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An *ex ante* bidding model to assess the incentive creation capability of a public–private partnership pipeline

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Abstract

The inherent risky nature of public–private partnerships requires contractors to develop expensive project proposals, which is seen as a burden to enter the playing field. It is believed that a pipeline of projects could succeed in triggering contractors' enthusiasm and increasing competition. This paper theoretically assesses whether the pipeline serves as an effective tool to levy this barrier to entry. A theoretical model and a simulation experiment that mimics the tendering process with heterogeneity in the bidders' cost structure are presented. In particular, the impact on the *ex ante* bid preparation effort willingness and the mark-ups is assessed by heuristically approximating the Bayesian Nash equilibrium. A statistical scenario analysis approves that mark-ups are lower when more projects are included in the pipeline, leading to fiercer price competition and a lower government procurement cost. Nonetheless, the incentive creation with respect to investment efforts is limited according to the experiment.
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Keywords: PPP; Contract procurement and tendering; Multi-project bidding; Simulation

1. Introduction

This paper offers a theoretical approach in analyzing the procurement stage of a public–private partnership (PPP) pipeline, which is defined as a sequence of similar projects that the government ensures to tender in the near future. Because of its complexity and riskiness, long-term PPP projects require more preparation than traditional infrastructure projects. After an initial prequalification of interested consortia by the government, qualified concessionaires are invited for tender. The consortia have to prepare a proposal that will be submitted to the government which involves pre-tender research costs (e.g., consulting costs, design costs, and market studies). Empirical evidence by KPMG (2010) reports average research costs of 1.5–2% of the total project cost. These pre-tender research costs or bidding costs are claimed to be a burden for the concessionaires because they do not guarantee to be awarded with the contract (Carrillo et al., 2008). Hence, policy makers often argue that the market is too narrow in some jurisdictions, like in Australia, New Zealand, or western European countries where often only two or three private entities show interest in high-risk PPPs.

Governments are seeking for ways to open up the playing field and incentivize the consortia to submit qualitative bid proposals and for possible entrants to penetrate the market. According to a consultancy report by KPMG (2010) based on empirical evidence in Canada for instance, a pipeline of projects would contribute to a PPP market's attractiveness. Moreover, a pipeline of projects could increase the eagerness of consortia to enter and stay in the PPP market of a particular country (KPMG, 2010). This pipeline reduces a consortium's risk of being unsuccessful, because instead of putting all one's eggs in one basket, a consortium can spread out its investments across different projects and it can offset former losses in future tenders. Due to the high cost and the extensive timeframe of PPP projects, the pipeline is usually of a limited nature.

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Governments change and long-term public budgets are hard to predict.

This paper translates the PPP pipeline concept into a theoretical multi-project procurement model. Through a simulation experiment and a Bayesian Nash equilibrium approximation, it is the purpose to determine a bidder's optimal *ex ante* strategy for a given project sequence. This is useful for two reasons. Firstly, the tendering procedure is often time-consuming and therefore, contractors often have to undertake bid preparations for several projects at the same time. Secondly, organizing a consortium involves fixed costs that may be depreciated across multiple projects. Therefore, an *ex ante* strategy for a bidder is defined by a budgeted bid preparation effort (i.e., the investment decision) and a budgeted mark-up percentage (i.e., the mark-up decision). Furthermore, the model accounts for the fact that bidders are heterogeneous in their experience levels. The past experience a bidder has obtained might lead to an increased ability to estimate the project cost and to efficiency gains that result in a lower expected cost. Subsequently, the scope is extended to the government to assess the reflection of the governmental policy mechanisms into the dynamics of the bidding behavior. On the one hand, public institutions are interested in the effect of the project pipeline on the procurement cost, and on the other hand, the impact of reimbursing a fraction of the research cost to the losing bidders, hereafter referred to as the reimbursement or compensation policy, is investigated in a multi-project setting.

