

On Specification and Inference in the Econometrics of Public Procurement

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Abstract

In **Paper [I]** we use data on Swedish public procurement auctions for internal regular cleaning service contracts to provide novel empirical evidence regarding green public procurement (GPP) and its effect on the potential suppliers' decision to submit a bid and their probability of being qualified for supplier selection. We find only a weak effect on supplier behavior which suggests that GPP does not live up to its political expectations. However, several environmental criteria appear to be associated with increased complexity, as indicated by the reduced probability of a bid being qualified in the postqualification process. As such, GPP appears to have limited or no potential to function as an environmental policy instrument.

In **Paper [II]** the observation is made that empirical evaluations of the effect of policies transmitted through public procurements on bid sizes are made using linear regressions or by more involved non-linear structural models. The aspiration is typically to determine a marginal effect. Here, I compare marginal effects generated under both types of specifications. I study how a political initiative to make firms less environmentally damaging implemented through public procurement influences Swedish firms' behavior. The collected evidence brings about a statistically as well as economically significant effect on firms' bids and costs.

Paper [III] embarks by noting that auction theory suggests that as the number of bidders (competition) increases, the sizes of the participants' bids decrease. An issue in the empirical literature on auctions is which measurement(s) of competition to use. Utilizing a dataset on public procurements containing measurements on both the actual and potential number of bidders I find that a workhorse model of public procurements is best fitted to data using only actual bidders as measurement for competition. Acknowledging that all measurements of competition may be erroneous, I propose an instrumental variable estimator that (given my data) brings about a competition effect bounded by those generated by specifications using the actual and potential number of bidders, respectively. Also, some asymptotic results are provided for non-linear least squares estimators obtained from a dependent variable transformation model.

Paper [VI] introduces a novel method to measure bidders' costs (valuations) in descending (ascending) auctions. Based on two bounded rationality constraints bidders' costs (valuations) are given an imperfect measurements interpretation robust to behavioral deviations from traditional rationality assumptions. Theory provides no guidance as to the shape of the cost (valuation) distributions while empirical evidence suggests them to be positively skew. Consequently, a flexible distribution is employed in an imperfect measurements framework. An illustration of the proposed method on Swedish public procurement data is provided along with a comparison to a traditional Bayesian Nash Equilibrium approach.

Keywords: auctions, dependent variable transformation model, green public procurement, indirect inference, instrumental variable, latent variable, log-generalized gamma distribution, maximum likelihood, measurement error, non-linear least squares, objective effectiveness, orthogonal polynomial regression, prediction, simulation estimation, structural estimation

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Also, kids, do not forget that "[e]verybody is identical in their secret unspoken belief that way deep down they are different from everyone else." -DFW

Umeå, May 2016
David

This thesis consists of an introduction and the following four self-contained papers relating to the applied econometrics of public procurement:

Paper [I]

Lundberg, S., Marklund, P-O., Strömbäck, E., and Sundström, D. (2015). Using Public Procurement to Implement Environmental Policy: An empirical analysis, *Environmental Economics and Policy Studies*, 17:487-520

Paper [II]

Sundström, D. (2016). "A Comparison of Techniques to Evaluate Policies in Public Procurement", *Umeå Economic Studies*, No. 928

Paper [III]

Sundström, D. (2016). "The Competition Effect in a Public Procurement Model: An error-in-variables approach", *Umeå Economic Studies*, No. 920

Paper [IV]

Sundström, D. (2014). "It's All in the Interval: An imperfect measurements approach to estimate bidders' primitives in auctions", *Umeå Economic Studies*, No. 899

1 Introduction

Legislative powers such as the European Union (EU) have regulated their public sectors' buying of goods and services. The institution governing these transactions is called public procurement. Public procurement is the unifying theme of this thesis. I study a few specification and inference matters in the applied econometrics of such procurements. In addition, I consider some related applied economic policy questions.

Public procurements turn over approximately 16 percent of the gross domestic product of the EU countries (European Commission, 2008) and 15 percent of the gross national product in the Organization for Economic Cooperation and Development (OECD) countries (Lunander and Lundberg, 2013). This makes it an important topic to study. As "[e]conomics is the science which studies human behavior as a relationship between ends and scarce means which have alternative uses [...]" (Robbins, 1932, p. 75) we know that those means could be put on other things. Consequently, it is of value to study the functioning of public procurements as well as the methods used to study them.

