Bid Rigging in Swedish Procurement Auctions*

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February 1, 2007

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 correlates between firms. If negative correlation is observed, one possible explanation is bid rigging. The overall results 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

*I would like to thank Matias Eklöf, Jan-Eric Nilsson, Pehr-Johan Norbäck, Mats Bergman and seminar participants at Stockholm University, the Swedish National Road and Transport Research Institute (VTI), the Infer Workshop on Competition Policy in the Transport Sector, the spring 2004 meeting with the International Competition Network in Sweden (Icon), and the ACLE Workshop on Forensic Economics in Competition Law Enforcement for valuable comments and suggestions on earlier versions of this paper. I would also like to thank Markus Rudling for excellent research assistance in collecting the data set, and several staff members at the National Road Administration for helping me understand the paving market. I gratefully acknowledge financial support from the Swedish Competition Authority and the Swedish National Road and Transport Research Institute (VTI). Special thanks to Christina Lönnblad for editorial assistance. The author is responsible for all errors.

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1 Introduction

Collusion amongst bidders may be a serious problem in many procurement auctions. Despite the fact that suspicions about collusion often exist, lack of evidence normally makes legal action difficult. Both antitrust authorities and researchers work at finding 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 a deterrence mechanism.

In this paper, the aim is to analyse the existence of collusive behaviour in the Swedish construction sector. A simple tool, introduced 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 independent of their competitors, 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 appearance 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 differ between markets and the methods for detection 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 of colluding may be bid suppression, 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 rigging. The data used in this paper indicates the average number of bids to be slightly above five.[1] The data also shows that the participation rate among the three largest firms in the industry exceeds 84 percent. Therefore, it is assumed that the appropriate collusive behaviour to investigate in the Swedish paving market

[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.

is bid rigging, at least among large firms.[2] Moreover, 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 one 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 of asphalt-paving auctions conducted by the Swedish National Road Administration (RA) during the 1990's. There are a number of reasons why it is interesting to analyse the paving market. At the beginning of 2003, the Swedish Competition Authority (CA) 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 are accused of limiting competition by making illegal agreements on territories and bids.[3] This still-ongoing case is the largest competition case in Swedish history. The CA has imposed that the firms should be given administrative fines amounting to approximately SEK 1.2 billion.[4] In 2007, the case will be decided in court.

Moreover, the market for asphalt paving is characterised by a number of collusion markers, e.g. firms only compete 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 different regions separately. The main findings are that the hypothesis of conditional independence can be rejected for a group of nine firms, both when using the whole available material and when testing each year and each region separately. All 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 CA, eight are

[2] The assumption of bid rigging is at least partly supported by the CA's cartel files. According to the ongoing investigation, colluding firms have agreed on both a bid-rigging and a bid-suppression behaviour.

[3] Eleven firms were initially accused of cooperating. However, since three of these firms belong to the same group, they are treated as one firm in the analysis carried out in this paper. In addition, in the course of the investigations, charges have been dropped against one firm, which is small and locally active, and one firm has gone bankrupt.

[4] Approximately USD 170 million.

represented with significant correlation in the tests[5]. Seven out of the nine firms are represented at least once every year and in every region, with a few exceptions, while the three largest firms often show up several times each year and in every region. The overall results indicate that collusion may be widespread in the industry and that at least the group of the three largest firms is potentially involved in bid-rigging activities. However, any test for collusion suffers from limitations, e.g. it is not possible to establish that a suspicious bid pattern is the result of illegal agreements; the same bid pattern may possibly be observed from tacit collusion. The results should be used with care as a first tool to determine if collusive behaviour may have occurred and if further investigation is warranted.

The contribution of this paper is twofold. First, the compilation of a unique set of data material gives new important insights into 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. The test results found in this paper point at the same group of firms as the one accused of collusive behaviour by the CA. The results also show that the larger firms are frequently represented with significant correlation in the tests. This is in line with the cartel investigation suggesting that the larger firms have had a leading role in the collusive behaviour, and that at least these firms have submitted collusive bids, while the smaller firms have abstained from bidding to a larger extent. Thus, the results support the view that the method used is a 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, 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-

[5] The data contains no information on the ninth firm. Also, the charges against this firm was later dropped.

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 the ranking of bids for non-cartel firms to 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 cartel firms. Also in their 1999 paper do 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 of 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 no strong conclusion is drawn due to the insufficient control for firm-specific differences.

