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Addressing Adverse Selection in Public-Private Partnership (PPP) Procurement: An Agent-Based Approach

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Abstract

In risky public-private partnership (PPP) projects, governments and public institutions tend to offer private investors certain guarantees for their participation. However, when public sector capacity and institutions are weak, these guarantees can generate moral hazard in the bidding process and lead to contractual renegotiations, resulting in a loss for taxpayers. Drawing on a sophisticated, agent-based model that recreates the complex dynamics of the PPP procurement process, this paper demonstrates public sector competency is crucial for limiting moral hazard when guarantees are offered in PPP projects.

Keywords

Public-private partnerships, procurement, adverse selection, moral hazard, guarantees

Introduction

Public-private partnerships (PPPs) represent a promising approach to help close the global infrastructure gap (Roehrich et al., 2014) and are set to play a crucial role in the

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aftermath of the COVID-19 pandemic, particularly when it comes to alleviating public budgets saddled by debt and accelerating the recovery (Baxter & Casady, 2020a, 2020b, Casady & Baxter, 2020, 2021). However, the urge to attract private capital into infrastructure can create an inefficient use of PPPs (Estache & Saussier, 2014). Across the United States, Europe, Australia, and Latin America, many public authorities have renegotiated PPP contracts, bailed out concessionaires, or even bought back the infrastructure assets themselves (Feng et al., 2022). Soecipto and Verhoest (2018) recently found that even the presence of well-developed PPP laws and political commitment cannot safeguard PPPs from being renegotiated when these contracts employ user-based remuneration schemes, especially in unfavorable macro-level business environments.

In such unstable economic conditions, brought about by events like the 2007-2008 global financial crisis (Coelho et al., 2009) or the COVID-19 pandemic, public authorities may decide to offer guarantees in PPP contracts to attract long-term, risk adverse investors. These guarantees can include credit enhancement, minimum revenue provisions and downside protection on equity return, or even take the form of availability payments (Gatti, 2014; Hellowell et al., 2015; Vecchi et al., 2015; Wang et al., 2018). The main aim of such guarantees is to reduce or eliminate the demand risk, thus securing the repayment of debt service obligations.

When a project is guaranteed by public authorities, the risk of strategic bidding by market players, adverse selection, and moral hazard increases (Wang, Cui, & Lui, 2018; Wang et al., 2019a, 2019b; Owusu-Manu et al., 2020; Di Bari, 2021). Actually, bidders may have no incentive to: (1) form optimal bidding consortia; (2) undertake careful and reliable assessments of the project's features (e.g., capital, operational costs, and demand); or (3) select the best contractors and ensure the project's overall efficiency. In other words, public guarantees can undermine the economic operator's incentives to identify, monitor, and minimize project risks, and thereby generate substantial additional fiscal burdens for governments and taxpayers when the authority is forced to act on its guarantee. In the worst circumstances, these authorities may need to commit additional capital or even rescue certain strategic projects (Bajari & Tadelis, 2001; Maskin & Tirole, 2008).

By focusing on the decision-making processes of market agents and public managers, this paper answers the call for additional managerial studies focused on addressing the issue of adverse selection, moral hazard, and contract renegotiation in PPP transactions (Bloomfield, 2006; Van Gestel et al., 2012), especially when public guarantees are used. Because PPP tenders are complex systems in which multiple players interact, we argue that an approach based on agent-based modelling may shed additional light on the hidden agency dynamics embedded in PPPs. By investigating these dynamics within the PPP procurement process, we intend to document the effects of guarantees on market agents' behaviors.

Agent-based simulation is viewed as one of the most useful approaches for studying complex social and organizational phenomena (Burton & Obel, 2011; Davis et al., 2007; Harrison et al., 2007; Macy & Willer, 2002; Prietula et al., 1998). The approach specifically captures the embedded behavioral characteristics of the players while accounting for their heterogeneity, thus revealing the micro-foundations of their decision-making. Moreover, it allows for the definition of rigorous assumptions and investigational boundaries without compromising flexibility and realism (Davis et al., 2007). This helps overcome some of the problems associated with bidding theory, which may not capture the complex and dynamic interactions of the PPP bidding process and the heterogeneity of its actors (Harrison et al., 2007). In fact, the reactions of market players to a call for bids are difficult to represent using traditional analytical models or field analyses because of the information asymmetry and the confidentiality of data, but they can easily be captured by agent-based models (Levine & Prietula, 2012). Finally, agent-based models are regarded as axiomatic and their results can be interpreted as propositions (Biava et al., 2011; Dastani, Meyer, & Grossi, 2011).