The idea behind public procurement is to drive down the prices the public sector pays for goods and services by inducing competition through auctions. In procurement auctions, firms increase their probability of winning the contracts by lowering their bids. If competition was to increase, firms would lower their bids even more (Krishna, 2009). Hence, public procurement transfers wealth from firms to the public. As firms make up the bidders in the procurements under study, I use the words firms and bidders interchangeably throughout.

Besides using public procurements to reduce the sizes of the transaction prices it has recently gotten in vogue to use public procurement to achieve some sort of political goal. Examples of such goals are to reduce the environmental burden of firms (Lundberg et al., 2015) or to promote small and medium sized firms (Krasnokutskaya and Seim, 2011). Using Swedish data I consider a policy implemented through public procurements. The policy is intended to reduce society's burden on the environment. This environmental policy is called green public procurement (GPP) (see, e.g., Lundberg and Marklund, 2013; Lundberg et al., 2015; Testa et al., 2012; Parikka-Alhola, 2008).

The impact of GPP on firms' behavior is an un-researched topic. When studying a novel topic it is reasonable to take an explorative approach (Paper [I]). Further, it is likely that thinking about and approaching a research topic in a different way will bring new knowledge (Feyerabend, 1993). Economic theory provides models regarding the behavior in auctions (see, e.g., Krishna, 2009). It is of value to involve such models in the empirical study of economic agents' behavior and also to compare such specifications to ones using less economic structure (Paper [II]). Public procurement relies on competition to benefit the public. Therefore, it is important to study how estimators of the effect of competition on bid sizes are affected by error in the measurement of competition (Paper [III]). Assumptions underpinning economic models may be fragile. It

is therefore worthwhile to consider potentially more robust views on economic behavior (Paper [IV]).

As mentioned, public procurement is an important institution to study. Of course, there are many more topics to study within public procurement than the ones listed above. I have chosen these particular topics as they constitute a blend of applied policy studies and methodological contributions as I find both these sides important to the scientific study of public procurement.

2 Public Procurement

Upon joining the EU in 1994, the EU procurement directives were implemented into Swedish legislation as the Swedish Public Procurement Act making the institution transparent to society. Since then public procurements have been held on a regular basis (Lunander and Lundberg, 2013). Before public procurements were implemented in their present form, private to public transactions were less transparent and potentially more expensive (to the public) than the transactions of today. Following EU directives, Swedish legislation requires public procurements to be arranged as auctions where the bids must be sealed. A public authority announces its will to procure a good or service in a call for tenders where a description of the good or service is provided in detail in addition to possible criteria that firms have to fulfill to become eligible for bidding. There are two types of auctions: either the lowest bidder wins, or the bidder that casts the most economically advantageous bid wins (MEAT)¹ (Lundberg, 2005). In this thesis I consider both types of auctions, but I focus on the former, i.e. the first price sealed bid auction.

To lend some structure to such an auction, suppose that a firm considers its expected profit

$$(b_i - c_i) P(b_i < b_j | c_i), \quad \forall j \neq i \in I_{-i}$$

when making decisions. Here, I take the viewpoint of firm i ; b_i and c_i are the magnitudes of firm i 's bid and cost, respectively. The I_{-i} denotes the set of all bidders except bidder i ; $P(\cdot)$ is the probability that firm i wins the auction, i.e., the probability that it is the lowest bidder. The bidders are assumed to behave as Bayesian Nash players. The firms are "Bayesian" as they act under imperfect information; they do not know other firms' costs, but they do know the distribution of those costs. All firms are assumed to use the same strategy; this leads to a Bayesian Nash Equilibrium (BNE) (Krishna, 2009). Under the BNE assumption and also presuming firms to maximize their expected profit the optimal bid can be written as

¹In MEAT-type procurement auctions, all qualified bids are ranked according to a multidimensional scoring rule including price and other criteria.

$$b_i = c_i + \frac{[1 - G(b_i)]}{g(b_i)} \frac{1}{N - 1} \quad (1)$$

where $G(\cdot)$ and $g(\cdot)$ denote the cumulative distribution function (cdf) and probability density function (pdf) of the bids, respectively (Guerra et al., 2000). The second term on the right hand side of (1) is firm i 's markup. Firm i faces $N - 1$ competitors. The markup and hence the bid is decreasing in N , i.e. $\partial b / \partial N < 0$. Here we see explicitly that public procurement benefits the public at the expense of the firms by competition.