The use of structural estimation techniques is growing in this line of research. 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 exists, 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 better fits the data than the competitive model. Bajari and Ye (2003) use bid data from highway-construction auctions and start by 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. Furthermore, for a comprehensive review of the literature on cartel detection, see Harrington (2004).

The remainder of this paper is structured as follows. A theoretical framework is presented in Section 2. Section 3 reveals the characteristics of the Swedish asphalt-paving market and discusses why collusion may exist in this market. The data and the empirical specification are discussed in section 4. In Section 5, the estimation and the 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 which is paid its bid.[6] 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.[7] This way of modelling bidding behaviour seems reasonable when it comes to the paving industry, since differences in

[6] 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 on Bajari and Ye (2003).

[7] 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.

production costs mainly seem to be firm specific.[8] All firms are furthermore assumed to be risk neutral. The model allows for asymmetries among bidders, i.e. the distributions from which costs are randomly drawn do not have to be identical across firms.[9] 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 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

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

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.

[8] 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).

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

The equilibrium properties of this model are well established in the theoretical literature. If the following 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, which can be solved by numerical methods, see e.g. Bajari and Ye (2003).

1. for all i, the cost distribution, $F_i(c_i)$ has support on $[\underline{c}, \overline{c}]$. The probability density function $f_i(c_i)$ is continuously differentiable in c_i

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

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 implies that after controlling for all information on costs that is publicly observable, firms should submit independent bids. In this paper, the hypothesis of conditional independence is tested to investigate if a given distribution of observed bids is consistent with the model of competitive bidding. If it is not, collusion may be one explanation.

Following Bajari and Ye, it is assumed that each firm's 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. 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. Vector z_i includes 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 the error term to be normally distributed with $E(\varepsilon) = 0$ and $VAR(\varepsilon) = \sigma^2$, implies that the distribution of costs is determined by the vector of parameters, $\theta = (\beta_1, \beta_2, \sigma^2)$, identical for all firms and z_i.

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 it does not hold, collusive behaviour may be one explanation. If collusion is explicit, one firm may be designated to win the auction and the others to submit higher bids to create an appearance of competition. Rigged bids are not necessarily a function of costs and may therefore be correlated conditional on z. However, correlated bids may also be the result of tacit collusion. The test for conditional independence cannot determine if the observed bidding pattern is the result of illegal agreements.

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 predicted bid level, using publicly available information. If the residuals are randomly distributed, the hypothesis of conditional independence cannot 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 results from one bid being systematically lower, and one bid being systematically higher than what is 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. However, another plausible explanation for positive correlation could arguably be collusive behaviour with more than two participating firms. Consider three firms taking turns submitting the low bid. The low bid will turn out to be 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 to be higher than what is predicted by the model and will therefore be positively 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 has been compiled; Skåne, Syd-Ost, Väst, Mälardalen and Stockholm. Every year, each region independently solicits bids for paving contracts. The auctions are normally held in early spring, with some exceptions[10], and the actual work is carried out during the season when the weather allows it, i.e. from May until October.[11]

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

[11] Occasionally, paving work can be carried out as late as in December.

All paving contracts are awarded through first-price sealed-bid auctions. All firms submit sealed bids and, with very few exceptions, the contract is awarded to the lowest bidder. 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 cancel the project, this rarely happens in practice. An important aspect concerning the contracts used in this paper is that several contracts, up to 15, can be 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 time period investigated.[12] It is also possible for firms to offer alternative bids, i.e. present alternative solutions to how to carry out a specific project.[13] During the time period investigated, 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 buyers is that if alternative bids provide good value for money they should be considered.

Relevant aspects of the asphalt-paving market are the following. The major input in producing asphalt is gravel. Larger firms typically produce their own gravel, while smaller firms must buy their gravel elsewhere. This also holds for asphalt production; larger firms are equipped with asphalt-production plants, and smaller ones 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 whether 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 span of warm asphalt is short. The time from cooking until the asphalt must be spread is short. Consequently, the asphalt cannot be transported long

[12] When submitting combinatory bids, firms always also submit independent bids.
[13] Alternative bids are found in approximately five percent of the auctions.

distances, on average not more than 80 kilometres.[14] Asphalt is normally spread in two or three layers, each layer having its own specific characteristics.

