively. The SPV then signs construction and operation contracts with the B and O with fixed payments R_B and R_O.

The building cost is denoted by $C_1=I-ai$, which is a function of basic investment I and the B's effort i in the construction phase. The operating cost is $C_2=M+\mu i$, where M denotes the basic operating and maintenance cost, μi presents an additional cost for providing the services caused by the effort i. Here, assuming $0<a<\mu$ indicates that the effort i brings a negative net marginal benefit ($a-\mu<0$) to the project. For example, the B may adopt advanced design or construction method to save the construction cost, but this leads to increased operating cost. Thus, the effort i is unproductive in the sense that it causes a negative externality.

Payments to the SPV partly (or all) come from the users of the service. The revenue from the service is stochastic. Even when there is a reasonable level of confidence in forecasts, they can be dramatically affected by competition from substitutable services (in transport for instance, competition may come from un-tolled roads, ferries, buses), changing user needs, and macroeconomic conditions (Iossa and Martimort 2015). The revenue is also influenced by the O's effort e exerted in the construction phase. For example, the O proposes ideas for the design or equipment installation that contribute to a high quality of infrastructure and services. In order to focus on the effects of bundling (e.g., the internalization of the externalities between the two phases), we do not consider that O expands effort in the operation phase.

The above features are captured by assuming $R=R_0+be+\varepsilon$, where R_0 represents the forecasted project revenue; be is the benefit generated from the O's effort e; ε denotes a random shock normally distributed with variance σ^2 and zero mean, representing the revenue risk (or demand risk). The marginal benefit of effort e is positive (b > 0), which indicates that it brings a positive externality in terms of operation revenue. In this sense, the effort e is productive. The efforts i and e are observable but not verifiable; therefore, they cannot be specified in the contract. For the sake of simplicity, we assume that the nonmonetary effort costs incurred by the B and O are $\phi(i)=\frac{i^2}{2}$ and $\psi(e)=\frac{e^2}{2}$, respectively, implying that the efforts cost the agent disutility $\phi(i)$ and $\psi(e)$ with $\phi'(i)>0$, $\phi''(i)>0$, $\psi'(e)>0$, and $\psi''(e)>0$. This is a common assumption used in the agency model.

The G determines the sharing of the revenue risk via a payment made to the SPV, $t(R) = \alpha - (1-\beta)R$. Therefore, the actual revenue obtained by the SPV is $\alpha + \beta R$, where α is a fixed payment (or subsidy) to the SPV paid upfront, and β represents the SPV's share of project revenue. So, in a payment mechanism based solely on user charges, the SPV receives its revenue directly through charges on the end users of the infrastructure facility and bears all revenue risk. This corresponds to the case $\alpha = 0$ and $\beta = 1$. Instead, with the payment mechanism based on availability, the government rewards the SPV for making the service available upon achieving and maintaining certain conditions and assumes all revenue risk. This corresponds to the case where $\alpha > 0$ and $\beta = 0$. Finally, $\alpha > 0$ and $0 < \beta < 1$ represent the case in which the G and SPV share the revenue risk. Note that $t(R) = \alpha - (1-\beta)R$ might be negative, indicating the G and SPV share the excessive profit. This means that the SPV can share the project's upside profit with the government in return for some protection from downside risk. In this sense, β represents the SPV's sharing ratio of the revenue risk.

Finally, assuming that the consortium is selected via a perfect competitive bidding, the G can extract all surplus and just leave the SPV indifferent between providing the service and getting outside opportunity normalized as zero. The risk-neutral G maximizes the social benefit of the service net of the payment made to the SPV; the SPV (the B and O) maximizes expected profit but it is risk-averse with constant absolute degree of risk-aversion *r*. The assumption of risk-neutrality for the G fits well the case where the PPP project is small relatively to the share of the overall budget. The assumption of risk-aversion for the B and O captures the fact that a PPP project might represent a large share of the firm's activities so that the firm can hardly be viewed as being fully diversified.

An overview of the model can be found in the timeline of key events. The game process starts with a consortium consisting of the B and O, which is selected via a perfect competitive bidding, forms the SPV. After signing the PPP contract which determines the risk sharing with the G, the SPV offers construction and operation contracts to the B and O, respectively, who then decide on the best efforts to exert at the construction phase so as to maximize their own expected profits. To solve the problem of optimal risk sharing, the best reactions of the B and O should be considered to be a constraint. Therefore, the solving process works backward: first, find the best efforts exerted by the B and O by maximizing the expected utility of their payoffs from the project. Then using the utility-maximizing efforts as a given condition, the G determines the optimal risk sharing between the government and the SPV.

