Competition and Efficiency in Procurement Auctions: Evidence from a million Brazilian auctions

Abstract: We provide evidence that the effect of competitiveness on the efficiency of governmental procurement auctions is non-linear. Analyses from data containing 1,366,002 procurement auctions in Brazil between 2015-2018 shows that both the number of participants of an auction and the number of bids are associated to a greater efficiency of procuring an item (i.e., lower prices compared to the estimated price of the item). However, the interaction between these two variables is also significant. We show that this is driven from a fiercer competition in auctions with more participants (i.e., the average difference between the bids is higher). We also show that this effect is concentrated on bigger and more specialized firms (firms that have won the most auctions, and firms with larger contributed capital), and also for firms that are located in the same state as the government unit. Finally, this non-linearity of efficiency is also equally distributed between the classes of products that are procured by the federal government of Brazil.

Keywords: reverse auctions, procurements, competition

A large proportion of global economic activity is carried out through procurement mechanisms. Public procurement processes account for a substantial part of public expenditure worldwide and for a significant portion of a country's gross domestic product (GDP). These figures highlight both the impact of government procurement auctions on the economy and the importance to optimize the efficiency of these auctions since effective public procurement avoids waste of public funds and mismanagement. One of the most discussed topics regarding procurement auctions is the effect of competitiveness on the outcome efficiency of the process. Properly evaluating and understanding the effects of the main variables of this relationship and its interaction is paramount to helping companies and governments to improve the results of procurement processes, better plan their budgets and ultimately optimize public resources allocation.

The main objective of this paper is to evaluate the relationship between the number of bidders and the level of efficiency of procurement auctions, testing the theoretical proposition that more bidders will increase competition. In this paper, we provide evidence of a non-linear effect of competitiveness on the efficiency of governmental procurement auctions in Brazil. We show that not only the number of participants of an auction but also the number of bids are associated to a greater efficiency of procuring an item. Even more, we highlight the importance of the interaction between these two variables due to an increase in the level of competition in auctions with more participants. We also show how this effect is distributed along with the sample according to the bidder's attributes and between the classes of products that are procured by the federal government of Brazil.

Governments have a strong desire to stretch their acquisition budgets as much as possible. For achieving sustainable growth and boosting mutual wealth for all, better management of the public procurement system with a high level of efficiency is critical.

Although procurement policies aim to achieve competitiveness through strategic and tactical levels, their effectiveness in several segments and different countries is constantly under evaluation. Ultimately, the objective of this study is to effectively contribute to the achievement of better results on public procurement auctions from a governmental perspective and justify policy recommendations.

The term procurement is frequently used to refer to acquisitions undertaken in the public sector, as opposed to purchasing, which is typically used for acquisitions made in the private sector (Quayle, 2000). On one hand, public procurement is one of the most important strategic tools available to governments for carrying out their mandates, achieving their goals, and enhancing the quality and efficiency of government spending. On the other hand, the public sector influences the private market and the expectations of how aggressively businesses will compete in the long term. This discussion will be deepened in the literature review section.

The two roles of government, as a market regulator and an influential buyer of goods and services, are interconnected by public procurement. Furthermore, it has been argued that public auctions have a significant effect on local ecosystems. In recent years, public procurement has played a broader social and political role. Through the enforcement of specific clauses such as local content, social provisions, or environmental impacts, the bidding process has been suggested to be used as a mechanism in wider social areas of society (Erridge, 2004). For instance, policymakers can influence business practices by requiring that bidders must comply with specific environmental regulations (e.g., recycled materials or use of renewable energy sources) or serve as a response to social issues (e.g., non-discrimination against minorities in the workplace or gender equality).

Public procurement policy is a comparatively recent concept. Most countries enacted procurement regulations in the 1990s or 2000s, except for Japan in 1947 and the United States two years later. In Brazil, the competition regime was successfully redesigned in 2011 with the introduction of the new Competition Law (Law 12.529/11). The reform effectively modernized antitrust enforcement and is now consistent with international practices. The new Law was a significant improvement for Brazil's competition policy and the changes rationalized the institutional framework by creating an integrated institution (The Administrative Council for Economic Defense – CADE). Brazil is now fully engaged with international competition policy institutions, such as the OECD's Competition Committee and the International Competition Network (ICN).