In October 2001, the CA received indications of collusive behaviour in this industry. Former employees of one of the firms stepped forward and witnessed on the existence of illegal agreements among firms. Shortly after, a "dawn raid" was made on a number of firms in the industry. Legal proceedings were initiated against nine firms in March 2003.[15] In the view of the CA, the nine firms have, at least since 1993, cooperated over asphalt contracts. More specifically, they are suspected of having made agreements concerning prices and geographic market division. The larger firms in the industry are supposed to have had a leading role in the cartel. At least, these firms are supposed to have submitted collusive bids, while the smaller firms are supposed to have either abstained from bidding or submitted predetermined bids in return for side payments. The fines that the CA has petitioned that the firms should pay amount to approximately SEK 1.2 billion.

There are a number of features in the Swedish road-construction industry that facilitate collusion.[16] Firms to a large extent only compete 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, 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 year's 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 at the beginning of the 90's changed the market structure. Many small and middle-sized firms went bankrupt or

[14] According to representatives of the RA.
[15] Swedish Competition Authority (2003).
[16] See Tirole (1988) and Porter and Zona (1993, 1999) for a general discussion on characteristics facilitating collusion.

were acquired 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 are typically vertically integrated 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 the level of homogeneity is higher within each group. All firms use the same production process that is to a large extent specified in detail in the contract. Bitumen, the oil-based substance that binds the asphalt together, is almost exclusively supplied by one firm.[17] 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 uses 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 of limiting 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 contact facilitates collusive schemes with the aim of allocating 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 CA decided that it had to end. However, according to RA representatives, it is plausible that collaboration continued after it officially ended.

RA demand for asphalt paving seems to be fairly inelastic. Demand is

[17] The Swedish firm Nynäs produces and sells approximately 95 percent of the total bitumen demand in Sweden. In December 2004, the CA 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.

restricted by the funds for road maintenance distributed by the state every year. The market for asphalt paving, and road maintenance at large, has 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.[18] In total, the data set includes detailed information on 536 contracts during this period. The number of bids submitted on these contracts amount to 2860.[19]

The total value of contracts awarded during the period and included in the data set amounts to 2.7 billion SEK in real terms.[20] The contracts vary greatly 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 one 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 have together won over 90 percent of the

[18] There is no information on contracts in regions Stockholm and Mälardalen awarded later than 2001 in the data set used.

[19] A number of contracts could not be used, the main reason being that the relevant information was missing in the RA files. Moreover, the contracts carried out in the county of Gotland are not used in this dataset.

[20] The bids have been deflated using an appropriate index, the base year being 1990.

auctions in the data set. Three firms out of these 10 stand out. Firms 26, 44 and 55 together captured a revenue share of almost 65 percent. Moreover, 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 for which a firm submits a bid 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 have 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 affecting 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. Moreover, differences in the capacity utilisation rate may be an important factor in explaining cost differences between firms. Firms with capacity constraints may have higher costs, in the sense of first-order stochastic dominance, than firms without constraints.

In the empirical analysis, two distance variables will be used, DRT and $DRTC$.[21] The variable DRT_{it} represents the sum of the distances from each

[21] The variables were constructed using information on asphalt-plant and project location.

road included in contract t to firm i's closest plant.[22] When constructing DRT, the fact that asphalt can only be transported for a limited time is considered. Firms without a plant sufficiently close to the site therefore need to buy from other producers. Bidders with a plant in the region are assumed to take asphalt from that plant, if there is no plant outside the region that is closer. Bidders without plants in the region are assumed to acquire their asphalt from the plant in the region closest to the site. Although almost all larger firms produce their own asphalt, this is not the case for smaller firms. Some of the smaller firms do not have a production plant in any of the five regions investigated. The variable $DRTC_{it}$ 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 constructed in a similar manner to the variable DRT discussed above. In the analysis, the distance variables will be used in logarithm form.

Potentially, there are problems with how the distance variables are constructed. First, there is no information at all on small mobile plants. Consequently, some of the distances used in the analysis are too long. However, since using a mobile plant is more expensive than using a permanent plant, the longer distances can be seen as proxies for the 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. These firms may in reality use mobile plants, or buy their asphalt from another plant further away from the site, which may have the effect that the measured distance is too short.