2.2. Game analysis

We solve the game using backward induction. The SPV bears R_B and R_O; hence, its expected profit is $\prod_{SPV} = E_\varepsilon\left[t(R) + R\right] - R_B - R_O$. Because in the project finance, the proceeds from the senior loan and equity from the sponsors, i.e., *I*, are used to pay the project costs including building cost C_1 and construction profit for the B, we assume $R_B = I$. On the other hand, because the G extracts all rent, the SPV therefore leaves no rent to the O in the operation contract, that is, $R_O = C_2$.

Having determined $(\hat{\alpha}, \hat{\beta})$, we first examine the best efforts chosen by the B and O. Since the equity allocation determines the profit sharing of the B and O, their consolidated payoffs are $\prod_B = R_B - C_1 - \frac{i^2}{2} + \eta \prod_{SPV} - \frac{\eta r \beta^2 \sigma^2}{2}$ and $\prod_O = R_O - C_2 - \frac{e^2}{2} + (1-\eta)\prod_{SPV} - \frac{(1-\eta) r \beta^2 \sigma^2}{2}$, where $\frac{\eta r \beta^2 \sigma^2}{2}$ and $\frac{(1-\eta) r \beta^2 \sigma^2}{2}$ represent the risk premiums that the SPV is required to pay to the B and O.

The B and O choose *i* and *e*, respectively, to maximize their own profits:

$$\max_i ai - \frac{i^2}{2} + \eta\left[\alpha + \beta(R_0 + be) - I - M - \mu i\right] - \frac{\eta r \beta^2 \sigma^2}{2},$$

$$\max_e -\frac{e^2}{2} + (1-\eta)\left[\alpha + \beta(R_0 + be) - I - M - \mu i\right] - \frac{(1-\eta) r \beta^2 \sigma^2}{2}$$

Based on the first-order conditions (FOCs), the best efforts of the B and O are

$$i^* = \max\{0, a - \eta\mu\} \text{ and } e^* = (1-\eta)\hat{\beta} b \quad (1)$$

Note that the B's best effort i^* is not affected by the sharing of revenue risk $\hat{\beta}$. Meanwhile, an increase in the $\hat{\beta}$ boosts the O's best effort e^*.

As the consortium is selected via a perfect competitive bidding, the G chooses the fixed fee α to extract all surplus from the SPV. Thus, anticipating the optimal reaction of the private partners, the G determines the optimal risk sharing β to maximize the social welfare:

$$\max_{\beta} W\left(i^*, e^*, \beta\right) = R_0 + be^* - C_1 - C_2 - \frac{i^{*2}}{2} - \frac{e^{*2}}{2} - \frac{r\beta^2\sigma^2}{2}$$

Based on the FOC, the optimal risk sharing is

$$\beta^* = \frac{(1-\eta)b^2}{(1-\eta)^2 b^2 + r\sigma^2} \tag{2}$$

Equation (2) implies that the G determines the sharing of revenue risk, β^*, based on shareholdings of the B and O, η and $1-\eta$, the marginal benefits of the O's effort b, and the magnitude of the operation risk σ^2. From Equation (1) and (2), the best efforts are $i^* = \max\{0, a - \eta\mu\}$ and $e^* = \frac{(1-\eta)^2 b^3}{(1-\eta)^2 b^2 + r\sigma^2}$.

Depending on the value of η, three types of consortium structure are classified: Type 1, $\eta = 1$; Type 2, $\eta = 0$; Type 3, $0 < \eta < 1$. In the following, we investigate the motivations of the B and O to expand their efforts under different types the consortium structure.

Type 1: $\eta = 1$

The Type 1 consortium is a non-equity alliance of the B and O, where only the B has a stake in the SPV. Meanwhile, the O is the non-equity partner of the B, and is responsible for the operating task. From Equation (1) and (2), the best efforts of the B and O are $i_1^* = 0$ and $e_1^* = 0$, that is, both the productive and unproductive efforts are 0. The corresponding risk sharing $\beta_1^* = 0$ implies the government assumes all the revenue risk.