For decades, a large number of studies regarding competition and efficiency of procurement auction took place under different methods, focused on a variety of variables and with data from many distinct segments and countries. The focus of this discussion on the literature revolves around the relationship between the number of participants and the price of the winning bid. The main issue is the range of different outcomes in the literature regarding the relationship between competition and efficiency, depending on the approach of the analyses. To illustrate the matter, we can point out Rancourt et al. (2014), Xu and Li (2019), and Onur and Tas (2019) studies. They identified reasons to positively correlate competition to efficiency in procurement auctions. On the other way around, Celentani and Ganuza (2002), Hong and Shum (2002), and Li and Zheng (2009) conclude the opposite (i.e., an increase in competition may lead to lower levels of efficiency). In the literature review we further develop those differences and other procurement procedures correlated to the level of competitiveness of the process. Due to this lack of a consensus on the literature, it seems that the topic still lies under question and robust results can help clarify the discussion.

Hence, this study is the first to show, to the best of our knowledge, that, on average, an increase in the number of bidders lowers the difference between the winning bid price and the previously estimated price, enhancing efficiency. The results are confirmed by changing the dependent variable from “efficiency” (estimated price minus final price) to “bid difference” (average difference between bids). This way we provide evidence for the hypothesis that this increase in efficiency is driven by a fiercer competition in auctions with more participants. Then, we estimate the non-linear effect of competition according to the strength and the geographic location of the firms. We present evidence that this non-linear effect is concentrated on “top firms" (top 100 firms that have won the most auctions with the federal government) and on “local firms” (firms that are located in the same state as the government unit).

Accordingly, the empirical analysis conducted in this paper provides applicable results, which can be used by policymakers to assess the level of efficiency in procurement auctions and administer policy actions to improve bidder participation. Finally, these results were achieved using a detailed data set containing 1,366,002 procurement auctions in Brazil covering the period from 2014 to 2018. These extensive data allowed us to conduct an empirical analysis of the efficiency of government procurement auctions regarding three major Brazilian ministries (Ministry of Health; Ministry of Education; Ministry of Defense). To the best of our knowledge, we are using one of the biggest and more complex data sets in the literature and the first to analyze the interaction between the number of actual participants and the number of bids to justify the non-linear effect of competitiveness over efficiency on public procurement auctions.

As will be seen in the literature review in the following section, the investigations on how competition affects efficiency, although it is extensive, do not present a conclusive outcome on the subject of public procurement auctions. That is the main

motivation of this paper, to properly address the issue and present a conclusive and decisively result, helping clarify such a divergent issue that still lacks consensus. Additionally, the present study is theoretically justified due to the scarcity of public procurement auction studies on developing countries.

The rest of the paper is organized as follows: Section 2 is devoted to the literature review of the main topics discussed. Section 3 describes the data set that was analyzed and presents an explanation of data mining. Section 4 presents the main and secondary results obtained and develops the structural framework and the empirical methodological procedure. The final section presents our conclusion and summarizes policy implications of the results, limitations, and some discussions that could be deepened or even suggestions of developments for future studies.

Literature Review

The literature on the relationship between competition and efficiency in procurement auctions does not present a conclusive result. The discussion seems to be extremely divergent depending on many factors, such as study assumptions (e.g., endogenous/exogenous participation - entry costs; common/private value; corruption, collusion or cartel; information asymmetry), auction format or design, bidder's features (e.g., firm size, knowledge, and geographic location) and the methodology applied for data analysis (econometric approach: structural or reduced-form). Local particularities may also play an important role in procurement auctions, including country legislation, economic power, and segment maturity. The main variable used to evaluate the impacts of competition on efficiency (i.e., the difference between the estimated price and the winning bids) is the number of bidders of a procurement auction. There is evidence suggesting both positive and negative correlations (monotonic relationship). On the other hand, some papers identify a non-monotonic (i.e., when two variables do not generally

change in the same direction) relationship between winning bids and the number of potential bidders. Furthermore, some authors search for an optimal number of participants that maximizes the level of efficiency of procurement auctions.

The motivation of this study revolves around this lack of consensus in the literature and due to the limited number of studies investigating the efficiency of public procurement auctions in developing economies mainly due to restricted access to comprehensive procurement auction data. A crucial finding of our study is the evidence that the effect of competitiveness on the efficiency of government procurement auctions is non-linear. A key theoretical contribution of this paper is that we present a non-usual approach to this discussion in order to evaluate the effect of competition on the level of efficiency in public procurement auctions. We empirically conclude that the interaction between the number of actual participants and the number of bids (the two independent variables studied) suggests a fiercer competition among bidders. In other words, the "competition effect" among bidders explains this non-linearity of efficiency.

