IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received May 13, 2020, accepted May 26, 2020, date of publication June 4, 2020, date of current version June 17, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.2999932

An Incentive Analysis of Availability Payment Mechanism in PPP Projects

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This work was supported by the National Natural Science Foundation of China under Grant 71672017.

ABSTRACT This study aims to investigate the incentive mechanism of different availability payment methods applied in Public Private Partnership (PPP) contracts. We present a basic model in a multitask environment in which a risk-averse private contractor chooses two types of noncontractible efforts: one is unproductive, in the sense that it saves building cost but sacrifices social benefits; the other one is productive, as it reduces operating cost without social loss. We find that the PPP contract using separate charges for availability and performance is more desirable than using single unitary charge if the government can detect the social loss cause by unproductive effort. However, the latter brings about more social welfare over the former if the social loss is not observable to the government and the observable value of benefit-cost ratio of the unproductive effort is relatively larger than the benefit-cost ratio of the productive effort.

INDEX TERMS PPPs, availability payment mechanism, bundling effect, incentive contract, risk sharing.

I. INTRODUCTION

In recent years, instead of traditional project delivery systems in which the government retained the responsibility for financing, design, construction, and operations, Public Private Partnerships (PPPs) have been widely used as a strategy to procure infrastructure services through private initiative. Compared to traditional project delivery systems, a relationship between both governments and private sectors can be of more mutual benefit in PPPs [1], [2]. The government wants to ensure that a service or asset is of benefit to the regional/national economy, and the private sector is commercial in its approach and driven by ensuring profitability mainly through two funding mechanisms: public budget that eventually is supported by taxpayers and direct charges to users [3].

The different funding mechanisms came with different payment mechanisms that define how the private contractor would be compensated and risk allocation strategy for the PPP projects. Cui *et al.* suggested proper allocation of risk is of critical importance for successful project implementation [4]. Since private contractors are responsible for both building and operation of the project, the pricing of the payment mechanism is more comprehensive than in traditional systems. The payment mechanisms employed on PPPs usually include direct tolling, shadow tolling, and availability payment. The main differences among those payment mechanisms are who makes the payment and who assumes the demand risk. Private contractors usually assume demand risk in PPP projects, adopting direct rolling, since the service user directly makes the payment. Alternatively, the payment is made by the government rather than the user in PPP projects, using shadow toll or availability payment; therefore, the demand risk is mainly borne by the government.

Out of all the payment mechanisms, this paper focuses on the availability payment mechanism, under which the contractor mainly assumes the construction and operational risks, while the government bears the demand risk. The idea behind this is having to pay for services only according to the performance achieved or quality delivered under the contract agreement. The availability payment mechanism normally involves two key determinants of payment: output of the facilities and the service, and performance of the service [5]. The former specifies certain conditions which must be met if the service is to be treated as available, while the latter emphasizes the quality of the performance of services normally working, in conjunction with availability regimes. Where the services are not available or do not meet the performance standards imposed by the government, penalties in the form of payment deduction are paid [6], [7]. For example, when a roadway is available, it implies that predetermined conditions such as traveling without encountering potholes or

The associate editor coordinating the review of this manuscript and approving it for publication was Davide Aloini.

damaged roadways are met by the operation and maintenance of the private contractor. If a roadway remains available for a specified time period, then a corresponding availability payment is made. If lanes on a roadway are closed for any reason, such as maintenance purposes, incident management, or snow removal, then the availability payment is reduced by the proportion of the shortage.

Although the availability payment mechanism has been widely used in both developed and developing countries, it has various definitions as well as ways of making availability payment. Among the methods, this article focuses on two typical ones; the first one is generally used in countries such as the UK and Australia, where the availability refers to the specified output and performance must meet certain conditions stipulated in the contract during the whole operation phase. The second one can be found in countries such as China and Canada, where the availability refers to the fact that the facility has completed meeting the standard defined in the design and is being ready to provide services, while performance is referred to the services in accordance with targeted objectives during the operation. Accordingly, in the PPP projects in the UK and Australia, there is a single unitary charge for the service (hereafter called PM A). PM A is made for using the constructed facility and its associated services and covers the building and operating costs. However, in the PPP projects in China and Canada, there are separate charges for the availability and performance (hereafter called PM B). The availability payment will compensate the private contractor with the construction investment, while the performance payment will cover the operating cost.

As such, the fact that different availability payment methods are used in PPP projects raises a concern about their effectiveness in achieving government objectives, especially in terms of project efficiency. In particular, the availability payment mechanism not only defines how the private contractor would be compensated but also has incentive effects. Grout and Zhang (2005) asserted that a key principle in PPP is the link between performance and incentive payments to the private sector based on the successful supply of services to the government [8], [9]. It implies that the key aspects of availability payment mechanism include measurable performance goals, specific performance standards, and valid quantifiable measures [10]. Only the measurable performance goals which are validly measured are properly linked to performance standards; the availability payment mechanism may provide the private contractors with incentives to accomplish the goals set by the government [11].

However, the availability payment mechanism may also disincentivize the private contractor during construction to use resources in ways that optimize asset. During operations, the private contractor may meet minimum standards but will have no incentive to go beyond these standards as the payment received remains constant. For example, the private contractor will not be active in improving the service quality because operations and maintenance costs may increase, in turn reducing the profit [12]. Furthermore, the private contractor will make unproductive efforts to reduce the cost while sacrificing the quality of services, which cannot be well-specified [13]. In summary, the availability payment mechanism includes both positive and negative incentive effects. However, without understanding the logic behind the incentive mechanisms, we cannot account for why and when different availability payment methods are adopted.

The main purpose of this study thus is to investigate the incentive mechanism of PM A and PM B used in PPP projects. Notably, PM A and PM B are supposed to have different incentive effects on project efficiency, in terms of reduction of cost and the quality of service. Suppose a risk-averse private contractor exerts two types of efforts, denoted by i and e respectively, in the building phase of a PPP project. The effort i is unproductive in the sense that it contributes to save the building cost but lowers the service quality. The effort e is productive as it reduces the operating cost without any social loss. Because the private contractor is responsible for both building and operation tasks, either PM A or PM B will provide the private contractor with an incentive to determine the level of effort i and e as to minimize the total project cost. As a result, an overinvestment on effort i may occur because penalty is not available in a case where the service quality is still beyond the government's predetermined standard. In this case, risk sharing between the government and the private contractor will matter. However, the two availability payment methods implement different risk sharing strategies, therefore providing the contractor with different incentives to choose the level of efforts. Furthermore, if the lowered service quality caused by effort i is not observable to the government, the two availability payment methods will differently impact the social welfare of the project. Our research questions are as follows:

(1) What impacts does PM A or PM B have on the risk sharing between the government and private contractor?

(2) Why and under what circumstances are PM A or PM B optimal considering the possibility of inability of the government to observe the quality of some services?

The remainder of this paper is organized as follows: Section II presents a literature review; section III provides a basic model in a multitask environment and analyzes the incentive mechanism of two different availability payment methods; section IV presents a numerical example, followed by a discussion of the results in section V; and finally, section VI offers the study conclusions.

II. LITERATURE REVIEW

A. AVAILABILITY PAYMENT MECHANISM IN PPP PROJECTS

The major developments of payment mechanisms were experienced in the UK, which is considered a leading country in using PPPs in schools, hospitals, prisons, roads, and defense facilities [14], [15]. The adoption of direct tolling as payment may have a negative impact since users are reluctant to accept direct charges. The tradition that the government must provide and maintain free road network for public interest may adversely affect the potential revenue that a project can generate. Furthermore, the private contractor will take the demand risk, which is difficult to be correctly estimated [7]. As a result, the cost to finance the project may become huge. Notwithstanding these risks, one of the main benefits of using direct tolling is the avoidance of burden upon public budgets.