Given the above discussion, this paper develops an agent-based simulation for PPP contracts protected by guarantees. To design the simulation, and to complement our knowledge of PPP mechanisms derived from the academic literature, grey literature, and practice, we undertook a detailed and broad study of international PPP tenders for which procurement documentation was available. This allowed us to identify key players (e.g., awarding authorities, individual bidders and/or consortia, market players' propensities to engage in strategic behavior) and derive their behavioral rules. Our agent-based model is built in a way that accounts for the randomness of the players' behaviors and the environments in which they operate. We perform several simulation experiments and test the agent-based model in a variety of scenarios (i.e., different combinations of calls for tender structures, environments, and agent behaviors) to derive insights. More specifically, we calculate the likelihood that a strategic player would be awarded a PPP contract based on the skills of the authority, the environment in which the bid was carried out, and the extent of guarantees. The results of our simulations substantiate the proposition that public sector capacity is key for counterbalancing the adverse-selection mechanisms that can result from the presence of public guarantees. This is not a new result in the context of PPP; however, it provides new management insights that enrich the literature on adverse selection and moral hazard, predominantly developed with an economic perspective. Further, the paper provides practical suggestions to public managers tasked with designing PPP tender solicitations.

The remainder of this article is structured as follows. In the next section, we summarize the extant research on adverse selection and moral hazard in PPP transactions. Then, in section 3, we present the propositions that are tested with the multi-agent model, which is explained in section 4. In section 5, we discuss the results, while in the final section, we draw some conclusions.

Adverse selection, moral hazard, and contract renegotiation in PPP transactions

PPP contracts should be able to mitigate the principal-agent problems typically associated with traditional procurement (Iossa & Martimort, 2012), such as conflicting goals, information asymmetries, and diverging levels of risk aversion (De Palma, Leruth, & Prunier, 2009; Eisenhardt, 1989; Bergen et al., 1998). PPP does so by transferring project risks to the private concessionaire (Greve & Hodge, 2013), thereby providing stronger incentives to achieve the delivery of the infrastructure on time, on budget and on quality (Casady & Geddes, 2019; Casady, Eriksson, Levitt, & Scott, 2019). Complete contracts, measurable output indicators, and credible punishments should be able to prevent moral hazard by strengthening incentives to deliver high-quality infrastructure and services. These measures are generally suitable for ensuring the transfer of endogenous risks to the private operator, such as those related to design, construction, operation, and maintenance (Engel et al., 2014), thereby avoiding or reducing the risk of renegotiation (Laffont & &Meleu, 2001). Contract renegotiation, which is defined as a change in the original contractual terms and conditions (as opposed to an adjustment that takes place within a contract's provisions), is one of the most pervasive problems in PPP (Guasch, 2004; Guasch et al., 2007, 2014; Lohmann & Roetzel, 2014; Neto et al., 2017; Sánchez Soliño & Gago Santos, 2010), because the underpinning contracts tend to be incomplete (Hart & Moore, 1988; Saussier, 2013). Renegotiations of PPP contracts also result from economic shocks, imperfections in the judicial and regulatory system (Tirole, 1999), and weaknesses in the institutional environment (Guasch, Laffont, & Straub, 2003; see also Casady, 2021, 2022; Casady et al., 2020; Casady & Peci, 2021). The most problematic issue arises when a public authority retains the demand risk (partially or totally and directly or indirectly). This is an exogenous risk and guarantees are often offered to make projects more bankable and appealing for investors. As discussed in section 1, such guarantees have become more and more common to attract long-term, risk adverse investors. In such cases, bidders have strong incentives to adopt strategic behaviors (Guasch, Laffont, & Straub, 2003), by including technical or financial features in their bids that they may not be able to meet, with the sole purpose of winning the contract (Bajari et al., 2014; Engel et al., 1997; Spulber, 1990). In fact, such bidders assume that the authority will activate the guarantee provided and, ultimately, renegotiate the contract to ensure the infrastructure is completed or operated. By reducing incentives upon the private player, public guarantees weaken the PPP arrangement, making it similar to standard procurement (Teisman & Klijn, 2002), and exacerbate the problem of adverse selection, which is quite common in the general public-procurement system where the preferred bidder may be the most optimistic bidder rather than the best one (a situation known as "winner's curse"; Kagel & Levin, 1986; Cruz & Marques, 2011; Saussier, 2013). This situation arises when bidders estimate lower construction costs using a called "low balling" strategy (Cruz & Marques, 2011; Guasch & Straub, 2009) or present optimistically biased traffic (de los Ángeles Baeza & Vassallo, 2010; Prozzi et al., 2009), revenue (Nikolaidis & Roumboutsos, 2013), and cost (Trujillo et al., 2002; Flyvbjerg, 2005) forecasts. To overcome these problems, theory and experience suggest to increase competition by limiting participation costs (Bajari et al., 2009; Goldberg, 1977; Tadelis, 2012) and lower barriers to entry which, in the PPP field, are naturally high, because of the complex nature and size of such contracts (Casady et al., 2019; Koppenjan & Enserink, 2009).