Several papers that overturn common wisdom that more competition is always desirable are based on the assumption that bidding is a costly activity. The critical finding that more bidders do not necessarily translate into lower procurement prices for government auctions (or higher winning bids) is grounded on the fact that bidder's participation decisions are endogenous. Empirical evidence can be found in Athey et al. (2011) for timber auctions and Bajari and Hortaçsu (2003) for Internet auctions. As pointed out by Perrigne and Vuong (1999), if the number of bidders is exogenous (meaning that the firm's entry decision is not made based on perceived profitability), the number of potential bidders and the number of actual bidders are equal. This means that the reserve price is nonbinding, complicating the identification and estimation of nonparametric models. We will observe below that, in costly bidding, the theoretical

evidence suggests that participation is usually endogenous and the relationship between the expected auction price (efficiency) and the number of potential bidders (competition) can be non-monotonic.

Studying mixed strategies of entry, Levin and Smith (1994), through their theoretical model, suggested that when the number of potential bidders exceeds a certain threshold, the expected winning bid decreases. Based on Levin and Smith (1994), Li and Zheng (2009) model with endogenous entry, provide evidence that bidders may become less aggressive if the number of bidders increases (i.e., increasing potential competition may not necessarily benefit the auctioneer in first-price auctions). The explanation revolves around the fact that the “entry effect", meaning barriers to a potential bidder to actually submit a bid (e.g., cost of bidding preparation, opportunity cost, or cost of acquiring information) dominates the “competition effect" (i.e., bidders become more aggressive when the number of participants increases). For the first time, they show that even within the independent private value paradigm, as the number of potential bidders increases, bidders’ equilibrium bidding behavior can become less aggressive and the expected procurement cost can rise (the “entry effect” is always positive and may dominate the negative “competition effect”).

At this point, it is worth mentioning that Bulow and Klemperer (2002) had previously questioned the monotone relationship between competition and efficiency in a “common-value” model because of the interaction of the positive “competition effect" with the negative “winner’s curse effect”. In the same context, Pinkse and Tan (2005) show that a non-monotonically increasing relationship between the equilibrium bid and the number of bidders can also occur in an affiliated private-value model (even considering the absence of the winner’s curse). This “affiliation effect” can offset the “competition effect” since more competition implies that, conditional on winning, the

rival's valuations are more likely to be low. Previously, Compte and Jehiel (2002) highlighted the roles of asymmetries between bidders and the multidimensional character of the private information arguing that a systematic promotion of the maximum participation in procurement auctions could deteriorate welfare.

Regarding procurement auctions, there is also a vast empirical literature for different countries and segments providing evidence that an increase in the number of competitors may lead a bidder to bid less aggressively in equilibrium. Hong and Shum (2002) developed a parametric model with both private and common value components and symmetric bidders and concluded that the procurement costs rise as the number of bidders increases. They argument that the winner's curse becomes more severe as the number of potential bidders increases, thus rational bidders will bid less aggressively (i.e., the "winner's curse effect" overlaps the "competition effect").

Previously, Paarsch (1992) also stated that in a common value paradigm the "competition effect" would be minimized when the number of bidders is large, because of the expected "winner's curse effect". Gupta (2002), Estache and Iimi (2008), and Onur and Tas (2019) even suggested an optimal number of participants in order to take full advantage of competition and achieve the minimum procurement price. More recently, Hanauerová (2019) focused on identify the main factors that influence the final price offered by a tender participant and whether this price corresponds to the extent of the service provided. She concludes that no direct link between the number of bidders and the efficiency rates was found.

On the other hand, some papers suggest a positive correlation between competition and efficiency in procurement auctions. Gavurova et al. (2018) found that the number of offers in a given sector positively influences public competition. Their model concluded that ensuring sufficient competition is paramount to saving public

resources. Rancourt et al. (2014) study found that competition levels explain a significant amount of variability in tariffs in the Ethiopian transportation market. Their empirical results based on econometric models show that competition intensity is a good market structure variable to predict the tariffs paid by the World Food Programme. They conclude that competition may be as important as road infrastructure investment in Ethiopia's development strategy.

Additionally, Shrestha and Pradhananga (2010) study concludes that the higher the number of bidders participating in the bidding process, the lower will be the winning bid. They based their study on the preceding work of Carr (2005), which presented a quantitative analysis of the impact of reduced competition on project bid prices. The study found that reducing the number of bidders would result in increased project bid prices. He claims that any restriction on competitiveness (e.g., prequalification, local preferences, shortened bid period, or poor advertisement) will be followed by a price penalty, directly affecting the efficiency of the bidding process. Ultimately, the author states that his study demonstrates that unfettered competition will have the highest probability to achieve the goals of competitive bidding. Previously, Gómez and Szymanski (2001) found that a higher number of bids is associated with a lower cost of service, providing empirical evidence of a standard proposition in auction theory. Additionally, their finding still holds when possible endogeneity problems in the number of bids variable are considered.