Of course, auctions are used to allocate other means than those related to public contracts. Hence, there is a related literature within other fields of application where the auction is the common factor. Examples of such applications are timber auctions (Athey et al., 2011; Baldwin et al., 1997), treasury bills (Nyborg and Sundaresan, 1996; Smith, 1966), internet auctions (Houser and Wooders, 2006; Lucking-Reiley et al., 2007), art auctions (Beckmann, 2004) as well as the auctioning of wine (Lecocq et al., 2005).

2.1 Data

Throughout the thesis I utilize data on public procurement auctions of Swedish internal cleaning services. Internal cleaning services are chosen as they comprise a quite homogenous good, keeping the object-specific heterogeneity low. Two datasets are used. The main dataset or subsets of it is employed in Papers [I]-[IV] and comprises 4706 bids on 722 contracts in total. The data were obtained from Visma Commerce AB. Their database is the most exhaustive one when it comes to public procurements in Sweden; it contains approximately 90 percent of all calls for tenders. I have information on Swedish authorities' procurements of internal cleaning services held from December 2008 throughout December 2010. These data contain information on the object or facility to be cleaned, contract and local market characteristics, all submitted bids, and whether or not a bid met all of the mandatory qualification criteria. Further, I have information on the identity of the buyer, i.e. the procuring authority. Authorities from all three levels of governance are included in the dataset. These are the state-, county- and municipality levels, respectively. The data also provide rich descriptions of the environmental criteria that are stipulated in each procurement auction. The stringency of the GPP policy varies over the contracts; the number of environmental criteria stated in the contracts ranges from zero to 15. Other criteria than environmental criteria are also included in the dataset. In terms of the number of employees, firm size ranges from zero to over 10000 employees

The second dataset utilized in Paper [IV] contains information on 1932 bids in 293 contracts of procurement auctions for internal cleaning services held during the years 1992-1998. These data were used by Lundberg (2001) in her dissertation on procurement.

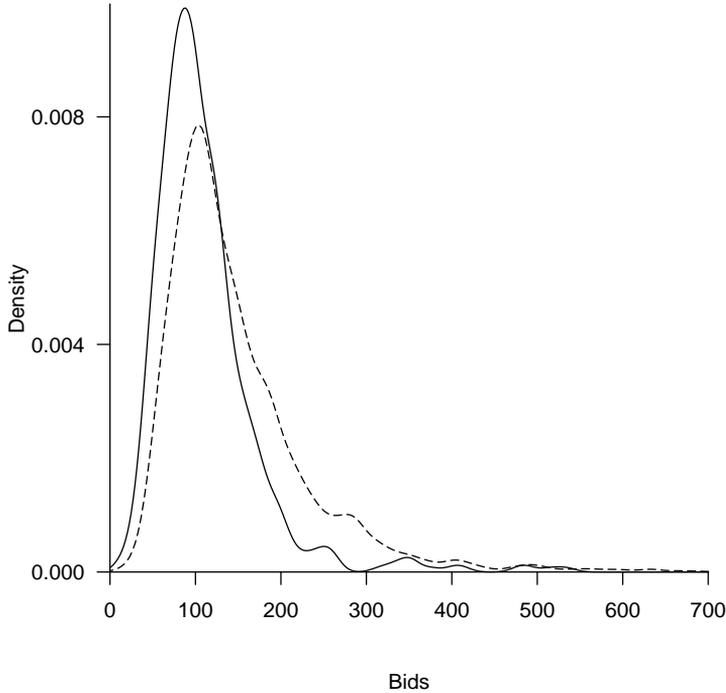


Figure 1: Kernel estimated densities of winning bids (solid line) and all bids (dashed line). The bids are interpretable as the inflation adjusted amount a firm requires to keep one square meter of space clean during a time period of one year. The distributions are truncated from the right excluding some outlying observations.

The data are described in more detail in each of the papers. Utilizing information in both datasets, Figure 1 shows descriptive evidence that public procurements lower the prices for the procuring authorities.