The outcome is intuitive. When only the B has a stake in the SPV, the negative externality (i.e., the effort *i* increases the operating cost) is internalized because the B gets reimbursed through the sum of building and operation profits, both of which are influenced by its effort *i*. More specifically, though the effort *i* increases the B's construction profit as it saves the building cost, it also increases the operating cost. The negative net marginal benefit of the effort *i* ($a - \mu < 0$) will prevent the B from exerting the unproductive effort *i*. Meanwhile, the O only can get reimbursed through the operating consideration, which is irrelevant to its effort *e*. In other words, the project revenue generated from the effort *e* is not allocated to the O. Thus, the O has no incentive to adopt productive effort *e*.

Furthermore, the government assumes all the revenue risk. The reason is also intuitive. If the government shares the revenue risk with the SPV, the risk will be eventually transferred to the B. It will only unnecessarily cost government the risk premium without a corresponding benefit because the B lacks operational expertise to improve the project revenue. In other words, the risk sharing cannot provide the B with an incentive to improve the revenue. Therefore, from the perspective of the agency theory, it does not make sense for the government to share the revenue risk with the SPV in which the B has all stakes.

Finally, the social welfare achieved in this case is $W_1^* = R_0 - I - M$.

Type 2: $\eta = 0$

In the Type 2 consortium, the O has all stakes in the SPV and enjoys the dividend exclusively. The B is the O's non-equity partner and responsible for the building task. From Equation (1) and (2), the best efforts of the B and O are $i_2^* = a$ and $e_2^* = \frac{b^3}{b^2 + r\sigma^2}$, respectively. Because the B's only concern is the construction profit, it will choose the effort *i* to maximize the construction profit without considering the effect of the effort *i* on the operating cost. The B thus adopt effort $i_2^* = a$ which leads to increased operating cost μa. That is, the negative externality is not internalized.

On the other hand, the risk sharing $\beta_2^* = \frac{b^2}{b^2 + r\sigma^2}$ will boost the O to exert effort $e_2^* = \frac{b^3}{b^2 + r\sigma^2}$ to maximize the project revenue. Note that the greater the marginal benefit (b) brought by the O or the smaller magnitude the risk (σ^2), the greater the revenue risk the SPV bears (β_2^*). It means the optimal risk sharing is determined by the government by trading off the incentive (benefit) and risk premium (cost).

The social welfare achieved in this case is $W_2^* = R_0 - I - M + \frac{b^4}{2(b^2 + r\sigma^2)} - a\left(\mu - \frac{a}{2}\right)$.

Type 3: $0 < \eta < 1$

The Type 3 consortium is the one where both the B and O have stakes in the SPV that then delegates the building and operating tasks to them. From Equation (1) and (2), the optimal risk sharing $\beta_3^* = \frac{(1-\eta)b^2}{(1-\eta)^2 b^2 + r\sigma^2}$, which is a decreasing function of the B's shareholding, η. The best efforts are $i_3^* = \max\{0, a - \eta\mu\}$ and $e_3^* = \frac{(1-\eta)^2 b^3}{(1-\eta)^2 b^2 + r\sigma^2}$. Therefore, given a and μ, the level of the effort i_3^* only depends on the B's shareholding, η. When $\eta < \frac{a}{\mu}$, $i_3^* = a - \eta\mu > 0$; otherwise, $i_3^* = 0$. This means that when the shareholding of the B is sufficiently small, the negative externality is not internalized because the net marginal benefit of effort *i* is positive. Conversely, when η is sufficiently large, the B will not adopt effort *i* because it does not benefit it.

The effort e_3^* adopted by the O is a decreasing function of the B's shareholding, η. This means the more shareholding of the O, the higher level of the effort *e* chosen by the O. Nonetheless, comparing with the Type 2 consortium, the O underinvests in the effort *e*, because it cannot exclusively enjoy the improved revenue.

Comparison

Comparing the foregoing three types of consortium, it is obvious that $\beta_1^* < \beta_3^* < \beta_2^*$. In addition, β_3^* is a decreasing function of the B's shareholding, η. Thus, we have the following:

Proposition 1: With the increase in the shareholding of the B in the SPV, the revenue risk transferred from the government to the SPV decreases.

Proposition 1 suggests that government should not transfer too much revenue risk to the SPV in which the B has a large stake. The purpose of the government's transfer of the revenue risk is to promote the SPV (eventually O) to strive to improve the project revenue. However, when only the B has a stake in the SPV, it is optimal that the government assumes all the operation risk, because the B lacks such expertise to invest *e*. When the B and O share stakes in the SPV, the O underinvests the effort *e* comparing to that in the case where O has all stakes in the SPV, i.e., $e_3^* < e_2^*$, therefore, the government transfers more revenue risk in the latter case.