Therefore, due to such a broad and divergent scenario with evidence reasoned from empirical studies, we aim to help clarify the discussion by adding a different approach to conclusively evaluate the relationship between competition and efficiency in procurement auctions. In terms of goals, our study should be seen as a contribution to an inconclusive literature that discusses the ways in which the level of competition of a

procurement auction affects efficiency. Our particular contribution is to identify the interaction between the number of actual participants and the number of bids. This study empirically suggests that a fiercer competition among bidders explains the non-linearity of efficiency.

The influence of corruption (in the context of auctions, corruption is commonly described as an act in which a bureaucrat manipulates the auction rules in exchange for bribes) on the competitiveness of a procurement auction is not included in the scope of this study. The existing literature around the discussion is extensive and, since there is strong evidence of a correlation between corruption and the competitiveness of a procurement auction, it is worth mentioning some results. Common sense tells that more competition helps to minimize the risk of corruption. Leading this negative correlation, Rose-Ackerman (1996) stated, "in general any reform that increases the competitiveness of the economy helps reduce corrupt incentives". The empirical studies of Ades and Di Tella (1999), Laffont and N'Guessan (1999), Wei's (2000), and Emerson (2006) also show support for the idea that higher levels of openness to trade (meaning more exogenous factors) are associated to lower corruption levels.

Contrary to conventional wisdom, Celentani and Ganuza (2002) and Alexeev and Song (2013) find a positive relationship between the strength of competition and the extent of corruption (i.e., competition may increase corruption). In addition, some authors paid attention through an opposite approach, evaluating the effects of corruption on competition. Compte et al. (2005) show that a key effect of corruption in public markets is to facilitate collusion between firms, undermining competition and generating a price increase that goes far beyond the bribe received by the bureaucrat. This may result in high public spending and inefficient allocation of resources. More recently, Amir and Burr (2015) and Xu and Li (2019) studied the effects of corruption on equilibrium competition

and social welfare in public procurement auctions. Finally, it is worth mentioning that OECD has created a police instrument (OECD Principles for Integrity in Public Procurement) to help governments efficiently manage public resources. OECD suggests recommendations based on principles (the principles reflect a global view of policies and practices that have proved effective for enhancing integrity in procurement) of integrity in public procurement, which are anchored in four pillars: transparency, good management, compliance, and accountability.

Since we evaluated the extension of the result of this study according to the bidder's characteristics (major auction winners, location, and contributed capital), we will next present some relevant literature suggesting how the size of the procurement process, the level of organizational knowledge (explicit and tacit knowledge that an organization possesses, according to Nonaka - 1994) and bidder's size and location affect the functioning and the result of a public procurement auction. The perceived profitability of one particular contract among bidders will depend on these features. Alexandersson and Hultén (2007) stated that the behavior of the firm may vary according to the size of the procurement because different sizes of bids have different importance for the bidder.

Regarding size and organizational knowledge, we may imply a positive correlation with the frequency of bids that the firm submits on a procurement process and, thus with the frequency that the bidder wins an auction. Hortaçsu and Puller (2008) suggest the existence of a learning curve and they claim that firms get more efficient as they submit more bids every time they participate in an auction (through the experience of earlier bidding a firm builds the capacity to successfully take part in future auctions). Previously, Flanagan and Norman (1985) stated that larger firms with more experience and expertise in how to calculate a bid tend to be the ones submitting in larger auctions.

On the side of the public entity, we can also suggest that the more organizational knowledge, the smaller will be the price variation of the bids submitted during the procurement process. According to Preuss (2011), being a local firm slightly increases the chance of winning an auction. He concludes that the location of a firm has an influence on the frequency with which the firm is bidding, meaning a small positive correlation between the firm being local and its participation in the procurement process. In addition, Parilli et al. (2010) offer an insight into the logistic impacts regarding the bidder's geographic location. Furthermore, Walker and Preuss (2008) evaluated the interaction between location and small and medium-sized enterprises (SMEs) and concluded that they are often locally based due to their limited size. They also highlight the impacts on the local economy and ecosystem when a small bidder wins an auction since SMEs are drivers of innovation and important providers of local job opportunities.

Moreover, Leitzel (1992) suggests that even competitive procurement practices (e.g., dual sourcing: simultaneous production from two sources; second sourcing: involves a technology transfer in the same manner as dual sourcing, but all future production is then awarded to one of the two firms) may not guarantee an increase in competition of the procurement process. His study with the US Department of Defense concludes that many aspects of defense procurement suggest non-competitive behavior and, thus, in isolation, these procurement reforms are unlikely to generate large gains. This pessimist view is based on the fact that if competition between firms for the initial production award is intense enough, additional competition from a second source for later production contracts will simply result in less intense presource selection competition. On the other hand, if the initial award is non-competitive, there is no reason to believe that a later production contract will extract competitive behavior. In addition, Rogerson (1989) previously argued that competitive procurement policies such as second or dual

sourcing which reduces economic profit might generate a reduction in the innovative process.