Following the above discussion, a measure of the capacity-utilisation rate is introduced in the analysis. A variable that measures the level of used capacity during each project period, $CAPU$, is constructed using the available information on project duration and contracts won. For each firm i, the monthly

RA representatives have been kind to provide information on the location of production plants. Information on project location was found in the contract protocols.

[22] The location coordinates of production plants and projects were manually collected using maps. Euclidean distances (as the crow flies) in kilometers were 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.

workload in terms of million SEK is found by dividing total contract value (i.e., the winning bid) by project duration in months, and summing over projects. The level of capacity used for each month is defined as the ratio of the monthly workload to the maximum monthly capacity for that particular year. Finally, to get the level of used capacity for each project period, the average is taken over the monthly levels of used capacity. The bid level may not only depend on the own use of capacity, but also the competitors' capacity-utilisation rate. To include this effect, the lowest of the competitors' capacity-utilisation levels is calculated and represented by $CAPUC$ in the analysis.

The capacity measures are based on contracts exclusively tendered by the state while the bidding firms also carry out work for municipalities and the private sector. Consequently, the capacity variables may not be reliable measures of the actual use of capacity. Note also that the capacity-utilisation rate could be considered to be endogenous, since it is determined by previous bidding behaviour. Moreover, as discussed above, the procurements are generally carried out during a short period of time at the beginning of each year and the winner is usually not announced before other bids are to be submitted. This implies that the capacity utilisation rate is generally unknown and therefore potentially unimportant for the bidding behaviour. Nevertheless, the two capacity variables discussed above will be included in some of the estimated specifications.

To further control for bidder asymmetries, a dummy variable, $RPLANT$, is used in the analysis. $RPLANT_i$ takes the value of one when firm i is the owner of an asphalt plant in the region where the contract is carried out, and zero otherwise. In line with the discussion on distance variables, the construction of plant dummies takes the importance of location into account. It is not sufficient to own a plant to benefit from cost advantages, it must be situated sufficiently close to the project site. 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. Due to the difficulties in homogenising this information, it will no be used to any large extent in the analysis. However, two variables based on auction-specific information will be included in the analysis, $LENGTH$ and ADT. The first variable measures the total length of each contract in meters. This is done by summing over the lengths of the roads included in the contract. The second variable measures the wear and tear of the roads. The number of daily passages is measured for each road (in fact, the daily yearly average), and if more than one road is included in a contract, an average is taken over the roads to construct ADT. These variables will be used in logarithm form in the analysis. In addition to these auction-specific variables, an approximate measure of contract size is included in the estimations, $MRBID$. The mean contract bid value is calculated to obtain this variable. Due to the difficulties in using auction-specific information, auction-specific dummies are introduced in some of the estimations. This solution seems to be quite standard in the literature, see e.g. Porter and Zona (1993) and Bajari and Ye (2003). Table A.1 in the appendix provides variable definitions, and Table A.2 summary statistics of the variables used in the analysis.

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

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

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- and (in some estimations) auction-specific variables and ε^b_{it}, the residual representing private information which affects firm i's cost at auction t. The residual has zero expectation and an observation-specific variance denoted σ^2_{it}. The specification is estimated using Ordinary Least Squares (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 Tables A.3 and A.4 in the appendix. In total, eight specifications are presented. Auction dummies are included in the estimations presented in Table A.3 to control for auction-specific differences.[23] In Table A.4, $MRBID$ and additional auction-specific information are introduced instead of auction dummies, as an alternative specification. Focusing first on Table A.3, the results are the following: The distance variables $LNDRT$ and $LNDRTC$ have a positive impact on the bid level in all four estimations, i.e. the bid level increases both with the own transportation distance, and the distance of the closest competitor.

In columns (2) and (4), the capacity utilisation variables are introduced. In both estimations, the coefficient in front of $CAPU$, own capacity utilisation, is negative and significant in contrast to what was expected. One explanation for this result might be a low capacity-utilisation rate in combination with a cost function that is U-shaped with respect to capacity utilisation. The variable that measures the lowest capacity-utilisation level among competitors, $CAPUC$, is negative but not significant. Following the discussion in section 3, the capacity variables suffer from a number of drawbacks that most likely contribute to explain the unsatisfactory result for these variables.

