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BIDDING PERFORMANCE OF FIRMS IN PUBLIC WORKS TENDERS: A STOCHASTIC FRONTIER APPROACH

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Abstract

This paper seeks to analyze firms' bidding performance in public works tenders called in the Asturias (Spain) between 2007 and 2010. For these purposes, a model including several variables regarding features of tender and contractors is estimated by OLS. The estimated coefficients suggest that tenders which involve larger public works or that award them by a simple lowest-bid auction are associated with higher discounts, as are firms which use its usable capacity more intensely. Additionally, differences in bidding before and after the outbreak of the economic crisis in Asturias in 2009 can reach about 13 percentage points. Then a stochastic frontier model is estimated, from which efficiency scores for each tender are calculated in order to elucidate bidding performance. A simple approximation suggests that 61.9 million euros could have been surcharged to the public purse between 2007 and 2010 due to market power inefficiency. Finally, a number of policy recommendations which are consistent with existent bidding literature are provided.

Key words: Bidding, tendering, stochastic frontiers, market power.

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1. Introduction

Effective competition is essential to ensure an efficient market outcome. This is illustrated in models of imperfect competition such Cournot's and Bertrand's, which state that the larger the number of firms in the market, the lower will be their market power, meaning the ability of each firm to raise alone its prices profitably. Furthermore, the same models show that when goods are homogeneous and competition is based on prices only, not many firms are needed to ensure effective competition in the market. Nonetheless, some firms may try to avoid competition by resorting to collusion, and therefore agreeing to share the market through different kinds of arrangements.

Lack of competition has significant consequences. Werden (2004) and Connor and Lande (2004) report the average overcharge induced by cartels in tendering could be between 15 and 30 percent. Similarly, Spain's National Competition Commission (*Comisión Nacional de la Competencia, CNC*)[1], based on studies conducted by various international organizations, states in its "Guide for public procurement" (*Guía para la contratación pública*) that collusion in tendering represents a 20 percent rise in public contracts, causing a considerable injury to public purse and thus to taxpayers, together with an unjust enrichment of those who participate in such anticompetitive arrangements. Thereupon these figures highlight an important matter of concern, to which no effort should be spared to watch over and in case to ensure an effective and fair competition among tendering firms.

Considering that, this empirical application aims to analyze firms' bidding performance in public works tenders in Asturias (Spain). Public works tenders have been chosen since it meets a number of features, as described by Ishii (2008) and Moreno (2011). First, public works are tendered on a recurrent basis and regularly over time, often yearly, which ensures a sufficiently large number of observations to be meaningful. Second, firms devoted to public works use conventional and standardized technology, which is shared by almost all participating firms; moreover, they consume almost the same kind of inputs, many of which are commodities like energy, fuel or cement, and thus the operational costs of tenderers are similar. Third, public works involves barriers of entry, both settled by regulation through requiring compliance of

[1] By the time this paper was finished, the National Competition Commission, together with other regulatory authorities, were all merged to form the new National Markets and Competition Commission (*Comisión Nacional de los Mercados y de la Competencia*, CNMC), which includes both the tasks of regulation and supervision of markets in Spain.

technical (i.e. a minimum experience in similar projects) and economic (i.e. a minimum level of billing or equity, or a security) clauses to participating firms, or imposed by the own nature of the public work through the presence of economies of scale. These barriers of entry push downward the number of tendering firms, and thereby, this might lead to less competitive pressure and thus to lower discounts, which translates into higher costs to public purse. Moreover, as the number of firms is smaller, the chances that they are able collude or reach an anticompetitive agreement increase.

The possibility of collusion is reinforced by the fact that, in order to participate in public work tenders, it is usual for firms to recur to consortiums (*Unión Temporal de Empresas*, UTE)[2], which constitutes approximately 7 percent of observations in the data set, and therefore demonstrating the possibility of sharing information, even about costs and profits, and cooperate with each other in order to be awarded with public works which at first instance may be beyond their means.

The foregoing in mind, the analysis of bidding performance may be based on two different approaches. First, the researcher may know which are the firms that actually engaged in anticompetitive arrangements and which did not, then comparing differences among their respective performance. This approach is typical of studies about previously uncovered cases of price collusion or bid rigging, wherein the contribution of the analysis lies mainly in determining the extent of the damage caused to consumers. An important contribution in this vein is that of Porter and Zona (1993, 1997).

On the other hand, the researcher may ignore which firms actually engaged in anticompetitive arrangements, and thus the aim of his analysis focuses on elucidating whether indications exist suggesting that firms in a market would plausibly have been involved in an anticompetitive arrangement given the pattern of their bidding performance. With that goal in mind, this literature often tries to ascertain the satisfaction of two conditions, established by Bajari and Ye (2003), named *conditional independence* and *interchangeability*. When these two properties do not hold, tendering procedure would indicate the existence of collusion. This approach is common when gathering information to contrast suspected anticompetitive practices, usually in the

[2] Consortiums constitute an arrangement whereby two or more firms temporary join to achieve a work or provide a particular service. They have no legal personality, and it exists whilst the work lasts. Consortiums are named *Unión Temporal de Empresas* (UTE) in Spanish Law, and their fiscal regime is developed in *Ley 18/1982, de 26 de mayo, sobre Régimen Fiscal de Agrupaciones y Uniones Temporales de Empresas y de las Sociedades de Desarrollo Regional*.

context of an ongoing public investigation, and thereby it is relies in comparing actual bidding with that would have been in the absence of such suspected arrangement among firms. Contributions in this vein include those of Bajari and Ye (2003), Ishii (2007, 2008) and Moreno (2011). For a more detailed discussion of the methods used in this literature, Froeb and Shor (2002) is recommended.

Nevertheless, in spite of the differences referred, a commonplace in this literature is that bidding data from all tendering firms, both awarded as not, is used in order to estimate a plausible counterfactual with which to compare actual observed bids, constructed on the assumption that bidding performance should reflect firms' expected utility maximization. That is the reason why in the absence of relevant data, such as that of tendering firms not awarded, direct estimation is not possible. Such is the case of the data set used in this empirical application, which only contains information regarding awarded firms, and therefore efficiency analysis based on behavioral estimation would seem out of reach. This notwithstanding, an indirect approach can be tested with the aim of approximating the relative importance of this possible bidding inefficiency, which consists in estimating the maximum discounts which would be plausible given available data from tenders and awarded firms, thus constructing an "efficient frontier", by maximum-likelihood method and then assuming that deviations from those values may be due to random disturbances of distinct nature.