3 Methodological Approaches

As in all quantitative empirical research, a choice of specification has to be made when studying public procurement empirically. A long-debated issue in model specification is how close one should be to theory. There are two dogmatic views on how science should progress: i) start with theory and then collect observations (theory-first/positivism) versus ii) collect observations and then build theory (data-first/antipositivism) (Mirowski, 1995; Leamer, 1978, 1983). These are two extreme views, and a better description of actual research practice probably lies somewhere in between i) and ii), where theory and exploration cross-

fertilize each other (Mirowski, 1995). By observing empirical economists' works in the light of i) and ii), a conclusion is that no consensus has been established. Haavelmo (1944) defined econometrics in the following statement. "The method of econometric research aims, essentially, at a conjunction of economic theory and actual measurements, using the theory and actual measurements as a bridge pier." (Haavelmo, 1944, p.iii). This definition includes both i) the theory-first and the ii) data-first approach. As estimators under i) are highly dependent on theory, or economic structure, this has come to be called structural econometrics (Reiss and Wolak, 2007; Keane, 2010; Einav and Levin, 2010). Studies classified to ii) are commonly called non-structural or reduced form studies.

Empirical studies of public procurement are made both in structural and reduced forms. Examples of more theory-close (i.e. structural) studies are Marion (2007), Krasnokutskaya and Seim (2011) and Nakabayashi (2013), while studies of a more reduced form that can be sorted under ii) are Lunander and Lundberg (2012) and Lunander and Lundberg (2013). As discussed above and by Mirowski (1995) there is no consensus on whether one should assume a theory-first or a data-first perspective when doing econometric analysis. This question extends to how much faith one puts in economic models. In my opinion there is little to gain by being dogmatic. Hence, I take explorative as well as structural approaches throughout this thesis. I focus on the consequences of choices of theories, specifications and measurements on inference. Paper [I] assumes a quite reduced form approach to study how the GPP policy affects firms' behavior in public procurement. In Paper [II] I compare reduced form approaches to structural estimation of the parameters in a specification of the type in equation (1). Paper [III] studies measurement error related to specification (1). Consequently, papers [II] and [III] are quite dependent on theory. In Paper [IV] I try to move beyond assumptions often made in structural setups and I estimate bidders' costs under less restrictive assumptions than the ones leading to (1).

Below I provide short discussions on some methodological dimensions I move through in this thesis.

3.1 Exploration

As mentioned before; public procurement is used to reduce transaction prices through competition but lately also to achieve some kind of political goal such as reducing the environmental burden (Lundberg et al., 2015) or to promote small and medium sized firms (Krasnokutskaya and Seim, 2011). The thesis by Strömbäck (2015) discusses some potentials and pitfalls of conducting policy by public procurement in the Swedish case.

When a research question is novel, an explorative data-first approach may be well-motivated. In Paper [I], my co-authors and I study how the GPP policy influences firms' decisions in an explorative manner. GPP is operationalized by requiring firms to fulfill some environmental criteria in order to be eligible bidders in a procurement auction. These criteria are specified in the call for

tenders. We study how requiring firms to fulfill such environmental criteria affects their behavior in the sense of i) the choice to participate in a procurement auction, ii) the number of actual participants in such an auction and iii) the probability of a bidder being qualified to participate in an auction. Here, the econometric modeling is somewhat agnostic about economic theory; the implicit theory, however, is that green criteria affects firm behavior somehow. Also, the specification used do not allow for dynamics. However, exploration yielded no signs of time-dependent behavior in the number of participants, i.e., regarding question ii). Statistical significant correlation and falsification/corroboration in the sense of Karl Popper (2005) is used as a guiding principle. We assume the explorative correlational approach as this is the first empirical study on how GPP affects firms' behavior. Evidence is provided that environmental criteria do not affect firm behavior in the i) and ii) sense above, at least not to a substantial extent. However, we find that an increased number of environmental criteria seems to induce a larger degree of disqualification. This indicates that GPP may be non-transparent to firms. It suggests that it may be fruitful to consider firms' ability to process information in future studies.

3.2 Structure

It may be that thinking about and approaching a given problem (e.g., a research topic) in a different way will bring new knowledge (Feyerabend, 1993). In Paper [II] I study the same policy as in Paper [I], but from a different modeling stand. It is different with respect to both the economics and the econometrics employed. As compared to Paper [I], I study the effect of the GPP policy on sizes of firms' i) bids and ii) costs in Paper [II].