From a managerial perspective, several authors (see e.g., Bloomfield, 2006; Casady, 2021; Casady et al., 2019, 2020; Kort & Klijn, 2013; Marques & Berg, 2010; Spackman, 2002) stress the role of public sector competence in PPP transactions to counterbalance potential aggressive behaviors of private players. Contract management capacities, notably in feasibility assessment, contract implementation (which includes the selection phase), and evaluation, are fundamental to reduce the threat of contract underperformance and to prevent "full-scale contracting disasters" (Brown et al., 2015). Competencies can also be helpful in ensuring the selection of the most appropriate selection procedure, which should be more flexible to deal with the strategic behavior of market players (Saussier, 2013).

Propositions

As discussed in the previous section, the presence of a competent authority is recognized by several scholars (see e.g., Brown et al., 2015; de Brux, 2010; Marques & Berg, 2010; McAfee & McMillan, 1986; Wang & Yang, 2009; Zitron, 2006) as a way of improving the likelihood of project success. Marques and Berg (2010) stress that a thorough preparatory study is of paramount importance for a project's success. However, the greater the information asymmetry and the less relevant knowledge the principals have, the more they will have to rely on their agents' discretion and initiative (Hendry, 2002). This lack of skills and absence of preparatory studies available to both prepare calls for tender and understand the offers submitted can become even more dangerous when guarantees are provided, thus exacerbating the risk of adverse selection. This yields our first proposition.

> Proposition 1: The probability of awarding a PPP contract with a guarantee to a strategic bidder is higher when public sector capacity (i.e., skills) is lacking and information asymmetry is high.

As Estache et al. (2009) argue, the regulatory quality and trustworthiness of the procurement system can help reduce the likelihood of adverse selection and renegotiations when multi-criteria auctions are utilized. However, evidence on the application of multi-criteria assessment mechanisms in PPP tenders is limited and controversial. Multi-criteria evaluations are difficult to implement because they are perceived as more complex, less transparent, and more susceptible to corruption (Burguet & Che, 2004; Farquharson et al., 2011; Klein, 1998). Therefore, authorities may be tempted to assess projects based on one criterion, such as price. They may also be risk-adverse in promoting the use of innovative solutions to select market players. Although this may be the right approach in standard public procurement, it could be a suboptimal solution in relation to PPP contracts (Saussier, 2013), especially when such contracts are covered by a guarantee. Multi-criteria assessments require discretion in the evaluation process, which can be useful for achieving optimal outcomes in awarding PPP contracts if applied in an informed, transparent manner (Saussier et al., 2009; Saussier, 2013). From these insights, we derive our second proposition.

Proposition 2: When guarantees are included, the application of a multi-criteria assessment mechanisms that emphasize quality and technical aspects over economic factors reduces the probability of awarding a PPP contract to a strategic bidder.

Simulating the dynamics of a PPP tender: an agent-based simulation

Advances in the field of agent-based simulation show that it is often possible to reconstruct the behavior of a socio-economic system based on our knowledge of the behavioral rules of its parts (agents). This is the basic principle of agent-based modelling (Axelrod & Tesfatsion, 2006; Waterman & Meier, 1998). Thanks to the rise in computing capabilities in recent years, this technique has become increasingly useful for studying economic and social phenomena. An in-depth overview of agent-based simulation cannot be provided here, but we refer to the *Handbook of Computational Economics* (Tesfatsion & Judd, 2006), the work of Farmer and Foley (2009), and the work of De Marchi and Page (2014) and Manzo (2014) for thorough overviews. Our aim is to use agent-based modelling to recreate the environment of a PPP tender and test the propositions outlined above.

In order to recreate the main traits of a realistic procurement process for a PPP contract—specifically, a design, build, finance, operate, and maintain (DBFOM) scheme, we performed an extensive analysis of 12 U.S. PPP highway projects found in the Federal Highway Administration's (FHWA) database (FHWA, 2015). These projects were selected based on the availability of sufficient procurement documentation at the time of data collection. Furthermore, we analyzed 11 European highway concessions included in the European Tenders Database (TED). We then undertook a comparative analysis of selected concession documents and chose salient features to design the model and make it coherent, reflecting key trends and features.[1]

Despite the general validity of the propositions derived from the simulation, the model was designed with reference to PPP contracts for building/revamping and operating highways, a field where PPP has been largely utilized in past years. Moreover, public guarantees, such as minimum payments and credit enhancement, are increasingly used in this sector to reduce the risk typically retained by investors.

In the following subsections, we describe the main traits of the agent-based model, including the authority (section 4.1), the market players/bidders (section 4.2) and the

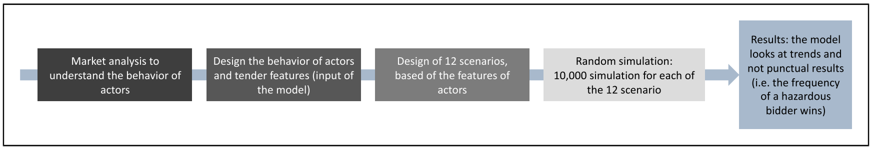

Figure 1. Steps in the Agent-Based Simulation of PPP Procurement.

inputs and quantities (section 4.3). Figure 1 depicts the steps followed in the agent-based model simulation.