This methodology, known as "stochastic frontier estimation", has been commonly used in empirical microeconomics in both production and cost analysis, whereas its application to other subjects has begun to spread recently. Thus, Polachek and Yoon (1987) use this methodology to study labor markets, where residuals from agents' earning functions are assumed to represent employee and employer ignorance of offer and reservation wages. Chawla (2002) uses it to study health care markets, where dispersion observed in prices for health services is ascribed to information asymmetries between patients and physicians. Similarly, Orea (2011, 2012) applies stochastic frontier analysis to both electricity and retail markets to estimate the inefficiency caused by market power and barriers to entry respectively. A special case is that of Hofler and List (2004), who apply this method to sealed-bid auctions for a baseball card and where it is assumed that the one-sided inefficiency component may capture the sentimental or nonuse value individuals confer to the item auctioned.

However, none so far have tried to apply this methodology to public works tenders in order to evaluate the existence and estimate, if possible, the relative importance of unobserved market-power inefficiency due to possible unobserved anticompetitive arrangements. As this approach only uses data from awarded firms, it is possible to carry it on when the data of the remaining participating firms is not recorded. Furthermore, as awarded firms are in any case a portion of those who could be part of an anticompetitive arrangement such as a cartel or a bid rigging, the efficient frontier estimated from their data would always capture, although maybe overestimating it, the inefficiency caused by firms' market power. Moreover, the remarkable contribution of Moreno (2011) aside, whereby paving tendering in Spain is analyzed with great detail, far as is known this paper is the first attempt to apply the methodology reviewed above specifically to the study of tendering in Asturias.

The paper is organized as follows. Section 2 introduces the theoretical background that justifies both the determinants and the frontier specifications of the empirical bidding model. Section 3 provides a description of the relevant variables of the data set, both which have been gathered from public databases and which have been constructed from those for estimation purposes, as well as a dissertation of their expected incidence on discounts inherent in bids submitted by firms actually awarded with public works. Section 4 and 5 contain the estimates calculated through OLS and MLE methods respectively, alongside an analysis of the sign and the significance of the coefficients and thus the effects associated with each variable. Section 6 retakes those results in order to elucidate the efficiency in bidding and thus in tendering in the time period covered. Section 7 offers some conclusions and policy recommendations consistent with the previous empirical results. Finally, Section 8 lists the relevant bibliography for further consultations.

2. Theoretical framework

On the assumption that the valuations of firms over public works are independent, the bidding equation for each firm at each tender can be approached through the following reduced form:

$$b_{it} = Z_{it}\,\beta' + \varepsilon_{it} \qquad (1)$$

where b_{it} represents the bid value each firm is willing to submit at each tender; Z_{it} groups a set of variables regarding features of both the tenders hold and the firms awarded; and ε_{it} as usual is a random term. Despite this characterization, it should be noted that as only data from awarded firms is available, there is just one observation for each tender (that of the awarded firm) and thus the model only needs to differentiate between tenders (or between firms awarded at each time, which is indifferent). This is the model which would be first estimated by OLS in Section 2.

Nevertheless, one might be interested in estimating how *efficient* are the bids awarded at each tender, meaning how much its value exceed that which would be consistent with firm features and hence that somehow would reflect its operational costs. In order to achieve that, awarded bids should be compared with their efficient equivalents, which together form a set of values that is supposed to be not exceeded, except as a consequence of purely random deviations, and can thus be considered a *stochastic frontier* of efficient bidding values.

This efficient frontier should be derived from the previous bidding equation. What follows is mainly based on the discussion that Orea (2011) provides on the empirical model used in his application. Indeed, based on this approach, the random term ε_{it} could be decomposed into two different components:

$$\varepsilon_{it} = v_{it} - u_{it}^{+} \tag{2}$$

where v_{it} is referred as the noise component as is conventionally assumed to be symmetric with zero mean, whilst u_{it}^{+} is referred as the one-sided inefficiency component as it is expected to be negative and asymmetrically distributed. This is because the nature of market power in tendering, illustrated in practices as rigging or collusion, is different to that of other unobserved technological and cost variables. Thereby, v_{it} can be interpreted as a term that captures specification error and hence it might take both positive and negative values. However, as market power captured by u_{it}^{+} directly affects the chances to be awarded in tendering and thus to the decision to bid in a particular tendering, and hence u_{it} is likely to be negatively distributed. Furthermore, while other unobserved technological and cost variables are probably market-driven, market power could also be determined by regulators through rigging the tender calling (i.e., setting targeted requirements or too restricted scoring criteria) or by anticompetitive practices, such as collusion or other forms of bid rigging.

In summary, since anticompetitive arrangements have an effect on market structure which is more direct, stronger and more certain than the effect of v_{it}, the random term u_{it} is likely asymmetrically distributed. And if u_{it} is asymmetric, then stochastic frontier techniques developed in the production literature (Kumbhakar and Lovell, 2000) could be applied in order to estimate firm's bidding performance.

Moreover, it can be assumed that the market power random term, u_{it}^{+}, satisfies the scaling property (Wang and Schmidt, 2002). In this case, u_{it} can be written as:

$$u_{it}^{+} = f(m_{it}, \delta) \cdot \varphi_{it} \tag{3}$$

where $f(m_{it}, \alpha)$ is a scaling function and φ_{it} is a random variable that does not depend on a vector of determinants of market power, m_{it}. This model has some features that may be found attractive. First, this type of model has a convenient economic interpretation. Thereby while the scaling function $f(\cdot)$ captures the effects of market power on bidding performance, φ_{it} is a random term which captures the effect of unobserved market power. Second, the coefficients α are just the derivatives of u_{it}^{+} with respect to m_{it}, and these do not depend on the distribution of φ_{it}. Third, simple scaling functions yield simple expressions for the effect of m_{it} on market power magnitude. Thus, in case of using the exponential scaling function, the market structure equation to be estimated would be:

$$b_{it} = Z_{it}\,\delta' + v_{it} - \exp(m_{it}, \delta) \cdot \varphi_{it} \tag{4}$$

Thereby (4) can be estimated using maximum-likelihood techniques (MLE). Besides supposing that the noise term v_{it} is symmetric with zero mean and standard deviation σ_v, this method relies on the assumption that a specific distribution for the asymmetric market power random term, φ_{it}. For instance, it may be assumed that this term can be modeled by allowing φ_{it} to follow a truncated normal distribution, which is one of the most frequently employed in the production frontier literature. Hence assuming that $\theta_{it} \sim N^{+}(\mu, \sigma)$ then:

$$h(\varphi_{it}) = \frac{1}{\sqrt{2\pi} \cdot \sigma} \cdot \Phi^{-1}(\mu/\sigma) \cdot \exp\left\{-\frac{(\varphi_{it} - \mu)^2}{2\sigma^2}\right\} \tag{5}$$

In this case the log likelihood function of $v_{it} = \varepsilon_{it} - \exp(m_{it}, \delta) \cdot \varphi_{it}$ can be derived from Stevenson (1980) with (μ, σ) in (5) being replaced with ($\exp(m'_{it}\,\delta) \cdot \mu$,

exp (m'_{it} δ) · σ). For estimation purposes, the model above is parameterized in terms of the overall variance, $\sigma_\varepsilon^2 = \sigma_u^2 + \sigma_v^2$, and an indicator of the relative importance of noise and unobserved market power, $\lambda = \sigma_u^2 / \sigma_v^2$. Once the parameters in (5) are estimated, efficiency scores can be estimated for each tender by decomposing the estimated residual into a noise component and a market power component, using the conditional distribution of the one-sided random term u_{it}^+ given the composed error term ε_{it}.