Alternative payment models employed bypass these concerns of the public as the payment is made by the government rather than by the user; such methods include shadow tolling and availability payment. The early DBFO projects in the UK utilized shadow-toll payment mechanisms, usually used in transportation-related PPPs. Shadow-toll refers to usage payment based on the number and type of vehicles using the road, made by the government. However, shadow tolling raises a risk of payments increasing beyond anticipated levels, unless payments are capped to a maximum level. Further, the UK National Audit Office (NAO) criticized the use of shadow-tolls for the reduction of the net savings that would be generated by the allocation of the traffic volume risks to the contractor [16].

Availability payment mechanism attempts to overcome this problem, letting the government assume the demand risk. If demand is highly uncertain and revenue from user fees is difficult to predict, then availability payment mechanism can lower the cost of debt [17] and ensure maintenance as well as future capital renewal costs to fully funded [18]. Because the government pays the availability fee to purchase services, its requirements in terms of performance output specification and performance management, which consist of the bases of availability payment, receive more attention at both the government and the academic/research level. For example, many documents from the UK government [19] indicate that the key features of PPP payment mechanisms include (1) "no payment until constructed facility and associated services are available"; (2) "single unitary charge for the service delivered (incorporating availability and performance)"; (3) "payment deductions for substandard performance"; and (4) "payment deductions reflect severity of failure." Some government documents [20], [21] highlight the importance of output specification and Performance Management System (PMS), which includes performance measurement and monitoring regimes [22]. In general, Treasury Taskforce Private Finance advises that the key to a successful payment mechanism includes a strong linkage and integration to output specification, key performance indicators (KPIs), performance measurement, and contract monitoring.

On the academic/research level, Heavisides and Price compared the current use of input vs output specifications for the UK National Health Services projects, highlighting the reliance on performance metrics for the latter [23]. Akintoye and Beck inferred that good output specifications clearly depict what the requirements of the government are and reduce the possibility of disputes later in the operating stage [24]. Further, Lawther and Martin argued the importance of the alignment among KPIs chosen to ensure that PPP projects meet societal or agency goals as well as project goals [25]. Yuan *et al.*, built a model to select appropriate performance objective levels for PPP projects [26]. Javed *et al.* however, found that too many and complex KPIs were specified in existing output specifications, which were difficult to monitor, measure, and implement by the client [27]. They suggested that output specifications be aligned with the type of PPP projects they represent. Generally, after the government specifies the level of service required in the output specification, the quality of service is measured and monitored through a PMS [28]. A PMS deals with what and how to measure; for the former, a typical approach is to create a matrix of KPIs [6], [28] and for the latter, it is usually based on weighting systems, where each section of the service delivered is given a weightage based on the level of their criticality [29]. In addition, Newcomer and Caudle pointed out that the key aspects of all such performance management efforts include measurable performance goals, specific performance standards, and valid quantifiable measures [10].

The corresponding level of performance is what determines the payments from the government. An effective availability payment mechanism depends on whether the performance benchmarks are reasonable and achievable [30], [31]. Ng and Wong examined the payment and monitoring mechanisms of PPP-based infrastructure maintenance schemes and indicated that the level of payment reduction due to poor performance is fair and the audit frequency is adequate to reflect the overall performance of the service provider [32]. Monitoring is conducted by the government to keep track of the performance of the services and to determine the amount of payment that they should allot according to the payment adjustment system preset in the contract. Further, failing to achieve the predefined performance standard could result in a certain sum being deducted from the payment. Moreover, Mays and Roy discussed the need for clearly defining the penalties for non-performance in the contract conditions [33]. Such penalties are intended to force the contractor to assume the controllable risk, therefore incentivize and improve the performance of the project contractor to ensure achievement of value-for-money for the government [34].

In summary, the above literature focused on the components of availability payment mechanism and provided a fundamental understanding of the bases of the availability payment. However, although some literature underscored that the successful availability payment mechanism depends on the proper linkage between output specification, performance measurement, and the payment, only few studies analyze how to properly design the linkage. Particularly when there exist different ways to make the availability payment, the linkage effects should be different as they provide the private contractor with different incentives to exert efforts. In addition, when KPIs are not properly chosen due to the complexity of the PPP project or the government is not able to precisely measure the performance, the incentive effects of the availability payment mechanism will be eroded. Therefore, this paper theoretically investigates the incentive mechanisms of different availability payment methods to find the incentive logic behind the availability payment mechanism, considering the possibility of the imperfection of KPIs (i.e., the quality of some services may not be observable).

B. INCENTIVE MECHANISM LITERATURE

Most infrastructure PPP projects (like water management, waste disposal services, sanitation, and public transportation) involve a complex array of tasks. Those activities necessitate, first, to build infrastructures and, second, to operate and maintain these assets. Delegation to the private contractor thus takes place de facto in a multi-task environment.

In traditional project delivery systems, governments first, choose private contractors to build assets and then choose operate contractors, either public or private, to manage these assets and provide the service. The construction risk and operational risk thus are separately assumed by the building contractor and the operation contractor respectively. However, PPPs delegate the whole task of building, operations, and maintenance to a single private contractor, who bears both the construction and operational risks. Compared with traditional systems, the PPP alternative is thus characterized by an important feature that the two tasks of building and operation are bundled.

The delegation of tasks is the focus of a branch of agency literature. When delegating the construction and operation tasks to the private contractor, the government cannot firmly predict the level of efforts the private contractor will actually expend, known as the moral hazard problem. Two cases are a priori feasible by private contractors considering moral hazard problem. First, an effort (e.g., better design of the infrastructure) in building phase may help to save operating cost, the case of a positive externality. Second, an opportunistic effort in building phase results in defection of unverifiable or indescribable services which decreases the social welfare from the operation of the project or increases the operating cost, the case of a negative externality. Liu *et al.* analyzed the impact of opportunistic tendencies on the benefits distribution and suggest the government should increase the proportion of benefits allocation for the investors to induce them to invest the optimal level of productive efforts [35]. Focusing on the externalities in PPPs, a large body of literature investigated bundling effects, namely internalization of externalities, in PPPs by comparing traditional project delivery systems. Maskin and Tirole, Martimort and Pouyet, and Iossa and Martimort found out that PPPs are more efficient than traditional project delivery systems when there is a positive externality between building and operation [36]–[38]. Their conclusions are consistent with the famous work done by Holmström and Milgrom, who showed that incentives in one task may destroy incentives in another when there is a negative externality between tasks and suggests that tasks should be split [39]. In the same spirit, Iossa and Martimort built an agency model to analyze how bundling affects incentives to raise demand, and the optimal allocation of demand risk [40]. Schmitz found that when the principal has a limited budget separation can be optimal [41]. Shi *et al.* proposed an optimal sharing ratio for risk influenced by the conduct of both the owner and the contractor [42].

On the other hand, some literature [43]–[47] assuming that the government cannot observe the real operating cost which is known as the adverse selection problem, have also discussed whether bundling tasks and having a single agent privately informed on cost parameters related to each task dominates unbundling with positive externality. In adverse selection frameworks, the government must pay an information rent to the operator who has the private information on the operating cost. Bentz *et al.* found that when the investment cost is small, the government paying the information rent to the private contractor in PPP not only reveals the true information on the operating cost but also induces the cost reducing investment on the asset as the positive externality is internalized [48]. Iossa and Martmort considered a case where the externality between the construction and operation is uncertain [49]. They emphasized that how unbundling may be preferred when operational risks are high and informational asymmetries can create an undue advantage to the private contractor.

