Bid Rigging in Swedish Procurement Auctions*

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Abstract

Using a unique data set of procurement auctions carried out by the Swedish National Road Administration this paper addresses the issue of bid rigging in the Swedish asphalt-paving sector. Both market characteristics and the fact that the Swedish Competition Authority in 2003 initiated legal proceedings against a group of firms active in the market indicate the existence of collusive behaviour. If firms act competitively they should submit independent bids, conditional on firm- and auction-specific differences. Reduced-form equations are estimated and the hypothesis of conditional independence is tested by analysing if the difference between observed and predicted bids correlate between firms. If negative correlation is observed one possible explanation is bid rigging. The results overall indicate that collusion may be widespread in the industry and suggest further investigation of the market.

Keywords: Bid rigging, Collusion, Reduced-form estimations, Procurement auctions

JEL classification: D44, H57, L0

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1 Introduction

Collusion amongst bidders may be a serious problem in many procurement auctions. Despite the fact that suspicions on collusion often exist, lack of evidence normally makes legal action difficult. Both antitrust authorities and researchers work to find methods to detect collusive behaviour. The development of efficient and simple to use methods is important for regulators, both to expose existing collusion and as deterrence mechanism.

In this paper the aim is to analyse the existence of collusive behaviour in the Swedish construction sector. A simple tool, developed in Porter and Zona (1999) and Bajari and Ye (2003), is used to screen the market for cartel activity. The analysis focuses on differences in the bidding behaviour between competitive and non-competitive firms. If firms act competitively they should submit bids independently of their competitiors, when conditioning on all publicly available information on auction- and firm-specific differences. If collusion is occurring, however, the bids may be correlated if firms submit "phantom" bids to create the appearence of competition. The hypothesis of conditional independence can be tested, and if it can be rejected, one plausible explanation is collusion.

Hendricks and Porter (1989) point out that collusive schemes may be different in different markets and the methods to detect them need to be tailored accordingly. Firms can e.g. agree on a bid-rigging scheme, i.e. firms agree on submitting one winning bid, and one or more "phantom" bids to create the illusion of competition. Other ways to collude may be bid supression, where one or more firms that are otherwise expected to bid, refrain from bidding. Firms could also use a market division scheme. High bid participation is one sign of bid bidding. The data used in this paper indicate that the average number of bids is slightly above five.[1] The data also show that the participation rate among the three largest firms in the industry exceeds 84 percent. Arguably, the apropriate collusive behaviour to investigate in the paving market is bid rigging, at least

[1] Bajari and Ye (2003) analyse bid rigging with an average number of bidders slightly above three. In Porter and Zona (1999) the mean number of bids is 1.8.

among the large firms.[2] Also, bid rigging seems to be the collusive scheme dealt with most in the empirical literature. However, it is hard to tell if this collusive scheme is the most commonly used, or just the scheme easiest to detect.

A unique data set has been compiled and is used in this paper. The data consists on asphalt-paving auctions conducted by the Swedish National Road Administration (RA) during the 1990's. There are a number of reasons why the paving market is interesting to analyse. At the beginning of 2003 the Swedish Competition Authority (SCA) initiated legal proceedings against a group of firms active in the Swedish road-construction sector. Nine firms participating in asphalt-paving procurements during the 1990's were accused of limiting competition by making illegal agreements on territories and bids. Also, the market for asphalt paving is characterised by a number of collusion markers, e.g. firms compete only on price since contracts are homogenous, there is repeated interaction in the market and there are entry barriers.

The hypothesis of conditional independence is tested both for the whole data set and for each year and for the larger contracts separately. The main findings are that the hypothesis of conditional independence can be rejected for a group of eight firms, both when using the whole available material and when testing each year separately. All of these firms, except one, belong to the group of largest firms in the industry.

Out of the nine firms accused of collusive behaviour by the SCA, eight are represented in the tests. The results overall indicate that collusion may be widespread in the industry and that at least the group of the three largest firms appear to be involved in bid-rigging activities. However, any test for collusion suffers from limitations. It is e.g. not possible to establish that a suspicious bid pattern is the result of illegal agreements, possibly the same bid pattern may be observed from tacit collusion. The results should be used carefully as

[2] The bid rigging assumption is partly supported by the SCA cartel files. According to the ongoing investigation colluding firms have agreed on both a bid-rigging and a bid-suppression behaviour.

a first tool to determine if collusive behaviour may have occured and if further investigation is warranted.

The contribution of this paper is twofold. First, the compilation of a unique data material gives new important insights into the bidding behaviour in the Swedish paving industry. Second, the results from the analysis are to a large extent consistent with evidence of collusion gathered in a totally different way. This supports the view that the used method is valuable econometric procedure for detecting departure from competitive behaviour.

A number of empirical papers have analysed collusive behaviour in procurement auctions. Porter and Zona (1993) and (1999) analyse the existence of bid rigging in highway-construction auctions on Long Island and auctions for school-milk contracts in Ohio in the 1980s. Collusion is known to exist in both markets. In the 1993 paper the authors estimate the bid level for cartel bids and non-cartel bids separately and find that different firm characteristics affect the bid level differently in the two groups. The authors also rank submitted bids and measures of firms' costs for cartel firms and non-cartel firms separately. They find that the ranking of bids for non-cartel firms match the ranking of costs, firms with higher costs submit higher bids. This is not the case for cartel firms. The authors conclude that bid rigging is consistent with the counterintuitive behaviour observed for the cartel firms. Also in their 1999 paper the authors compare cartel and non-cartel bids. In line with the earlier study they find that bids submitted by cartel firms are not generated by the same process as bids submitted by non-cartel firms.

In contrast with the above-discussed papers, where the identity of the cartel members is known beforehand, Eklöf (2000) analyses collusion on a market where it is not known to exist. He carries out tests of conditional independence using road markings bid data from Sweden. He finds that some firms behave in a way that may be consistent with collusive behaviour but that it still not possible to draw the conclusion that collusion exists in the market.

Jakobsson and Bergman (2001) use a small data set consisting on asphalt-paving auctions carried out in Sweden during the 1990's. Tests for conditional independence show that some firms fail to submit independent bids. Collusion is one possible explanation, but due to the insufficient control for firm-specific differences no strong conclusion is drawn.

The use of structural estimation techniques is growing in this line of reasearch. Baldwin, Marshall and Richard (1997) estimate competitive and collusive models on oral-timber auction-data using maximum likelihood. They find that one of the models, based on the assumption that collusion exist, outperforms the models with no collusion. Banerji and Meenakshi (2004) also compare the performance of collusive and competitive models, using data from oral ascending auctions for rice. They also find that the collusive model fits the data better than the competitive model. Bajari and Ye (2003) use bid data from highway-construction auctions and start with conducting tests of conditional independence in order to determine the identity of the cartel firms. The authors extend the analysis by introducing structural tests for collusion. They compare a competitive and a collusive model and conclude that the model of competitive equilibrium performs better than the model of collusive equilibrium. Also, for a comprehensive review of the literature on cartel detection see Harrington (2004).

The remainder of this paper is structured as follows. In section 2 a theoretical framework is presented. Section 3 reveals the characteristics of the Swedish asphalt-paving market and discusses why collusion may exist in this market. The data and the emprical specification is discussed in section 4. In Section 5 the estimation and tests results are presented and discussed. The last section of the paper concludes.

2 Theoretical Framework

This section examines a model of competitive bidding that can be used as a starting point when analysing collusive behaviour. Consider a procurement auction with N competitive firms bidding for a contract to build a single indivisible object. Firms' submit sealed bids and the contract is awarded to the lowest bidder who is paid its bid.[3] All firms have information about the set of bidders at each auction. Firm i knows its own cost estimate, c_i, but does not have information about the cost estimates of its competitors, only about the distributions from which the competitors costs are drawn.