3. Data set and variables

This empirical application seeks to establish an approach to the determinants of the bids submitted by firms, and so the discount they entail, in public works tenders called by Asturias during the years 2006-2012. Data have been gathered manually from the official announcements of public works tenders and awards published in the regional administration's gazette, named "Official Journal of the Principality of Asturias" (*Boletín Oficial del Principado de Asturias,* BOPA). This approach was decided after the request for direct access to public database was rejected by the relevant authorities, who claimed to be in a process of internal reorganization[3], thus forcing the need to resort to an indirect route to gather the data.

Besides the BOPA, tendering and contracts awarded by Asturias are published on the regional administration's website, in a section called "Contractor profile" (*Perfil del contratante*). Despite containing a more extensive and detailed information, the time span covered by this service is limited due to technical constraints, making the data effectively available only since 2011; and in any case the relevant information about the bids of participating firms and their scoring is not directly tractable, as it can be only found by consulting the scanned documentation, thus also forcing a manual data gathering.

[3] The internal reorganization alluded might likely be due to the so called "Marea case" (*caso Marea),* which is an ongoing scandal involving the public administration of Asturias which was uncovered in 2010. It started due to irregularities and malpractice allegedly committed by a civil servant who detracted an amount of money estimated in 1.1 million euros between 2003 and 2010. While being investigated, a bid rigging involving suppliers of the Department of Education of Asturias was discovered. Contracts were split in order to be considered minor ones and thus not requiring to be publicly announced. The case is being discussed in court at the moment and recently led to the creation of a Commission of Inquiry at the Asturian parliament, which issued a report that included several recommendations to reform tendering to promote transparency in the Asturian administration.

Therefore given these technical limitations and the aims of this paper, but also the need of a significant time span, the data collection through the BOPA was finally decided. Nevertheless, this gathering method has a number of limitations that should be brought forth. First is that usually only public works which by their characteristics require to be published are actually published in the BOPA; for example, the so called "minor contracts" (*contratos menores*), which have been a recurring procedure in regional procurement, need not be published, or in any case the information published only contains a summary of information regarding the public work awarded and the winning bid is offered[4]. Second is that since only tendering is published, relevant information regarding other procurement methods cannot be summoned, for example, that relative to contracts awarded directly by negotiation with the firm, of which only data regarding the firm awarded and its bid is published in the BOPA; though it can be discussed whether this procurement method is driven by the same factors as tendering and for that reason has not been considered in this application. Third is tendering information submitted to the BOPA is prepared by the awarding authority in each case, and since it may vary depending on the public work, a systematic treatment of tendering data is not ensured, often with different terms used for the same concept. In this sense, the information gathered has been subsequently systematized for treatment. And last is that any gathering method which implies a manual data collection has inherent risks, which are increasing with the volume of information handled. In order to minimize possible errors committed because of this, a double-checking collection was done; first gathering the data from award announcements and then matching them with the data from their corresponding and previous tender announcements. Several observations were lost due to the inability to find the corresponding match through the BOPA database. Nevertheless, despite the due care in the gathering process, the existence of some non-systematic errors in the data collection, though minimal, is inevitable.

Despite data on most variables is available from 2006, the period of time analyzed in the empirical exercise begins in 2007, because of the existence of a lag in the construction of firms' backlog variables, and ends in 2010, due to the scarcity of observations in the last two years compared with the previous. This latter fact is

[4] As defined by the "*Real Decreto Legislativo 3/2011, de 14 de noviembre, por el que se aprueba el texto refundido de la Ley de Contratos del Sector Público",* a minor contract is everyone that is worth less than 50,000 euros whether referred to public works, and less than 50,000 whether referred to supplies and services. Minor contracts involve a shorter procedure and do not need to be publicly announced.

explained by the holding of regional elections, an event that usually slows down when not completely paralyze the functioning of public administration and therefore the call for new tenders, both in 2011 and in advance in 2012, after regional government-in-minority was unable to garner support for the regional budgetary approval[5].

In summary, the dataset covers 755 observations of public works tenders from 2006 to 2012, of which 530 are taken for the empirical application purposes. The main descriptive statistics are summarized in Table 1. All monetary variables have been deflated using the official Industrial Price Index (*Índice de Precios Industriales*, IPRI) prepared by the INE for Asturias[6].

Regarding tendering features, the data set contains 149 different firms (not counting consortiums) which were awarded with 703 public works between 2006 and 2012. In order to analyze market sharing, the Herfindahl-Hirschman Index and several concentration ratios are provided in Table 1.

Thereby the first five firms concentrate around one quarter of the tenders awarded, whereas the first third of the firms concentrate three quarters of them. The concentration ratios convey the image of a decentralized market characterized by the presence of both a few large and several little firms, thus resulting in a significant although asymmetric market sharing. This is confirmed by a Herfindahl Index of 245.13, a figure which is in the range between 100 and 1,500, and hence indicative of an unconcentrated market. Thus in principle direct market power influence due to market structure should be expected to be small, size asymmetries among firms might allow them to exert market power indirectly through unobserved anticompetitive arrangements like price collusion or bid rigging.

[5] In May 2011 Foro Asturias (FAC), an outsider party created by Francisco Álvarez Cascos, a former government minister and directive of the Popular Party (PP), won regional elections, leading to the formation of a minority government in Asturias. The new government found a hard opposition from both the Socialist Party (PSOE) and the Popular Party (PP). This confrontation escalated to the point that the government was unable of gain support for its budgetary project, after which it decided to call for early elections, which took place in March 2012. Since the government previous to that of Foro Asturias prorogated regional budgets, and given the last fell before approving new ones, funding for investments were blocked, and thus no new tenders could be called then. That is the main reason that explains, together with the customary absence of tendering in months close to elections, the reduced number of observations in the data set in years 2011 and 2012.

[6] The Industrial Price Index (IPRI) is an index prepared by the National Institute of Statistics (*Instituto Nacional de Estadística*, INE) of Spain. It measures the monthly development of the price of manufactured and sold products in the domestic market, during the first step of its commercialization. The IPRI covers the sales prices coming out of the factory obtained by industrial establishments in the transactions which are carried out, excluding transport and commercialization costs and VAT invoiced. Since January 2013 the Industrial Price Index (IPRI) in base 2010 has been implemented.