The Authority

In our model, we distinguish between two types of authorities: a skilled authority capable of preparing an accurate shadow bid, and an unskilled authority that does not prepare a shadow bid or prepares an inaccurate one. The shadow bid is used to benchmark the offer or, more generally, reduce information asymmetry in the evaluation of the offers. The unskilled authority, therefore, has less information about the trustworthiness of the offers during the evaluation process. Section 4.3 describes the features of the calls for tender and the assessment process.

The Bidders

Bidders for a PPP contract can be individual companies or consortia. Individual players include engineering, procurement, and construction (EPC) contractors; operations and maintenance (O&M) contractors; and purely financial investors. After a contract is awarded, the winning bidder selects complementary players needed to execute the project. For instance, a financial investor will select an EPC and an O&M contractor, and an EPC contractor will select an O&M contractor and a financial investor. Alternatively, agents may decide to bid within a consortium.

Based on their competencies, experiences, and business models, these agents perform with different levels of efficiency. Therefore, we can categorize them as "efficient" or "inefficient."

- An *efficient EPC contractor* is a highly experienced builder with a reputation for using high-quality materials and relevant technologies (thereby lowering life-cycle costs). This contractor relies on reputable and specialized consultants for demand forecasts and can obtain a bank commitment[2] for their proposal. Their aim is to maximize the construction margin.
- An *inefficient EPC contractor* aims to maximize its own profit through construction but has not invested in innovation and skilled human resources. Furthermore, they are unable to obtain a bank commitment for their proposal.

Table 1. Possible Bidders From Combining the Five Types of Actors.

	Efficient EPC	Inefficient EPC	Efficient O&M	Inefficient O&M	Efficient Investor
Efficient EPC	Alone with an O&M contractor		Efficient consortium (A)	Suboptimal consortium (C)	
Inefficient EPC		Alone with an O&M contractor	Suboptimal consortium (D)	Inefficient consortium (B)	
Efficient O&M	Efficient consortium (A)	Suboptimal consortium (D)	Alone with an EPC contractor		
Inefficient O&M	Suboptimal consortium (C)	Inefficient consortium (B)		Alone with an EPC contractor	
Efficient Investor					Alone with EPC and O&M contractors

- An *efficient O&M contractor* is highly experienced in the sector, able to forecast traffic demand with reasonably accuracy and manage infrastructure efficiently. They can obtain a bank commitment for their proposal. Their aim is to maximize the operating margin. If an efficient O&M contractor does not set up a consortium with an EPC contractor, they tend to be conservative in building-cost estimates in order to ensure the use of high-quality materials and technologies.
- An *inefficient O&M contractor* has not invested in innovation and skilled human resources. They are unable to obtain a bank commitment for their proposal.

Because financial investors are not involved in the project's operations, the only condition for maximizing their profitability is to select efficient contractors. For this reason, we assume that a financial investor is always efficient.

We also assume that the formation of consortia depends on the availability of guarantees; without guarantees, efficient players have no incentive to team up with inefficient ones.

In combining these actors based on the assumptions outlined above, we derive nine possible agents: five individual bidders and four consortia, as summarized in Table 1.

When a guarantee supports the contract, the nine agents can opt to bid strategically. If they do so, they offer project quality and features that are the same as or superior to those they would have offered in the case of non-strategic behavior, but with lower operational and capital costs. This allows them to estimate a lower tariff, a lower availability fee, or lower-than-expected demand to achieve the financial equilibrium in the project (i.e., the target return). This approach allows strategic bidders to obtain higher scores and, therefore, implies that they are more likely to win the contract.

In the absence of public guarantees, market players do not bid strategically. They know that the authority will not activate the guarantee and/or renegotiate the financial conditions of the contract if the execution of the project gives rise to some differences in the forecasts.

To make the agent-based simulation consistent with the different institutional, social, and economic scenarios, we model the environmental propensity for strategic behavior as an external pressure on agents to adopt strategic behavior. The environment in which the bid is carried out can be more or less tolerant with moral hazard behaviors. In other words, we account for the fact that the probability of an opportunistic behavior varies in line with government's ability to control corruption, trust in institutions, and general civic views, which are determinants of social capital (Putnam, 1995).

Simulation inputs, model specification, and predicted quantities

PPP contracts are generally awarded following a two-step selection process. In the first stage, the authority publishes a request for qualification. In this phase, bidders are asked to prove their experience with similar projects, their technical capabilities, and their financial soundness. Candidates may also be required to submit a conceptual proposal in order to demonstrate their ability to understand the project's features and the authority's needs. The output of this first phase is a shortlist of candidates that have the potential to enter the second stage of the selection process, during which they submit their final offers. Those offers may also be the result of negotiations with the authority.