An underlying assumption of most of the above studies is that the government can perfectively observe the outcome of (productive and unproductive) efforts exerted by the private contractor. Thus, the government can properly transfer the risk to the private contractor via contracts by taking into consideration the negative effects of the unproductive effort. However, when the government cannot observe the social loss caused by the unproductive effort, – for example, the government may not be able to monitor the quality of the service or cannot well-define the outputs of facility – the incentive contract will not work well. Scott and Robinson emphasized there is also a need for more objectivity in determining performance metrics or scores [50]. Furthermore, few studies have analyzed the different impacts of different payment methods on the bundling effect as different strategies are adopted for risk sharing by the government and the private contractor.

This paper is closely related to the series of papers from Iossa and Martimort that compares the costs and benefits of PPPs and the traditional project delivery system by focusing on the bundling effect [38], [40], [49]. In their studies, a building contractor is assumed to be able to perform a productive or an unproductive effort which both reduces the operation costs, although only the productive effort raises benefits. This paper however assumes that the unproductive effort reduces the building cost by sacrificing the service which maybe not observable to the government and focuses on the impacts of different incentive payment methods on the bundling effect, as well as the risk sharing between the government and private company. An optimal sharing of risks also creates a ''win–win'' condition for the private contractor and the government.[1]

[1] We thank one anonymous reviewer for this point.

The theoretical contributions of this paper are tripartite: first, focusing on productive and unproductive efforts exerted by the private contractor, we investigated the effects of different availability payment methods to an extent to which the bundling effect is achieved; second, we investigated the role of risk sharing in restraining the unproductive effort; third, we incorporated the possibility of inability of the government to observe the quality of some services and investigated the effectiveness of PPP incentive contracts using different availability payment methods.

III. BASIC MODEL

A. ASSUMPTIONS

A government relies on a private contractor to build and operate an infrastructure PPP project and to provide a public service for the society. Examples of such PPP projects include transportation, energy production, sewage treatment, and so forth. In such settings, the government purchases the service using availability payment mechanism and assumes the demand risk.

The PPP project is divided into two phases: building and operation. The main feature of a PPP can be viewed as the bundling of building and operation phases. In the beginning of the building phase, the private contractor employs two types of efforts, denoted by i and e respectively. i is an unproductive effort that contributes to a reduction of the building cost but adversely impacts the quality of service provided in the operation phase. The effort e, however, reduces the operating cost without sacrificing the quality of services. Both efforts are observable but not verifiable; therefore, cannot be specified in the contract. The effort costs incurred to the private contractor are $i^2/2$ and $e^2/2$ respectively.

Since the government assumes the demand risk, major construction risk and operational risk affect PPP projects. The building cost C_1 is a function of the effort i and construction risk:

$$C_1 = I_0 - ai + \eta_1 \tag{1}$$

The random variable η_1 captures construction risk. It is normally distributed with variance σ_1^2 and zero means. I_0 is the base level cost of building the asset; a is a positive parameter.

After completing the building task, the private contractor starts to operate the asset and provide services. The operating cost is also stochastic; it depends on effort e and operational risk:

$$C_2 = C_0 - \mu e + \eta_2 \tag{2}$$

The random variable η_2 captures operational risk. It is normally distributed with variance σ_2^2 and zero means. C_0 is the base level cost of operating the asset. μ is a positive parameter which corresponds to a positive externality. For example, a better design of a prison with better sightlines for the staff reduces the number of security guards. In other terms, effort e is productive in the sense that marginal benefit μ is positive.

The government withdraws benefits from providing the service. As the demand risk is assumed by the government, the base benefit thus is fixed and cannot be affected by competition from substitutable services. The whole benefit however, is influenced by unproductive effort i which reduces the building cost by sacrificing the quality of services. For example, in the case of a water network, the contractor may try to save the building cost by cutting down the quantity of leakage, quality of the tubes, etc.

The above features are captured by assuming that the service yields a benefit to the society's worth

$$B = B_0 - bi \tag{3}$$

$B_0 > 0$ denotes the base benefit for providing services. $-bi$ represents the social loss caused by the effort i. Assume:

$$a < b \tag{4}$$

Equation (4) indicates that the net marginal benefit of the effort i is $a - b < 0$, which implies that the effort i is unproductive. The benefit reflects the performance of the service, which can be verified via the audit, the government can thus make a payment according to the realized benefit (performance).

Furthermore, we assume that the private contractor never lets the performance of the project be lower than the predetermined standard. Put differently, the realized quality will not influence the "availability" of the project, i.e., $q \geq \hat{q}$, where q and $\hat{q}$ represent realized quality and standard quality respectively.[2] Namely, penalty is not available to restrain the unproductive effort i. Because the project is "available" during the PPP project period, thus the government makes a full payment. However, the sharing of risk embedded in the payment mechanism is linked to $-bi$ if it is observable. We will later on observe a case where $-bi$ is not observable.

Finally, assume that the government is risk-neutral, the private contractor is risk-averse with constant degree of risk aversion r.

B. CONTRACTS

Assume that the project cost including the building and operating costs is observable and contracted upon. Using PM A, the government makes a unitary payment. The private contractor is paid $t(C_1 + C_2) = \alpha + (1 - \beta)(C_1 + C_2)$. With PM B, the government makes a payment $t_1(C_1) = \alpha_1 + (1 - \beta_1)C_1$ and $t_2(C_2) = \alpha_2 + (1 - \beta_2)C_2$. The former is paid when the infrastructure asset is completed following the requirement determined in the contract; while the latter is paid for purchasing the service provided by the contractor. The case $\beta = 0$ or $\beta_j = 0 (j = 1, 2)$ corresponds to a cost-plus contract where the contractor is fully reimbursed for its own costs, whereas $\beta = 1$ or $\beta_j = 1 (j = 1, 2)$ holds

[2] This assumption reflects the fact that the private contractor lacks the incentive to improve the service quality beyond the standard predetermined by the government in the PPP projects using availability payment. In this case, the risk sharing matters since penalty is not effective to improve the service quality.

for fixed-price contract, where the contractor receives a fixed payment. Thus, $0 \leq \beta \leq 1$ represents the sharing of total construction and operation risks between the government and the private contractor under PM A, while $0 \leq \beta_1 \leq 1$ and $0 \leq \beta_2 \leq 1$ show the sharing of construction risk and operation risk respectively under PM B. In this sense, construction and operation risks are closely linked to PM A and PM B. As to be shown later, α or $\alpha_j (j = 1, 2)$ is a fixed fee that covers the expected corresponding project costs, the effort costs, and risk premiums borne by the private contractor. Both payments occur in the operation phase after observing the benefits and costs. The payoffs obtained by the private contractor thus are:

PM A: $\Pi^{con} = \alpha - \beta(C_1 + C_2) - i^2/2 - e^2/2$

PM B: $\Pi^{con} = \alpha_1 - \beta_1 C_1 - i^2/2 - e^2/2 + \alpha_2 - \beta_2 C_2$

The risk-neutral government maximizes consumer surplus net of the payment to the contractor. The objective function of the government is written as follows:

PM A: $\Pi^{gov} = B_0 - bi - t(C_1 + C_2)$

PM B: $\Pi^{gov} = B_0 - bi - t_1(C_1) - t_2(C_2)$

Note that the government determines β or $\beta_j (j = 1, 2)$ taking into account both the project costs and the social loss $-bi$ if it is observable.