Recognizing that the procurements are arranged as first price sealed bid auctions I add structure by utilizing mainstream economic auction theory in a form similar to (1) and involve it directly in the estimation process by indirect inference (Gourieroux et al., 1993). I bring in measures on the stringency of the environmental policy to study how it affects the optimal BNE bids.

The BNE assumption may seem quite strong to some. Yet, the structural BNE approach comes with the advantage of allowing for *ceteris paribus* comparative static analysis, or, equivalently: causal effects with respect to the policy (Heckman, 2000). However, given the quite strong rationality assumptions of the BNE economic model, it is of good practice to recognize that the model may be an inferior description of real behavior. Therefore, I demonstrate how of some alternative non-structural specifications perform when evaluating policy in public procurement under the assumption that the economic model is the data generating process (DGP). As for these alternative specifications, I utilize orthogonal polynomials and dummy variable specifications where estimation is by ordinary least squares (OLS). This can be seen as a study of a middle way between the structural and reduced form explorative approaches striving to bridge the gap between the explorative approach of Paper [I] and the structural approach in (1).

Here, I find that the GPP criteria have a statistically significant impact on firms' bids and costs. So, by lending structure to the empirical specification from an economic model reveals an effect of GPP on firm behavior in a statistical significance sense. I study only participating firms, however. So, even though our exploratory approach in Paper [I] brought about the conjectures that GPP has i) little effect, if any, on firms' participation in a procurement auction, that it ii) does not affect the number of actual participants in procurement auctions, and iii) decreases the probability of a firm being qualified to participate in a procurement auction, GPP still affects the behavior of the firms that are actually participating in the procurement auctions.

3.3 Measurement

As compared to scientists, economists do not commonly want to measure *things*, but phenomena (Boumans, 2005); for instance, competition is not a *thing*. This requires an operationalization of the notion of the phenomena to enable for measuring them in terms of things. Phenomena are generally stable while data contain idiosyncrasies and observational errors (Woodward, 1989). I consider this matter in Paper [III] where the phenomenon of interest is firms' perceived magnitude of competition in public procurements denoted as N in specification (1). I also study the effect of N on the size of the bid, i.e. the competition effect $\partial b / \partial N$. This paper is set in the same economic-theoretical realm as Paper [II], i.e. BNE behavior is assumed.

I study consequences of the potential mismeasurement of competition, i.e. if the firms' perceivment of their competition differs from the econometrician's recording of the competition, implying an error-in-variables situation. As seen in (1), firms' perceivment of competition is crucial in the Bayesian Nash paradigm as it determines the sizes of their bids. This is important to study as policy may depend on the size of $\partial b / \partial N$. For example, if $\partial b / \partial N$ is erroneously estimated and policy makers base their creation of policy on it, society may have benefitted from a different institution than public procurement to allocate its scarce means with alternative uses.

3.4 Rule-of-thumb Decisions

Even though most auctions (such as public procurements) happen over time, econometric analyzes are often based on static BNE models; examples are Paarsch (1992), Laffont et al. (1995), Guerre et al. (2000), Krasnokutskaya and Seim (2011) and Nakabayashi (2013) as well as Papers [II] and [III] in this thesis. This is likely due to the complexity of multiple equilibria of dynamic auctions; game theory turns quite complicated in dynamic settings that may not allow for feasible estimation in the general case. The study by Jofre-Bonet and Pesendorfer (2003) is an exception. However, they observe the magnitudes of the firms' earlier commitments which they use for the identification of their model.

In Paper [IV], I leave the BNE assumption behind and take a rule-of-thumb decision rule as point of departure. The decision rule assumes that the firm will not bid under its cost and that no firm will allow a rival to make profit if the firm's cost structure allows it to beat its rival's bid. The latter assumption is reasonable if firms have observed the behavior of their competitors before which is common to be the case in public procurements. No maximizing behavior is assumed. The rule implies a model specification largely agnostic about dynamics, i.e., I do not assume a static setting (nor a dynamic setting). In rule-of-thumb models it is desirable that the assumed behavior is more reasonable than what is assumed in the rational choice models (Ellison, 2006), such as the static BNE-models used in the studies mentioned above. Even though most auctions take place in different points in time, the static BNE-assumptions are more believable in some settings. For example, I would say that auctioning off art during a time window of a few hours is more believably considered a static setting than auctioning of public contracts every other year during time periods of 20 years or longer even though both settings are dynamic as they happen over time. In industries such as the one considered in Paper [IV] with repeatedly active firms, the bidders probably know enough about each other's cost structure due to years of experience to make the rule-of-thumb decision rule assumed reasonable.