The estimation results further show that the parameter estimate in front of $RPLANT$ is negative and significant, indicating that if a firm is the owner of a

[23] The joint significance of the auction dummies in each estimation is tested. The hypothesis of no joint significant effect from the auction dummies can be rejected. The test statistics are presented in Table A.3.

production plant in the region where the contract is carried out, the submitted bid will be lower than if this were not the case. The magnitude of the firm-specific variables does not change to any considerable extent 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.[24] Possibly, firm heterogeneity goes beyond what is captured with the firm-specific variables. Ideally, additional variables to control for bidder asymmetries should be included in the estimations.

Next, the results presented in Table A.4 show that when replacing the auction dummies with $MRBID$ and other auction-specific variables such as $LNADT$ and $LNLENGTH$, the results for the distance variables carry through in all four estimations. The parameter in front of $RPLANT$ is negative but lose its significance when firm-specific effects are included, in column (3) and (4).

For the capacity variables the results have changed significantly compared to the results presented in Table A.3. The own capacity utilisation level is positive in the specification presented in column (2) and negative in column (4), but the effect is not significant in either of the specifications. The competitors' level of used capacity, on the other hand, is positive and significant when included. Regional dummies are included in this set of estimations, and to a large extent they turn up significant. Moving on to the auction-specific variables, the results show that both $LNADT$ and $LNLENGTH$ are significant and have the expected sign. The size of the contract, approximated by $MRBID$, is significant in all four specifications. However, the hypothesis of no firm-fixed effects cannot be rejected in either of the specifications.[25]

[24] F tests have been carried out to test the joint significance of the ten firm-specific dummies. The null hypothesis of no firm-fixed effects could be rejected at the 5-percent level in both columns (3) and (4). The test statistic is F distributed and equals 4.14 and 3.32 for the two estimations respectively, with 2312 and 2306 degrees of freedom.

[25] F tests have been carried out to test the joint significance of the ten firm-specific dummies. The null hypothesis of no firm-fixed effects could not be rejected in either of the two columns (3) and (4). The test statistic is F distributed and equals 1.13 and 1.22 for the two estimations respectively, with 2086 and 2079 degrees of freedom.

5.2 Potential Sample-Selection Bias

Data reveals that not all eligible bidders participate in the bidding. On average five out of the invited ten 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. Heckman's two-step method (1976, 1979) will be used as an attempt to solve the potential selection bias.

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

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

where w'_{it} is a vector of observable firm-specific variables that affect the decision to submit a bid, i.e., distance and capacity variables. The vector z_{it} contains dummy variables; $RPLANT$, auction- and firm-specific variables, and an exclusion restriction needed to identify the model, are included. The error term is represented by ε^s_{it}. A bid from firm i in auction t will only be observed when the latent variable $SUBM^*_{it} > 0$. This is captured by the observable variable $SUBM_{it}$ which takes the value of 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

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

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

$$\ln b_{it} = x'_{it}\beta^x + \beta^\lambda \hat{\lambda}_{it} + d'_{it}\beta^d + \varepsilon^b_{it}, \quad (9)$$

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.5 reports results from estimating the bid-submission decision, using as the dependent variable an indicator variable that takes the value of 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 when and where these firms have been active is then used to construct the binomial variable $SUBM_{it}$. Two different specifications are reported for the bid-submission estimations, and for the resulting bid-level estimations: 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 strongly affecting the chances for observation but not the outcome under study.[26] In the present setting, this means a variable that affects 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 of one if a firm gets an invitation to participate in an auction, and zero otherwise. Naturally, the bid-level decision might be correlated with a prior invitation if the invited firms belong to a certain type. However, including firm-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 were used. When this was not possible, the auction was dropped and not used in the estimations.

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

First, I turn to the bid-submission estimations reported in columns (2) and (4). The results show that the coefficients in general have the expected sign. Firm-specific variables are important for the decision to submit a bid. The probability of submitting a bid decreases with the own transportation distance and increases in competitors' transportation distance. Plant ownership increases the probability of submitting a bid in column (2) but this effect is no longer significant when including the capacity variables. The own capacity utilisation rate is positive and significant, in contrast to what was expected. The bad quality of this variable discussed earlier might possibly explain this finding. The competitors' use of capacity is significant and positive, indicating that the more the competitors use their capacity, the higher will the submitted bid be. 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.