The bidding behaviour is modelled in an independent private values (IPV) setting, i.e. firms' cost estimates would not be changed if they got information on their competitors' cost estimates.[4] This way of modelling the bidding behaviour seems reasonable when it comes to the paving industry since differences in production costs seems to be mainly firm specific.[5] All firms are further assumed to be risk neutral. The model allows for asymmetries among the bidders, i.e. the distributions from which costs are randomly drawn do not have to be identical across firms.[6] Asymmetries in the paving industry can arguably arise from differences in e.g. capacity constraints and production-plant location.

Firm i's bidding strategy is a function $B_i(c_i)$. Suppose an equilibrium exists that is a strictly increasing and differentiable function. Suppose further that all competitors follow strategies $B_{-i}(c_{-i})$. If firm i bids b_i and wins, it will earn $b_i - c_i$. The probability that the bid b_i is the winning bid, $\Pr\left(c_j > B_j^{-1}(b_i)\ \forall\ j \neq i\right)$, where $B_j^{-1}(b_i)$ is the inverse bid function, depends on the distribution of competitors costs and the bidding strategies adopted by competitors. Firm i's expected profit from participating in the auction can be expressed as

$$\pi_i(b_i, c_i; B_{-i}) = (b_i - c_i)\,\vartheta_i(b_i) \tag{1}$$

[3] This auction type is a *reverse* first-price sealed-bid auction. For a discussion on this and other auction types, see Krishna (2002). This section mainly draws from Bajari & Ye (2003).

[4] The independent private value model is an extreme case. At the other extreme is the common value model where no firm knows the true cost of winning the auction. This model is e.g. applicable for mineral-or oil-rights auctions. See e.g. Krishna (2002). In reality most auctions contain elements of both. A general model that includes both common and independent private value aspects is developed in Milgrom and Weber (1982).

[5] The independent private values setting is used for analysing procurement auctions in the paving industry in e.g. Porter and Zona (1993) and Bajari and Ye (2003).

[6] Maskin and Riley (2000) developed this theoretical feature. Analytically it implies that before firms submit bids in an auction the market participants expect some firms to have relative cost advantages.

where

$$\vartheta_i(b_i) = \prod_{j \neq i} \left[1 - F_j\left(B_j^{-1}(b_i)\right)\right] \tag{2}$$

denotes the probability that firm i wins the contract. Firm i's expected profit is thus a markup times the probability that it will win the auction, i.e. that firm i is the lowest bidder. Firm i chooses its optimal bid, b_i, to maximise the expected profit. The optimal bid satisfies the following first-order condition

$$\frac{\partial}{\partial b_i}\pi_i = (b_i - c_i)\,\vartheta_i'(b_i) + \vartheta_i(b_i) = 0,\ \forall\ i = 1, ..., n \tag{3}$$

where n is the number of participating firms. Equilibrium in this asymmetric auction model is reached when a solution to all firms' profit-maximisation problems is found simultaneously.

The equilibrium properties of this model are well established in the theoretical literature. If the following below assumptions hold, then Lebrun, (1996), (1999) and Maskin and Riley (2000) have shown that there exists a unique equilibrium in pure strategies. They have also shown that this equilibrium can be characterized as the solution to a system of n first-order differential equations. That system can be solved by numerical methods, see e.g. Bajari and Ye (2003).

1. for all i, the cost distribution, $F_i(c_i)$ have support on $\left[\underline{c}, \bar{c}\right]$. The probability density function $f_i(c_i)$ is continously differentiable in c_i

2. for all i, the probability density function $f_i(c_i)$ is bounded away from zero on $\left[\underline{c}, \bar{c}\right]$.

2.1 Conditional Independence

Bajari and Ye (2003) identify a set of conditions concerning a distribution of bids that are implied by the above model. One of these conditions is conditional independence. In this paper conditional independence will be used to test if a given distribution of bids is consistent with the model of competitive bidding. If it is not, one explanation may be collusion.

Following Bajari and Ye it is assumed that each firms' cost distribution can be parametrized by a vector of parameters, θ, and a set of covariates, z_i, that is unique for firm i. Before submitting a bid on a specific contract, each firm calculates cost estimates for itself (and its competitors). Firm i's cost estimate may be written as

$$c_i = \beta_1 + \beta_2 z_i + \varepsilon_i \tag{4}$$

where β_1 represents characteristics affecting all bidders such as the size of the contract. The vector z_i include variables that affect firm i's private cost, such as the transportation distance from production plant to project site, and if the firm has its own production plant. The error term, ε_i, represents private information for firm i. Assuming that the error term is normally distributed with $E(\varepsilon) = 0$ and $VAR(\varepsilon) = \sigma^2$, implies that the distribution of costs is determined by the the vector of parameters, $\theta = (\beta_1, \beta_2, \sigma^2)$, identical for all firms.

Let $G_i(b; z)$ be the cumulative distribution of firm i's bids, and $g_i(b; z)$ be the probability density function, where z is the entire vector with firm-specific covariates, $z = (z_1, ..., z_n)$, observable to all firms. Bajari and Ye (2003) show that conditional on z, firm i's cost estimate c_i, is independently distributed. Since bids depend on c_i, this implies that conditional on z, firm i's and firm j's bids should be independently distributed in equilibrium. This condition must hold when bidding is competitive. If collusion on the contrary exists, firms have agreed on a bidding scheme before bidding. One firm may be designated to win the auction and the others to submit higher bids in order to create the appearance of competition. Rigged bids are not necessarily a function of costs and may therefore be correlated conditional on z.

If the bids $b = (b_1, ..., b_N)$ are conditionally independent the following relation must hold

$$G(b_1, ..., b_N; z) = \Pi G_i(b_i; z) \tag{5}$$

where $G(b_1, ..., b_N; z)$ is the joint distribution of all firms' bids at an auction. Following Porter and Zona (1993), (1999) and Bajari and Ye (2003) it is possible to test if bids are independent by estimating $G_i(b_i; z)$ using a reduced-form bid-level equation and thereafter testing if the residuals are independent. The residuals measure how much the observed bids diverge from the bid level predicted using publicly available information. If the residuals are randomly distributed, the hypothesis of conditional independence can not be rejected. If, on the other hand, the residuals show a persistent correlation pattern, the hypothesis of conditional independence typically fails. The tests for conditional independence are presented in section 4.

The existence of negative correlation result from one bid being systematically lower, and one bid systematically higher than predicted by the model. Consequently, with a correctly specified model negative correlation could be the result of a bid-rigging scheme with one "winning" bid and two or more bids exceeding the winning bid.

Positive correlation, on the other hand, could be explained by unobserved characteristics that affect the bidders equally, such as changes in input prices that are not controlled for in the estimation. Hovewer, another plausible explanation for positive correlation could arguably be collusive behaviour with more than two participating firms. Consider three firms taking turn in submitting the low bid. The low bid will turn out lower, and the high bids higher than predicted by the model, and negative correlation will therefore be observed. The two high bids will both turn out higher then what the model predicts and will therefore be postitively correlated. Findings of positive and negative correlation in combination could therefore be a sign of cartels with three or more participating firms.

3 The Market

Most of the Swedish roads are administered by the Swedish National Road Administration (RA). It has divided the country into seven regions, each region being in charge of its own road construction and maintenance. In this paper the focus is on a specific road maintenance process, namely asphalt paving, and data from five of the seven regions have been compiled; Skåne, Syd-Ost, Väst, Mälardalen and Stockholm. Every year each region independently solicit bids for paving contracts. The auctions are normally held in the early spring, with some exceptions[7], and the actual work is carried out during the season when the weather allows it, i.e. from May until October.[8]

All paving contracts are awarded through first-price sealed-bid auctions. All firms submit sealed bids and the contract is, with very few exceptions, awarded to the lowest bidder.[9] After the bid opening the bids and the bidders are publicly announced. Although the RA has the right to reject the bids if they are too high, and to cancel the project, this happens rarely in practice. An important aspect concerning the contracts used in this paper is that several contracts, up to 15, can procured at the same time. Firms do not necessarily submit bids on all contracts auctioned. This means that bids submitted on a specific contract are evaluated separately and very often the contracts are awarded to different bidders. Combinatory bidding is allowed but normally not rewarding for the firms. Only in rare cases did a combination bid win an auction during the investigated time period.[10] It is also possible for firms to offer alternative bids, i.e. present alternative solutions on how to carry out a specific project.[11] During the investigated time period contracts were normally not awarded to alternative bids. However, there has been an increase in the number of alternative bids during the last couple of years and the attitude among the buyers is that if alternative bids provide good value for money they should be considered.