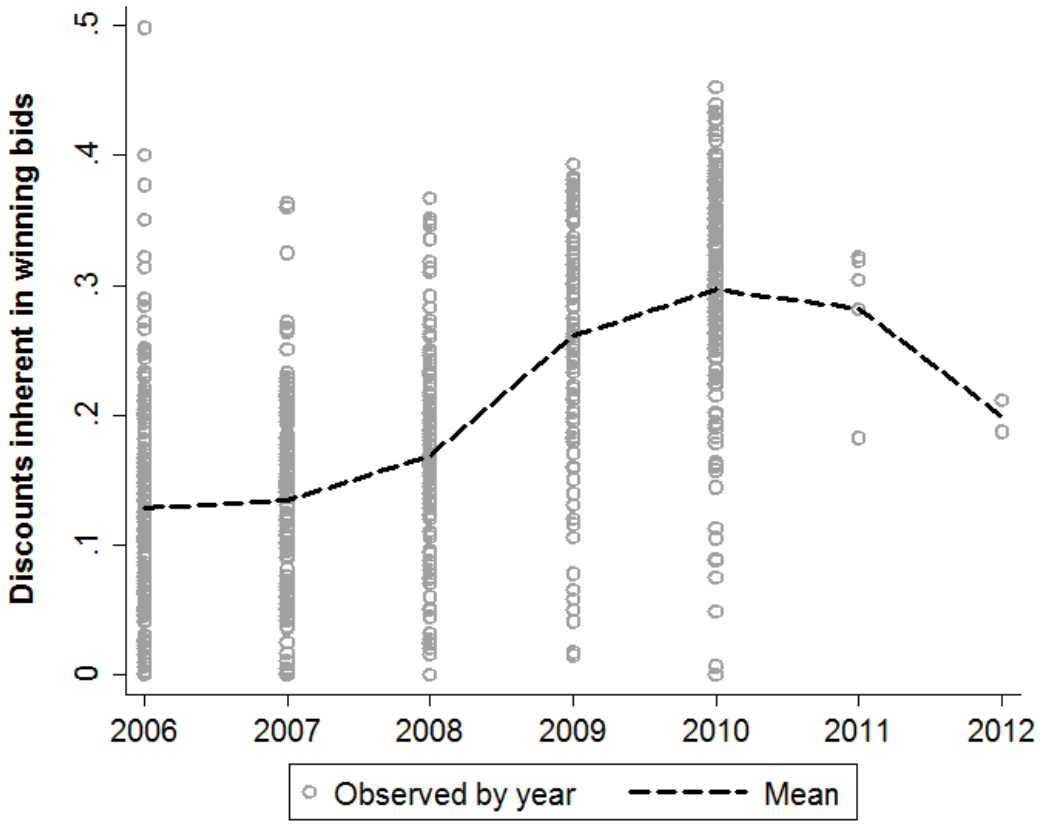
Table 1. Concentration ratios (%) and Herfindahl-Hirschman Index (HHI)

C3	20.62
C5	26.45
C10	37.41
C50	74.39
C100	93.02
HHI	245.13

Turning now to variables, several are included to capture differences among public works tenders. The first variable, which is also the dependent one along this empirical application, measures the implied discount on the bids submitted by firms, DISCOUNT. The average discount is 21.65 percent, while the maximum discount in the database is 45.2 percent. This variable is constructed by subtracting the ratio between the tender's base bid, BIDTENDER, and the bid submitted by the tender's winning firm, BIDAWARD, to one, thus reflecting the bidding discount itself. Both variables are expressed in constant euros divided by million. The average base bid and the average winner bid are respectively 1.62 and 1.25 million euros, while the maximum of both variables exceeds 54 million euros, indicating the preponderance of small-scale public works.

Figure 1 displays observed discounts inherent in winning bids (the DISCOUNT variable), grouped by the calling year of the tender to which they were submitted, alongside the average and the median discount for each year. Thereby, it can be observed how discounts have been gradually increasing, especially after the outbreak of the economic crisis in 2009, until tendering suddenly stop in 2011 due to persistent institutional instability, and thus making discounts submitted unrepresentative. This increase is noticeable both in mean and in variance, hence indicating the possible existence of heteroscedasticity in the data, even after the sample is restricted for estimation purposes.

Figure 1. Discounts inherent in winning bids submitted from 2006 to 2012, grouped by the calling year of the tender



The second one seeks to capture tenders' heterogeneity through public works lead time expressed in months, LEADTIME, ranging from just one to a maximum of forty months with an average lead time close to 9 months. As a longer lead time allows firms to plan and therefore to adjust their input management to execution requirements more closely, a positive value for the parameter associated with LEADTIME is expected. Furthermore, as larger or more complex public works usually entail longer lead times, it could be assumed that only the largest firms, which are also the most efficient ones in presence of economies of scale, would be able to carry them out, thus pointing to the existence of a positive correlation between longer lead times and greater discounts.

The third variable refers to the tender award procedure, SIMPLE, which is a dummy variable that takes value one if tender is awarded by a simple procurement auction and zero if awarded by a scoring procurement. Only 15.66 percent of tenders in the database are awarded by simple procurement. As this kind of tenders are only driven

by the value of the bids, hence larger discounts are expected, and thus a positive value for the parameter associated with SIMPLE. And the fourth one, URGENT, which is also a dummy variable, takes value one if tender is called by urgent procedure and zero otherwise. About 75 percent of tenders in the database are called by this procedure. In this case, as a call by urgent procedure means less time for firms to prepare their bids firms would tend to submit lower discounts in order to ensure the tender.

These previous variables, not counting DISCOUNT, have been directly collected from tenders and awards announcement published in the BOPA, later being transformed only for manageability purposes.

Thereafter three variables are constructed to capture heterogeneity among participating firms, following Porter and Zona (1993). The first one aims to reflect the firm's workload or backlog, BACKLOG, and thus it is constructed by adding the constant base bid value of the public works the firm is carrying out at the moment it wins a tender, while the time that a public work is carried out is determined by its lead time minus. Therefore, to pose some examples, a firm that had won a public work tender with a base bid value of 1 million and a lead time of five months in January and a second tender with a base bid value of 2 million and a lead time of ten months in February would have a workload measured by BACKLOG of 3 million euros by March, because the firm would be carrying out both public works at the same time, and a BACKLOG of only 2 million euros by September, since the public work awarded in January would have been theoretically ended in June. Hence all firms have a BACKLOG equal to zero at the time they win their first tender in the period covered by the database. This is the main reason to remove observations from 2006 while performing estimations. As with previous variables in monetary terms, BACKLOG is expressed in constant euros and divided by one million. The average firm's backlog is near 3 million euros, while the maximum backlog is close to 24.7 million.

The second variable seeks to capture differences in firm's size through an approximation of maximum capacity, CAP. This variable is defined by the maximum BACKLOG value the firm has had before at the moment it wins a tender since the beginning of the database, whereas whether BACKLOG value equals zero, because the firm is not carrying out any public work at the moment of winning a tender, CAP takes the maximum BIDTENDER value of a tender that the firm has won in the past. Thus $CAP_i = \max \{BACKLOG_i, BIDTENDER_i,\}$. CAP range between 53,700 and 54.16

million euros, with an average near to 7.5 million euros, meaning that there are firms whose capacity only allow them to carry out public works valued in just 50,000 euros while others have the ability to deal with public work whose value is as large as 54 million euros, which highlights a large size heterogeneity among participating firms. As a greater capacity, and so a larger size, can be indicative of greater efficiency in presence of economies of scale, in that case one might guess a parameter with positive sign associated with CAP. However, in absence of such economies of scale or in the case that most of the large firms only get involved with large public works, then a more ambiguous effect should be expected.