Suppose that the private contractor is selected via a competitive bidding. Based on the risk allocation strategy (β or $\beta_j (j = 1, 2)$) announced by the government, potential private companies submit bidding prices (α or $\alpha_j (j = 1, 2)$) and the one who submits the lowest price is awarded the contract. Now, suppose that a perfect competition is realized, namely the equilibrium amount of fixed fee makes the private contractor just indifferent between providing the service and getting an outside option worth 0.

C. BENCHMARK

At first best, the efforts are observable and verifiable thus contractible. The risk-averse contractor is fully insured by the risk-neutral government: its reward being independent of the realized costs. That contract also forces the contractor to choose the first-best effort i^{FB} and e^{FB} that maximize the overall expected surplus.

$$\begin{aligned}(i^{FB}, e^{FB}) &= \arg\max_{i,e} E_{\eta_1,\eta_2}(B - C) - i^2/2 - e^2/2 \\ &\equiv B_0 - (I_0 + C_0) + (a - b)i + \mu e - i^2/2 - e^2/2 \\ &= (0, \mu) \end{aligned} \tag{5}$$

Considering the nonnegativity constraint $i \geq 0$, the first-best unproductive effort i^{FB} is 0 since the net marginal benefit is negative. The productive effort e^{FB} trades off the marginal benefit of lowering the operating costs (μ) with its marginal cost (e).

D. PPP CONTRACTS ADOPTING PM A OR PM B

We now provide a rationale for adopting PM A or PM B in PPP contracts. The private contractor is responsible for both the building and operation, thus chooses the level of the efforts so as to maximize the sum of its total profits in the building as well as the operational phase. The government pays $t(C_1 + C_2)$ contractor using PM A or makes a payment $t_1(C_1)$ and $t_2(C_2)$ using PM B to the private contractor. In the following, we compare the different incentive effects in terms of efforts chosen by the private contractor as well as the social welfare achieved via PM A and PM B. We first investigate the case (Case I) where the social loss ($-bi$) is observable and is taken into account in the incentive contract. Then, we analyze the case (Case II) where the social loss caused by effort i is not observable to the government.

Case I: The Social Loss ($-bi$) is observable

PM A. The government pays a unitary $t(C_1 + C_2)$ to the private contractor, who maximizes the certainty equivalent of its expected payoff. Given α and β, the corresponding incentive constraint is written as:

$$\begin{aligned}(i_A, e_A) &= \arg\max_{\tilde{i},\tilde{e}} \alpha - \beta E_{\eta_1,\eta_2}(C_1 + C_2) - \tilde{i}^2/2 - \tilde{e}^2/2 \\ &\quad - r\sigma_1^2\beta^2/2 - r\sigma_2^2\beta^2/2 \\ &\equiv \alpha - \beta(I_0 - a\tilde{i} + C_0 - \mu\tilde{e}) - \tilde{i}^2/2 - \tilde{e}^2/2 \\ &\quad - r\sigma_1^2\beta^2/2 - r\sigma_2^2\beta^2/2 \\ &= (\beta a, \beta\mu) \end{aligned} \tag{6}$$

As (6) shows, an increase in the incentive power β, the share of the construction risk and operational risk borne by the private contractor, boost both productive and unproductive efforts. However, as more risks are transferred to the private contractor, the risk premium $r\sigma_1^2\beta^2/2 + r\sigma_2^2\beta^2/2$ also increases. As we assume that the perfect competition is realized in the bidding, the fixed fee α just makes the private contractor yield an expected pay-off equal to 0. The government's expected pay-off that coincides with the social welfare thus is expressed by the expected value of the project net of the risk premium:

$$\begin{aligned}\Pi_A^{gov}(i_A, e_A, \beta) = W_A = B_0 - bi_A - (I_0 - ai_A + C_0 - \mu e_A) \\ - i_A^2/2 - e_A^2/2 - r\sigma_1^2\beta^2/2 - r\sigma_2^2\beta^2/2 \end{aligned} \tag{7}$$

Maximizing the above expression while considering the incentive constraint (6) yields the following expressions of the share of the risk borne by the private contractor and the second-best efforts:

$$\beta^* = \begin{cases} \dfrac{\mu^2 - a(b-a)}{a^2 + \mu^2 + r\sigma_1^2 + r\sigma_2^2}, & \text{if } \mu^2 > a(b-a) \\ 0, & \text{if } \mu^2 \leq a(b-a) \end{cases} \tag{8}$$

$$\left.\begin{aligned} i_A^* &= \frac{[\mu^2 - a(b-a)]a}{a^2 + \mu^2 + r\sigma_1^2 + r\sigma_2^2}, \\ e_A^* &= \frac{[\mu^2 - a(b-a)]\mu}{a^2 + \mu^2 + r\sigma_1^2 + r\sigma_2^2} \end{aligned}\right\} \text{if } \mu^2 > a(b-a)$$
$$i_A^* = 0, \quad e_A^* = 0, \text{ if } \mu^2 \leq a(b-a) \tag{9}$$

Since providing incentives requires the private contractor to bear more risks, the second-best productive effort e_A^* is lower than its first-best level so as to reduce the corresponding risk premium. As for unproductive effort i, the government should trade off the social loss caused by the unproductive effort i and benefit generated from the productive effort e as the sharing ratio of construction risk and operational risk are the same. If the marginal benefit of the effort e is relatively larger (in the case where $\mu^2 > a(b-a)$), the government shifts more risks to the private contractor so as to induce a higher level of effort e_A^* as well as i_A^*, which is higher than its first-best level. However, if the marginal benefit of effort e is relatively small (in the case where $\mu^2 \leq a(b-a)$), the government will bear all risks and give up the productive effort e_A in order to restrain the unproductive effort i_A, i.e., $i_A^* = e_A^* = 0$

Using the value of efforts i_A^* and e_A^*, we obtain the following expression of fixed fee and the expected social welfare:

$$\alpha^* = \begin{cases} \frac{[\mu^2 - a(b-a)](I_0 + C_0)}{a^2 + \mu^2 + r\sigma_1^2 + r\sigma_2^2} \\ -\frac{[\mu^2 - a(b-a)]^2(a^2 + \mu^2 - r\sigma_1^2 - r\sigma_2^2)}{2(a^2 + \mu^2 + r\sigma_1^2 + r\sigma_2^2)^2}, \\ \quad \text{if } \mu^2 > a(b-a) \\ 0, \quad \text{if } \mu^2 \leq a(b-a) \end{cases} \tag{10}$$

$$W_A = \begin{cases} B_0 - I_0 - C_0 \\ + \frac{\left\{\mu^2 - a(b-a)\right\}^2}{2\left(a^2 + \mu^2 + r\sigma_1^2 + r\sigma_2^2\right)}, & \text{if } \mu^2 > a(b-a) \\ B_0 - I_0 - C_0, & \text{if } \mu^2 \leq a(b-a) \end{cases} \tag{11}$$