In the next section we provide the data description which we will use to test the effect of competition in the efficiency of public procurement auctions.

Data

The data was collected from the Brazilian federal government website that records web auctions from all states of the country (divided by Ministries). Therefore, our data only include online auctions, which mostly cover smaller purchases of "common" items, such as food, office supplies, maintenance supplies, etc. This standardization of the items purchased in the sample and the format of the auction (e-procurement reverse auctions) decisively contributes to the homogenization of the sample, allowing us to properly analyze it and present general results. These attributes also minimize some issues in procurement auctions previously discussed in the literature review, such as cost entry effects and information asymmetry.

The data set was comprised of 1,516,257 observations from 2015 to 2018. However, since just three ministries comprise 94.61% of all observations, we decided to limit our dataset to contain just data from the Ministry of Education, Health, and Defense. This reduced our dataset to 1,366,002 observations as displayed in Tables 1 and 2. The inflation effect was captured by year fixed effects (FE) as a statistical strategy since the use of a single price index would not properly represent the reality (sample with a large variety of products).

<INSERT TABLES 1 AND 2 AROUND HERE>

The data contains detailed information on the number of participating firms (bidders), the total number of bids in the auctions, the expected winning bid price, and the actual winning bid price. All those variables were used in the empirical analysis in

order to evaluate the dependent variables (efficiency and bid difference). Table 3 presents the summary statistics of our main variables.

<INSERT TABLE 3 AROUND HERE>

The Efficiency variable, as previously described, measures the efficiency of the public reverse auction procedure in procuring an item for less than its estimated price (i.e., the budget for that procedure, usually set based on the average of quotations from selected providers), thus it is estimated as the pre-auction estimated price minus the price paid for the items (thus a value above zero shows a positive efficiency).

The average number of bids per procurement is around 30 and the average number of participants per procurement is around 6, thus we can perceive that those procedures are not very competitive.

The quantity purchased refers to how many items of that specific product the government wished to buy and the estimated price, as aforementioned, is the "target" price of the government and guides the budget for the governmental unit that is procuring the product. We use these variables as control variables in our estimations.

Notwithstanding, all the distributions are skewed to the right since the means are larger than the medians. Thus, we employ 5^{th} and 95^{th} percentiles winsorizations in all variables.

Results

Main Results

The main specification for the estimation is as follows:

$$\begin{aligned}\text{Efficiency}_{i,j,k,t} = \alpha + \beta_1 \text{Number of Bids}_{i,j,k,t} + \beta_2 \text{Number of Participants}_{i,j,k,t} + \\ \lambda(\text{Number of Bids}_{i,j,k,t} \times \text{Number of Participants}_{i,j,k,t}) + Z\gamma + \Theta + E_{i,j,k,t} \quad (1)\end{aligned}$$

Where "Efficiency" stands for the measure of efficiency in Brazilian Reais (i.e., the estimated price minus the final bid, ultimately, the price paid) for auction *i* at the

ministry *k*, won by firm *j* in year *t*, the "Number of Bids" stands for the number of bids and the "Number of Participants" stands for the number of firms that actually participated in the auction process (i.e., with bids). The λ is the main coefficient of interest: it denotes the non-linearity in competition. Z is a vector of control variables and Θ is a vector of fixed effects. To estimate the coefficients an Ordinary Least Squares (OLS) series of models were estimated. The results are presented in Table 4.

The estimated price used in the efficiency calculation is the price that the government unit used in its internal procurement process as the "target price", hence a positive value shows that the procurement process generated a price even lower than what was expected, and a negative value shows that the government unit purchased the item at a higher price than was expected. As previously mentioned, due to the presence of outlies in the data (large purchases) we winsorized the data at the 5^{th} and 95^{th} percentiles.

<INSERT TABLE 4 AROUND HERE>

Results show that, for every extra bid the efficiency increased between 1.63 BRL and 4.25 BRL, which were significant in all models. Moreover, for every extra bidder (i.e., participant in the reverse auction), then the increase in the efficiency was between 416.53 BRL and 436.43 BRL.

However, the main result is that for every new participant in the auction the effect of every new bid on the efficiency increases between 0.49 BRL and 0.63 BRL, which is a relative increase of between 11.53% and 38.65% on the main effect.