[7] Some contracts are not put on the market until during the summer months. This happens when the RA receives more funds than expected for road maintenance.

[8] Occationally paving work can be carried out as late as in December.

[9] During a few years in the end of the 90's some regions used "soft parameters", such as quality and previous experience, toghether with the offered price to select the winning bidder. RA representatives argue that this method was very hard to use. This was also the reason behind its fast disappearence. However, the use of soft parameters did not have any major impact on the awarding procedure - contracts were still awarded to the lowest bidder. Today all firms have to fulfill certain requirements in order for their bids to be considered.

[10] When submitting combinatory bids firms always also submit independent bids.

[11] Alternative bids are found in approximately 5 percent of the auctions.

Relevant aspects of the asphalt-paving market are the following. In producing asphalt the major input is gravel. The bigger firms typically produce their own gravel while the smaller firms have to buy their gravel elsewhere. This also goes for the asphalt production, the bigger firms are equipped with asphalt-production plants, and the smaller not. To produce asphalt the gravel is mixed together with bitumen, a petrol-based substance that binds the asphalt together. The production process is identical among firms. The properties and the quality of the asphalt differ depending on the size of the gravel and the mixture of gravel and bitumen, as well as if the asphalt is cold or warm. Warm asphalt is of higher quality than cold and is therefore used on roads with more intense wear. The life length of warm asphalt is short. The time from cooking until it the asphalt has to be spread is short. Consequently the asphalt cannot be transported for long distances, in average not more than 80 kilometres.[12] Asphalt is normally spread in two or three layers, each layer having its own specific characteristics.

In October 2001 the SCA got indications of collusive behaviour in this industry. Short after, a "dawn raid" was made on a number of firms in the industry. Legal proceedings was initiated in March 2003 against nine firms.[13][14] In the view of the SCA the nine firms have, at least since 1993, cooperated over asphalt contracts. More specifically they are suspected to have made agreements concerning prices and geographic market division. The SCA have petitioned that the firms should pay approximately SEK 1.6 billion in administrative fines.

There are a number of features in the Swedish road-construction industry that facilitate collusion.[15] Firms compete to a large extent only on price. Each contract is specified in detail both when it comes to material and the way in which the work is to be done. Product differentiation is normally not allowed. A cartel producing and selling a homogenous product need only coordinate bids,

[12] According to representatives of the RA.

[13] See Stämningsansökan Asfaltskartellen, SCA (2003).

[14] In total 11 firms accused of cooperating. Three of them belong to the same group and are therefore treated as one firm in the analysis.

[15] See Tirole (1988) and Porter and Zona (1993), (1999) for a general discussion on characteristics that facilitate collusion.

which simplifies collusion. The regularity in both the timing of the auctions and the number of contracts to be let in each region from year to year facilitates coordination. According to RA representatives it is not uncommon that firms contact the road administration in the fall to find out the value of next years contracts. This should make it easy for a potential cartel to calculate future profit and divide contracts among its member in advance.

The economic crisis Sweden suffered in the beginning of the 90's changed the market structure. Many small and middle-sized firms went bankrupt or were aquired by larger firms, and some larger firms merged. Today only a few firms have the capacity to handle the largest projects. Two types of firms bid on contracts, large nation-wide firms and small firms active on a regional basis. Large firms typically integrated vertically and are therefore self-supporting when it comes to gravel and asphalt. Smaller firms without their own production plant use the larger firms as sub-contractors. The cost structure therefore differs between large and small firms, but within each group the level of homogeneity is higher. All firms use the same production process that to a large extent is specified in detail in the contract. Bitumen, the oil-based substance that binds the asphalt together is almost exclusively supplied by one firm.[16] Wages are regulated through central agreements. Within each group the firms face more or less the same factor costs and can therefore be considered homogenous in the long run, a fact that facilitates collusion. In the short run on the other hand the costs may very well vary between firms due to different use of capacity.

Entry into the local asphalt-paving markets is limited. One reason is the control of local facilities by incumbents. Environmental regulations with the aim to limit the number of gravel plants has also made it difficult to enter the market (Statens Pris- och Konkurrensverk [1992]). Markets are easily defined according to region boundaries, a fact that facilitates division of territory. Firms meet in more than one geographic market, especially larger firms. Multi market

[16] The Swedish firm Nynäs produce and sell approximately 95 percent of the total bitumen demand in Sweden. In December 2004 the SCA initiated legal proceedings against Nynäs. The firm is suspected of having made price and market-division agreements with a newcomer in the market, as well as of abusing its dominant position.

contact facilitates collusive schemes with the aim to allocate territories. Communication between at least some of the competitors is facilitated since firms are frequent buyers both when it comes to the final product and inputs. During the investigated time period at least two of the larger firms worked closely together. They collaborated as a syndicate until the mid 90's when the SCA decided that it had to end. However, according to RA representatives it is plausible that the collaboration continued after it officially ended.

The RA demand for asphalt paving seems to be fairly inelastic. Demand is restricted by the funds for road maintenance distributed every year by the state. The market for asphalt paving, and road maintenance at large, have not been very sensitive to changes in the economic situation during the investigated time period.

Finally, the policy of publicly announcing the bids and the bidders after the auction makes it difficult to deviate from cartel agreements without being noticed by fellow colluders. A cartel agreement is therefore more likely to be stable.

4 Data and Econometric Specification

The data used in the analysis is a unique data set of road contracts in five of the seven RA regions in Sweden, compiled for this particular study. The data was collected using RA files and contains detailed information on asphalt-paving projects from 1992 through 2002.[17] In total the data set includes detailed information on 536 contracts during this period. The number of bids submitted on these contracts amount to 2859.[18]

The total value of contracts awarded during the period and included in the data set amounts to 2.7 billion SEK in real terms.[19] The contracts vary greatly

[17] There is no information on contracts in Stockholm and Mälardalen awarded later than 2001 in the used data set.
[18] A number of contracts could not be used. The main reason being that the relevant information was missing in the RA files. Also, the contracts carried out in the county of Gotland is not used in this dataset.
[19] The bids have been deflated using an appropriate index, the base year being 1990.

in size. The value of the smallest contract is approximately 120.000 SEK and the value of the largest contract amounts to 32.7 million, the mean value being 5.1 million. In total 53 firms have submitted at least one bid during the time period and, out of those, 27 firms have won at least one contract. Firms differ greatly in size. In total 10 firms have a revenue share of 1 percent (of the total contract value) and above. Details of the bidding activities of these firms are summarised in Table 1. where firms are represented with their respective identification number. These 10 firms together have won over 90 percent of the auctions in the data set. Out of these 10 firms there are three firms that stand out. Firms 26, 44 and 55 together captured a revenue share of almost 65 percent. Also, each of these firms submitted bids in almost 85 percent of the auctions included in the data set.

Table 1. Bid Participation and Revenue Share

ID No.	No. of Bids	No. of Winning Bids	Participation %	Rev. Share %	Mean Bid	Prod. Plant
14	76	11	14.2	1.1	5.3	y
21	57	5	10.6	1.5	9.2	y
26	524	136	97.8	27.0	5.4	y
30	73	7	13.5	2.4	9.2	n
33	173	20	32.3	3.8	6.4	y
37	158	49	29.5	13.7	7.1	y
43	227	28	42.4	4.3	5.5	n
44	523	124	97.6	22.6	5.4	y
50	214	23	39.9	2.5	5.0	n
55	453	88	84.5	14.9	5.8	y
Total	2478	491		93.8		

a. The participation rate is calculated as the fraction of the total number of contracts a firm submit bid for and the revenue share is calculated as the fraction of the total project value won by a particular firm.

b. Firm 50 was active between 1993 and the beginning of 1997 as a subsidiary of firm 33. In 1997 the two firms merged. It is reasonable to believe that the plants belonging to firm 33 has also been used by firm 50.