PM B. The payment made by the government now is divided into two parts: availability payment $t_1(C_1) = \alpha_1 + (1-\beta_1)C_1$, and performance payment $t_2(C_2) = \alpha_2 + (1-\beta_2)C_2$. The private contractor chooses the level of efforts to maximize its expected pay-off. Given α and β, the corresponding levels of effort thus solve:

$$\begin{aligned}(i_B, e_B) = \arg\max_{\tilde{i}, \tilde{e}} \alpha_1 - \beta_1 E_{\eta_1}(C_1) - \tilde{i}^2/2 - \tilde{e}^2/2 \\ -r\sigma_1^2\beta_1^2/2 + \alpha_2 - \beta_2 E_{\eta_2}(C_2) - r\sigma_2^2\beta_2^2/2 \\ \equiv \alpha_1 - \beta_1(I_0 - a\tilde{i}) - \tilde{i}^2/2 - \tilde{e}^2/2 - r\sigma_1^2\beta_1^2/2 \\ +\alpha_2 - \beta_2(C_0 - \mu\tilde{e}) - r\sigma_2^2\beta_2^2/2 \end{aligned} \tag{12}$$

We obtain the following incentive constraint:

$$(i_B, e_B) = (\beta_1 a, \beta_2 \mu) \tag{13}$$

Note that unproductive effort i only depends on the sharing of the construction risk, while productive effort e only relies on the sharing of the operational risk. It is because effort i only influences the building cost while effort e only reduces the operating cost.

As shown before, the fixed fee α is determined so as to make the private contractor to get the expected pay-off equal to 0. The government's maximization problem is written as follows:

$$\begin{aligned}\Pi_B^{gov}(i_B, e_B, \beta) = W_B = B_0 - bi - (I_0 - ai_B + C_0 - \mu e_B) \\ -i_B^2/2 - e_B^2/2 - r\sigma_1^2\beta_1^2/2 - r\sigma_2^2\beta_2^2/2 \end{aligned} \tag{14}$$

We obtain the following expression of the sharing of the construction risk and operational risk, taking into account the incentive constraint (13)

$$(\beta_1^*, \beta_2^*) = \left(0, \frac{\mu^2}{\mu^2 + r\sigma_2^2}\right) \tag{15}$$

The government assumes all construction risk since it wants to avoid the social loss caused by the unproductive effort i. As for productive effort e, the government trades off the incentive intensity and operational risk premium. Shifting more operational risk (i.e., high value of β_2) induces higher level of the effort e.

Accordingly, the level of efforts chosen by the private contractor is written as follows:

$$i_B^* = 0 \quad \text{and } e_B^* = \frac{\mu^3}{\mu^2 + r\sigma_2^2} > e_A^* \tag{16}$$

Using values of efforts expressed by (16), the expression for the fixed fee and expected welfare can be written as:

$$(\alpha_1^*, \alpha_2^*) = \left(\frac{\mu^6}{2(\mu^2 + r\sigma_2^2)^2}, \frac{\mu^2 C_0}{\mu^2 + r\sigma_2^2} - \frac{\mu^4(2\mu^2 - r\sigma_2^2)}{2(\mu^2 + r\sigma_2^2)^2}\right) \tag{17}$$

$$W_B = B_0 - I_0 - C_0 + \frac{\mu^4}{2(\mu^2 + r\sigma_2^2)} > W_A \tag{18}$$

We can thus conclude the following:

Proposition 1: PM B is strictly desirable if the social loss $(-bi)$ is observable.

In a PPP contract adopting PM A, the government determines the sharing of the whole risk (construction and operational risks) to provide the private contractor with incentives to exert both productive effort e and unproductive effort i. When the marginal benefit of the productive effort e is large enough, the private contractor is forced to bear a predetermined sharing of the whole risk and chooses second-best effort i_A^* and e_A^*. On the contrary, the government will assume all the risks to prevent the private contractor from inputting both efforts when the marginal benefit of effort e is relatively small.

PM B is characterized by the different sharing ratio of construction and operational risks between the government and the private contractor. Accordingly, the different sharing of construction risk and operational risk impacts the contractor's choice on efforts i and e respectively. In other terms, the government can provide the private contractor with different incentives taking into account the productivity of each effort. Because the payment is linked to the social loss caused by i, the effort i_B is thus restrained so as to equal to 0, while the second-best effort e_B^* is lower than the first-best effort e^{FB} but is larger than e_A^*. As effort e represents the positive externality between the building and operation phase, PM B achieves a larger extent of the bundling effect.

Proposition 1 indicates that the PPP contract using PM B yields more social benefit than that using PM A. This is however not intuitive. Note that the government faces two trade-offs in the PPP contract using PM A while only one trade-off in the PPP contract adopting PM B. In the contract using PM A, the first trade-off facing the government is between the marginal net loss $(b - a)$ caused by the unproductive effort i and marginal benefit (μ) generated from productive effort e, while the second trade-off is the incentive intensity and risk premium. On the other hand, because the government can separately induce two types of efforts via the different sharing of construction and operational risks under PM B, it only trades off the incentive intensity and risk premium of the operational risk. More trade-offs bring more restrictions to the government and result in more agency costs. In this sense, PM B is more desirable than PM A.

Case II: The Social Loss $(-bi)$ is not observable

In this case, the government is not able to observe the social loss caused by unproductive effort i; thus, the payment is not linked to $-bi$.

PM A. The government's problem is to maximize its expected pay-off while taking into account the incentive constraint (6):

$$\max_{\beta} B_0 - (I_0 - ai_A + C_0 - \mu e_A) - i_A^2/2 - e_A^2/2 - r\sigma_1^2\beta^2/2 - r\sigma_2^2\beta^2/2 \quad (19)$$

Note that $-bi$ is not included in the government's objective function as it is not observable. In this sense, the government's objective does not coincide with social welfare. This yields the following expressions of the incentive power and second-best efforts:

$$\beta^{**} = \frac{a^2+\mu^2}{a^2+\mu^2+r\sigma_1^2+r\sigma_2^2} \quad (20)$$

$$i_A^{**} = \frac{a^3+a\mu^2}{a^2+\mu^2+r\sigma_1^2+r\sigma_2^2} > i^{FB} \quad \text{and } e_A^{**} = \frac{a^2\mu+\mu^3}{a^2+\mu^2+r\sigma_1^2+r\sigma_2^2} < e^{FB} \quad (21)$$

Here, the government also faces two trade-offs: one is between the incentive intensity and the risk premium; the other is between the marginal benefit (a) of effort i and marginal benefit (μ) of effort e, as the government is not able to detect the social loss caused by effort i. As a result, the government shifts too many risks on to the operator, such as higher levels of both productive effort e and unproductive effort i compared to Case I.

$$\beta^{**} > \beta^{*}, \quad i_A^{**} > i_A^{*} \quad \text{and } e_A^{**} > e_A^{*} \quad (22)$$

Using these values of efforts, the expression for the fixed fee and the expected welfare can be written as:

$$\alpha^{**} = \frac{(a^2+\mu^2)(I_0+C_0)}{a^2+\mu^2+r\sigma_1^2+r\sigma_2^2} - \frac{(a^2+\mu^2)^2(a^2+\mu^2-r\sigma_1^2-r\sigma_2^2)}{2(a^2+\mu^2+r\sigma_1^2+r\sigma_2^2)^2} \quad (23)$$

$$W_A' = B_0 - I_0 - C_0 + \frac{\left(a^2+\mu^2-2ab\right)\left(\mu^2+a^2\right)}{2\left(a^2+\mu^2+r\sigma_2^1+r\sigma_2^2\right)} \quad (24)$$

PM B. In the PPP contract using PM B, the government's problem is to maximize:

$$B_0 - (I_0 - ai_B + C_0 - \mu e_B) - i_B^2/2 - e_B^2/2 - r\sigma_1^2\beta_1^2/2 - r\sigma_2^2\beta_2^2/2 \quad (25)$$

Subject to the incentive constraint (13), we yield the following expressions of the incentive intensities:

$$\beta_1^{**} = \frac{a^2}{a^2+r\sigma_1^2} > \beta_1^{*} \quad \text{and } \beta_2^{**} = \frac{\mu^2}{\mu^2+r\sigma_2^2} = \beta_2^{*} \quad (26)$$

The corresponding second-best efforts are as follows:

$$i_B^{**} = \frac{a^3}{a^2+r\sigma_1^2} > i_B^{*} = i^{FB} \quad \text{and } e_B^{**} = \frac{\mu^3}{\mu^2+r\sigma_2^2} = e_B^{*} < e^{FB} \quad (27)$$

Compared with Case I, the productive effort e_B^{**} remains unchanged, while the unproductive i_B^{**} is higher.

