Nova Economia
ISSN: 0103-6351
ne@face.ufmg.br
Universidade Federal de Minas Gerais
Brasil

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Nova Economia, vol. 26, núm. 2, 2016, pp. 369-392
Universidade Federal de Minas Gerais
Belo Horizonte, Brasil

DOI: http://dx.doi.org/10.1590/0103-6351/2935

Efficiency, cost and benefits in contracts of public private partnerships

Eficiência, custos e benefícios em contratos de parcerias público-privadas

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Abstract

This paper presents a theoretical model in order to better understand the elaboration of Public-Private Partnership contracts. Starting from the model developed by Iossa and Martimort (2012), we consider an additional parameter that measures the sensibility of the effort made in between the stages of the project. We also delimitate the numerical range of the variable that determines the technology flexibility. In this regard, a *bundling* regime, under which the companies form a consortium, presents better results than when they are contracted separately. This is a consequence of the first model, in which the companies are able to internalize the externalities of the productive process. On the other hand, even though the *bundling* regime is more efficient, the government should seek mechanisms to monitor the quality of services.

Keywords

public-private partnerships; contracts.

JEL Codes H54; L14.

Resumo

Este trabalho desenvolve um modelo teórico para compreender a elaboração do desenho de Parcerias Público Privadas. Toma-se como base o modelo de Iossa e Martimort (2012), modificando-o com a adição de um parâmetro que mede a sensibilidade dos esforços entre os estágios do projeto e também delimitando a variável que determina a flexibilidade da tecnologia. Neste sentido, o regime de bundling*, em que as empresas são agregadas em um consórcio, mostra-se se superior ao que as empresas são contratadas separadamente. Isto se dá porque no primeiro modelo, as firmas conseguem internalizar as* externalidades *advindas do processo produtivo. Por outro lado, mesmo que este regime se mostre mais eficiente, o governo deve procurar mecanismos que monitorem eficientemente o índice de qualidade dos serviços.*

Palavras-chave

parcerias público-privadas; contratos.

Códigos JEL *H54; L14.*

1 Introduction

Governments are economic agents responsible for providing basic goods such as: infrastructure, education, safety and health. Due to bad management of public resources or credit/budget constraints there are historical difficulties to supply these services. During the last decades of the 20th Century, many researchers as well as policymakers, devoted themselves to develop alternatives to obtain a higher social welfare.

As an alternative policy to directly supply State services by governments, in the mid-1980s, privatizations were adopted in order to offer basic services and infrastructure to the population. In the following decade, the concession policy arose as a mechanism which provides better results to supply public goods.

It was in the UK that a new form of integration between the private and public sectors arose, the Private Finance Initiative (PFI). This contractual model allowed the public sector to be partly responsible for service provision, but using private funding and management methods, considering the reduction of the government's investment capacity due to limits imposed by the Treaty of Masstrich.[1] This type of partnership has proved to be very well suited and, with the passing of time, PFI projects have been expanded and currently are called Public-Private Partnerships. Recently, PPPs have shown to be a very important tool for the enrichment of this theme.

Within this context, according to Grimsey and Lewis (2004), PPPs might be defined as a bundle of rules that allow a public entity to participate or support infrastructure service supplying, which were previously provided by the public sector. This new contractual arrangement has many forms and it may set one or many tasks for the private partner that can include management, financing, developing or repairing a building or a service.

Since their emergence, PPPs are being used in many infrastructure sectors, in parts of the European continent, the USA and Latin America. The larger concentration of these public contracts occurs in the health sector, sanitation, prisons, roads and schools (European PP Report, 2009). It can be highlighted that the UK, as a precursor country in these contractual relationships, has sig-

1 This treaty is also called the Treaty on European Union and was signed on February 7, 1992 in the Dutch city of Maastricht. The importance of it is related to the existing integration between various European countries which would then become a political unification. Therefore, the European Community name is replaced by the current name of the European Union.

ned around 70 projects from 1998 to 2006 (HM Treasury, 2006). In the world scenario, in 2005, according to Price Waterhouse Coopers (2005), contracts signed using the PPP model were around 55 billion dollars.

In the Brazilian context, PPPs were regulated by Law N° 11,079 of December 30, 2004. According to the Planning, Budget and Management Ministry,[2] from 2009 to 2010 the Federal Government signed several contracts under this arrangement form, among them, a Data Center management of Caixa Econômica Federal, in partnership with Banco do Brasil, the Pontal Project of irrigation in Pernambuco, and Digital Television Network. At the state level, the Public Private Partnerships Observatory launched in 2011 the first database of state PPPs report. This report identifies 17 projects in seven Brazilian states, whose contracts are valuated at more than 15 billion Reals. The most representative sector involves building or reforming of football stadiums for the 2014 World Cup, followed by sanitation, roads and subway systems (Pereira; Prol, 2011).