Next, I turn to the bid-level estimations reported in columns (1) and (3). The results show no large qualitative differences as compared to the results found earlier in the paper. In addition, the coefficient in front of Heckman's lambda is not significant in the estimation presented in column (1). In column (3), however, the parameter in front of lambda is negative and significant, but given that the only difference between the estimations is the inclusion of the capacity variable, which should not be trusted following the discussions in this and the previous section, I focus on column (1) [27] There can be at least two explanations to the fact that lambda is not significant. One explanation is that the estimated model is no good in correcting for selection bias, maybe because the exclusion restriction used in the analysis does not only affect the submission decision, but also the bid-level decision. Alternatively, the sample selection bias is not an issue in the analysis. In any case, using the model may create more problems than it solves. The analysis in the next section will therefore be based on the OLS estimations presented in the previous section.

[27] Several different specifications, with and without auction dummies, have been estimated without the results changing in any significant way.

5.3 Test for Conditional Independence

To test the hypothesis of conditional independence, Spearman's rank correlation test is used.[28] For each firm, a vector of residuals is constructed on basis of the bid-level estimation presented in column (3) in Table A.3. in the Appendix.[29] The residuals in each vector are ranked by putting the values of the residuals in order and numbering them: the lowest value is given rank 1, the second lowest value is given rank 2 etc. The Spearman correlation coefficient is used as a measure of the 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 in a conditionally independent way, i.e. that residuals should not be correlated. The null can be rejected when the calculated p-value is low. In comparison with other correlation tests, the Spearman rank correlation test behaves well when the correlation is not linear.

The analysis carried out is restricted to not only include 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.

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

[29] Similar results for the correlation tests are found when using the alternative specifications in Table A.3. However, when using the specifications presented in Table A.4 possitive correlation is found in every test. This suggests that auction-specific information is not controlled for in a satisfactory way.

Table 2. Spearman's correlation coefficients and simultaneous bids

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(8, 26)	22	−.054	.812	(30, 43)	41	−.024	.882
(8, 44)	21	−.030	.898	(30, 44)	73	−.530***	.000
(14, 26)	74	−.171	.144	(30, 50)	34	.050	.778
(14, 43)	68	.023	.851	(30, 55)	64	−.336***	.007
(14, 44)	74	−.165	.160	(32, 44)	28	−.535***	.003
(14, 50)	56	−.092	.501	(32, 55)	24	.014	.949
(14, 55)	68	−.221	.070	(33, 37)	55	−.021	.878
(19, 26)	37	.335**	.043	(33, 44)	169	−.300***	.000
(19, 44)	33	.673***	.000	(33, 49)	21	.168	.468
(19, 50)	26	−.590***	.002	(33, 55)	162	−.049	.535
(19, 55)	33	−.592***	.000	(37, 43)	62	−.123	.340
(21, 26)	56	−.367***	.005	(37, 44)	151	−.344***	.000
(21, 33)	44	−.218	.156	(37, 50)	41	−.400***	.010
(21, 44)	55	.353***	.008	(37, 55)	111	−.028	.768
(21, 55)	56	−.052	.703	(43, 44)	222	.026	.696
(26, 30)	73	−.440***	.000	(43, 49)	24	−.483**	.017
(26, 32)	28	−.643***	.000	(43, 50)	171	.044	.571
(26, 33)	170	−.241***	.002	(43, 55)	198	−.492***	.000
(26, 37)	155	−.227***	.005	(44, 49)	51	−.701***	.000
(26, 43)	226	−.050	.457	(44, 50)	211	−.200***	.004
(26, 44)	512	.277***	.000	(44, 55)	442	−.266***	.000
(26, 49)	50	−.356***	.011	(49, 50)	23	−.325	.130
(26, 50)	212	−.318***	.000	(49, 55)	51	−.170	.235
(26, 55)	444	−.242***	.000	(50, 55)	194	−.036	.620
(30, 37)	23	−.413**	.050				

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

The table reports the following results. Among all 49 pairs with at least 20 simultaneous bids, the hypothesis of conditional independence can be rejected for as many as 26 pairs, at least at the five-percent level of significance. These firm pairs are marked with stars in the table. Some of the firms represented with significant correlation in the tests presented above only bid against each other three or four times each year.[30] 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, significant 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. For as many as twelve firms it is possible to

[30] 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 the private sector.

reject the hypothesis of conditional independence at least once.[31] For these firms significant negative correlation is found. In addition, significant positive correlation is found for four out of these twelve firms. As argued earlier in the paper, negative correlation and positive correlation in combination could, given that the empirical specification is correct, also be consistent with a bid rigging scheme.