The fixed fees and expected welfare are expressed by:

$$\alpha_1^{**} = \frac{a^2I_0}{a^2+r\sigma_1^2} - \frac{a^4(a^2-r\sigma_1^2)}{2(a^2+r\sigma_1^2)^2} + \frac{\mu^6}{2(\mu^2+r\sigma_2^2)^2} \quad \text{and } \alpha_2^{**} = \frac{\mu^2C_0}{\mu^2+r\sigma_2^2} - \frac{\mu^4(2\mu^2-r\sigma_2^2)}{(\mu^2+r\sigma_2^2)^2} \quad (28)$$

$$W_B' = B_0 - I_0 - C_0 + \frac{\mu^4}{2\left(\mu^2+r\sigma_2^2\right)} - \frac{a^3\left(2b-a\right)}{2\left(a^2+r\sigma_1^2\right)} \quad (29)$$

Using the value of effort i and e under two payment methods, we obtain the following relationships:

$$\begin{cases} i_A^{**} \geq i_B^{**} \\ e_B^{**} \geq e_A^{**} \end{cases} \Leftrightarrow a/\sqrt{\sigma_1^2} \leq \mu/\sqrt{\sigma_2^2},\ \beta_2^{**} > \beta^{**} > \beta_1^{**} \quad (30)$$

The ratio $a/\sqrt{\sigma_1^2}$ and $\mu/\sqrt{\sigma_2^2}$ represent the benefit-cost ratio of effort i and e respectively. (30) indicates that the relationship of the effort level between the two payment methods depends on the benefit-cost ratio of the two efforts. If the benefit-cost ratio of effort i is not larger than that of effort e, improving the effort i brings less net benefit to the government comparing with improving effort e. The government using PM B thus transfers more operational and less construction risk to the private contractor to promote effort e_B and restrain effort i_B, while the government cannot differentiate the sharing of two risks using PM A. As a result, adopting PM B will induce more productive effort i and less unproductive effort e than PM A. We can thus conclude:

Proposition 2: In the case where the social loss $(-bi)$ is not observable, PM B is desirable only if $a/\sqrt{\sigma_1^2} \leq \mu/\sqrt{\sigma_2^2}$.

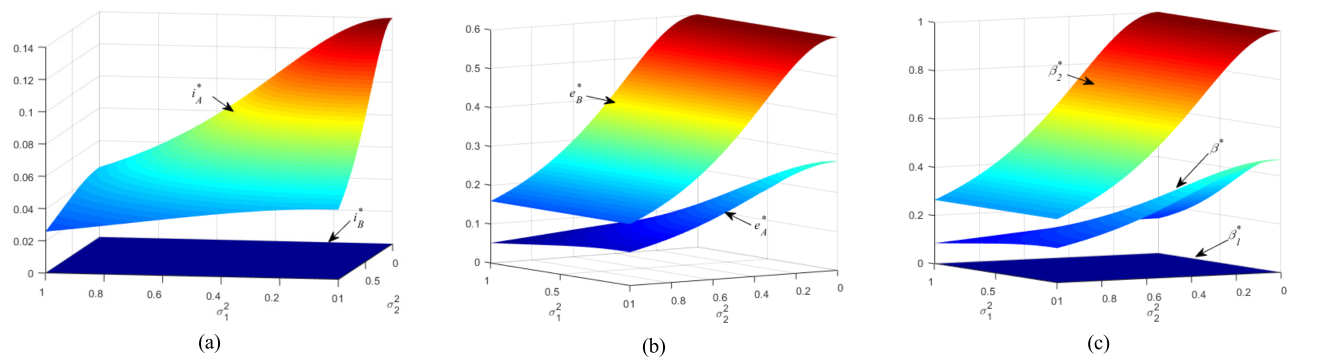


FIGURE 1. **Relations of efforts and risk sharing under PM A and PM B (Case I).**

Proof: Using(24) and (29),

$$W_B' - W_A' = \frac{\mu^4}{2\left(\mu^2+r\sigma_2^2\right)} - \frac{a^3\left(2b-a\right)}{2\left(a^2+r\sigma_1^2\right)} - \frac{\left(a^2+\mu^2-2ab\right)\left(\mu^2+a^2\right)}{2\left(a^2+\mu^2+r\sigma_1^2+r\sigma_2^2\right)}$$
$$= \frac{\left\{2ab(\mu^2+r\sigma_2^2)+\mu^2 r\sigma_1^2 - a^2 r\sigma_2^2\right\}\left(\mu^2 r\sigma_1^2 - a^2 r\sigma_2^2\right)}{2(a^2+\mu^2+r\sigma_1^2+r\sigma_2^2)(a^2+r\sigma_1^2)(\mu^2+r\sigma_2^2)}$$

As

$$2ab(\mu^2+r\sigma_2^2)+\mu^2 r\sigma_1^2 - a^2 r\sigma_2^2 > 2a^2(\mu^2+r\sigma_2^2)+\mu^2 r\sigma_1^2 - a^2 r\sigma_2^2 = 2a^2\mu^2 + a^2 r\sigma_2^2 + \mu^2 r\sigma_1^2 > 0$$
$$2(a^2+\mu^2+r\sigma_1^2+r\sigma_2^2)(a^2+r\sigma_1^2)(\mu^2+r\sigma_2^2) > 0,$$

whether $W_B' - W_A' \geq 0$ depends on the value of $\mu^2 r\sigma_1^2 - a^2 r\sigma_2^2$. If $\mu^2 r\sigma_1^2 - a^2 r\sigma_2^2 \geq 0$, $W_B' \geq W_A'$.

Q.E.D.

Although Proposition I shows that PM B is desirable in a case where the government can observe the social loss caused by effort i, Proposition II indicates that PM B may not be optimal anymore in the opposite case. If $a/\sqrt{\sigma_1^2} > \mu/\sqrt{\sigma_2^2}$ holds, PM B induces much more unproductive effort i and less productive effort e, PM B thus becomes socially suboptimal. As (30) shows, only if $a/\sqrt{\sigma_1^2} \leq \mu/\sqrt{\sigma_2^2}$, PM B induces more productive effort e and less unproductive effort i than PM A, thus is more desirable.

Finally, we compare the social welfare accomplished via the PPP contract using PM A and PM B between Case I and II. As the above analysis shows, whether the social loss $(-bi)$ is observable or not has great effects on the efficiency of contracts using PM A or PM B. Using(11), (18), (24), and (29), we obtain $W_A > W_A'$ and $W_B > W_B'$.