The theoretical model of competitive bidding discussed above implies that a firm's bidding strategy depends on its own costs, as well as on the cost of competitors. To be able to control for cost asymmetries across firms, characteristics that affect firms' costs of completing a contract need to be identified. These characteristics also need to be publicly observable. Transportation distance, i.e. the distance between asphalt plant and project site, may contribute to differences in costs across firms, shorter transportation distance leading to cost advantages.

In the empirical analysis two distance variables will be used, DRT and DRC.[20] For firm i and contract t the variable DRT_{it} measures the shortest distance between firm i's plant and the project site.[21] When constructing DRT consideration is taken to the fact that asphalt can only be transported for a limited time. Firms without plant sufficiently close to the site therefore need to buy from other producers. Bidders with plant in the region are assumed to take asphalt from that plant, unless one of their plants outside of the region is situated closer to the site. Bidders without plants in the region are assumed to aquire their asphalt from the plant closest to the site. Almost all the larger firms produce their own asphalt. This is not the case for the smaller firms, some of them are not represented with production plant in any of the five regions investigated. The variable DRC_{it} measures the shortest transportation distance among firm i's competitors, i.e. all potential bidders, at auction t, and will be used as an attempt to control for competitors costs. This variable is contructed in a similar manner to the variable DRT discussed above. In the analysis the distance variables will be used in logarithm form.

There are potentially problems with how the distance variables are constructed. First, there might be information missing on production plants. In particular, there is no information at all on small mobile plants. Second, it might be erroneous to assume that bidders without plants in the region buy asphalt from the plant closest to the site. This may have as effect that the measured distance is too short.

To further control for bidder asymmetries a dummy variable, $RPLANT$, is used in the analysis. $RPLANT_i$ takes the value one when firm i is the

[20] The variables were constructed using information on asphalt-plant and project location. RA representatives have been kind to provide information on the location of production plants. Information on project location was found in the contract protocols.

[21] The location coordinates of production plants and projects were collected manually using maps. Euclidean distances (as the crow flies) in kilometers was thereafter calculated using : $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$, where (x_2, y_2) and (x_1, y_1) are the plant- and project-location coordinates respectively.

owner of an asphalt plant in the region where the contract is carried out, and zero otherwise. In line with the discussion above this variable considers the importance of the production plant location. It is not enough to own a plant to benefit from cost advantages, it has to be situated close enough to the project site.

It may not only be the transportation distance, and ownership of asphalt plant, that determine the cost of carrying out a contract. The capacity utilisation rate may be an important factor in controlling for cost differences accross bidders. In this paper capacity variables are not considered. One reason for this is that the available data is not sufficient in constructing reliable capacity variables. The data consists only of auctions carried out by the state, while the bidders carry out work also for municipalities and the privat sector. Note however that the capacity utilisation rate could be considered endogenous since it is determined by previous bidding behaviour. As discussed earlier the procurements are generally carried out during a short time period and the winner is usually not are annonced before other bids are to be submitted. This implies that the capacity utilisation rate generally is unknown and therefore unimportant for the bidding behaviour. To control for some of the variation in bidders costs that is not captured by the variables discussed above, firm specific dummies for the large firms are included in the analysis.

Aside from the bids and the location of projects the records contained detailed information on the contracts. However, due to the difficulties in homogenising this information it is not used in the analysis. The kind of work carried out differs a lot, both within contracts, accross roads that belong to the same contract, and across contracts. The data is therefore difficult to use. Included in the estimations are instead auction specific dummies to control for differences between contracts. This solution seems to be quite standard in the literature, see e.g. Porter and Zona (1993) and Bajari and Ye (2003). In some estimations an alternative for controlling for differences between contracts is used, $MRBID$, the mean contract size. Table A.2 in appendix provides summary statistics of the variables used in the analysis.

The empirical specification used in the analysis is the following reduced-form bid equation

$$\ln b_{it} = x'_{it}\beta^b + d'_{it}\beta^b + \varepsilon^b_{it} \tag{6}$$

where $\ln b_{it}$ is the logarithm of the bid submitted by firm i at auction t, d_{it} a vector with dummy variables, x_{it} a vector of observable firm-specific variables and ε^b_{it}, the residual representing private information that affect firm i's cost at auction t. The residual has zero expectation and observation-specific variance denoted σ^2_{it}. The specification is estimated using OLS.

5 Estimation Results and Test for Conditional Independence

This section presents the estimation results, discusses the potential problem of selection bias and presents the test for conditional independence.

5.1 Estimation Results

The bid-level estimations are presented in Table A.3 in appendix. Four specifications are presented. Dummies are included in two of the four specifications to control for auction-specific differences. In the other two specifications $MRBID$ is used. The results are the following. The distance variables $LNDRT$ and $LNDRC$ have a positive impact on the bid level in all four estimations, i.e. the bid level increase both with the own transportion distance, and the distance of the closest competitor. The magnitude of these variables does not change much when including firm-specific dummies, as shown in columns (3) and (4). Unobserved bidder heterogeneity does not seem to bias the estimates. However, in both specifications the hypothesis of no significant firm fixed effects can be rejected, indicating that firm heterogeneity exists that is not accounted for in the estimations.[22] Ideally more variables to control for bidder heterogeneity should be included in the estimations.

The results from the bid-level estimations further show that the parameter estimate in front of $RPLANT$ is negative, indicating that if a firm is the owner of a production plant in the region where the contract is carried out, the bid-level will be lower than if this was not the case.

5.2 Potential Sample-Selection Bias

Data reveal that not all eligible bidders participate in the bidding. In average 5.4 out of the invited 10.5 firms participate in the auctions. If non-participation is not a random decision sample-selection bias is a potential problem. Refraining from bidding in the present context could potentially be a non-random behaviour. Neglecting the bias may e.g. underestimate the coefficients on firm-specific variables. As an attempt to solve the potential selection bias Heckman's 2-step method will be used (1976), (1979).

Heckman proposes to treat the sample-selection bias as a specification error. As a first step a probit bid-submission equation of the following form is estimated

$$SUBM^*_{it} = x'_{it}\beta^s + w'_{it}\beta^s + \varepsilon^s_{it} \tag{7}$$

where x'_{it} is a vector of observable firm-specific variables that affect the decision to submit a bid, same as above, w_{it} is a vector with dummyvariables, including the exclusion restiction needed to identify the model, and ε^s_{it} is the error term. A bid from firm i in auction t will only be observe when the latent variable $SUBM^*_{it} > 0$. This is captured by the observable variable $SUBM_{it}$ that takes the value one if a bid was actually submitted. Using the estimated parameters from equation (7) Heckman's λ, sometimes referred to as the inverse of Mill's ratio, is calculated as

[22] Wald tests have been carried out to test the joint significance of the firm-specific dummies. The null hypothesis of no firm fixed effect could be rejected in both column (3) and (4). The test statistic is chi-square distributed with 10 degrees of freedom and equals 3.35 and 4.16 for the two estimations respectively.

$$\hat{\lambda}_{it} = \frac{\phi\left(z'_{it}\beta^s + w'_{it}\beta^b\right)}{\Phi\left(z'_{it}\beta^s + w'_{it}\beta^b\right)} \tag{8}$$

where ϕ and Φ are the normal density and cumulative distribution functions. In a second step, consistent parameter estimates are achieved by including λ in the bid-level estimation

$$\ln b_{it} = x_{it}\beta^b + \beta_\lambda \hat{\lambda}_{it} + d'_{it}\beta^b + \varepsilon^b_{it} \tag{9}$$

where the error term ε^b_{it} has zero expectation and an observation-specific variance denoted by σ^2_{it}.The parameters of equation (7) and (9) are estimated using maximum likelihood.