Next to its contribution to the PPP procurement literature, which only rarely considers competitive mechanisms, this study contributes to the procurement auction literature. It offers a methodological approach that favors the practical soundness of the model over limited analytical results that are subject to stringent assumptions. From a procurement auction perspective, this setting pioneers in combining the heterogeneity among bidders and the uncertainty in the project outcome with a multi-unit auction format without information revelation.

The remainder of the paper starts with highlighting the bridge with traditional auction theory and maps the PPP procurement process within the field. Section 3 covers the analytical foundation and subsequently discusses the algorithm that has been implemented for the equilibrium identification. The theoretical findings that result from the simulation output are statistically analyzed in Section 4 and balanced against the qualitative findings from practitioners in the global PPP field in Section 5, leading to policy guidelines and model extension opportunities.

2. Literature review

The reviews of Ke et al. (2009) and Tang et al. (2010) prove that PPPs have gained increasing attention within the academic construction literature. Nevertheless, with respect to the procurement process, the literature has mainly considered the risk identification and allocation aspect. Both empirical (e.g., Chan et al., 2011; Jin, 2010; Li et al., 2005) as well as, but to a lesser extent, theoretical studies (e.g., Khazaeni et al., 2012; Medda, 2007; Scandizzo and Ventura, 2010) deal with this particular PPP challenge. However, bidding models focusing on the PPP competitive dialog are rather scarce. It is mainly pricing peculiarities of PPPs that have been considered, without explicitly taking the competition aspect into account. From a pricing perspective, the determination of the concession period has received considerable attention (e.g., Carbonara et al., 2014; Ng et al., 2007; Zhang, 2009). A second stretch relates to the multi-interest feature of PPPs in which financial, social, and corporate stakes are taken to the challenge (e.g., Liou et al., 2011). Last but not least, an important field is the pricing of governmental interventions to support a minimum revenue (Brandao and Saraiva, 2008; Liu et al., 2014) and how governmental capacity regulations are reflected in the concession price (Subprasom and Chen, 2006). Studies that do consider the competition aspect are for instance from Iyer and Sagheer (2012) for the bid winning potential of mark-ups and from Xu et al. (2012) who explicitly take competition into account in their system dynamics model for pricing the concession. This paper's PPP model does not focus on detailed pricing aspects but represents the mark-up as a single figure for the entire consortium. Nevertheless, this paper does include the competition among contractors.

Empirical evidence shows that bidding for PPPs is expensive (Carrillo et al., 2008; Chen and Doloi, 2008; De Schepper et al., 2015) and could even be a burden for contractors to enter the PPP field. Since renegotiations or defaults come at a high cost for the procuring government, they should create appropriate incentives to guarantee high-quality bids (Bajari and Tadelis, 2001). The upfront investment question has only rarely been studied. Ho (2008) builds a game-theoretical model in which the second-best bidder receives a reimbursement for the investment efforts. Nevertheless, he argues against the reimbursement because it does not significantly improve the quality of the bids. However, the author considers homogeneous bidders, while the empirical findings of Oo et al. (2010) acknowledge the heterogeneity among bidders, which is also considered in De Clerck and Demeulemeester (2014) and Ho and Hsu (2014) who argue in favor of compensations in settings with gaps in the experience levels.

The study of the PPP competitive bidding model that is addressed in this paper is highly intertwined with auction theory. The multi-unit auction literature deserves particular attention in order to position the competitive PPP procurement model with a pipeline of projects. On the one hand, multiple units might be auctioned simultaneously, so that bidders could bid on different packages of objects. Well-supported by the growth of online auctions, the combinatorial auction design has received considerable interest within the operations research community (e.g., Olivares et al., 2012; Pekeč and Rothkopf, 2003). On the other hand, auctioning may be organized in a strictly sequential fashion. Within this setting, an important question relates to the price trend of the objects in the sequence. The majority of auction studies claims that bid prices are declining, meaning that bidding for objects becomes less aggressive later in the sequence (Branco, 1997; Jeitschko, 1999). The declining price effect is usually attributed to the decreased competition in later stages due to capacity constraints. Engelbrecht-Wiggans (1994) and Menezes and Monteiro (2004), however, relate the price trend to the

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