Proposition 3: The unobservability of the social loss $(-bi)$ lowers the social welfare of PPP contracts using either PM A or PM B.

The fact that the social loss $(-bi)$ is not observable to the government changes cost-reimbursement rules. If the government cannot detect the social loss caused by effort i, it fails to identify the unproductive effort and believes that both efforts are productive. The government using PM A shifts too many risks on the private contractor and increases incentives to improperly boost both unproductive and productive efforts. PM B however induces overinvestment of unproductive effort i, while keeping the same level of effort e as in Case I. As a result, the social welfare of the PPP project using either PM A or PM B decreases as compared to Case I.

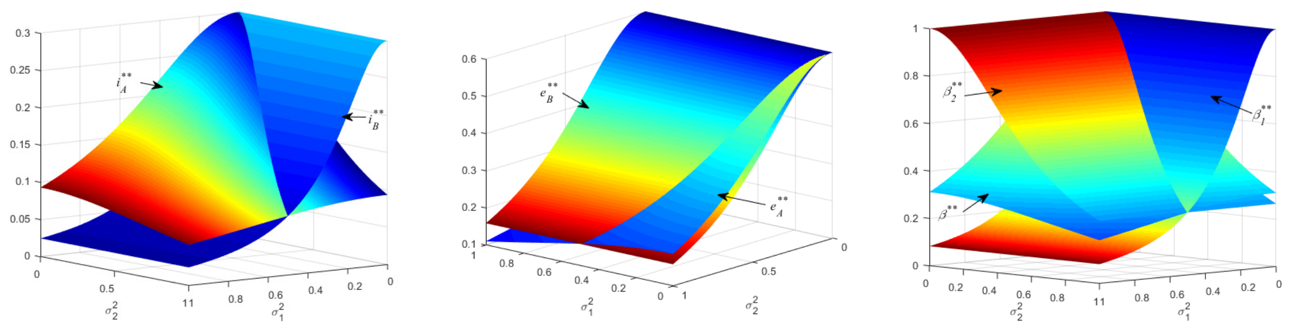
IV. NUMERICAL EXAMPLE

To further enhance the understanding, this section demonstrates the application of the model by furnishing a numerical example. Since the comparative advantage in bundling effect and social welfare between PM A and PM B only depends on parameters representing marginal benefits, loss of two efforts, as well as the variances of construction and operational risks, we omit the values of project costs and social benefits in this example. Instead, we assign the marginal benefits and loss brought about by efforts i and e as $a = 0.3$, $b = 0.8$, $\mu = 0.6$, and standardize the values of the variance of construction and operational risks $\sigma_1^2 \in [0, 1]$ and $\sigma_2^2 \in [0, 1]$ respectively. Finally, we suppose that the private contractor has a constant degree of risk aversion $r = 1$.

Figures 1 and 2 indicate the relations of efforts as well as the sharing ratio of risks between PM A and PM B in Case I and Case II respectively. In both cases, the level of efforts chosen by the private contractor are second-best, as the level of unproductive effort i is either equal to or larger than the first-best level and productive effort e is underinvested under either PM A or PM B.

As Figure 1(a) shows, the unproductive effort chosen by the private contractor under PM A is always larger than that under PM B, i.e., $i_A^* > i_B^*$. On the contrary, PM B always induces higher level of productive effort than PM A, i.e., $e_B^* > e_A^*$, as shown in Figure 1(b). Figure 1(c) indicates that the sharing ratio of the whole risk under PM A is between the sharing ratio of construction and operational risks under PM B.

Providing the value of a, b, and μ, the relations of efforts and risk sharing under PM A and PM B depend on the variance of construction and operational risks in Case II. Figures 2(a) and 2(b) show $i_A^{**} < i_B^{**}$ and $e_A^{**} > e_B^{**}$ only when



(a) (b) (c)

FIGURE 2. **Relations of efforts and risk sharing under PM A and PM B (Case II).**

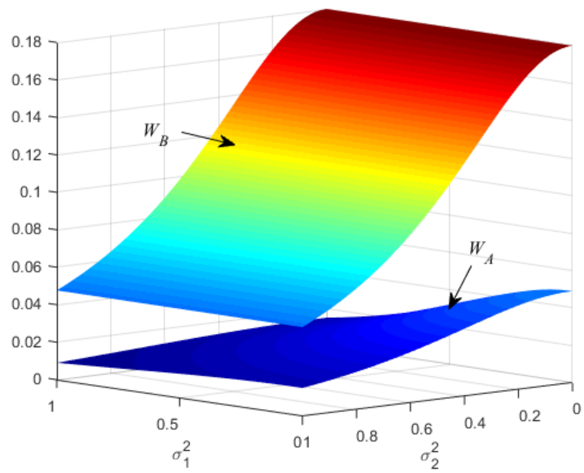


FIGURE 3. **Comparison of social welfare between PM A and PM B in Case I.**

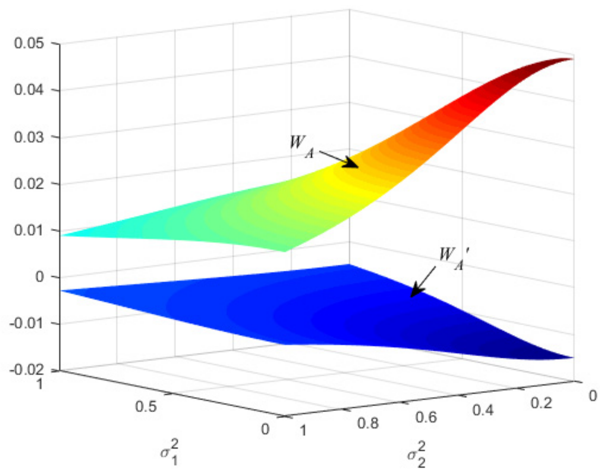


FIGURE 5. **Comparison of social welfare brought about by PM A between Case I and Case II.**

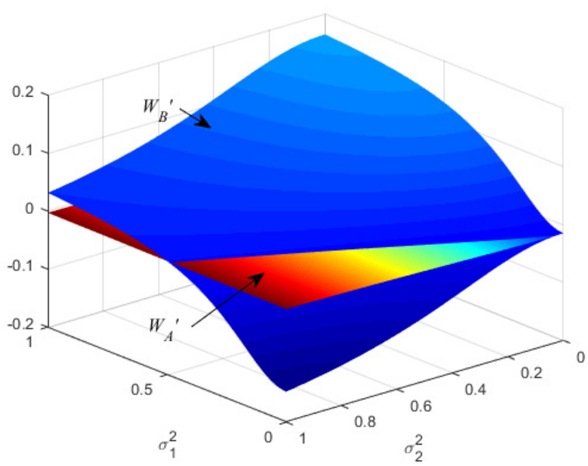


FIGURE 4. **Comparison of social welfare between PM A and PM B in Case II.**

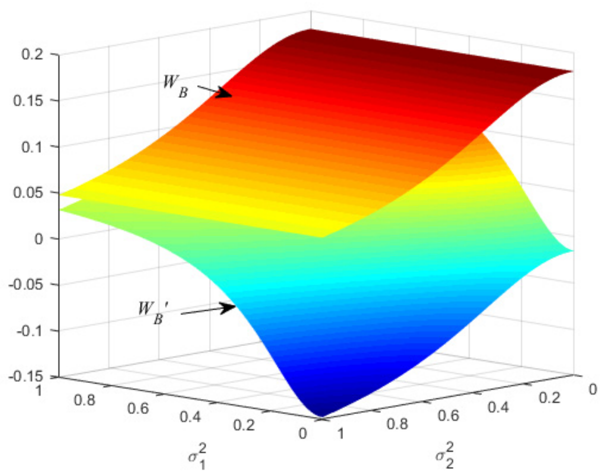


FIGURE 6. **Comparison of social welfare brought about by PM B between Case I and Case II.**

$a/\sqrt{\sigma_1^2} < \mu/\sqrt{\sigma_2^2}$, i.e., $2/\sqrt{\sigma_2^2} < 1/\sqrt{\sigma_1^2}$. The sharing ratio of the whole risk under PM A is still between the sharing ratio of construction and operational risks under PM B, as shown in Figure 2(c).