Despite this growth, PPP performance evaluation remains inconclusive. In the UK, the PFI projects are cheaper and more efficient when compared to public traditional contracts. According to HM Treasury Report (2003), 76% of PPP projects have been completed within the period stipulated in the contract. In turn, only 30% of projects executed by traditional procurement were completed within the contractual period.

On the other hand, the PPPs had lower results in provision of services related to water supply in France. In addition, sectors that have rapid technological change do not seem to be appropriate in these partnership contexts (Iossa; Martimort, 2009). Existing evidence also suggests that renegotiations have played a significant role in PPP arrangements worldwide. In Latin America, there are numerous cases where governments have failed to honor contractual terms and the projects were abandoned (Guasch; Straub, 2009).

This evidence questions the results provided by PPP contracts, but they also stress the need of theoretical model development for the understanding of incentives in this contractual arrangement. Thus, the main PPP contract components are:

(1) *Bundling*: The PPP involves grouping design, construction, financing and project operation, which are contracted services, with a consortium for-

2 See http://www.planejamento.gov.br/hotsites/ppp/conteudo/projetos/projetos.html.

med by private firms. In a general way, this consortium includes a company responsible for the management and another for constructing or reforming.

(2) *Risk transfer*: When compared to a traditional concession, the PPP contract involves a larger risk transfer. In this new arrangement, the government specifies the service and desired basic patterns, but it leaves the consortium with the responsibility and control of delivery and accomplishment of the specified prerequisite standards. Thus, the design, construction and operational risk are substantially transferred to the private sector.

(3) *Contractual time*: The average PPP contract time is between 20-35 years. The payments to the private sector can be made by the government, such as in PFI projects or directly by the general public as service users, such as it occurs in the default concession contracts.

Under this scope, this article develops a theoretical model for PPP contracts aiming to understand how contract *bundling* or *unbundling* affects the incentives in this arrangement. To achieve this goal, we constructed a model based on Iossa and Martimort (2012) with two main changes. The first one consists in delimiting the parameter that measures the technology flexibility. The second one is to add a term which measures the builders' effort sensibility in relation to the operator costs.

These changes are important because technology is a preponderant variable for the procedures related to the infrastructure. In Iossa and Martimort (2012) this variable has total flexibility of change. Here we limit this flexibility capacity to evaluate its impact in PPP contract performance. The parameter addition that measures the effort sensitivity serves as an indicator of a task delegation process within a PPP concession contract. The task distribution, whether in ungrouped or consortium forms, modifies the incentives received and can affect the success of PPP contracts. For these cases, we present the contractual *bundling* schemes (companies aggregated in a consortium) and *unbundling* (contractors separately), evaluating the performance obtained.

This article is structured in five sections. Section one is this introduction. In section two, the main differences between common concessions and PPPs in the Brazilian legal system are highlighted. The literature review is made in section three. The following sections have the theoretical model and the final remarks. The proofs of propositions are presented in the appendix.

2 **Concessions and PPPs: a brief analysis of the Brazilian case**[3]

In Brazil, the concessions law[4] came into effect in 1995. This complies with Federal Constitution Article 175, which allows the State to grant, in general, to the private operator running a service which can be provided by the public entity through bidding process in competition mode, which shows the capacity of performance at their own risk and for a specified period.[5]

After that, a new concession type, named as special, emerged. This new procurement form is called by Public-Private Partnership (PPP) and it is regulated by Law N° 11,079 of December 30, 2004. The national emergence of this new form of public service was given as a potential measure to reduce the infrastructure bottlenecks observed in Brazil.

In this sense, the PPP opportunities are concentrated in two modalities "sponsored" or "administrative". The first two paragraphs written in the Article 2 of this law assigns to the sponsored mode, in which the private partner might be paid by rate charged from service users or, receiving a direct payment from the public sector, while the private partner administratively provides the service having the Direct Administration as service recipient.

Within this scope there are important distinctions between these contractual arrangements. First, the common grant is guided by Law N° 8,987 which states that there cannot be payment by the State to a private entity for a service provided by the latter. Thus, the payment of the concession holder derived from the fee for the end user of the service. Moreover, in the conventional way of granting all damages caused to the conceding power, to consumers or third parties, are the responsibility of the concessionaire; that is, a major difference when it comes to PPPs.

Regardless of the adopted form, this contractual arrangement provides risk sharing between related parties, such as economic crises, natural disasters and currency fluctuations. This allows the public administration to become responsible for that debt, even when it is due to the mishandling of the PPP or illegal act by the private partner.

Finally, there is another important point that distinguishes the common concession from the PPP arrangement, that is: a society must be legally

3 This section was based on Fernandez *et al.* (2014).

4 Law n°. 8,987/95.

5 Law n°. 8,987/95, article 2, II.

created with the specific purpose of the partnership management and the patrimony assigned to it. The company management can be performed by the private sector, and there is an impediment of Public Administration to hold the majority of voting shares in this institution.