In order to provide evidence for the hypothesis that this increase in efficiency is driven by a fiercer competition, we estimate the equation (2), changing the dependent variable for bid difference, as follows:

$$\text{Bid Difference}_{i,j,k,t} = \alpha + \beta\ \text{Number of Participants}_{i,j,k,t} + Z\gamma + \Theta + E_{i,j,k,t} \qquad (2)$$

In the above model we calculate the bid difference using the following relation:

Bid Difference = (First Bid – Final Bid) / # of Bids,

which is equal to the average bid gap. This is the reason that we do not include the number of bids in (2). Ceteris paribus, if the number of bids increase then the bid difference would decrease, since it would increase the denominator. Thus, this coefficient has no economic meaning in this context.

Our main results from Table 5 show that the effect of the number of participants is positive and significant, showing support for the hypothesis that, for every new bidder the average difference between consecutive bids increases. Moreover, we estimate that, for every new bidder, the bid difference increases in about 3 BRL. Thus, we find evidence that the number of participants in a public procurement auction not only has a direct effect (i.e., more bids from that participant), but also has an indirect competitive effect on the behavior of the other bidders, which bid more aggressively.

<INSERT TABLE 5 AROUND HERE>

Firm Characteristics: "Top" vs "Bottom" Firms

We now estimate the non-linear effect of competition for two types of firms: those classified as "top firms" and also those classified as "bottom firms". For "top firms" we select the 100 firms that won the most auctions with the federal government, while the "bottom firms" are the firms that won the least auctions. For "bottom firms", as a matter of robustness, we estimated models for firms that have won 1, 5, 50 and 100 or less auctions. Results were similar, and in Table 3 we present the results for firms that won 100 or less auctions during the 2014-2018 period.

We then proceeded to estimate model (1) presented in the previous subsection. The results are presented in Table 6.

<INSERT TABLE 6 AROUND HERE>

The results show that for auctions that "top firms" won, we have a positive non-linear effect of competition, while for those that the "bottom firms" won, we have a negative one. This provides evidence that either the "top firms" participate in bigger and/or more profitable auctions with bigger competition, while the "bottom firms" usually participate in less crowded auctions, or that the "top firms", being more efficient, drive the price down and hence increases competition. For objectivity purposes, only the relevant effect (interaction) was presented since the effects of the other variables are theoretically irrelevant.

Firm Characteristics: "Local" vs "Non-Local" Firms

In this subsection we proceed to analyze if the competitive advantage of local firms vs. non-local firms results in different auction behaviors when these firms compete and win the procurement auction.

It can be argued that local firms have competitive advantage since they are closer to the governmental unit procuring the item, which could lead to a reduction in costs and hence more efficiency in the procurement process. Nevertheless, a different argument can be made. Perhaps firms outside the state unit may be closer to the industrial and/or financial hubs of the country. This can lead to those firms having smaller costs to supply the items, even taking into consideration the freight costs and taxes for sales in a different state unit. Thus, it is not possible ex-ante argue for one hypothesis or the other.

Results are presented in Table 7, which shows that local firms improve more the efficiency of auctions than non-local firms, hence providing support for theory that local firms have competitive advantage due to the fact that they are closer to the governmental unit procuring the item, which leads to a reduction in costs and hence more efficiency in the procurement process.

<INSERT TABLE 7 AROUND HERE>

Firm Characteristics: Contributed Capital

As a final test of firm characteristics, we merged the data of the procurement procedures with the data from the Brazilian IRS (the Receita Federal). Hence, we could collect data about the companies, and the only financial information available was the contributed capital that the partners (limited liability company) or shareholders (corporation) invested in the company. We use this information as a proxy for the size of the company. Bigger firms tend to demand more capital for its inception and further growth, which is captured in this variable.

In the end we had a new sample size of 939,684 observations that matched to the registries of Receita Federal. Regarding the distribution of the contributed capital, half of all the winners of the procurement procedures had 10,000 BRL (around 3,000 USD at the time that the data was collected) or less in contributed capital, and thus most of the auctions were won by small firms.

We calculated the tertiles of the contributed capital variable and we estimate the equation (1), our basic model, in the highest contributed capital tertile (i.e., bigger firms) and on the lowest contributed capital tertile (i.e., smaller firms). Results are presented in Table 8.

<INSERT TABLE 8 AROUND HERE>

These results mirror what was found for “top” vs. “bottom” firms: the participation of bigger firms increase competition, while smaller firms decrease competition. Thus, this new estimation provides not only robustness to our previous findings and interpretations, but also paints a picture that should encourage governments to nudge larger firms to participate in the procurement process.

Types of Products

We repeat the “top” vs “bottom” firms approach, but now instead of comparing firms, we apply the same criteria for products (100 most procured products vs. products that were procured 100 times or less). Results presented on Table 9 show no difference between these two groups, hence suggesting that the efficiency of the procurement process is not tied to the product itself, but rather to the firms participating in it.