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

It is also interesting to test the hypothesis of conditional independence 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 only active 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.6-A.16 in the appendix. Significant correlation is observed in every year except for 1999 and 2002.[32] Further, the results show that for a total of twelve firms the hypothesis of conditional independence can be rejected, and the correlation is negative, at least once when testing each year separately.[33] All firms, except firms 14 and 25, are represented with significant correlation 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 (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.

Tests carried out on each region separately are presented next. Since the

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

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

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

market for asphalt paving is to a large extent regional, the bidding behaviour may differ between regions. Possibly, it is even easier to keep a cartel stable in a smaller geographic area, with fewer bidders. Tables A.17 to A.21 present the results for testing the hypothesis of conditional independence separately for each of the five regions. Ten firms in total are represented with significant correlation in any of the five regions, and all of these firms show up in the tests presented above. The three largest firms, 26, 44 and 55, are individually represented in each region with one exception. In some regions, there are more tests that turn out significant than in other regions. In region Väst, as many as ten out of fourteen tests are significant, while only one out of eight tests is significant in region Syd-Ost.

Out of the nine firms accused of bid rigging by the CA, only one is not represented in the tests presented above. This firm is small and locally active, which is the reason 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 reveals some interesting features. Until 1997, firm 50 was active as a subsidiary to firm 33. After this date, 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.[34] In the correlation tests, firm 50 shows 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 could have benefited from collaborating even before the acquisition took place. Moreover, firm 43 was active until 1997 when it was taken over by firm 26. These firms could also have benefited from collaborating before the acquisition.

Summing up, the tests of conditional independence give the following results. In total, there is a group of nine firms that show up with negative correlation,

[34] 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.

both when testing calculating correlation coefficients on the whole material and when testing each year and each region 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, and every region tested separately, with a couple of exceptions. These firms are observed with negative and positive correlation both together with each other and together with other firms. They have individually participated in almost 85 percent of all auctions. In some cases they are alone in competing. The fact that this small group meets regularly and sometimes does 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 CA's 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 of 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 has 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 ensured 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.

Another possible reason for incorrectly concluding that collusion exists in the market is the existence of strategic considerations. The bidding firms may alter the bid that they submit depending on the characteristics of the firms they bid against. A strong bidder knowing that it faces a weak bidder, may scale up its bid to increase the profit. The weak firm, on the other hand, may bid lower than expected to increase the probability of winning. If this behaviour is systematic, a consequence might be that the hypothesis of conditional independence is incorrectly rejected.

Potentially, a further drawback of testing for conditional independence is that in theory, it is possible that the hypothesis of conditional independence cannot be rejected, even though firms collude. The bidding pattern can potentially be designed with the aim of hiding the collusive scheme, i.e. creating 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 method used tests firms 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 consequence, 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 asphalt-paving sector for collusive behaviour. A unique set of bid data, from the 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 CA to initiate legal proceedings against a group of firms, and since the market is characterized by a number of features facilitating collusion.

The collusive behavior analysed is bid rigging. The high participation rate (a group of firms has 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 screen the market for collusive behavior. The method used 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. Given a correctly specified model, the unexplained part of the submitted bids should not be correlated if firms bid independently. 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 specifically, the test are carried out for each year, as well as for each region separately. In several cases, the hypothesis of conditional independence could be rejected.

The main findings are that a group of nine firms are frequently represented in the tests, both when using the full data set and when carrying out tests on yearly and regional sub-samples. This group of firms, except one, belongs to the group of largest firms in the industry. Out of the nine firms charged with collusive behavior by the CA, 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 projects.

The findings suggest that collusion might be widespread in the market and that at least the group of the three largest firms appears to be involved in bid-rigging activities. The results suggest 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 (million SEK)
MRBID	The mean bid (real) value of a contract (million SEK)
DRT	The distance between production plant and contract site, the own plant if one exists in the region, if not, the closest plant in the region (in kilometres)
DRTC	The shortest competitor distance between contract site and production plant, the own plant if one exists in the region, if not, the closest plant in the region (in kilometres)
RPLANT	One for plant ownership in the region, zero otherwise
CAPU	The use of capacity during the project period
CAPUC	The lowest capacity utilisation level among competitors
LENGTH	The total length in metres of the roads included in the contract
ADT	The daily passages on the road
VST	One if the auction is carried out in region Stockholm, zero otherwise
VSO	One if the auction is carried out in region Syd-Ost, zero otherwise
VMN	One if the auction is carried out in region Mälardalen, zero otherwise
VSK	One if the auction is carried out in region Skåne, zero otherwise
VV	One if the auction is carried out in region Väst, zero otherwise
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 submits a bid at the auction, zero otherwise

a. 1 SEK $\approx$ 0.14 USD.