3 **Evaluation of public-private partnership contracts: Some contributions**

The key point in public-private partnership performance is the possibility provided to governments to expand the supply of public goods and services using private resources and somehow increasing their budget. According to Bettignies and Ross (2009), the entry into a partnership with the private sector contributes better than the traditional contractual arrangement because the partnership is a better incentive towards the adoption of innovative ideas that could serve as a tool to assist the government to achieve lower costs in the provision of public services.

These advantages are highlighted by Li and Akintoye (2008). The first is the competition among private agents interested in entering a partnership with the State. These authors also reiterate the fact that the private sector's innovative capacity is something that should be considered. Thus, they justify this hypothesis value, taking into account that in the private market there is intense competition, so innovation is a competitive advantage for companies.

Conversely, risk sharing must be considered when a PPP concession is made. According to Dewatripont and Legros (2005) and Sadka (2007), risks can be divided into two major groups: exogenous and endogenous. The first is due to some event that is out of control of the contractual partners, such as bad weather. On the other hand, endogenous risks occur when one party is better informed than the other and then, there is the agency problem.

The correct risk allocation should be done according with which partner has more control over the occurrence of the risk. Furthermore, if the partners have similar responsibilities, it should be allocated to whom is the most able to bear it, i.e., who is less risk averse. This implies that it is not efficient to transfer exogenous risks to the private partner, if it is not in a better situation to deal with the possible consequences. In this sense, if the company is forced to bear these risks, it will require a higher return without any concomitant benefits in terms of better quality or reducing infrastructure costs.

Concerning the investments, Hart *et al*. (1997) developed a theoretical model that seeks to identify which conditions the government should be responsible for the service provision, or alternatively, when this benefit can be transferred to the private sector. The authors suggest that the provision of public services should continue being the government's competence when possible reductions in undertaking costs have a large effect on the quality of the service. Conversely, privatization is better when cost reductions may be controlled by a competitive contract, or when the innovation process concerning design quality characteristics is important.

Within this incomplete contract context, Hart (2003) develops a PPP model where the public entity is an active owner after the project is finished and which possesses two options: hire a third party to build and operate the project (bundling regime) or contract two different companies (unbundling regime). The author assesses PPP as a good option when service quality can be well defined in the initial contract, while the building quality cannot.

Under the government spending perspective, Maskin and Tirole (2008) report that bundling not always induces the building and operation firms responsible to internalize operational cost reduction. This procedure could lead to an efficiency loss because the best builder is not necessarily the best operator. Moreover, bundling might encourage choices that lead to future cost reduction over the service quality because of collusion between the operator and the regulator, who together can manipulate the project's accounting in their favor.

It's also important to quote the Balduzzi's (2011) extension of Hart's (2003) model, analyzing the theoretical role of the labor force in the PPPs. According to the author, public provision is the best choice when employer and employee efforts are complementary and relevant to the project. In general, health services require a very high investment level to the private enterprise and must be kept under the public sector. Otherwise, PPPs are the best choice.

The evidence points out the need of studying theoretical models to understand PPP contractual mechanism design. The literature highlights the task process delegated by the government in an environment where public agents must hire one or more companies, joined by a consortium or separately. In this management task process, it stresses the agency problems, the role of risk transfer and ownership structure.

In a nutshell, the literature reports that PPPs could be a good mechanism for providing public infrastructure services if the project's quality can be well specified contractually and whether they have been provided with mechanisms to enable regulation and monitoring of this variable. In the next section the theoretical model for PPPs, which focuses on the design of aggregate or separate contracts, is presented.

4 **Contract model of PPPs**

This section presents the contractual model that is the theoretical basis for performance evaluation of public-private partnerships contractual design. The theoretical basis for this model is Iossa and Martimort (2012). Along the section, we have added some changes aiming to evaluate the performance to be achieved in the bundling and unbundling regimes. At the end of this section, we compare our results to their results.

4.1 **Basic structure**

PPP contract development, according to Barros and Giralt (2009) can be summed up in two different contractual structures. The first one consists of joining investment and service provision within a single contract. The second, that has shown to be more common in sectors such as health, education and technology information, etc, is characterized by having two different contracts, one for investment and another for service provision.

The model for building or remodeling an infrastructure is characterized as a traditional agency problem wherein the government (principal) must contract a firm or a consortium (agent) to build or remake and operate the infrastructure.

In this sense, we based our analysis on Iossa and Martimort's (2012) dynamic contractual model in a multitasking environment. It is recognized that neither public authority nor the private sector can predict all contingencies *ex-ante* (productivity shocks) that might arise during operations. The incentives are provided by a Q. quality index.

It is supposed that a contractual design must be performed, basically, in two stages. In the first, the firm responsible for providing infrastructure[6] (builder) chooses how it is going to perform that procedure. We follow Hart's (2003) hypothesis, that is, incomplete contracts are generated because the constructor could modify the nature of the building or services without violating contractual terms. To exert effort "a" that company improves the project's quality and increases its social value. To run investment "a" has a cost $\frac{a^2}{2}$.