Each offer is evaluated based on a set of pre-defined assessment criteria, including economic factors and technical criteria (so called MEAT, the "most economically advantageous tender"). The authority generally assesses the technical value of each project by analyzing the technical skills of the project team, as demonstrated, for instance, by its track record, and its approach to construction, operation, and maintenance. Then it assesses the cost of the contract. For PPPs, costs are represented by user charges for toll/tariff-based concessions or shadow tolls and availability charges paid by the authority; the contract may also include a grant. Higher project costs (investment, maintenance, and the cost of the capital) dictate the need for higher revenues, which represent the cost for the authority or for users.

In its simplest form, the evaluation of proposals, as set out in a call for tenders, may rely on the following multi-criteria linear function:

$$S = w_1 S_1 + w_2 S_2 + \ldots + w_n S_n \tag{1.1}$$

where w_i is the weight of criterion i and S_i is the score assigned to the project according to criterion i. There are $i = 1, 2, \ldots, n$ criteria. The model makes use of three assessment criteria, with an overall total score to be assigned of 100.

1. *Technical quality*: This criterion can be weighted from 0 to 90 percent and is composed of two sub-criteria with equal sub-weights: (i) the quality of the construction plan, and (ii) the quality of the operation and maintenance plan.
2. *Price*: This criterion can have a weight from 10 to 100 percent.
3. *Trustworthiness of the offer*: The weight of this criterion equals 0 percent in the case of an unskilled authority. It assumes a weight of 10 percent in the case of a skilled authority and a weight of 20 percent in the case of a competent, highly skilled authority. As such, it proportionally reduces the weight of the other two criteria.

The combined assessment criteria generate a basket of 30 different calls for tender.

To assess the technical features, the authority can assign a score in the range of 0–five to each of the two equally weighted sub-criteria, where five denotes excellence. The final scores are then weighted given the overall weight assigned to the technical features in the call. Scores are assigned based on the following rules:

- *Efficient EPC* always takes the maximum score (5) for the quality of the construction plan, as it is related to the company's core business. It takes an average score (3) for the quality of the operation and maintenance plan.
- *Efficient O&M* always takes the maximum score for the quality of the operation and maintenance plan, as it is related to the company's core business. It takes an average score (3) for the quality of the construction plan.
- *Inefficient EPC* always takes a low score (2) for the quality of the construction plan and the lowest score (1) for the quality of operation and maintenance plan. The opposite is true for *inefficient O&M*.
- *Investor* always takes the maximum score on the two elements of project quality, as it is able to involve the most efficient subcontractors.
- *Consortia* take scores based on the features of the consortia's members.

The model assigns the same scores to the non-strategic (honest) and strategic bidders, as they submit projects with the same quality standard. As a robustness check, we also considered the possibility that strategic bidders could mislead the technical assessment with the appearance of superior quality, thereby receiving a higher score the case of an honest offer, but only in relation to their non-core activities. Therefore, Table 2 shows the scores the model assigns to the technical component of the bids where a strategic EPC contractor obtains one more point than an honest EPC contractor for the operation and maintenance plan but not for the project construction plan (for which it already receives the highest score). Following the same logic, there are differences in scores assigned to efficient and inefficient O&M contractors, but there is no difference among honest and strategic investors and consortia. We also tested other variations in score assignments, but the results remained unchanged. These results are available upon request.

Table 2. Scores assigned to technical offers.

	Efficient EPC		Inefficient EPC		Efficient O&M		Inefficient O&M		Efficient Investor		Consortium A		Consortium B		Consortium C		Consortium D	
	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.	H.	D.
Technical Proposal (same quality)																		
O&M Plan (weight 50%)	3	3	1	1	5	5	2	2	5	5	5	5	2	2	2	2	5	5
Project Construction Plan (weight 50%)	5	5	2	2	3	3	1	1	5	5	5	5	2	2	5	5	2	2
Technical Proposal (superior quality of strategic bid)																		
O&M Plan (weight 50%)	3	4	1	2	5	5	2	2	5	5	5	5	2	2	2	2	5	5
Project Construction Plan (weight 50%)	5	5	2	2	3	4	1	2	5	5	5	5	2	2	5	5	2	2

To assess the price component and assign a score to the i offer (S_i), we applied the following formula, where W_e is the weight of the economic offer, that assigns the highest score to the lowest price (the toll T_L) offered and proportionally lower scores to the other offers (T_i). The same is applied in case of availability charge.

$$S_i = T_L/T_i{*}W_e \tag{1.2}$$

Following these specifications, the modelling of the realistic dynamics of a PPP call for tenders can be summarized in four steps.