Figures 3 and 4 illustrate the comparison of social welfare of the PPP project using PM A and PM B in Case I and Case II respectively. As shown in Figure 3, the social benefit using PM B is always larger than when using PM A in Case I.

However, Figure 4 indicates that the difference between PM A and PM B depends on the variance of construction and operational risks providing the value of a, b, and μ. Only when $a/\sqrt{\sigma_1^2} < \mu/\sqrt{\sigma_2^2}$, i.e., $2/\sqrt{\sigma_2^2} < 1/\sqrt{\sigma_1^2}$, PM B brings about more social welfare than PM A.

Finally, Figures 5 and 6 show that the social welfare of the PPP project using either PM A or PM B is undermined if the government cannot detect the social loss caused by the unproductive effort.

These observations are consistent with Proposition I, II, and III.

V. DISCUSSION AND IMPLICATIONS

This article assumes that the private contractor exerts two types of efforts, i and e, in the building phase of a PPP project. Effort i is unproductive in the sense that it saves the building cost but sacrifices the social benefit of the project, while effort e is productive and reduces the operating cost without social loss. As the efforts are not verifiable, the government has to shift risks to the private contractor and indirectly control both the productive and unproductive efforts. In other words, the government adopts incentive contracts to provide incentives with the private contractor to choose the appropriate level of efforts. Note that the sharing of construction risk only influences the choice of effort i by the private contractor, while the sharing of operational risk solely provides the private contractor with an incentive to exert effort e. The logic behind these is that the positive externality is internalized by bundling two building and operation tasks to one private contractor. Because effort e lowers the operating cost (positive externality), shifting the operational risk to the private contractor will promote the positive externality to be internalized. However, as effort i only influences the building cost, it is only affected by the sharing of the construction risk.

This article indicates that different payment methods have different impacts on the efforts chosen by the private contractor and social welfare. Two types of availability payment methods, i.e., PM A and PM B, result in different incentive intensities as they are equipped with different cost-reimbursement rules. PM A, which consists of a unitary payment, involves one control tool, i.e., sharing of the whole risk (construction and operational risks), which is utilized by the government to determine the incentive intensity for both productive and unproductive efforts. On the other hand, the PPP contract using PM B is equipped with two control tools, i.e., sharing of construction as well as operational risks. PM B is thus used to incentivize the private contractor to exert high level of the productive effort and restrain the unproductive effort separately. In this sense, PM B is desirable if the payment is perfectly linked to the project performance as it provides more control tools than PM A and enlarges the extent of the bundling effect.

However, if the government (partly) fails to link the payment mechanism with the specified performance standards, the benefits of incentive contracts erode. For example, if KPIs are too complex to be monitored and measured, the government may not find the defect of some services triggered by the unproductive effort. Put differently, the government cannot distinguish between the productivity of efforts, therefore it brings out distorted incentives which results in damages to the welfare of the PPP project using PM A or PM B. The benefit of PM B is significantly undermined particularly since the government wrongly regards unproductive effort i as a productive one and shifts too many construction risks to increase the incentive.

To summarize, it is important to keep in mind that the incentive effect of the availability payment mechanism depends on whether it is correctly linked to the project performance (outputs). If that is the case, PM B is more effective as it is equipped with two control tools, i.e., the sharing of construction risk and that of operational risk. If such is not the case, for instance if the KPIs don't correctly reflect the social welfare of PPP projects, the availability payment mechanism provides the private contractor with distorted incentives. The government thus discriminates between PM A and PM B, taking into account the observable risks and benefits of efforts. As stated in Proposition II, the advantages of PM A or PM B depend on the observable benefit-cost ratio of efforts i and e. Only if the former is smaller than the latter will the contract adopting PM B be optimal because it will better restrain the unproductive effort i and maintain a high level of bundling effect.

VI. CONCLUSION

Notwithstanding the policy relevance, little theoretical work has been carried on the topic of the payment mechanism of PPPs so far. This article analyzes the incentive mechanisms of availability payment methods PM A and PM B, as well as the impacts of those on project efficiency in terms of bundling effects and social welfare. We especially assumed two types of efforts: the unproductive effort, i, which saves the building cost but sacrifices social benefit; and the productive effort, e, which reduces the operating cost without social loss. Our analysis showed that PM B, which provides the government with two control tools (sharing of construction risk and sharing of operational risk) to effectively restrain the unproductive effort and promote bundling effect (boost the productive effort), is more desirable than PM A, which is only equipped with one control tool (sharing of the whole risk) if the payment is perfectly linked with the project performance.

Our results also emphasized that PM B may be unsuitable in the opposite case, where the government fails to detect the social loss caused by unproductive effort i. If the government cannot identify the unproductive effort, it provides the private contractor with distorted incentives to promote both productive and unproductive efforts. The benefit of PM B therefore is undermined as the government cannot prevent the unproductive effort, which in turn limits the bundling effect. The effectiveness of PM A and PM B finally depends on the observable benefit-cost ratio of effort i and effort e. Only if the former is smaller than the latter is PM B optimal, and vice versa.

It should be noted that the weight of operational costs vs construction costs will have an important effect on efforts *i* and *e*. For example, in the case of social PPPs (hospitals, prisons, schools), operation costs can be a lot more important and thus incite the private contractor to focus on increasing productive effort *e* in order to optimize the operational costs.[3] It suggests that PM B is dirsable since the benefit-cost ratio of effort *e* is larger than the benefit-cost ratio of effort *i*.

Notably, three important issues have been left out of the analysis. The first relates to the bargaining power in the contract negotiation at the beginning of PPP projects. This article assumes that a perfect competition is realized in the bidding; the government thus has all the bargaining power to extract all the surplus. In the real world, however, there are significant transaction costs. For instance, the costs of participating in the bidding process. Thus, in many cases, the number of bidders is restricted and the private contractor might have some bargaining power. The effects of the bargaining power of the private contractor over the effectiveness of the incentive contract requires to be studied in depth.

Second, we haven't included much of the institutional context in which PPP contracts are designed. Institutions shape behaviors of both the government and the private contractor. In particular, the long-term nature of a PPP contract leads the government to behave opportunistically in a weak institutional framework [51]. Observing construction costs, the government updates its beliefs about the firm's efficiency. It may be then tempted to take regulatory actions that expropriate firm rents. In this sense, the government's opportunism may also influence the incentive effects of PPP contracts using different payment methods, as well as the rationale of adopting these methods. This, like other important issues on the design and usefulness of PPP incentive contracts, await further research.

Finanlly, we have not yet investigated how to estimate the input data used in the theoretical model in reality. Quantitative analysis of the optimal payment method settings should be carried out in the future.

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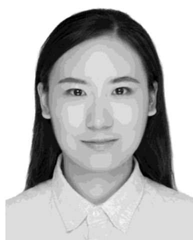

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