To operate the project, the responsible company receives an amount γ for services rendered. If services are not paid directly by the consumer, the government still will pay a sum γ to that company and will get $1-\gamma$ and it might be considered as a social benefit resulting from this service provision. So, the stochastic revenue received by the operator can be shown to be as:

$$R = e + \xi, \xi \sim N\left(0, \eta^2\right)$$

This benefit depends exclusively on the operational effort "e" exerted by the operator. This variable captures operational undertaking efficiency, being that, the former increases the benefit, but it presents a higher cost to the operator firm. This cost could be considered as effort disutility and it is measured in monetary terms as:

$$\frac{\mu}{2}\left(e - \delta a - \theta\right)^2$$

Where: θ: represents a productivity shock and captures the uncertainty between the building and operation stages, being that, $\theta \sim N\left(0, v^2\right)$;
μ : reflects technology flexibility during the operational stage, being that, $\mu \in (0,1)$. When μ is closer to one, the less flexible is the technology.
δ : is a sensitivity measure[7] which measures the effort weight (transfer) from the building to the operational stage. Defined as $\delta \in (0,1)$.

6 The Constructor is the firm responsible for infrastructure services. It is not necessary that the project be built from scratch. This firm could be responsible only for adapting the infrastructure.
7 This sensitivity measure could be considered as a measure of transfer of externalities among the stages of the project.

Regarding the Iossa and Martimort (2012) model, we modify the technology parameter (μ) restricting its flexibility. This change allows measuring or estimating, approximately, the impact of a technological change in the incentive parameters. In contrast, a parameter (δ) is added, related to how the construction company's effort sensitivity affects the operator's performance. This effort transfer can not be full. In other words, if the construction project were flawless, it does not necessarily impact a cost reduction of 100% on the operation phase.

Revenue R is verifiable and it might be employed by using performance indicators. However, public authority cannot discern the external variable impact ζ, in the operational effort and in R. Insofar, building and operation costs are not verifiable. The government has at its disposal the quality index Q employable to check the infrastructure quality.

$$Q = a + \varepsilon,\ \varepsilon \sim N\left(0, \sigma^2\right).$$

Thus, Q is defined as the set of specifications of the project under the minimum acceptable quality level.

4.2 **Contractual arrangements**

PPP contracts are usually performed in *unbundling* or *bundling* schemes. In the first form, the operator does not see the constructor's efforts, but it can perfectly see the equilibrium value of this variable. The Constructor receives a reward supplied by quality index.

$$t_B\left(Q\right) = \alpha_B + \beta Q$$

The Operator keeps the same revenue parcel under a linear scheme.[8]

$$t_O\left(R\right) = \alpha_O + \gamma R$$

α_O, α_B, β and γ are greater than zero.

The parameters α_O and α_B are *ex post* payments made by the public au-

8 We follow Holmstrom and Milgrom (1991), that is, contracts are linear in the contracting variables.

thority and β and γ are presenting incentive intensity. The Operator chooses an effort level which depends on the effort made by the constructor in the previous stage. As a result, the constructor also could be paid with revenues, internalizing the impact of subsequent stages. In the *bundling* case, the payment scheme is:

$$t\ (Q,R)=\alpha+\beta Q+\gamma R$$

Companies have an external opportunity cost normalized to zero. Contracts are designed before productivity shocks take place. The Government is risk neutral and maximizes its liquid revenues minus infrastructure service costs. In a welfare analysis, the public agent's goal is to choose the optimal β and γ parameters seeking to encourage firms to exert the highest effort level. Formally, under *unbundling*, the public sector's principal aim is to:

$$R-t_B(Q)-t_O(R)-I$$

And the main goal under *bundling* is:

$$R-t(Q,R)-I$$

The Government pays investment I and arrogates itself of all revenues. Only for convention's sake, it is determined that, the constructor must invest I and receives a payment $t(Q,R)+I$. Firms are risk averse and have a constant aversion risk grade $r\geq 0$ and a utility function $V(x)=1-exp(-rx)$. When there is a consortium formation, this case is compounded by only two firms, we suppose that their risk profile does not change, that is, the conglomerate risk aversion coefficient is also greater or equal to zero.

According to Iossa and Martimort (2012), risk aversion assumption captures the fact that a PPP project to operate or build an enterprise could represent a big portion of the firm's activities, in such a way that the firm will hardly be able to diversify its activities. Under the *unbundling*[9] regime, the constructor and the operator maximize:

$$E\left(V\left(t_B(Q)-\frac{a^2}{2}\right)\right) \text{ and } E\left(V\left(t_O(R)-\frac{\mu}{2}(e-\delta a-\theta)^2\right)\right)$$

9 E (.) is the expectation operator.

And under the *bundling* regime, the aim of the consortium is to maximize:

$$E\left(V\left(t(Q,R)-\frac{a^2}{2}-\frac{\mu}{2}(e-\delta a-\theta)^2\right)\right)$$

Thus, we constructed the basic structure of the theoretical model. Next, the canonical contract model is presented and then the performances in *bundling* and *unbundling* regimes are shown, to the amplified cases of Iossa and Martimort's (2012) model.