1. The design of the call for tenders is based on different weights assigned to each assessment parameter. The authority can choose from among 30 different call structures, as described above.
2. The decisions of market players to bid, the subsequent selection of partners, and the elaboration and submission of their offers based on the features of the call for tenders. At this stage, bidders can decide to bid strategically.
3. Assessment of the offers by the authority, score assignment based on the rules, and the award of the contract. Notably, the authority ignores whether offers are strategic. If the authority is skilled, it can only assess the coherence of the bid with the shadow bid.
4. Implementation of the contract and the activation of relevant guarantees with subsequent contract renegotiation.

Since the behavior of the players is stochastic, each run of these four steps produces different results. In fact, players can choose how to bid and adapt their offers to the features of the call for tenders. To account for the players' stochastic behavior, the above steps are repeated N times, thereby simulating N possible results. As such, the model produces a significant amount of information. However, we only consider the frequency of contractual award to an opportunistic bidder as the main outcome of interest.

An important step in the model is the simulation of the financial plans. We prepared two financial plans, based on market data (Vassallo & Baeza, 2007)—one reflecting their true views about the project (honest bid) and one representing their strategic offer[3] in order to estimate the value of the economic offer (i.e., level of revenues—tariffs/demand or availability charge—to achieve the financial equilibrium) from each bidder.[4] To enable the evaluation of the bid's trustworthiness, we also included a benchmark financial plan (shadow bid) prepared by the skilled authority in the model. The shadow bid was prepared using the construction costs of an efficient EPC firm, the operation costs of an efficient O&M provider, and the weighted average costs of the financial investor's capital. Although the figures used in the business plans are realistic, we stress that the agent-based model is designed to capture trends rather than to forecast exact values (Levine & Prietula, 2012). Therefore, we are interested in the change in the frequency of strategic wins across alternative scenarios rather than a precise point estimate.

Results

To summarize our results, we created 12 relevant scenarios. These are documented in Table 3.[5] Each scenario is based on a certain combination of features associated with calls for tenders and agents' characteristics.

To illustrate, let us consider scenario six in Table 3. In this scenario, the agent-based simulation assumes a skilled authority and assigns a weight of 10 percent to the trustworthiness criterion. In this scenario, strategic bidders offer a technical quality superior to that offered by their non-strategic counterparts.

To obtain significant results, we ran 10,000 simulations per scenario—i.e., a total of 120,000 simulations. Each simulation round starts with the random extraction of a call for tenders and produces the "story" of an individual call for tenders, following the four-step procurement process described in section 4.3. Figure 2, which presents a plot of the results for these 120,000 simulations and considers the probability of awarding the project to a strategic bidder (vertical axis) as a function of the environmental propensity for strategic behavior (horizontal axis) for different skill levels of the awarding authority (red: unskilled; orange: skilled; blue: highly skilled).

For example, consider a value on the horizontal axis of $p_E = 20\%$. This value represents the player's propensity to engage in strategic bidding. Then consider the point (square marker) corresponding to $p_E = 20\%$. This value shows a probability of

Table 3. Features of the 12 scenarios tested in the model.

	Authority's level of competence			Quality offered by strategic bidders compared to non-strategic bidders	
Scenario	Unskilled	Skilled	Highly skilled	Same technical offer (same TO)	Superior technical offer (superior TO)
1	X			X	
2	X				X
3	X			X	
4	X				X
5		X		X	
6		X			X
7		X		X	
8		X			X
9			X	X	
10			X		X
11			X	X	
12			X		X

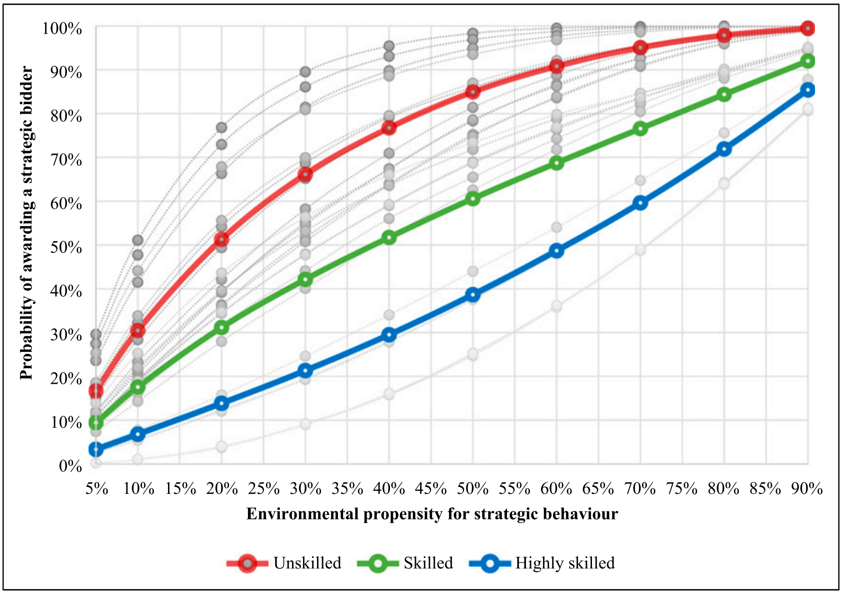

Figure 2. Probability of awarding contract to a strategic bidder in different simulation scenarios.