Table A.4 reports results from estimating the bid-submission decision, using as dependent variable an indicator variable that takes the value one when a bid is observed and zero otherwise. The set of potential bidders is constructed in the following way. Firms that have submitted at least one bid during the investigated time period are considered. Information on where and when these firms have been active is then used to construct the binomial variable $SUBM_{it}$. For the bid-submission estimations, and for the resulting bid-level estimations two different specifications are reported: without firm-specific dummies and with a set of firm-specific dummies.

The literature on Heckman's selection procedure discusses the importance of an exclusion restriction, i.e. a variable that strongly affects the chances for observation but not the outcome under study.[23] In the present setting this means a variable that affect the bid-submission decision but not the bid level, conditional on the bid-level equation being correctly specified. The exclusion restriction used in the analysis is the dummy variable $INVIT$ that takes the value one if a firm gets an invitation to participate in an auction, and zero otherwise. The bid-level decision could of course be correlated with a prior invitation if the invited firms belong to a certain type. However, including firm-

[23] Formally an exclusion restriction is not necessary but then identification of the selection bias comes only from the functional form. Such results are more difficult to take seriously since the functional-form assumptions have no foundation in theory.

specific dummies for the firms that are usually invited should solve this potential problem. The variable is constructed using invitation lists provided by the RA. When there was no information on invited firms in the material, invitation lists for other auctions in the same region and the same year was used. When this was not possible the auction was dropped and not used in the estimations.

Turning first to the bid-submission estimations reported in columns (2) and (4). The results show that all coefficients have the expected sign. Firm-specific variables are important for the decision to submit a bid. The probability to submit a bid decreases with the own transportation distance and increases in competitors' transportation distance. Also, plant ownership increases the probability to submit a bid. As expected, the parameter in front of $INVIT$ is significant in both estimations. This result indicates that the probability of participating in an auction increases with a prior invitation.

Turning next to the bid-level estimations reported in columns (1) and (3). The results show no qualitative differences compared to the results found earlier in the paper. Also, the coefficient in front of Heckmans lambda is not significant in any of the two estimations. This result can have at least two explanations. One explanation is that estimated model is no good in correcting for selection bias, maybe because the exclusion restriction used in the analysis not only affects the submission decision, but also the bid-level decision. The other explanation may be that sample selection bias is not an issue in the analysis. In any case, using the model may create more problem than it solves. The analysis in the next section will therefore be based on the OLS estimations.

5.3 Test for Conditional Independence

To test the hypothesis of conditional independence Spearman's rank correlation test is used.[24] For each firm a vector of residuals is constructed based on the bid-level estimation presented in column (4) in Table A.3. in appendix. The residuals in each vector are ranked by putting the values of the residuals in

[24] See e.g. Altman (1991) for an explanation of the test.

order and numbering them: the lowest value is given rank 1, the second lowest value is given rank 2 etcetera. The Spearman correlation coefficient is used as a measure of linear relationship between the two sets of ranked residuals. The coefficient is calculated as

$$r_s = 1 - 6\left[\frac{\Sigma d_i^2}{n\left(n^2-1\right)}\right] \tag{10}$$

where d_i is the difference in rank between the value of the i:th residual and n is the number of residuals ranked. The correlation coefficient takes a value between -1 and +1. If the correlation is close to zero there is no correlation between the ranks. The test is carried out under the null hypothesis that firms behave conditionally independent, i.e. that residuals should not be correlated. The null can be rejected when the calculated p-value is low. In comparison with other tests of correlation the Spearman Rank Correlation test behaves well when the correlation is not linear.

The analysis carried out is restricted to include only those firms that have submitted at least 20 bids simultaneously with another firm. The Spearman Rank correlation coefficients and the number of simultaneous bids are presented in Table 2 below.

Table 2. Spearman's Correlation Coefficients and Simultaneous Bids

Firms	n	r_s	p-value	Firms	n	r_s	p-value
$(8, 26)$	22	$-.042$	.852	$(30, 43)$	41	$-.027$	.865
$(8, 44)$	21	$-.030$	.898	$(30, 44)$	73	$-.530^{***}$	.000
$(14, 26)$	74	$-.169$	.150	$(30, 50)$	35	.040	.819
$(14, 43)$	68	.029	.817	$(30, 55)$	64	$-.340^{***}$	.006
$(14, 44)$	74	$-.163$	.165	$(32, 44)$	28	$-.535^{***}$	.003
$(14, 50)$	56	$-.095$	.488	$(32, 55)$	24	.014	.949
$(14, 55)$	68	$-.223$	.067	$(33, 37)$	55	$-.063$	.648
$(19, 26)$	37	$.335^{**}$	.043	$(33, 44)$	168	$-.308^{***}$	.000
$(19, 44)$	33	$.673^{***}$	.000	$(33, 49)$	21	.165	.475
$(19, 50)$	26	$-.590^{***}$	.002	$(33, 55)$	161	$-.066$	.403
$(19, 55)$	33	$-.592^{***}$	.000	$(37, 43)$	62	$-.126$	.331
$(21, 26)$	56	$-.361^{***}$	.006	$(37, 44)$	151	$-.325^{***}$	.000
$(21, 33)$	43	$-.214$	.169	$(37, 50)$	41	$-.399^{***}$	.010
$(21, 44)$	55	$.355^{***}$	.008	$(37, 55)$	111	$-.007$	.946
$(21, 55)$	56	$-.058$	.673	$(43, 44)$	222	.025	.713
$(26, 30)$	73	$-.438^{***}$	.000	$(43, 49)$	24	$-.483^{**}$	.017
$(26, 32)$	28	$-.643^{***}$	.000	$(43, 50)$	172	.055	.473
$(26, 33)$	169	$-.259^{***}$	.001	$(43, 55)$	198	$-.496^{***}$	.000
$(26, 37)$	155	$-.207^{***}$	.010	$(44, 49)$	51	$-.701^{***}$	.000
$(26, 43)$	226	$-.053$	.431	$(44, 50)$	211	$-.203^{***}$	.003
$(26, 44)$	512	$.282^{***}$	.000	$(44, 55)$	442	$-.264^{***}$	.000
$(26, 49)$	50	$-.358^{***}$	.011	$(49, 50)$	23	$-.325$	.130
$(26, 50)$	213	$-.320^{***}$	.000	$(49, 55)$	51	$-.170$	.232
$(26, 55)$	444	$-.235^{***}$	.000	$(50, 55)$	195	$-.039$	.584
$(30, 37)$	22	$-.413^{**}$	.050				

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

The table reports the following results. Among all the 49 pairs which have at least 20 simultaneous bids, the hypothesis of conditional independence can be rejected for as many as 26 pairs at the 5-percent level of significance. These firm pairs are marked with stars in the table. Some of the firms represented in the tests presented above only bid against each other three or four times each year.[25] Such infrequent bidding should make it difficult to keep a cartel stable. This is the case for firms (19,50) and (30,37). When eliminating these firms from the list correlation is observed for 24 firm-pairs.

Negative correlation is observed for 20 out of these firm-pairs and positive correlation for four firm-pairs. A total of twelve firms show correlation correlation at least once when tested together with another firm.[26] Further, twelve

[25] In this analysis consideration is only taken to the auctions carried out by the RA. It is likely that the firms meet more than 3 or 4 times a year when also considering auctions carried out by municipalities and by the private sector.

[26] These firms are: 19, 21, 26, 30, 32, 33, 37, 43, 44, 49, 50 and 55.

firms show negative correlation and four firms show positive correlation. As argued earlier in the paper negative correlation and negative and positive correlation in combination could, given that the empirical specification is correct, be consistent with a bid rigging scheme.

All of the twelve firms, except for firm 19, 32 and 49, belong to the 10 largest firms in the industry. The three largest firms in the industry, firm 26, 44 and 55, show up between five and ten times in the tests. Firm 26 and 44 are represented in the tests with both negative and positive correlation.

It is also interesting to calculate correlation coefficients for each year individually. One reason is that keeping a cartel stable for several years is more difficult than for a shorter time period. If a potential cartel is active only a limited time period the results from testing the whole time period could be misleading.