4.3 **Contractible efforts and shocks**

We suppose that the efforts of the building and operation stages are fully contractible and all shocks can be predicted. In this sense, builder and operator have the most efficient effort level that generates the highest benefit. So, companies receive a sum $R=e$ and $Q=a$ minus the costs to exert the effort. Independently of the chosen contractual arrangement, firms are insured against all risks. Hence we have that the operator's problem is:

$$\max_e V(x)=1-\exp\left[-r\left(e-\frac{\mu}{2}(e-\delta a-\theta)^2\right)\right]$$

and the optimal "e" choice is:

$$e(\theta)^*=\delta a+\frac{1}{\mu}+\theta$$

Analogously the contractor chooses its optimal efforts level:

$$\max_a V(x)=1-\exp\left[-r\left(a-\frac{a^2}{2}\right)\right]$$

And then we have that:

$$a^*=1$$

The operational cost $e(\theta)^*$ depends on the transferring degree of this effort between project stages. Intuitively, in an environment where companies have all available information, it is reasonable to suppose that they will cooperate and then $\delta \to 1$. Note that a better coordination between stages implies a higher builder effort level and that affects the operator's effort directly. It is important to note that if the technology is less flexible ($\mu \to 1$) the lower the effort level during the operational stage. A more flexible technology allows for a better adaptation consisting of an increase of $e(\theta)^*$.

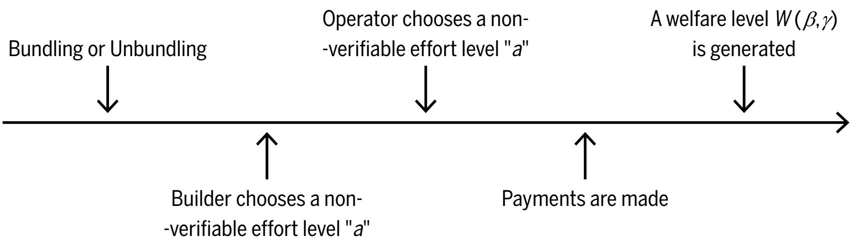
Alternatively, we could capture the effect of good phase coordination between project stages, considering that operator revenues had been an increasing effort function ($\lambda > 1$) of first stage:

$$R = \lambda a + e + \varepsilon,\ \varepsilon \sim N\left(0, \sigma^2\right)$$

This hypothesis maintains that a good project design[10] can reduce operation costs allowing a revenue increase. This fact also generates a positive externality to the government which has the social value $S = \lambda a$. Thus, optimum first phase effort level remains strictly positive and we would have quality index as a gauge of an infrastructure social value.

Finally, figure 1 presents the contractual choice game stages using a temporal line:

Figure 1 **Contractual choice game timeline**



Source: authors

The game starts when the Government decides whether to choose the aggregate or separate contract arrangement. Independently of contractual arrangements, in the first project stage the contractor exerts the effort level

10 In the sense that construction facilitates the operation process.

"a"; after this phase, the operator exerts effort level "e". Finally, payments are made and the social benefit is generated. Next, the structure of this contractual arrangement, in an incomplete contracts regime, is shown.

4.4 **Organizational form under incomplete contracts**

To check the benefit of *bundling* tasks in a PPP project, we infer a shock θ that cannot be *ex-ante* contracted. However, this variable could be verified *ex-post*. At this stage, the operator adapts its effort level, but payment is not readjusted and this captures an incomplete contract environment.

4.4.1 *Unbundling*

If the tasks are not aggregate, the government (principal) will contract firms independently. Now, consider builder compatibility incentives constraint. This firm will seek the highest effort level that maximizes its certainty equivalence of profitability, i.e.:

$$a = \arg\max_{\tilde{a}} \alpha_B + \beta\tilde{a} - \frac{\tilde{a}^2}{2} - \frac{r\sigma^2\beta^2}{2} \tag{1}$$

Participation constraint in terms of certainty equivalence has the following format:

$$U_B = \alpha_B + \left(1 - r\sigma^2\right)\frac{\beta^2}{2} \geq 0 \tag{2}$$

Consider now the operator firm. As it knows θ and can perfectly anticipate the builder's first stage effort, its incentive compatibility constraint could be written as:

$$e(\theta,\gamma,a) = \arg\max_{\tilde{e}} \alpha_O + \gamma\tilde{e} - \frac{\mu}{2}(\tilde{e} - \delta a - \theta)^2 - \frac{r\eta^2\gamma^2}{2}$$