We also have $i_1^* < i_3^* < i_2^*$, $e_1^* < e_3^* < e_2^*$, which means both the productive and unproductive efforts are greatest in PPP projects with the Type 2 consortium where the O has all stakes of the SPV. It suggests that the positive and negative externalities cannot be internalized at the same time under all three types of consortium.

Finally, by comparing the social welfare under the three types consortium, we obtain

Proposition 2: When $\mu^2 > \frac{b^4 r\sigma^2}{\left[b^2 + r\sigma^2\right]^2}$, $W_3^*(\eta) > W_2^* > W_1^*$ holds if and only if $\frac{b^4}{2(b^2 + r\sigma^2)} > a\left(\mu - \frac{a}{2}\right)$ and $0 < \eta < \hat{\eta}$ where $W_3^*(\hat{\eta}) = W_2^*$; $W_3^*(\eta) > W_1^* > W_2^*$ holds if and only if $\frac{b^4}{2(b^2 + r\sigma^2)} < a\left(\mu - \frac{a}{2}\right)$ and $\breve{\eta} < \eta < 1$ where $W_3^*(\breve{\eta}) = W_1^*$; When $\mu^2 < \frac{b^4 r\sigma^2}{\left[b^2 + r\sigma^2\right]^2}$, $W_2^* > W_3^*(\eta) > W_1^*$ always holds.

3. NUMERICAL ANALYSIS

A simple numerical analysis is presented in this section to further enhance the understanding of the model. First, taking the other parameters as given (see **Table** 1), we set $a = 0.1$, $\mu = 0.5$ and $b = 0.45$, which represent the marginal benefits of the effort *i* and *e*, for a numerical example to compare the optimal sharing of revenue risk (β^*) in PPP projects with different types of the consortium.

Table 1. Value setting of key parameters.

R_0	I	M	α	r	σ^2
3.15	2	1	3	0.5	1

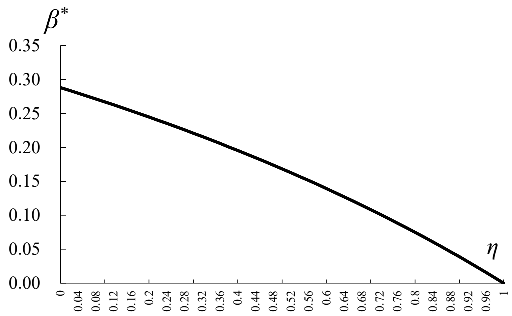

Figure 1. Relationship between the B' shareholding (η) and optimal sharing of revenue risk (β^*)

As shown in **Figure** 1, with the increase in the shareholding ratio of the B (O), the revenue risk transferred from the government to the SPV decreases (increases). As a result, the government most transfers revenue risk to the SPV when the O has all stakes in the SPV (i.e., Type 2 consortium, $\eta = 0$), and assumes all the revenue risk when the B has all stakes in the SPV (i.e., Type 1 consortium, $\eta = 1$).

Second, by changing the parameters *a*, *b* and μ, **Figures** 2, 3 and 4 show the comparison of the social welfares brought about by PPP projects with three types of consortium. **Figure** 2 shows the case in which $\mu^2 < \frac{b^4 r\sigma^2}{\left(b^2 + r\sigma^2\right)^2}$ ($a = 0.1$, $\mu = 0.5$ and $b = 1.2$), implying the benefit from avoiding the unproductive effort i is sufficiently small or the benefit from the promoting the productive effort e is sufficiently large. In this case, $W_3^*(\eta)$ is a decreasing function of η, that is, $W_2^* = W_3^*(\eta = 0) > W_3^*(\eta)(0 < \eta < 1) > W_1^* = W_3^*(\eta = 1)$ always holds. Thus, PPP projects with the Type 2 consortium which maximizes the productive effort *e* can bring about greatest social welfare.