The hypothesis of conditional independence is therefore tested for each year separately, for firms that have submitted at least 10 bids simultaneously with another firm during the year. The results are presented in tables A.5-A.15 in appendix. Significant correlation can be observed every year except for 1999 and 2002.[27] Further, the results show that a total of 11 firms are represented with significant negative correlation, at the 5-percent level, at least once.[28] All firms, except firms 14 and 25, are represented in the tests using the whole period presented above. All the largest firms in the industry are represented in this group. The three largest firms, firm 26, 44 and 55 are individually represented every year, with two exceptions. These firms show negative and positive correlation both together with other firms and within the group.

In the data, larger contracts get fewer bids than smaller contracts since fewer firms have the capacity to carry out the larger projects. Arguably it is therefore easier to keep a cartel stable that focuses on larger contracts. To test the hypothesis of conditional independence on the larger contracts Spearman's correlation coefficients have been recalculated for contracts of a value of 10 million SEK and above. Out of the total of 536 contracts, 90 contracts have

[27] In two of the five regions data is missing for year 2002. In 1999 the number of observations is low but as far as I am aware there should not be any missing observations.

[28] These firms are: 14, 21, 25, 26, 30, 33, 34, 37, 43, 44, 49, 50 and 55.

a value of 10 million SEK or more. The three largest firms bid frequently on these contracts. They individually participate in more than 69 out of the 90 contracts. A larger group of seven firms participate in between 20 and 30 out of these 90 auctions. The results are presented in table A.16 in appendix and suggest that the hypothesis of conditional independence can be rejected for a number of seven firm pairs. All of them belong to the group of largest firms in the industry.

Among the nine firms that are accused of bid rigging by the SCA, only one do not show up in the tests presented above. This firm is small and active locally why there is no information on its bidding in the data.

Six firms not accused of participating in the collusive scheme are represented in the tests presented above, these are firms 14, 19, 25, 32, 43 and 50. Looking closer at some of these firms reveal some interesting features. Until 1997 firm 50 was active as a subsidiary to firm 33. After this data the firm was fully incorporated into firm 33. During this time the two firms never competed for the same contracts. It is therefore plausible that firm 50, interchangeably with firm 33, could have taken part in the alleged collusive behaviour.[29] In the correlation tests firm 50 show up together with firms 19, 26, 37 and 44. Further, firm 14 was active in the market until March 1997 when it was taken over by firm 44. Arguably, the two firms would have benefited from collaborating even before the aquisition took place. Also, firm 43 was active until 1997 when it was taken over by firm 26. Also these firms could have benefited from collaborating before the aquisition.

Summing up, the tests of conditional independence give the following results. In total there is a group of eight firms that show up with negative correlation both when testing calculating correlation coefficients on the whole material and when testing each year separately. The three largest firms in the industry, by and large, show up when calculating correlation coefficients for the whole material, and for every year tested separately. These firms are observed with

[29] Correlation tests have been carried out treating firm 33 and firm 50 as one single firm. The results show no major differences from the tests presented in this section.

negative and positive correlation both together and together with other firms. They have indivudually participated in at almost 85 percent of all auctions. In some cases, when projects are large, they are alone in competing. The fact that this small group meet regularly and sometimes not face outside competition, should make collusion both profitable and feasible. An interesting result from testing each year separately is that the hypothesis of conditional independence could not be rejected for any firm pairs in 2002. This could indicate that any previous collusive behaviour ended when the SCA investigation started in 2001. However, due to the missing data for that specific year this result should not be taken too seriously.

Being able to reject the hypothesis of conditional independence in such a large number of tests suggests that collusion may be widespread in the asphalt-paving industry. However, a serious drawback from testing the hypothesis of conditional independence is that it may in some cases be incorrectly rejected. This can happen if firm- or auction-specific cost differences are not completely controlled for. As an example, consider two firms bidding on a contract, one with spare capacity and one with no capacity left. The first firm bids low since it is anxious to win the contract, and the firm with no available capacity bids high. If differences in capacity are not controlled for, we may be misled to believe that one firm have submitted a low bid and one firm a high bid, which may be the result of collusive agreements. The estimations suggest that there might be firm-specific information that is not controlled for in the analysis. However, by including firm-specific dummies in the estimations this problem should diminish. Particularly when looking at each year separately firm-specific dummies should arguably to a large extent control for the differences between firms.

Possibly, negative correlation could also be the result of dependence among certain firms. Firms that e.g. do not have access to their own production plants are forced to buy asphalt at prices offered by the sellers. If the aim of the selling firm is to win an auction this can be made sure by offering asphalt at very high prices. As a result the selling firm will bid low at the same time as the asphalt-buying firm must bid high due to the high input price it faces. However, the firms frequently represented in the tests presented above have their own plants. This suggests dependence among firms, at least in this aspect, not to be important in explaining the existence of negative correlation.

Potentially, a further drawback from testing for conditional independence is that it in theory is possible that the hypotesis of conditional independence cannot be rejected, even though firms collude. The bidding pattern can potentially be designed with the aim to hide the collusive scheme, i.e. create conditional independence. However, in the analyses of collusive behaviour referred to in this paper, see e.g. Porter and Zona (1993), (1999) and Bajari and Ye (2003), collusion was accompanied with failure of conditional independence.

A more serious flaw might be that the used method tests firm in pairs, while in reality cartels often consist of more than two firms. This is e.g. the case with the potential cartel active on the market analysed in this paper. As a concequence, the method may fail to reveal the full collusive pattern. However, developing methods to analyse bid rigging with more than two participants is left open for future research.

6 Conclusions

In this paper I set out to screen the Swedish ashalt-paving sector for collusive behaviour. A unique set of bid data, from asphalt paving auctions carried out by the RA during the 1990's, is used in the analysis. The existence of collusion in this auction market is plausible both since enough evidence is found by the SCA to initiate legal proceedings against a group of firms, and since the market is characterized by a number of features that facilitate collusion.

The collusive behavior analysed is bid rigging. The high participation rate, a group of firms have participated in almost 85 percent of the auctions, and the high average number of bids submitted at auctions, together support the choice of bid rigging as the appropriate collusive scheme to analyse, at least among the large firms in the industry.

This paper uses one strategy to sceen the market for collusive behavior. The used method can be a valuable tool for detecting departure from competitive behaviour. However, it cannot establish that a suspicious bid pattern is the result of illegal agreements. The focus is on differences in the bidding behaviour between cartel firms and non-cartel firms. If firms submit independent bids the unexplained part of the bids should not be correlated. The hypothesis of conditional independence is tested for firms in pairs for the whole available sample as well as for sub-samples of the data. More specifiacally, the test are carried out for each year, as well as for the larger projects separately. In several cases the hypothesis of conditional independence could be rejected.

The main findings are that a group of eight firms are frequently represented in the tests, both when using the full data set and when carrying out tests on yearly subsamples. This group of firms, except one, belong to the group of largest firms in the industry. Out of the nine firms charged with collusive behavior by the SCA, eight are represented with negative correlation in the test of conditional independence carried out in the paper. The three largest firms in the industry are frequently represented in the tests. These firms do not face outside competition when bidding for some of the larger projects.

The findings suggest that collusion maybe is widespread in the market and that at least the group of the three largest firms appear to be involved in bid-rigging activities. The results suggests further investigation of the asphalt-paving market.

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7 Appendix

Table A.1. Variable definitions

Variable	Definition
$RBID$	The (real) bid submitted at an auction
DRT	The distance between production plant and contract site, the own plant if there exist one in the region, if not, the closest in the region
DRC	The shortest competitor distance between contract site and production plant, the own plant if there exist one in the region, if not, the closest in the region
$RPLANT$	One if the firms has a production plant in the region where the auction takes place, zero otherwise
$MRBID$	The mean bid (real) value of a contract
FXX	One if firm XX is the bidder, zero otherwise
$INVIT$	One if the firm is invited to participate in an auction, zero otherwise
$SUBM$	One if the firm submit a bid at the auction, zero otherwise

Table A.2. Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Bid	2859	5.821	4.605	0.121	32.686
Mean bid per auction	2859	5.821	4.564	0.143	30.276
Distance	2859	242.056	324.774	2	5102.673
Distance of closest competitor	2859	128.530	134.729	2	1029.175
Plant ownership in the region	2859	0.654	0.476	0	1
Number of bids	536	5.345	1.333	2	10
Winning bid	536	5.082	4.048	0.121	25.736
Winning firms distance	536	223.477	277.698	4.123	2214.367

a. Bids are denoted in real term SEK.
b. Distance is denoted in kilometres.