And we have that:

$$e(\theta,\gamma,a)=\delta a+\frac{\gamma}{\mu}+\theta \tag{3}$$

Note that "e" grows according to θ and γ increases. The operator keeps a portion of its revenue, but only a fraction of productivity risk has an impact on its expected *payoff*. Using equation (3) the certainty equivalent payoff in θ state became $\alpha_O+\gamma e(\theta,\gamma,a)-\left(\frac{1}{\mu}+r\eta^2\right)\frac{\gamma^2}{2}$. Even taking into account the extra risk premium arising out of uncertainty under productivity shocks, the operator's participation constraint, takes the following form:

$$U_O(a)=\alpha_O+\gamma a+\left(\frac{1}{\mu}-r\left(\eta^2+v^2\right)\right)\frac{\gamma^2}{2}\geq 0 \tag{4}$$

Proposition 1: The optimal scheme under the *unbundling* regime entails the following incentive intensities and first-stage effort level:

$$\gamma_U=\frac{\frac{1}{\mu}}{\frac{1}{\mu}+r\left(\eta^2+v^2\right)}<1 \quad \text{and} \quad \beta_U=a_U=\frac{\delta}{1+r\sigma^2}<1 \tag{5}$$

The intensity of incentives γ_U captures the transference of the demand and operational risk to the operator firm. A higher transfer of these risks to the operator consists of a lower level of γ_U that generates a much lower operational effort. The same occurs to the builder when the quality index is imprecise, that is, when it has a high σ^2. If the government does not adequately specify the quality index, the builder has an incentive to exert less effort. In sum, riskier projects demand more compensation in terms of risk premium to stimulate the operator and the builder.

A less flexible technology (higher μ) also causes the incentive intensity γ_U to be lower. If the technology is more flexible it will provide a higher level of this variable and consequently will increase the companies exerted efforts generating a better level in terms of building and operating hospital services. Furthermore, the effect of δ (closer than 1) represents that the operator can perceive more efficiently the constructor's behavior and this increases its incentives to make a higher effort level.

4.4.2 *Bundling*

Consider now the case where companies are added to a consortium. It is assumed that there are no information or coordination problems at this stage. This is because the conglomerate's members have a strong incentive to cooperate, which would increase their benefits. In practical terms, the consortium is formed by two companies, without government interference, and this consortium would dispute the tender for the PPP project, competing with other equals.

The incentive compatibility constraint of the second stage remains unchanged, being equal to the equation (3). The consortium anticipates the effort impact of the second stage in its revenues. More precisely, the first stage effort is determined by the equation that represents the builder's participation constraint:

$$a = \arg\max_{\tilde{a}} \alpha + \beta\tilde{a} + E_{\theta}\left(\gamma e(\theta,\gamma,\tilde{a}) - \frac{\mu}{2}\left(e(\theta,\gamma,\tilde{a}) - \delta\tilde{a} - \theta\right)^{2}\right)$$
$$-\frac{\tilde{a}^{2}}{2} - \frac{r\sigma^{2}\beta^{2}}{2} - \frac{r\left(\eta^{2}+v^{2}\right)\gamma^{2}}{2}$$

The last terms represent the conglomerate's risk premium. Inserting (3) in the equation above, we have a new participation constraint:

$$a = \arg\max_{\tilde{a}} \alpha + \beta\tilde{a} + \gamma\delta\tilde{a} + \left(\frac{1}{\mu} - r\left(\eta^{2}+v^{2}\right)\right)\frac{\gamma^{2}}{2}$$
$$-\frac{\tilde{a}^{2}}{2} - \frac{r\sigma^{2}\beta^{2}}{2}$$

Solving for $\tilde{a}$:

$$\tilde{a} = \beta + \delta\gamma \tag{6}$$

Inserting (6) into the new participation constraint, we will have this equation in the certainty equivalent form, as follows:

$$U(a) = \alpha + (\beta + \gamma\delta)a + \left(\frac{1}{\mu} - r\left(\eta^{2}+v^{2}\right)\right)\frac{\gamma^{2}}{2} - \frac{\tilde{a}^{2}}{2} - \frac{r\sigma^{2}\beta^{2}}{2} \geq 0 \tag{7}$$

Proposition 2: The optimum scheme under the *bundling* regime follows this incentive intensity for efforts:

$$1 > \gamma_B = \frac{\frac{1}{\mu} + \frac{\delta^2 r\sigma^2}{1+r\sigma^2}}{\frac{1}{\mu} + \frac{\delta^2 r\sigma^2}{1+r\sigma^2} + r\left(\eta^2 + v^2\right)} > \gamma_U \tag{8}$$

$$1 > \beta_U > \beta_B = \frac{\delta}{1+r\sigma^2} \frac{r\left(\eta^2 + v^2\right)}{\frac{1}{\mu} + \frac{\delta^2 r\sigma^2}{1+r\sigma^2} + r\left(\eta^2 + v^2\right)}$$

First stage effort a_B is higher than the same variable under the *unbundling* scheme, but it is still less than a^*, that is, the *first-best*[11] effort level:

$$a_B = \frac{\delta\left(1+\gamma_B r\sigma^2\right)}{1+r\sigma^2} \in \left(a_U, 1\right) \tag{10}$$

Under *bundling* the government knows that γ_B and β_B promote the right incentives for optimum effort levels of the building and operation of project stages. As the consortium internalizes the externalities of the production process, the agency costs in this contractual scheme present scope economies.