Moreover, it is important to make appropriate parametric assumptions for inference to be valid. Asymmetric parametric models are usually assumed in the empirical literature on auctions (Paarsch and Hong, 2006). In Paper [IV] I assume the flexible log-generalized gamma distribution (Prentice, 1974; Farewell and Prentice, 1977) that contains a continuum of asymmetric distributions as well as the symmetric normal distribution as a special case. This makes inference less fragile to parametric misspecification.

4 Summary of the Papers

Paper [I]: Using public procurement to implement environmental policy: an empirical analysis

We give empirical evidence how GPP affects i) a potential supplier's decision to submit a bid, ii) the number of participants in an auction and iii) the probability of a bid being qualified. We study how the probability of entry and qualification is related to firm size. GPP policy may give relatively more environmentally friendly firms advantages making them participate in public procurements more often. Hence, the firms' expected net profit varies between firms; a firm submits a bid when the the expected profit is non-negative. The firms' profit functions are not observed, but their choice to participate or not is observed. The participation decision is assumed to be a function of supplier-specific characteristics, contract characteristics, and procurement characteristics. From an environmental policy point of view, it is important that the contracting authority specifies transparent and adequate environmental criteria with respect to some environ-

mental objective. If a firm miscomprehends the criteria posed in the call for tenders they may make inferior decisions when it comes to whether or not to submit a bid. This motivates the study of the relationship between the GPP criteria and whether a firm is qualified or not. The probability of a bid becoming qualified in the post-qualification process serves as indication for the complexity of the auction. The qualification decision is assumed to be a function of supplier-specific characteristics, contract characteristics, and procurement characteristics. To study the decisions in i) and iii) above we use a logistic distributional assumption and the dependent variable is a dummy variable. Question ii) is studied by employing a negative binomial distributional assumption with truncation at zero. In all specifications, parameter estimation is by maximum likelihood (ML).

Our main findings are that GPP criteria have a limited impact on firms' participation decision and on the number of firms partaking in the auctions. We find no evidence for systematic self-selection into procurements of different categories of environmental criteria with respect to firm size. Consequently, GPP appears to have limited or no potential to function as an environmental policy instrument in this particular context. Our study of the qualification process reveals that GPP is associated with increased complexity as indicated by the reduced probability of a bid becoming qualified. All in all, we find no obvious support for the political expectations of GPP being an environmental policy instrument.

Paper [II]: A Comparison of Techniques to Evaluate Policies in Public Procurement

I consider the empirical evaluation of policy conducted through public procurement. In the literature such studies are made using non-linear structural specifications as well as linear reduced form specifications. The economic model of first-price sealed bid auctions is non-linear in both parameters and variables. Policy makers are potentially interested in how a policy p affects a firm's bid b , i.e. the marginal effect $\partial b / \partial p$. I estimate the parameters of a structural econometric specification, i.e. where the estimator is highly dependent on economic structure, by indirect inference (II) (Gourieroux et al., 1993). I use II because it is an under-researched estimator when it comes to microeconometrics (Li, 2010).

As the structural specification under study is non-linear I suggest that $\partial b / \partial p$ potentially can be estimated by utilizing a specification including orthogonal polynomial expansions of p where parameter estimation is by OLS. As p is a count variable I also propose a specification using dummy variables, where each dummy variable indicates one level of p . One motivation to estimate by OLS is that estimator behavior under, e.g., omitted variable bias is better understood when estimation is by OLS as compared to other estimators.

In a small Monte Carlo study, I find the variability in the predicted marginal effects to be quite high under the orthogonal polynomial and dummy variable specifications. In an empirical application, employing data on first-price public

procurement auctions conducted between December 2008 and the end of December 2010 I find the dummy variable specification to be better fitted to data than a linear specification and some orthogonal polynomial specifications. Hence, I use the dummy variable specification as the auxiliary model in the II estimation procedure. I find that GPP has a statistically significant effect on the size of the bids in the non-structural as well as the structural specifications.