Table A.3. Estimates on bid-level decisions

	(1)	(2)	(3)	(4)
LNDRT	0.063	0.021	0.064	0.016
	(0.016)***	(0.004)***	(0.020)***	(0.005)***
LNDRC	0.031	0.423	0.031	0.427
	(0.016)*	(0.041)***	(0.020)	(0.040)***
RPLANT	-0.044	-0.048	-0.045	-0.026
	(0.022)**	(0.005)***	(0.038)	(0.009)***
MRBID	0.166		0.165	
	(0.004)***		(0.004)***	
*F*14			0.024	-0.011
			(0.055)	(0.011)
*F*21			-0.015	0.002
			(0.065)	(0.015)
*F*26			0.014	-0.035
			(0.042)	(0.010)***
*F*30			0.119	0.024
			(0.058)**	(0.016)
*F*33			0.074	0.011
			(0.045)*	(0.013)
*F*37			0.111	-0.040
			(0.040)***	(0.013)***
*F*43			0.062	-0.009
			(0.040)	(0.012)
*F*44			0.014	-0.028
			(0.042)	(0.010)***
*F*50			-0.058	-0.025
			(0.043)	(0.009)***
*F*55			-0.013	-0.020
			(0.036)	(0.009)**
CONST	0.042	-1.923	0.029	-1.906
	(0.041)	(0.244)***	(0.048)	(0.238)***
Auction dummies		Yes		Yes
R^2	0.76	0.99	0.76	0.99
N	2859	2859	2859	2859

a. Dependent varibale is *LNRBID*.
b. White's Heteroskedasticity-robust standard errors in parenthesis.
c. ***, ** and * denotes significance at the 1, 5 and 10 percent levels respectively.

Table A.4. Estimates on bid-submission decisions and bid levels

	(1)	(2)	(3)	(4)
$LNDRT$	0.021	-0.654	0.017	-0.285
	(0.004)***	(0.046)***	(0.004)***	(0.062)***
$LNDRC$	0.423	0.374	0.427	0.095
	(0.037)***	(0.076)***	(0.036)***	(0.106)
$RPLANT$	-0.047	2.010	-0.030	1.181
	(0.010)***	(0.064)***	(0.009)***	(0.106)***
$INVIT$		3.292		2.721
		(0.138)***		(0.131)***
$F14$			-0.012	0.161
			(0.010)	(0.100)
$F21$			0.001	0.235
			(0.013)	(0.104)**
$F26$			-0.040	2.362
			(0.012)***	(0.164)***
$F30$			0.021	0.515
			(0.015)	(0.100)***
$F33$			0.010	0.136
			(0.013)	(0.098)
$F37$			-0.038	0.261
			(0.013)***	(0.085)***
$F43$			-0.016	2.071
			(0.012)	(0.097)***
$F44$			-0.034	2.210
			(0.013)***	(0.154)***
$F50$			-0.030	1.380
			(0.011)***	(0.097)***
$F55$			-0.026	1.846
			(0.012)**	(0.089)***
Heckmans λ	0.001		-0.006	
	(0.010)		(0.008)	
$CONST$	-1.924	-1.933	-1.897	-1.954
	(0.220)***	(0.189)***	(0.215)***	(0.272)***
Auction dummies	Yes	Yes	Yes	Yes
Log pseudolikelihood	-135.0812		513.5746	
N	9817		9817	

a. Dependent variable in the bid-submission estimations is $SUBM$.

b. White's Heteroskedasticity-robust standard errors in parenthesis.

c. ***, ** and * denotes significance at the 1, 5 and 10 percent levels respectively.

Table A.5. Year 1992: Spearman's Rank Correlation Coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(8, 26)	10	0.139	0.701	(26, 55)	30	−0.118	0.536
(14, 26)	16	0.085	0.754	(37, 43)	20	−0.011	0.965
(14, 43)	13	−0.258	0.394	(37, 44)	27	−0.636***	0.000
(14, 44)	14	0.512	0.061	(37, 50)	10	−0.139	0.701
(17, 26)	14	−0.266	0.358	(37.55)	16	0.415	0.110
(17, 44)	12	−0.308	0.331	(43, 44)	28	−0.376**	0.049
(26, 37)	31	−0.686***	0.000	(43, 55)	17	−0.260	0.314
(26, 43)	32	−0.280	0.120	(44, 50)	18	0.241	0.337
(26, 44)	55	0.382***	0.004	(44, 55)	27	−0.669***	0.000
(26, 50)	17	0.632***	0.006	(50, 55)	10	−0.249	0.489

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.6. Year 1993: Spearman's Rank Correlation Coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(8, 26)	12	−0.007	0.983	(26, 50)	29	−0.233	0.224
(8, 44)	12	−0.147	0.649	(26, 55)	34	−0.260	0.138
(14, 26)	20	0.469**	0.037	(30, 44)	11	−0.064	0.853
(14, 43)	19	0.291	0.226	(43, 44)	33	0.033	0.856
(14, 44)	22	0.179	0.425	(43, 50)	23	−0.126	0.568
(14, 50)	16	0.638***	0.008	(43, 55)	27	−0.794***	0.000
(14, 55)	21	−0.738***	0.000	(44, 50)	28	−0.033	0.868
(26, 30)	11	0.018	0.958	(44, 55)	35	−0.427***	0.011
(26, 43)	33	−0.253	0.155	(50, 55)	24	0.083	0.701
(26, 44)	43	0.382***	0.012				

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.7. Year 1994: Spearman's Rank Correlation Coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(26, 43)	35	−0.035	0.842	(43, 50)	32	0.354**	0.047
(26, 44)	41	0.424***	0.006	(43, 55)	34	−0.461***	0.006
(26, 50)	37	−0.307	0.065	(44, 50)	37	−0.456***	0.005
(26, 55)	40	−0.375**	0.017	(44, 55)	40	−0.300	0.061
(43, 44)	35	−0.198	0.276	(50, 55)	37	0.005	0.976

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.8. Year 1995: Spearman's Rank Correlation Coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
$(14, 26)$	17	-0.010	0.970	$(30, 50)$	18	-0.177	0.484
$(14, 43)$	17	-0.022	0.933	$(30, 55)$	20	-0.517^{**}	0.020
$(14, 44)$	17	-0.289	0.260	$(37, 43)$	13	-0.209	0.494
$(14, 50)$	14	-0.398	0.159	$(37, 44)$	13	0.429	0.144
$(14, 55)$	17	-0.096	0.715	$(37, 55)$	13	0.319	0.289
$(19, 26)$	10	-0.067	0.855	$(43, 44)$	67	-0.069	0.578
$(19, 55)$	10	-0.394	0.260	$(43, 49)$	13	-0.599^{**}	0.031
$(26, 30)$	20	-0.320	0.169	$(43, 50)$	58	0.039	0.772
$(26, 37)$	13	0.566^{**}	0.044	$(43, 55)$	66	-0.272^{**}	0.047
$(26, 43)$	67	-0.339^{***}	0.005	$(44, 49)$	14	-0.675^{***}	0.008
$(26, 44)$	73	0.254^{**}	0.030	$(44, 50)$	61	0.073	0.577
$(26, 49)$	13	-0.445	0.128	$(44, 55)$	72	-0.226	0.056
$(26, 50)$	63	-0.338^{***}	0.007	$(49, 50)$	12	-0.252	0.430
$(26, 55)$	73	-0.069	0.563	$(49, 55)$	14	0.147	0.615
$(30, 43)$	20	0.379	0.099	$(50, 55)$	62	0.041	0.751
$(30, 44)$	20	-0.337	0.146				