In this contractual model, the conglomerate keeps a larger revenue share, measured by the benefit R. It should be stressed that the government should not strictly trust the quality index,[12] since this variable is imprecise (presenting a high σ^2), this entails a lower builder effort and it also reduces the operational effort.

Another important point is that when the consortium receives a big part of R, the incentive to exert a greater effort level in the building stage is higher. It happens because the consortium considers this impact over its operational costs, hence with a reduction of these costs, the operational effort increases, that also makes R grow.

Thus, it is worth mentioning that operational efforts, when comparing two contractual schemes, are always higher in a *bundling* regime.

11 Situation where shocks and efforts are contractible.

12 One of imprecision forms of quality index is, if that variable is exclusively measured by the clients' opinion who are attended at the company.

Using the definition of the second-stage efforts in both organizational forms we have:

$$e(\theta,\gamma_B,a_B) > e(\theta,\gamma_U,a_U)\ ,\ \forall\theta \tag{11}$$

Incentive intensities γ and β move in opposite directions. A quality index with a greater variance (a bigger noise) is not a good mechanism to provide incentives on building or repairing stages. Likewise, when (μ falls) technology becomes more flexible and γ_B increases while β_B declines. The Principal needs a larger revenue share because the consortium's operational effort is more sensitive to the second effort level.

Proposition 3: *Bundling* is the optimal organizational form.

The comparison performed by the model considers the uncertainty process in the mapping on effort level among PPP project stages. *Bundling* offers a potential PPP gain during the project's delegation stage to the private sector, if considered, that at this stage, there is a large uncertainty process.

Furthermore, using the *bundling* scheme allows that externalities are being internalized by the consortium, which turns possible higher effort levels to the conglomerate. An extreme situation is when technology is very flexible ($\mu \to 0$) which means that externality between the stages is very large. Finally, it considers whether operational risk is low, *bundling* shows itself strictly superior.

In summarizing, the results of the bundling and unbundling regimes are in accordance to those in Iossa and Martimort (2012). However, restricting the technology parameter, limits the extent of the incentive parameters, without changing the main results. What surely impacts the estimates and makes those parameters have a smaller magnitude is the sensitivity of the operator's effort in relation to the builder's effort. When its transfer is perfect ($\delta \to 1$), we have the same researchers results; when it is around [0.1], the effect of incentives is lower. This means that problems during the production stage could be avoided if companies had information on the value of δ. Obviously this better knowledge is more plausible in *bundling* regimes.

5 **Final remarks**

This article has developed a theoretical model to understand PPP design contracts. The model is based on Iossa and Martimort (2012), modifying it by adding a parameter which measures effort sensibility between project stages and also restricts the variable that determines technology flexibility.

With these changes, the *bundling* contractual scheme that aggregates the firms responsible for the construction (repair) and for the project's operation, are superior to a scheme where companies are separately contracted. This occurs because there is a potential gain when there are no coordination problems. In this case, the consortium is able to internalize the *externalities* of the production process reducing operational costs. This scheme is also superior if the demand risk is low and the quality index is not precise. These results indicate that the government should worry more regarding the design of a mechanism that could favor a better monitoring of the adequate quality index, given the relevance of this variable for providing services.

Finally, as a suggestion for a new research agenda, it is interesting to highlight the role of the contract renegotiations, the possibility of subcontracting and the time duration of contractual PPPs. Renegotiations have political implications, because there may be governmental changes influencing the public decision on possible contingencies related to contracts already signed by previous governments, subcontracting considers the agency problem between the firms that will be responsible to execute the project and plus horizon time to evaluate the development of technology over time, which is an extremely important variable for the major projects related to infrastructure.

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The authors thank very much the two anonymous referees and an editor for the constructive suggestions and comments. In particular, we would like to thank: Cristiano M. Costa, Claudio D. Shikida, Felipe Garcia, Hudson Torrent, Klenio Barbosa, Giácomo Balbinotto Neto and Regis Augusto Ely for their valuable contributions and comments. It is important to stress that any errors or omissions are exclusively the authors' responsibility.

About the article

Submission received on June 16, 2015. Approved for publication on May 3, 2016.