Given the previous variables, a third one is constructed to capture differences in capacity utilization among participating firms, UTIL, which is defined as the workload or the backlog a firm had at the moment of winning a tender with regard to its maximum usable capacity, and thus is calculated as the ratio between BACKLOG and CAP. Hence UTIL value is comprised by definition between zero and one. The average capacity utilization of firms in the database is around 26.5 percent, and thus indicating that most of the participating firm usually operates with a wide scope for action. Because capacity utilization points out an efficient management of available resources, a positive value for the parameter associated with UTIL is expected. Nevertheless, as capacity utilization approaches its maximum the pressure on firm's costs increases due to diminishing returns, opening the possibility of nonlinear effects in capacity utilization that should be taken into account.

Next a dummy variable is constructed to account for possible discontinuities caused after the outbreak of the current economic crisis, whose impact in Asturias actually came well into the year 2009, due to a combination of a lag in state income transfers advantageous for regional public finances, a weight of construction lower than the national average and the implementation of important stimulus packages, both state and regional, during that year[7]. This variable, CRISIS, takes value one whether the tender is called after the year 2008, and zero otherwise. As a result of the current crisis, both input prices and government revenues have declined, with the consequent fall in

[7] The "Spanish Plan to Stimulate the Economy and Employment" (*Plan Español para Estimular la Economía y el Empleo*) or, for short, *Plan E*, was a set of more than one hundred economic policy measures proposed by the government of José Luis Rodríguez Zapatero (PSOE) in January 2009 and developed along the IX legislature. The Plan E was split in two parts: the first one injected 7,836 million euros into the economy, and the second 5,000 million more. At the same time, the government of Vicente Álvarez Areces (PSOE) announced in late September 2009 the launch of its own stimulus plan, known as *Plan A*, with a budget of 100 million euros.

the number of public works tenders, and thus greater discounts in the bids submitted by participating firms can be assumed due to lower costs and increased competition, which implies a positive sign for the parameter associated with CRISIS.

Moreover, two competition variables are included, following Ishii (2008). The first one is constructed by adding the base bid value, BIDTENDER, of all the public works the firm has been awarded previously in the database at the moment of winning a tender, WINVALUE. Thus this variable aims to capture effects in bidding associated with the firm's historical performance, and so with its experience. As with other monetary variables, WINVALUE is expressed in constant euros and divided by one million. WINVALUE ranges from zero, in the case of firms that only won one tender, to 43.16 million, with its mean in 8.74 million euros. Since it can be assumed that greater experience with public work tenders is related to a more accurate setting of bids, a positive value for the parameter associated with WINVALUE is expected.

Additionally, a variable is constructed to measure the time span that elapses since a firm wins a tender to the time it wins the following, expressed in months, LAGMONTH. The average lag in the database between tenders is 6.67 months, with a maximum lag of 45 months. It can be assumed that the effect of longer lags on bidding behavior depends on the firm's capacity utilization, with a low one probably implying an insufficient output level to adequately cover firm's costs and therefore a greater need to been awarded with new public works, leading the firm to submit bids with lower margins and thus greater discounts. In that case a positive value for the parameter associated with LAGMONTH could be expected. However, in case the firm's capacity utilization is high, with no means available to carry out new public works, the firm would be likely unwilling to engage in new tenders and thus less competitive bids and consequently a more ambiguous effect on their implied discounts could be expected. In any case, since only firms that win at least two tenders can exhibit a time lag between them, and given that an important part of firms in the database only win once, this causes that LAGMONTH present a significant number of missing values, actually reducing suitable observations for estimation to 418.

Finally, the last variable takes the cumulative value of the month at which the tender is called, TREND, which is constructed the sum of the sequence comprising tendering months in the data set since its beginning. Thereby, as the first month available in the estimation sample is January 2007, the minimum value of TREND is

13, meaning that month is the thirteenth in the data set. Hence this variable aims to capture the bidding trend that the other explanatory variables do not.

Table 2. Descriptive Statistics (dummy variables are highlighted in italics)

Variable	Obs	Mean	Std	Min	Max
DISCOUNT	530	.2165	.1070	0	.4520
BIDTENDER	530	1.6216	4.1169	.0741	54.9886
BIDAWARD	530	1.2510	3.4636	.0462	54.1638
LEADTIME	530	9.3537	6.7504	1	40
SIMPLE	530	.1566	.3637	0	1
URGENT	530	.7490	.4339	0	1
BACKLOG	530	3.0091	4.9122	0	24.7079
CAP	530	7.4988	8.8774	.0537	54.1638
UTIL	530	.2653	.3038	0	1
CRISIS	530	.5000	.5004	0	1
WINVALUE	530	8.7432	11.8711	0	43.1654
LAGMONTH	418	6.6746	7.7617	1	45
TREND	530	36.8867	14.2119	13	60

4. Estimating the determinants of bidding performance

With the purpose of identifying the determinant factors on bidding pattern, several specifications are proposed for estimation by OLS method, whose results are summarized in Table 3. The first one, which will be referred as the "basic model", includes the variables relatives to public works tenders' characteristics. As expected, the

parameter associated with LEADTIME has a significant and positive sign, which indicates that firms competing for public works that have a greater lead time tend to submit bids with greater inherent discounts, probably due to the fact that they expect being able to manage its inputs and production rate more accurately given a longer period of time. This result holds in all specifications. Specifically, estimations suggest that an additional month in public work's lead time induce an increment in bids' inherent discounts between 2 and 3 basis points.

Similarly, the parameter associated with SIMPLE has a significant and positive sign as expected, and thus bids submitted to tenders awarded by simple procurement, driven only by bid-price, have greater inherent discounts than bids submitted to tenders awarded by scoring. This result makes sense as competition is stronger when firms compete in only one dimension, especially if it is on prices, and its effects also hold in all specifications; in particular, bids submitted to tenders awarded by simple procurement have inherent discounts between 3 and 5 percentage points above those submitted to tenders awarded by scoring procurement. The opposite occurs with the variable URGENT, which is not significant in any specification tested, therefore suggesting that tender's calling procedure has no impact on the value of bids submitted.