awarding the contract to a strategic bidder of about 50 percent when the authority is unskilled (i.e., when the authority does not make any moves to keep a strategic bidder from winning the contract). This 50 percent represents the frequency of strategic wins over the 10,000 simulations. Then, consider the triangle marker at $p_E = 20\%$. This triangle signals the probability of awarding the contract to a strategic bidder is 30 percent. Note the authority has a higher skill level in this scenario. Finally, consider the circular marker, which signals the probability of awarding the contract to a strategic bidder when the authority is highly skilled. The value is at about $p = 13\%$. This value, which is lower than the previous two, is again obtained as an average of 10,000 possible bids in which the authority is skilled. We can conclude that given an environmental propensity for strategic bidding of 20 percent, an increased level of competence in the public sector reduces the probability of awarding the contract to a strategic bidder. Notably, the specific numerical values are not interesting in their own right. Rather, we are interested in the trend—the fact that the probability of awarding the contract to a strategic bidder falls as public sector capacity increases. Figure 2 suggests that this trend is true at any value of the parameter representing the environmental propensity for strategic behavior.

Now consider a fixed level of authority skills (e.g., the unskilled situation) and the probability of awarding the contract to a strategic bidder as a function of the environmental propensity for strategic bidding. This relationship is represented by the line joining the squares in Figure 2. This line indicates as values of the environmental propensity for strategic bidding increase, the frequency of a strategic win is systematically higher. This monotonic behavior conforms with our intuition. We would expect that the higher the environmental propensity for strategic behavior, the higher the probability of awarding the contract to a strategic bidder for any level of authority skill. However, let us compare the three curves in Figure 2. The curve describing the probability of awarding the contract to a strategic winner in the case of a highly skilled authority is always lower than in case of skilled and unskilled authorities. These results confirm proposition 1. In other words, a competent authority that prepares the procurement strategy and the call for tender based on an accurate feasibility study will be better able to counterbalance the moral hazard that may be generated or exacerbated by the presence of a guarantee.

Next, we simulate the impact of multi-criteria assessments on the probability of awarding the contract to a strategic bidder. Figure 3 shows the results given a 50 percent environmental propensity for strategic behavior in three scenarios.[6]

In Figure 3, the first three bars are the estimated probabilities that the authority will award the contract to a strategic bidder when it only evaluates offers on the basis of economic elements (e.g., the toll/tariff or the availability charge). Each bar refers to a different skill level of the authority. The second set of bars shows the results when the authority assigns a 50 percent weight to the economic offer. The third group of bars shows the probability of awarding the contract to a strategic bidder when the authority

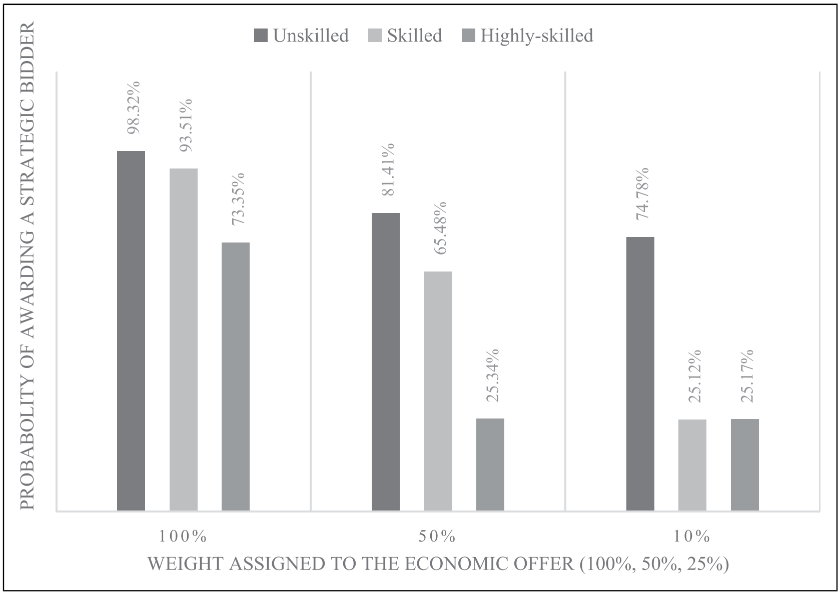

Figure 3. Probability of contract award to a strategic bidder as a function of the weight assigned to the economic offer, given varying authority skills.

assigns a weight of only 10 percent to the economic offer. Overall, as the weight of the economic offer decreases, the probability of awarding the contract to a strategic bidder also decreases. Therefore, when an unskilled authority evaluates a bidder only on its economic offer, the probability of awarding the contract to a strategic bidder is 98 percent. If the same authority introduces qualitative elements into its assessment, this probability falls to 74 percent. As we expect, the effect is greater when an authority is skilled because the authority is better able to assess the quality and the technical merits of an offer. Moreover, this result confirms proposition 2. When guarantees are included in the PPP contract, the authority should choose to assign higher scores to the technical and qualitative features, rather than to financial elements.