Next consider two cases in which $\frac{b^4 r\sigma^2}{\left(b^2 + r\sigma^2\right)^2} < \mu^2 < \frac{b^4}{r\sigma^2}$ (**Figure 3**) and $\mu^2 > \frac{b^4}{r\sigma^2}$ (**Figure** 4). In either case, the relationship between W_1^* and W_2^* determines the relationship between them and W_3^*, therefore two situations are considered in either case. Figure 3a ($a = 0.4$, $\mu = 0.5$ and $b = 0.8$) and **Figure** 4a ($a = 0.4$, $\mu = 0.5$ and $b = 0.65$) represents the situation in which $W_2^* > W_1^*$, while **Figure** 3b ($a = 0.1$, $\mu = 0.5$ and $b = 0.55$) and **Figure** 4b ($a = 0.1$, $\mu = 0.5$ and $b = 0.45$) describes the converse situation in which $W_2^* < W_1^*$. As shown in **Figure** 3a and **Figure** 4a, by defining $W_3^*(\hat{\eta}) = W_2^*$, we have $W_3^*(\eta) > W_2^* > W_1^*$, if $0 < \eta < \hat{\eta}$ and $W_2^* > W_3^*(\eta) > W_1^*$ if $\hat{\eta} < \eta < 1$, where $\hat{\eta} \approx 0.38$ (**Figure** 3a) and $\hat{\eta} \approx 0.62$ (**Figure** 4a). Conversely, as shown in **Figure** 3b and **Figure** 4b representing the cases in which $W_2^* < W_1^*$, by defining $W_3^*(\breve{\eta}) = W_1^*$, we have $W_3^*(\eta) > W_1^* > W_2^*$ if $\breve{\eta} < \eta < 1$ and $W_1^* > W_3^*(\eta) > W_2^*$ if $0 < \eta < \breve{\eta}$, where $\breve{\eta} \approx 0.22$ (**Figure** 3b) and $\breve{\eta} \approx 0.08$ (**Figure** 4b). These suggest that when $W_2^* > W_1^*$, implying the PPP project with the Type 2 consortium brings about more social welfare than that with the Type 1 consortium, the social welfare will be improved when both the B and O have stakes in the SPV and keeping the shareholding of the B at a sufficiently low level. However, when $W_2^* < W_1^*$, both the B and O have stakes in the SPV and keeping the shareholding of the B at a sufficiently high level will improve the social welfare.

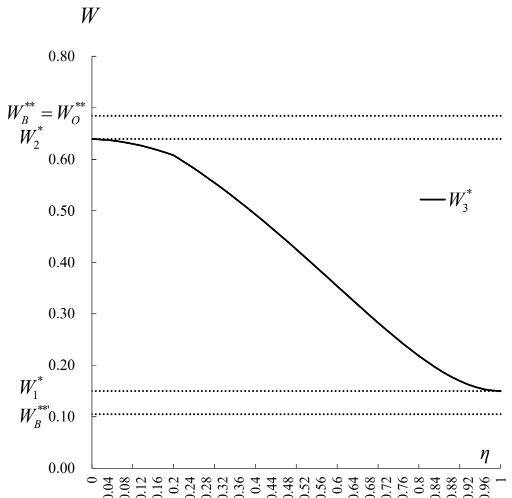

Figure 2. Relationship of social welfares ($\mu^2 < b^4 r\sigma^2 \big/ \left(b^2 + r\sigma^2\right)^2$).

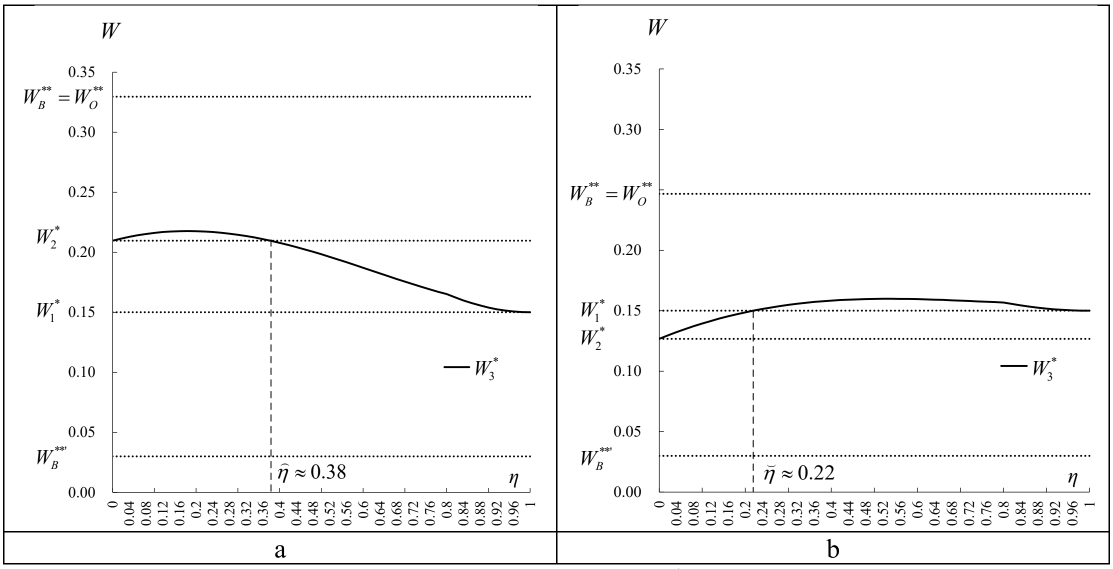

Figure 3. Relationship of social welfares ($b^4 r\sigma^2 \big/ \left(b^2 + r\sigma^2\right)^2 < \mu^2 < b^4 \big/ r\sigma^2$).