Afterwards several variables are included to control by firms' characteristics, following Porter and Zona (1993) as stated before. Such is the case of the variable capturing firm's capacity utilization, UTIL, and firm's maximum capacity, CAP. These variables do not appear to be significant on their own, but they do when nonlinear effects of both are taken into account. Thereby the parameter associated with UTIL has a significant and positive sign while the parameter associated with its quadratic form has a significant and negative one, both as were expected. This result points out that as capacity utilization increases, firms bid with greater discounts, but at a diminishing rate; hence an average firm using a 25 percent of its capacity

After controlling for capacity utilization, the inclusion of CAP allows to capture the possible effects on bidding pattern associated with firms' size. However, unlike the previous one, the significance of CAP is more ambiguous. Only in the last specification the parameter associated with the quadratic term of CAP becomes significant, but in that case its sign is the same as expected; therefore, all else being equal, as capacity increases, firms would tend to bid with greater and greater discounts, but at a diminishing rate. Hence these variables point in the same direction, and thus larger and

more efficient firms appear to bid with greater discounts, at least when they actually win public works tenders.

Table 3. OLS Parameter Estimates (t-ratios between parenthesis)

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
(Constant)	.18536 ***	.18557 ***	.18062 ***	.18499 ***	.12599 ***
	(17.75)	(17.74)	(17.19)	(16.85)	(13.69)
LEADTIME	.00319 ***	.00331 ***	.00337 ***	.00356 ***	.00235 ***
	(4.46)	(4.57)	(4.73)	(4.92)	(4.12)
SIMPLE	.03349 ***	.03030 **	.03741 ***	.03608 ***	.05024 ***
	(2.62)	(2.30)	(2.92)	(2.73)	(4.84)
URGENT	-.00525	-.00635	-.00362	-.00533	.00126
	(-.48)	(-.58)	(-.33)	(-.49)	(.15)
UTIL		-.00009	.00512 ***	.00504 ***	.00312 **
		(-.17)	(2.78)	(2.68)	(2.12)
UTIL ^{2}			-.00003 ***	-.00003 ***	-.00002 **
			(-3.00)	(-2.93)	(-2.21)
CAP		-.00056		-.00003	.00096
		(-1.05)		(-.05)	(1.61)
CAP ^{2}				-.00005	-.00008 **
				(-1.38)	(-2.41)
CRISIS					.13046 ***
					(18.12)
Obs.	530	530	530	530	530
R^2	.0432	.0453	.0594	.0665	.4273
	p-value: p < .1 (*), p < .05 (**), p < .01 (***)				

Finally, in order to capture differences in bidding pattern over time, and more specifically those regarding the outbreak of the current economic crisis, the variable

CRISIS is included in the last specification. The parameter associated with CRISIS has a significant and positive sign as expected. Its effect is of considerable magnitude indeed, to the point that bids submitted after the crisis outbreak past 2008 have inherent discounts that are 13 percentage points higher than those present in pre-crisis bids, which might be a sign of structural change in bidding pattern regarding deeper changes in fundamental or competitive factors due to the economic crisis, as was advanced. Furthermore, the inclusion of CRISIS greatly improves the explanatory power of the model, from a R^2 of less than ten percent to one near 43 percent, thus providing the model quite acceptable explanatory power.

Nevertheless, one might guess the plausibility of such effects. Figure 3 aims to address this question. Public works tenders are ordered chronologically from early 2007 until late 2010. Clearer dots refer to tenders called before the crisis outbreak past 2008, whereas darker dots refer to tenders called after that event. The dashed line shows fittest value regression taken into account the entire sample, while red lines show fittest values for data sets at each side of the crisis outbreak. It can be seen how bidding pattern has changed over time, with gradually higher but also more variable discounts. Thereby, both the mean and the variance of discounts have increased after the crisis outbreak and thus a structural change can be identified, therefore it is possible to improve regression fitness by taking into account the differences in bidding pattern, captured by the variable CRISIS, that arise on both sides of the sample.

In summary, estimations suggest that public work's lead time, procurement procedure, maximum capacity and capacity utilization are determinant factors that lay behind firms' bidding pattern. Moreover, they point out that the outbreak of the crisis may have caused a structural change in that pattern, probably due to deeper changes in economic fundamentals, such as input prices, or competition dynamics.

5. Estimating an efficient bidding frontier

Estimating the determinants of bidding pattern allows to elucidate which factors lie behind inherent discounts in the bids actually observed. Hence the choice of a simple procurement method over a scoring one appears to have influenced prices downward, whereas calling the tender by an urgent procedure does not seems to have had effect when compared to those which had been called by an ordinary one.

However, one also might be interested in elucidating whether those winning bids actually submitted were *efficient*, meaning their value given tenders' base bid were the lowest and thus their inherent discounts were the highest possible in each tender, considering firms' fundamentals and competition dynamics. Those efficient bids could be estimated by maximum-likelihood techniques, and in doing so, the predictions obtained would constitute a frontier from which inherent discounts actually observed would randomly deviate, either by noise or by other sources of unobserved disturbance, hence the "stochastic frontier" term employed.

All specifications use a half-normal distribution (i.e., $\mu = 0$) in order to avoid convergence problems when both μ and σ parameter are estimated (see Ritter and Simar, 1997). The results are presented in Table 3.

The first model, Model 1, estimates an efficient bidding frontier under the assumption that both random elements u_{it} and v_{it} are homoscedastic. It incorporates all relevant variables used in OLS estimations, albeit possible differences in discounts caused by the outbreak of the crisis are not controlled. The coefficients estimated point out that the lead time of the public work awarded, the procurement method selected (either a simple or a scoring auction) and the capacity utilization of awarded firms are significant in determining the efficient bidding frontier. Differences in procurement procedure (either urgent or ordinary) and in maximum capacity of firms do not seem to be relevant. Moreover, the indicator of the relative importance of noise and unobserved market power inefficiency in the model estimated models is statistically significant and close to one, indicating the existence of relevant influences exert through the market power of participating firms.

As in the previous one, Model 2 assumes homoscedasticity and includes all relevant variables used in OLS estimation, taking also into account differences between years previous and subsequent to the crisis outbreak. This specification holds the significance of the same variables as in Model 1, indicating in turn that the coefficient associated with the crisis outbreak is also significant and of considerable magnitude, as it would point out an upward shift of the efficient bidding frontier of 13 percentage points, thus indicating the existence of important structural changes as a consequence of the impact both in public and private sectors due to the economic crisis. As before, the indicator of the relative importance of unobserved market power inefficiency is also statistically significant in Model 2, but in this case the market power inefficiency

appears to exceed in more than double that of the noise, hence confirming that the influence exerted by market structure or by the possible existence of unobserved anticompetitive arrangements among firms would be quite significant in order to explain deviations of actually observed bidding pattern from its efficient frontier.

Unlike previous ones, Model 3 discards the assumption that the purely random term, v, is homoscedastic. Hence the variable TREND is included to control residual variability over time. Nonetheless, the estimated coefficient associated with this variable does not seem to be significant, although the significance and even the magnitude of the remaining variables remain unchanged.