<INSERT TABLE 9 AROUND HERE>

Conclusion

In this study, we investigate the relationship between competitiveness and efficiency in public procurement auctions. A unique and extensive data set was collected from the Brazilian federal government website that records web auctions from all states of the country. Support for the assumption that more bidders and bids in a procurement auction mean more competition and thereby lower final prices for the auctioneer (meaning higher efficiency) was found in the study. Data analyses concluded that not only the number of participants in an auction but also the number of bids (independent variables) are associated with greater efficiency in procuring an item.

Moreover, we highlight the importance of the interaction between these two independent variables due to an increase in the level of competition in public procurement auctions with more participants. To the best of our knowledge, this is the first study to identify a non-linear positive correlation between competition and efficiency in public procurement auctions through the analysis of this interaction. Our main empirical result shows that for every new participant in the procurement auction the effect of every new bid on the efficiency increases between 0.49 BRL and 0.63 BRL, which is a relative increase of between 11.53% and 38.65% on the main effect.

Additionally, we show that the non-linear effect of the competition is concentrated on bigger and more specialized firms (“top firms”) and also on firms that are located in

the same state as the government unit ("local firms"). Furthermore, we show how the non-linearity of efficiency is equally distributed between the classes of products that are procured by the federal government of Brazil. Finally, we merged the data of the procurement procedures with the bidder's contributed capital (data from the Brazilian IRS as a proxy for the size of the company), since bigger firms tend to demand more capital for their inception and further growth, which is captured in this value. In line with previous results, we conclude that the participation of bigger firms increases competition.

From a practical point of view, our findings have important policy implications. Governments can devise policies to attract more bidders in public procurement auctions, which may lead to an increase in competition that, ultimately, contributes to considerable savings of public funds, optimizing budget allocation. The results also suggest that governments should encourage the participation of larger firms in the public procurement process in order to maximize efficiency.

Many interesting insights into future research can be identified to further investigate the specific results of this paper or to deeper evaluate any of the many other discussions briefly touched in this study, all relating to the wide area of public procurement auction. The development of this paper is possible in the direction of the research on the optimal number of participants in public procurement auctions, putting into perspective some other effects, such as entry costs (endogenous participation), corruption or collusion (small bidders as winners of major bids – "superefficient bidders") and information asymmetry (incumbent analysis). The evaluation of different auction formats and designs to encourage SMEs in public procurement (e.g., scoring auctions) could provide a better ecosystem to promote smaller innovative firms with new products or services that could in the longer-term perspective increase the productivity of local economies and help developing new segments. There is also in the literature a discussion

of the social effect of procurement auctions and the responsibility of the public entities as buyers in the market.

Finally, it is worth mentioning that some assumptions of this work might be considered limitations or a simplification in order to allow a conclusive analysis and reach broader results. Since our data only include online auctions (e-procurement), which mostly cover smaller purchases of "common" items (e.g., food, office supplies, etc.), we considered no entry costs (exogenous participation) and no information asymmetry.

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Tables

Table 1 – Sample distribution by Ministry

Ministry	Freq.	Percent
Education	1,145,450	83.85
Health	138,100	10.11
Defense	82,452	6.04
Total	1,366,002	100.00

Table 2 – Sample Distribution by Year

Year	Freq.	Percent	Cum.
2015	350,589	25.67	25.67
2016	363,582	26.62	52.28
2017	336,748	24.65	76.93
2018	315,083	23.07	100.00
Total	1,366,006	100.00	

Table 3 – Summary statistics.

Variable	Mean	Median	SD
Efficiency	2,798.68	146.08	6,431.38
Number of Bids*	30.08	15.00	42.99
Number of Participants*	5.80	5.00	4.72
Quantity Purchased	672.70	48.00	1598.61
Estimated Price	11,836.75	1,645.20	24,084.18

* Number of bids and of participants per procurement.

Table 4: Main results

	Model 1	Model 2	Model 3	Model 4	Model 5
Dep. Var.:	Efficiency	Efficiency	Efficiency	Efficiency	Efficiency
No. of Bids	1.63***	1.74***	2.19***	4.25***	4.25***
	(0.21)	(0.21)	(0.20)	(0.20)	(0.29)
No. of Participants	436.43***	440.23***	422.06***	416.53***	416.53***
	(1.57)	(1.57)	(1.58)	(1.57)	(2.28)
Interaction	0.63***	0.61***	0.59***	0.49***	0.49***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
Obs	1,366,002	1,366,002	1,366,002	1,366,002	1,366,002
R^2	0.14	0.14	0.15	0.17	0.17
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes
Month FE	No	Yes	Yes	Yes	Yes
Ministry FE	No	No	Yes	Yes	Yes
Provider's State FE	No	No	No	Yes	Yes
Gov. Unit's State FE	No	No	No	Yes	Yes
Robust SE	No	No	No	No	Yes

Significance value: *p<0.10, **p<0.05, ***p<0.01. Standard errors in parentheses.