Conclusions

Taken together, these findings advance the field of management studies on adverse selection and moral hazard in complex PPPs—i.e., transactions characterized by a high proportion of lose-lose outcomes (Brown et al., 2015; Girth, 2014). By using an agent-based modelling approach, this article demonstrates the importance of design in tender calls and the public authority's ability to understand the risk of adverse selection in the bidding phase, thereby filling a critical gap in extant studies on procurement processes (Kauppi & van Raaij, 2014).

From a policy perspective, this study represents the first known attempt outside of contract economic theories to develop a comprehensive analysis that mirrors the complex features and interactions among players bidding for a PPP contract. The model specifically highlights the importance of public authority choices, especially those related to guarantees and tender-process design, in shaping competition and private actors' behaviors.

From a managerial perspective, our analysis demonstrates that when a guarantee scheme (e.g., a minimum revenue guarantee, a credit guarantee, or an availability charge) is included in a PPP contract to attract investors (Hellowell et al., 2015), the likelihood of strategic behavior among market participants and the risk of adverse selection may increase. Our study shows that when skilled managers are involved in the design and implementation of a PPP call for tenders, information asymmetries can be effectively addressed. In doing so, the risk of selecting a strategic contractor, which may force the fulfillment of the guarantee and contract renegotiation, is substantially lower, even in settings where there is a higher probability of strategic behaviors.

We modelled the role of skills by introducing a trustworthiness check, via a shadow bid, which allows authorities to assess offers more effectively. The role of this competent and informed type of discretion is enhanced in calls for tenders that assign a higher weight to the technical elements of the project as opposed to price-only bids. This is a fundamental finding of our study because awarding processes based on qualitative and, thus, more discretional elements of evaluation have been often perceived as less objective and transparent than price-only bids (Doloi, 2009; Waara & Bröchner, 2006; Zhang, 2004).

Other implications of our work can be summarized by three additional considerations. First, governments cannot fight the risks of moral hazard and adverse selection in public contracts solely through the standardization of processes and documentation (i.e., tender notices and contract clauses). Authorities must carefully design their selection processes according to the market environment in which they operate and the specific features of the PPP contract. This is particularly true when authorities offer public guarantees to make contracts more appealing by reducing the risks borne by investors. This conclusion complements Van Den Hurk and Verhoest's (2016) views on contract standardization.

Second, as stressed by Kauppi and van Raaij (2014), agency problems can be addressed not only through contract enforcement and monitoring but also by enhancing public managers' competences and investing in the preparation of sound preliminary studies/shadow bids. On the one hand, these studies are necessary for gathering benchmark information against which to compare offers. On the other hand, they increase the reputation of the authority and inform market participants about public priorities and goals, thereby creating conditions conducive for a better alignment of public and private interests. This point highlights the relevance of creating nodal units or specialized taskforces as part of institutional reforms supporting the implementation of complex public-private contractual arrangements (Spackman, 2002; Van Den Hurk & Verhoest, 20160; Casady & Geddes, 2016, 2019).

Third, public mangers should not be afraid to exercise some discretional power and consider qualitative measures, even if they appear to be less objective, when evaluating offers related to complex PPP contracts (Saussier, 2013). However, this discretion must be applied within a solid governance framework (Estache et al., 2009).

Finally, additional research is needed to model the impact of other sets of procurement choices (e.g., auction vs. negotiation) (Chong et al., 2014) and consider the impacts of different forms of public measures aimed at attracting investors in PPP transactions (e.g., availability payments, minimum revenue guarantees, debt guarantees) (Gatti, 2014). This is especially important in the aftermath of the COVID-19 pandemic as governments look to attract private capital to help close the global infrastructure gap and achieve the sustainable development goals.

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Notes

1. Because of the complexity and granularity of information, they are not included but are available upon request.
2. "Bank commitment" means that the bidder receives a binding commitment from a bank to finance the project if the bidder wins the contract.

3. In the case of a consortium, we considered a combination of values based on the type of actors involved. For example, to determine the business plan of consortium A, we considered the construction costs of the efficient EPC contractor and the operational costs of the efficient O&M contractor. The cost of capital is an average of the costs of capital for the two consortium members. The strategic offer is obtained by reducing the cost factors of honest offers by 20 percent.
4. The financial plan is available upon request.
5. The authority's skill level has been included as a scenario feature because it is a crucial component of the model. This also helps clarify the results. However, this element has been modelled as an assessment criterion, as explained in the model specification.
6. Additional results are available upon request.

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