Model 4 goes a step further as it also discards the homoscedasticity assumption with respect to the unobserved market power coefficient, u^+. Therefore, the variable WINVALUE is included to control for heteroscedasticity, thus seeking to capture the possible higher market power that is exerted by firms with more experience. The estimated coefficient for this variable has a significant and negative sign, hence indicating that firms which undertook either more public works or public works of greater size, or both, and hence firms with more experience, would be able to submit bids with higher discounts as its component u^+ would be reduced. A possible explanation for this outcome is that greater experience allows firms to improve its accuracy when bidding, therefore with no need to reserve much margin for possible unforeseen contingencies. Additionally, a greater experience could indicate that the firm has achieved a name in the market, which would allow it to be more independent from market power pressures and hence being able to submit higher discounts.

Finally, Model 5 incorporates to previous specification another control variable for coefficient associated with the unobserved market power, which in this case is the one corresponding to the time elapsed since the awarded firm won its last tender, LAGMONTH, though its inclusion causes a reduction in the number of observations for estimation. Albeit this variable does not seem to be relevant in explaining the unobserved market power coefficient, incorporating it makes significant the variable that captures maximum capacity, CAP, which has a negative sign as with the OLS estimation. The remaining variables remain unaltered however.

Table 3. MLE Parameter Estimates (t-ratios between parenthesis)

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
(Constant)	.26946 ***	.20515 ***	.20543 ***	.20131 ***	.19367 ***
	(9.76)	(20.65)	(20.73)	(19.70)	(15.43)
LEADTIME	.00379 ***	.00232 ***	.00233 ***	.00261 ***	.00230 ***
	(4.99)	(4.33)	(4.32)	(4.90)	(3.42)
SIMPLE	.04014 ***	.05784 ***	.05713 ***	.05821 ***	.06959 ***
	(2.98)	(5.97)	(5.90)	(5.76)	(5.39)
URGENT	-.00506	.00685	.00687	.00341	.00051
	(-.47)	(.84)	(.85)	(.42)	(.06)
UTIL	.00456 **	.00290 **	.00279 **	.00263 **	.00296 **
	(2.39)	(2.33)	(2.23)	(2.17)	(2.37)
UTIL ^{2}	-.00003 ***	-.00002 **	-.00002 **	-.00001 **	-.00002 **
	(-2.73)	(-2.49)	(-2.40)	(-2.33)	(-2.47)
CAP	-.00008	.00047	.00047	-.00090	-.00150 **
	(-.11)	(.86)	(.86)	(-1.34)	(-1.98)
CAP ^{2}	-.00005	-.00004	-.00004	-.00001	.00004
	(-1.23)	(-1.44)	(-1.40)	(-.29)	(1.09)
CRISIS		.13130 ***	.13252 ***	.12750 ***	.12793 ***
		(19.72)	(19.26)	(18.37)	(15.43)
(Constant v)	-4.98868 ***	-6.11343 ***	-5.87746 ***	-5.9159 ***	-12.43 ***
	(-13.98)	(-29.10)	(-14.59)	(-14.56)	(-2.57)
TREND			-.00677	-.00377	.00061
			(-.66)	(-.40)	(.06)
(Constant u)	-4.53199 ***	-4.42605 ***	-4.41367 ***	-4.52610 ***	-4.77117 ***
	(-6.90)	(-29.58)	(-30.07)	(-27.28)	(-17.39)
WINVALUE				-.03255 ***	-.03691 ***
				(-3.16)	(-2.57)

LAGMONTH					.01002 (.82)
$\sigma_u^2 + \sigma_v^2$	.01757	.01417			
$\lambda = \sigma_u^2 / \sigma_v^2$	1.25651	2.3249			
Log Likelihood	451.8261	593.3579	593.5779	599.3941	483.6828
Obs.	530	530	530	530	418
	p-value:	p < .1 (*),	p < .05 (**),	p < .01 (***)	

From the results above it can be stated that determinants of bidding efficiency essentially coincide with those obtained in the previous section, and as there, structural changes caused by the outbreak of the economic crisis allow to explain a significant part of the differences in bidding performance between the two periods. The results also point out that bids submitted by firms with greater experience seems to be less influenced by market power inefficiency and thus the discounts they entailed would be higher, whereas there would not be sign that the purely random term follows any kind of trend over the time covered.

Furthermore, the unobserved market power inefficiency has a significant relative importance in explaining actual bidding performance from the estimated efficient bidding frontier, to the point that it might double that of the purely random term as suggested in Model 2. Moreover, the relative importance of this market power inefficiency is presumed to hold significant in the three last models, as the coefficients associated to the variables attached to it in are very similar in the all cases. Only Model 6 presents remarkable differences both in the coefficient associated to CAP variable, as it turns significant, and in the constant term within the unobserved market power component, which may be due to the reduction in the number of observations involved.

6. Analysis of bidding efficiency

Once the estimated coefficients of both bidding performance and its efficient frontier have been examined, bidding efficiency scores can be estimated for each tender

by decomposing the estimated residual into a noise component and a market power component. These scores can be calculated through the following formula:

$$BE_i = \frac{b_i}{b_i^*(\cdot)} = 1 - \hat{u}_i^+ \quad (6)$$

where the bidding efficiency score BE_i is calculated as the ratio between actual submitted bids and those stochastically efficient estimated, which is the same as the difference between one and the coefficient associated with unobserved market power inefficiency $\hat{u}_i^+$ estimated for each tender. In both cases the score captures the percentage of actual discounts that could be explained by the features of tenders and awarded firms, which can be referred as the fundamental bidding value, and thus reflects the bidding efficiency of awarded firms.