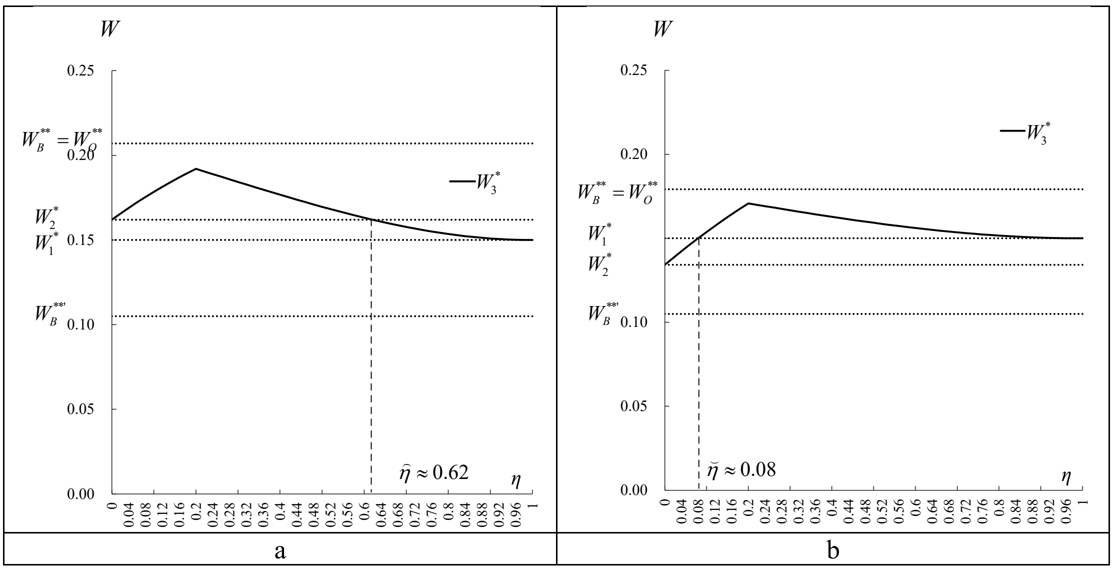

Figure 4. Relationship of social welfares ($\mu^2 > b^4 \big/ r\sigma^2$).

Conclusion

This study investigates the how the internal conflicts of interest between operational sponsors (building firm and operating firm) affects their motivations to invest in the project and the risk sharing between government and the SPV. By focusing on two types of externalities, that is, a negative externality arising from the unproductive effort of the building firm for saving the building cost while sacrificing the operating cost, and positive externality generated from the productive effort expanded by the operating firm for improving the project revenue (service quality), we find that the two externalities cannot be internalized at the same time when the building and operating firm are only experienced in construction and operation respectively. Thus, the government determines the optimal sharing of the revenue risk by trading off the benefit and cost brought about by the two externalities. The findings show that the government should transfer more revenue risk to the SPV when the operating firm has relatively large stakes in the SPV. Conversely, this suggests that the building firm having a majority stakes in the SPV can brings about more social welfare only in government-pay PPP projects in which the government assumes all revenue risk.

Some issues remain to be addressed in future studies. First, this study only targets operational sponsors of PPP projects. In future studies, financial sponsors in PPP projects could be added to further clarify the impacts of conflicts of interest between the operational and financial sponsors on the efficiency of the PPP project. Second, the project finance used in PPP projects may also influence the implication of the model. In particular, non-recourse or limited recourse features of the project finance may trigger the SPV to implement high-risk/high-return investments which may lower the service quality. Future studies should further investigate such constraints of project finance. Third, this study uses qualitive analysis to analyse how the parameters representing the marginal benefits of the efforts influence the motivations of the private partners, empirical studies (e.g., case studies and expert interviews) should also be implemented for more impactful insights into practice. Lastly, although this study suggests that the operational sponsor should have comprehensive performance capability, how to properly evaluate it in the bidding process is a considerably important issue that deserves more in-depth study.

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