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.9. Year 1996: Spearman's Rank Correlation Coefficients

$Firms$	n	r_s	$p-value$	$Firms$	n	r_s	$p-value$
$(26, 37)$	10	-0.139	0.701	$(43, 44)$	36	0.533^{***}	0.001
$(26, 43)$	36	0.479^{***}	0.003	$(43, 50)$	33	0.142	0.430
$(26, 44)$	43	0.601^{***}	0.000	$(43, 55)$	32	-0.370^{**}	0.037
$(26, 50)$	39	-0.470^{***}	0.003	$(44, 50)$	39	-0.341^{**}	0.034
$(26, 55)$	39	-0.435	0.006	$(44, 55)$	40	-0.193	0.234
$(37, 43)$	10	-0.249	0.489	$(50, 55)$	35	-0.100	0.568
$(37, 44)$	10	-0.139	0.701				

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.10. Year 1997: Spearman's Rank Correlation Coefficients

$Firms$	n	r_s	$p-value$	$Firms$	n	r_s	$p-value$
$(14, 26)$	10	-0.651^{***}	0.038	$(37, 44)$	12	-0.350	0.265
$(14, 44)$	10	-0.636^{***}	0.048	$(37, 55)$	11	0.227	0.501
$(14, 55)$	10	0.394	0.260	$(43, 44)$	23	0.063	0.774
$(26, 37)$	12	0.126	0.697	$(43, 50)$	18	0.022	0.932
$(26, 43)$	23	0.096	0.664	$(43, 55)$	22	-0.348	0.112
$(26, 44)$	40	0.551^{***}	0.000	$(44, 50)$	28	-0.524^{***}	0.004
$(26, 50)$	28	-0.686^{***}	0.000	$(44, 55)$	39	-0.350^{***}	0.029
$(26, 55)$	39	-0.640^{***}	0.000	$(50, 55)$	27	-0.012	0.954
$(37, 43)$	12	0.196	0.542				

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.11. Year 1998: Spearman's Rank Correlation Coefficients

$Firms$	n	r_s	$p-value$	$Firms$	n	r_s	$p-value$
$(21, 26)$	21	-0.007	0.978	$(26, 55)$	69	-0.223	0.065
$(21, 33)$	16	-0.227	0.400	$(30, 44)$	12	-0.455	0.138
$(21, 44)$	19	0.779^{***}	0.000	$(30, 55)$	11	-0.509	0.110
$(21, 55)$	21	-0.309	0.173	$(37, 44)$	30	0.026	0.893
$(26, 30)$	12	-0.308	0.331	$(37, 55)$	21	-0.243	0.289
$(26, 33)$	55	-0.454^{***}	0.001	$(44, 49)$	11	-0.364	0.272
$(26, 37)$	31	-0.121	0.515	$(44, 50)$	66	-0.378^{***}	0.002
$(26, 44)$	76	0.464^{***}	0.000	$(49, 55)$	12	0.294	0.354
$(26, 49)$	12	0.000	1.000				

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.12. Year 1999: Spearman's Rank Correlation Coefficients

$Firms$	n	r_s	$p-value$	$Firms$	n	r_s	$p-value$
$(26, 32)$	10	-0.006	0.987	$(32, 44)$	10	0.042	0.907
$(26, 33)$	21	-0.082	0.724	$(33, 44)$	21	-0.138	0.552
$(26, 44)$	22	0.062	0.786	$(33, 55)$	20	-0.050	0.835
$(26, 55)$	21	0.123	0.594	$(44, 55)$	22	-0.190	0.396

Table A.13. Year 2000: Spearman's Rank Correlation Coefficients

$Firms$	n	r_s	$p-value$	$Firms$	n	r_s	$p-value$
$(21, 26)$	20	-0.212	0.370	$(26, 55)$	48	0.075	0.614
$(21, 33)$	16	-0.462	0.072	$(30, 44)$	10	-0.552	0.098
$(21, 44)$	21	-0.283	0.214	$(33, 47)$	44	-0.209	0.158
$(21, 55)$	20	0.006	0.980	$(33, 55)$	46	-0.267	0.073
$(26, 33)$	46	-0.030	0.845	$(34, 44)$	14	-0.714^{***}	0.004
$(26, 34)$	14	0.266	0.358	$(37, 44)$	11	-0.173	0.612
$(26, 37)$	11	-0.436	0.180	$(44, 55)$	52	-0.118	0.403
$(26, 44)$	61	-0.141	0.279				

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.14. Year 2001: Spearman's Rank Correlation Coefficients

$Firms$	n	r_s	$p-value$	$Firms$	n	r_s	$p-value$
$(21, 26)$	12	-0.706	0.010	$(26, 55)$	36	-0.295	0.080
$(21, 33)$	10	-0.285	0.425	$(33, 35)$	14	-0.407	0.149
$(21, 44)$	12	0.532	0.075	$(33, 37)$	19	0.221	0.363
$(21, 55)$	12	0.189	0.557	$(33, 44)$	30	-0.181	0.339
$(25, 26)$	10	-0.673^{**}	0.033	$(33, 55)$	26	-0.654^{***}	0.000
$(25, 44)$	10	0.127	0.726	$(35, 44)$	14	-0.420	0.135
$(25, 55)$	10	0.139	0.701	$(35, 55)$	14	0.024	0.935
$(26, 33)$	30	-0.192	0.311	$(37, 44)$	23	-0.637^{***}	0.001
$(26, 37)$	23	-0.069	0.754	$(37, 55)$	16	-0.629^{***}	0.009
$(26, 44)$	43	-0.231	0.136	$(44, 55)$	36	0.257	0.130

a. *** and ** denotes significance at the 1 and 5 percent levels respectively.

Table A.15. Year 2002: Spearman's Rank Correlation Coefficients

$Firms$	n	r_s	$p-value$	$Firms$	n	r_s	$p-value$
(26, 33)	14	0.182	0.533	(33, 44)	15	−0.275	0.321
(26, 37)	12	0.552	0.063	(33, 55)	13	−0.539	0.058
(26, 44)	15	0.046	0.870	(37, 44)	13	0.006	0.986
(26, 55)	12	−0.378	0.226	(37, 55)	11	−0.073	0.832
(33, 37)	13	−0.071	0.817	(44, 55)	10	0.423	0.150

Table A.16. Large projects: Spearman's Rank Correlation Coefficients

$Firms$	n	r_s	$p-value$	$Firms$	n	r_s	$p-value$
(14, 26)	10	−0.479	0.162	(30, 55)	20	−0.266	0.257
(21, 26)	20	−0.099	0.677	(33, 44)	24	-0.475^{***}	0.019
(21, 33)	14	0.165	0.573	(33, 55)	26	0.177	0.388
(21, 44)	12	0.173	0.454	(37, 43)	13	0.006	0.986
(21, 55)	20	−0.096	0.687	(37, 44)	27	0.107	0.594
(26, 30)	23	-0.458^{**}	0.028	(37, 50)	12	−0.336	0.286
(26, 33)	24	0.1157	0.591	(37, 55)	11	−0.013	0.949
(26, 37)	25	0.232	0.264	(43, 44)	28	0.448^{**}	0.017
(26, 43)	29	0.109	0.572	(43, 50)	23	−0.247	0.256
(26, 44)	62	0.394^{**}	0.002	(43, 55)	26	-0.603^{***}	0.001
(26, 49)	12	−0.559	0.059	(44, 49)	13	-0.791^{***}	0.001
(26, 50)	22	−0.383	0.078	(44, 50)	24	−0.277	0.191
(26, 55)	60	0.245	0.059	(44, 55)	60	0.044	0.738
(30, 43)	17	0.108	0.680	(49, 55)	13	0.077	0.803
(30, 44)	21	-0.669^{***}	0.001	(50, 55)	22	0.189	0.399
(30, 50)	14	−0.068	0.817				

a. Includes contracts with a (real) value of 10 million SEK or more.

b. *** and ** denotes significance at the 1 and 5 percent levels respectively.