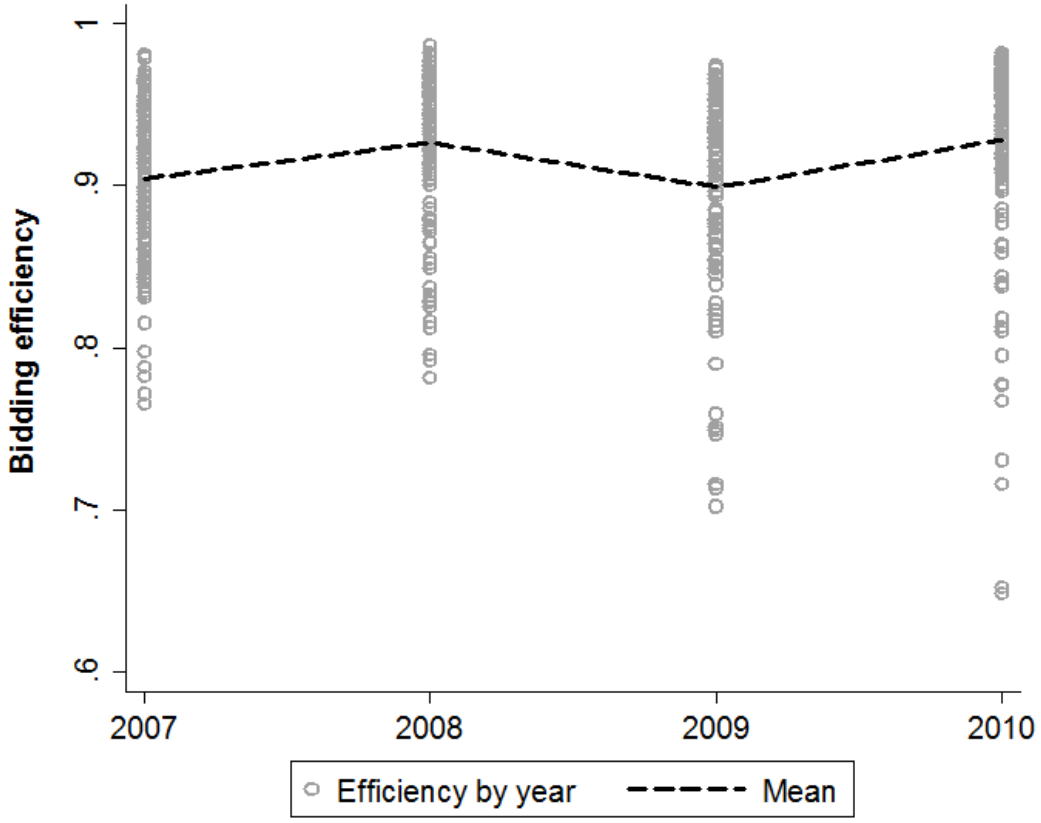
The efficiency scores have been calculated for each tender using the parameter estimates of Model 4, in which the historic record of firms' participation in tendering and thus their experience, WINVALUE, has been shown to be significant explaining the unobserved market power coefficient u^+. The results, grouped by years, are displayed in Figure 2.

The average efficiency score is 91.6 percent, which indicates that the average surcharge caused by tenderers' market power is 8.4 percent. Both the mean and the variance of scores vary over time, although the first one barely does so. This outcome points out that if bids were submitted in a context of effective competition among tendering firms, then their inherent discounts would be around 8 percent higher. Furthermore, efficiency scores does not seem to be correlated neither with the size of the public work awarded nor with the remaining explanatory variables.

Hence one might conclude that, on average, market power exerts a stable and significant, although not too large, influence on tenderer's bidding performance. To elucidate its impact, from these results it would be possible to estimate the value of the surcharge on the public purse caused by this by tenderers' market power inefficiency. The total sum of the amount paid by the public administration in tendering to awarded firms, BIDAWARD, between 2007 and 2010 was around 663 million euros. Now, considering that the bid awarded in each tender reflects both its fundamental value and to the market power surcharge, it would be possible to calculate which part of the previous amount is intended to cover the market power surcharge, which by definition

equals in each tender to the coefficient u^+, as the product of both this market power coefficient and the value of the awarded bid in each tender.

Figure 2. Bidding efficiency of awarded firms between 2007 and 2010



As a result, it is found that a total amount of about 61.9 million euros, that is, 9.3 percent of the total amount paid in tendering in that period, would correspond to the surcharge caused by tenderer's market power, and therefore might be construed as an economic rent seized by the tendering firms directly from the public purse. This amount would correspond only to the time period between 2007 and 2010. Nonetheless, this outcome highlights the importance of market power influence while confirming the concerns rose at the beginning about the need to monitor and mitigate its damages to the public purse and thus to taxpayers.

7. Conclusions

This paper seeks to analyze firms' bidding performance in public works tenders carried out in Asturias between 2007 and 2010. In particular, the models provided aim to elucidate the determinants of discounts inherent in bids submitted by awarded firms. The estimated OLS coefficients indicate that features related to the public work tendered, such as its expected lead time, and to the tendering procedure, that is, depending on whether the auction process is simple or scored, are significant to explain bidding performance. Specifically, larger public works are associated with higher discounts, as are those which are awarded through a simple auction process wherein competition among tendering firms is more intense as is only driven by prices. Thereby simple lowest-bid sealed bidding seems to be associated with a 5 percentage points increase in discounts submitted.

Similarly, firm characteristics are also relevant to explain discounts. Hence estimates point out that tendering firms with higher capacity utilization tend to bid with higher discounts, likely due to greater efficiency associated with input and output levels, although this behavior weakens as firms approach their capacity limit. At the same time, albeit its influence is more ambiguous, firms with greater capacity and thus larger also seem to bid with higher discounts.

Furthermore, the impact of the current economic crisis might have caused significant structural changes either in firms' management or in competition dynamics, as it seems able to account for more than 10 percentage points of differences in discounts since its outbreak in Asturias around 2009.

Then, as bidding data from awarded firms is available, a stochastic frontier is estimated in order to elucidate bidding efficiency. The estimated ML coefficients essentially coincide with those obtained previously. More interestingly, they suggest that the unobserved market power exert a significant influence on deviations of actually observed bidding performance from its alleged efficient frontier. Moreover, the relative importance of the market power effect could even double that of pure noise, thus being determinant in explaining bidding deviations.

Based on these results, an approximation of the additional costs surcharged on the public purse due to unobserved market power influence is provided. It suggests that this surcharge might reach around 61.9 million euros, which corresponds to 9.3 percent of

the total amount paid in tendering by the regional public administration between 2007 and 2010. Therefore this figure highlights the possible existence of a significant source of economic rents that tendering firms would have been seizing at the expense of the public purse and thus of the taxpayers.

These results allow to raise a number of policy recommendations regarding tendering design. First, as larger public works seem to be associated with submitting higher discounts, public authorities should try to avoid splitting public works whenever possible. In the same vein, contract splitting should be always motivated or otherwise prosecuted. Second, public works should be awarded by lowest-price sealed bidding also whenever possible, since his award regards only bids' value and hence competition among firm is enhanced. This type of tendering, as noted by Rose-Ackerman (2010), is often recommended in literature regarding procurement of standardized goods whose production technology is well known by firms in the market, which is indeed the case of most public works.

Both proposals are consistent with those analyzed by Kovacic et al. (2006). Additionally, they provide other policy recommendations, such as that procurers should reveal all relevant information about the public work tendered to the entire bidding public before calling a tender; that procurers should use an aggressive pricing policy, allow tenderers to submit multiple bids; that tenders should be hold at long and irregular intervals; or that bid solicitations should generally prohibit subcontracting as it can be pre-collusive, among many other insightful proposals which are worth taking into consideration.

Furthermore, the application of transparency rules on government procurement might also weaken the market power influence on tendering. A study conducted by Ohashi (2009) in Japan reveals that improved transparency reduces procurement cost by a maximum of three percent. Otherwise, introduction of transparent practice seems to be insufficient to warrant efficiency in public procurement, so it is necessary that government simultaneously combat suppliers' conspiratory practices in the public procurement tendering system. As the regional government of Asturias announced its intention to submit a transparency bill before the end of the present parliamentary term, its processing should be harnessed to reform government procurement in order to enforce transparency and to promote efficiency and fairness in tendering.

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