Paper [III]: The Competition Effect in a Public Procurement Model: An error-in-variables approach

In this paper I acknowledge that firms' perception of competition N in specification (1) may differ from the econometrician's. That is, the measurement of competition may not be equivalent to the competition as experienced by the firms. In data, I have a measurement on the actual number of participants n_a in the procurement auctions as well as a measurement on the potential number of competitors n_p . If firms perceive neither n_a nor n_p as relevant competition this implies an error-in-variables situation. Measurement error will have consequences for the estimation of the parameters in a specification of type (1) and hence the calculation of the competition effect $\partial b / \partial N = - \{ [1 - G(\cdot)] / g(\cdot) \} (N - 1)^{-2}$.

By interpreting (1) as a dependent-variable transformation model I derive consistency and asymptotic normality for the corresponding semi-parametric non-linear least squares estimator. In a small-scale Monte Carlo exercise, I study how the estimator performs when competition is measured as n_a and n_p and additionally when an erroneous measurement for competition is used. The estimator performs well when the correct measurement is used, and poorly when the incorrect measurement is used. I propose an instrumental variable estimator to use when both n_a and n_p are suspected to be erroneous measurements of N in specification (1). The instrumental variable estimator performs well in the simulations. In an empirical illustration, I use two instruments: the number of potential bidders as well as the municipality population size. I estimate the parameters of the instrumental variable model by minimizing a generalized method of moments (GMM) type of criterion function. Using data on first-price public procurement auctions conducted from December 2008 throughout December 2010, I find that the competition effect $\partial b / \partial N$ generated by the instrumental variables estimator is bounded by those generated by the semi-parametric non-linear least squares estimator using n_a and n_p , respectively.

Paper [VI]: It's All in the Interval: An imperfect measurements approach to estimate bidders' primitives in auctions

I consider measuring firms' costs in auctions. The proposed method relies on very few (merely two) economic assumptions. The methodological philosophy

gathers more inspiration from imperfect measurements in statistics and less influence by game theory than is common in cost estimation using auction setups. The assumptions (partly inspired by Haile and Tamer (2003) and Varian (1982, 1983, 1984, 1985)) are 1) that the firm will not bid under its cost and 2) competition is an efficient sorting mechanism.

The first assumption is rather weak and straightforward. The second assumption says that a firm with a low cost will cast a lower bid than a firm with a high cost will do. That is, the auction allocates the contract efficiently in the economic sense of the word. The assumptions enable for bounding firms' costs into intervals. Observing the bids of, e.g., firms $i = (1, 2, 3)$ in a given auction and ordering them with respect to magnitude as $b_1 < b_2 < b_3$ and using 1) and 2) implies $c_1 \in [0, b_1]$, $c_2 \in [b_1, b_2]$ and $c_3 \in [b_2, b_3]$ where c_i denotes the cost of firm i . Consequently, firms' costs can be interpreted as interval censored random variables. Using techniques that view the random cost variable to be interval censored I obtain point estimates of the firms' costs.

As auctions are heterogenous in general, I propose a technique to homogenize the intervals with respect to contract heterogeneity. I do this by specifying a cost function that depends on contract and municipality characteristics. As costs sometimes are found to be asymmetrically distributed (O'Hagan et al., 2003), I utilize the quite flexible log-generalized gamma distribution which contains a skewness parameter. Estimation is by ML. The log-generalized gamma distribution contains a continuum of asymmetric distributions and a symmetric distribution as a special case. This brings about a way to test for symmetry of the cost distribution. I cannot reject that the log of the firms' costs are normally distributed. Using the estimated parameters I obtain predicted values of the costs and I calculate their expected value given that they are contained in the proper interval: $E[c_2 | b_1 < c_2 < b_2]$.

The proposed method outlined above is applied to data on Swedish public procurements in an empirical illustration using data on fixed price cleaning service contracts auctioned between 1992-1998 and December 2008 throughout december 2010. I study how the price of buying and cost of selling these services have evolved over the years from when the Swedish Public Procurement Act was young as compared to more recent times. This information gives the opportunity to study whether the cost of providing the services has changed, implicitly assessing whether the market power has changed over the years. I consider firms' cost to be generated according to $b = cu$ where u is a markup factor larger than one and, as before, b and c are the magnitudes of the corresponding bid and cost. After point-estimating the costs I use them to study whether the firms' markup factor, i.e., u , has changed through time. I find no evidence that the market power has changed over the sample time period. Using these data I also compare my proposed method to a Bayesian Nash approach. I find some differences in estimated costs and markups.

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