APPENDIX

Proof of proposition 1

Principal expected payoff is:

$$E_\theta\left(\left(1-\gamma\right)e\left(\theta,\gamma,a\right)\right)-\beta a-\alpha_B-\alpha_O-I$$

The Government's problem consists of maximizing liquid surplus minus risk premium left by the builder and the operator.

$$\max_{(U_B,U_O,\beta,\gamma)} E_\theta\left(e\left(\theta,\gamma,a\right)-\frac{\mu}{2}\left(e\left(\theta,\gamma,a\right)-\delta a-\theta\right)^2\right)-\frac{a^2}{2}-\frac{r\sigma^2\beta^2}{2}$$
$$-\frac{r\left(\eta^2+v^2\right)\gamma^2}{2}-U_B-U_O\left(a\right)-I$$

Subject to (1), (2), (3) and (4). Participation constraints (2) and (4) are bidding on optimal. Using (1) and (3) and inserting (2) and (4) equals zero, we have:

$$\max_{(\beta,\gamma)} W_U\left(\beta,\gamma\right)=\delta\beta-\frac{\beta^2}{2}+\frac{1}{\mu}\left(\gamma-\frac{\gamma^2}{2}\right)-\frac{r\sigma^2\beta^2}{2}-\frac{r\left(\eta^2+v^2\right)\gamma^2}{2}-I$$

This optimization results in γ_U and β_U.

c.q.d.

Proof of proposition 2

Under *bundling*, principal expected payoff is:

$$E_\theta\left(\left(1-\gamma\right)e\left(\theta,\gamma,a\right)\right)-\beta a-\alpha-I$$

Considering conglomerate payoff expression and following the Principal problems:

$$\max_{(U_O,\beta,\gamma)} E_\theta\left(e\left(\theta,\gamma,a\right)-\frac{\mu}{2}\left(e\left(\theta,\gamma,a\right)-\delta a-\theta\right)^2\right)-\frac{a^2}{2}-\frac{r\sigma^2\beta^2}{2}-$$

$$-\frac{r\left(\eta^2+v^2\right)\gamma^2}{2}-U_O(a)-I$$

Subject to the constraints (3), (6) and (7). Inserting the constraints (3) and (6) in maxim and, and considering constraint (7) as active, we have:

$$\max_{(\beta,\gamma)} W_B(\beta,\gamma)=\delta\beta+\delta^2\gamma+\frac{1}{\mu}\left(\gamma-\frac{\gamma^2}{2}\right)-\frac{(\beta+\delta\gamma)^2}{2}-\frac{r\sigma^2\beta^2}{2}-$$

$$-\frac{r\left(\eta^2+v^2\right)\gamma^2}{2}-I$$

The results of this optimization results in γ_B and β_B.

c.q.d.

Proof of p Proof of proposition 3:

Note that:

$$\max_{(\beta,\gamma)} W_U(\beta,\gamma)=\delta\beta-\frac{\beta^2}{2}+\frac{1}{\mu}\left(\gamma-\frac{\gamma^2}{2}\right)-\frac{r\sigma^2\beta^2}{2}-\frac{r\left(\eta^2+v^2\right)\gamma^2}{2}-I$$

Inserting β in the above equation:

$$\max_{\beta} W_U(\beta,\gamma)=\frac{\delta^2 r\sigma^2}{2\left(1+r\sigma^2\right)}+\frac{1}{\mu}\left(\gamma-\frac{\gamma^2}{2}\right)-\frac{r\left(\eta^2+v^2\right)\gamma^2}{2}-I$$

Meanwhile:

$$\max_{(\beta,\gamma)} W_B(\beta,\gamma)=\beta+\delta^2\gamma+\frac{1}{\mu}\left(\gamma-\frac{\gamma^2}{2}\right)-\frac{(\beta+\delta\gamma)^2}{2}-\frac{r\sigma^2\beta^2}{2}-$$

$$-\frac{r\left(\eta^2+v^2\right)\gamma^2}{2}-I$$

Performing the same procedure:

$$\max_{\beta} W_B\left(\beta,\gamma\right)=\frac{\delta^2}{2\left(1+r\sigma^2\right)}+\frac{\delta^2\gamma}{\left(1+r\sigma^2\right)}\left(1+2r\sigma^2+\gamma\left(1-r\sigma^2\right)\right)+$$

$$+\frac{1}{\mu}\left(\gamma-\frac{\gamma^2}{2}\right)-\frac{r\left(\eta^2+v^2\right)\gamma^2}{2}-I$$

$$\Delta W\left(\gamma\right)=\max_{\beta} W_B\left(\beta,\gamma\right)-\max_{\beta} W_U\left(\beta,\gamma\right)\geq 0$$

$$\Delta W\left(\gamma\right)=\frac{\delta^2\gamma}{\left(1+r\sigma^2\right)}\left(1+2r\sigma^2+\gamma\left(1-r\sigma^2\right)\right)\geq 0$$

$$\max_{(\gamma,\beta)} W_B\left(\beta,\gamma\right)\geq\max_{(\gamma,\beta)} W_B\left(\beta,\gamma_U\right)>\max_{(\gamma,\beta)} W_U\left(\beta,\gamma_U\right)=\max_{(\gamma,\beta)} W_U\left(\beta,\gamma\right)$$

The strict inequality comes from the fact that $\gamma_U \in (0,1)$.

c.q.d.