Table 5: Bid differences

	Model 6	Model 7	Model 8	Model 9	Model 10
Dep. Var.:	Bid difference	Bid difference	Bid difference	Bid difference	Bid difference
No. of Participants	2.71***	3.35***	4.36***	3.86***	3.86***
	(0.11)	(0.11)	(0.12)	(0.12)	(0.13)
Obs	1,239,877	1,239,877	1,239,877	1,239,877	1,239,877
R^2	0.01	0.01	0.01	0.03	0.03
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes
Month FE	No	Yes	Yes	Yes	Yes
Ministry FE	No	No	Yes	Yes	Yes
Provider's State FE	No	No	No	Yes	Yes
Gov. Unit's State FE	No	No	No	Yes	Yes
Robust SE	No	No	No	No	Yes

Significance value: *p<0.10, **p<0.05, ***p<0.01. Standard errors in parentheses.

Table 6: Top vs. Bottom firms

	Model 11	Model 12	Model 13	Model 14
Sample:	Top	Top	Bottom	Bottom
Dep. Var.:	Efficiency	Efficiency	Efficiency	Efficiency
Interaction	0.94***	0.73***	-0.77***	-1.05***
	(0.03)	(0.06)	(0.05)	(0.05)
Obs	363,595	363,595	266,284	266,284
R^2	0.13	0.17	0.15	0.22
Controls	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes
Month FE	No	Yes	No	Yes
Ministry FE	No	Yes	No	Yes
Provider's State FE	No	Yes	No	Yes
Gov. Unit's State FE	No	Yes	No	Yes
Robust SE	No	Yes	No	Yes

Significance value: *p<0.10, **p<0.05, ***p<0.01. Standard errors in parentheses.

Table 7: Local vs. Non-Local Providers

	Model 15	Model 16	Model 17	Model 18
Sample:	Local	Local	Non-Local	Non-Local
Dep. Var.:	Efficiency	Efficiency	Efficiency	Efficiency
Interaction	0.87***	0.70***	0.53***	0.37***
	(0.04)	(0.06)	(0.02)	(0.04)
Obs	509,552	509,552	856,840	856,840
R^2	0.14	0.17	0.14	0.17
Controls	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes
Month FE	No	Yes	No	Yes
Ministry FE	No	Yes	No	Yes
Provider's State FE	No	Yes	No	Yes
Gov. Unit's State FE	No	No	No	Yes
Robust SE	No	Yes	No	Yes

Significance value: *p<0.10, **p<0.05, ***p<0.01. Standard errors in parentheses. Test for difference of coefficients: $x^2(1) = 22.86$, $p < 0.01$ (model 15 vs. 17); $x^2(1) = 15.64$, $p < 0.01$ (model 16 vs. 18). "Local" stands for providers located in the same state as the governmental unit, and "Non-Local" stands for providers located in a different state to the governmental unit.

Table 8: High vs. low firm contributed capital

	Model 19	Model 20	Model 21	Model 22
Sample:	High Capital	High Capital	Low Capital	Low Capital
Dep. Var.:	Efficiency	Efficiency	Efficiency	Efficiency
Interaction	1.17***	1.01***	-0.55***	-0.81***
	(0.03)	(0.06)	(0.07)	(0.08)
Obs	261,799	261,799	329,046	329,046
R^2	0.19	0.21	0.11	0.17
Controls	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes
Month FE	No	Yes	No	Yes
Ministry FE	No	Yes	No	Yes
Provider's State FE	No	Yes	No	Yes
Gov. Unit's State FE	No	Yes	No	Yes
Robust SE	No	Yes	No	Yes

Significance value: *p<0.10, **p<0.05, ***p<0.01. Standard errors in parentheses.

Table 9: High vs. low number of auctions (products)

	Model 23	Model 24	Model 25	Model 26
Sample:	High	High	Low	Low
Dep. Var.:	Efficiency	Efficiency	Efficiency	Efficiency
Interaction	0.88***	0.52***	0.68***	0.61***
	(0.04)	(0.07)	(0.02)	(0.04)
Obs	659,886	659,886	706,116	706,116
R^2	0.10	0.15	0.18	0.21
Controls	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes
Month FE	No	Yes	No	Yes
Ministry FE	No	Yes	No	Yes
Provider's State FE	No	Yes	No	Yes
Gov. Unit's State FE	No	Yes	No	Yes
Robust SE	No	Yes	No	Yes

Significance value: *p<0.10, **p<0.05, ***p<0.01. Standard errors in parentheses.