Table A.2. Summary statistics

	Obs.	Mean	Std.dev	Min	Max
I. Contracts					
BIDS	536	5.33	1.34	2	10
INVITED	536	10.53	4.62	2	27
MRBID	536	5.56	4.43	0.14	30.28
LENGTH	469	29106	25092	170	144001
ATD	421	5217	8308	84.54	55000
II. Winning firms					
RBID	536	5.08	4.04	0.12	25.74
LNRBID	536	1.28	0.92	-2.12	3.24
DRT	536	223.48	277.70	4.12	2214.13
LNDRT	536	4.80	1.19	1.42	7.70
DRTC	536	130.95	135.41	2	1029.18
LNDRTC	536	4.35	1.12	0.69	6.94
RPLANT	536	0.75	0.43	0	1
CAPU	535	0.79	0.19	0	1
CAPUC	535	0.26	0.30	0	1
III. The full data set					
RBID	2860	5.82	4.60	0.12	32.69
LNRBID	2860	1.42	0.91	-2.12	3.49
DRT	2860	242.07	324.72	2	5102.67
LNDRT	2860	4.85	1.20	0.69	8.54
DRTC	2860	128.56	134.71	2	1029.18
LNDRTC	2860	4.34	1.12	0.69	6.94
RPLANT	2860	0.65	0.48	0	1
CAPU	2855	0.63	0.32	0	1
CAPUC	2855	0.26	0.30	0	1

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

Table A.3. Estimates on bid-level decisions, with auction dummies

	(1)	(2)	(3)	(4)
LNDRT	0.021	0.018	0.016	0.014
	(0.004)***	(0.004)***	(0.005)***	(0.005)***
LNDRTC	0.423	0.428	0.427	0.432
	(0.041)***	(0.041)***	(0.040)***	(0.039)***
RPLANT	-0.048	-0.033	-0.026	-0.022
	(0.005)**	(0.005)***	(0.009)**	(0.009)***
CAPU		-0.066		-0.070
		(0.010)***		(0.011)***
CAPUC		-0.026		-0.021
		(0.016)		(0.017)
F14			-0.010	0.007
			(0.011)	(0.012)
F21			0.002	-0.019
			(0.015)	(0.015)
F26			-0.035	-0.009
			(0.010)***	(0.011)
F30			0.024	0.027
			(0.016)	(0.015)*
F33			0.006	0.029
			(0.012)	(0.013)**
F37			-0.039	-0.012
			(0.013)***	(0.014)
F43			-0.008	0.014
			(0.012)	(0.013)
F44			-0.029	-0.008
			(0.010)***	(0.011)
F50			-0.025	-0.013
			(0.009)***	(0.010)
F55			-0.019	-0.004
			(0.009)**	(0.010)
CONST	-1.922	-1.878	-1.907	-1.880
	(0.244)***	(0.241)***	(0.238)***	(0.234)***
AUCTION DUMMIES	YES	YES	YES	YES
$\bar{R}^2$	0.99	0.99	0.99	0.99
F - statistic	2910.64	9135.33	2733.44	3845.52
DF	2322	2316	2312	2306
N	2860	2855	2860	2855

a. Dependent variable is $LNRBID$.

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

c. The joint significant effect of the auction dummes is tested for each estimation using F-tests. The results show that the hypothesis of no joint significant effect can be rejected for all estimations. The test results are, for column (1) through (4); F(534, 2322) = 2252.81, F(533, 2316) = 2569.04, F(534, 2312) = 1901.49 and F(533, 2306) = 2205.96.

d. ***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

Table A.4. Estimates on bid-level decisions, without auction dummies

	(1)	(2)	(3)	(4)
LNDRT	0.055	0.054	0.056	0.054
	(0.017)***	(0.018)***	(0.023)**	(0.023)**
LNDRTC	0.106	0.104	0.104	0.102
	(0.018)***	(0.019)***	(0.023)***	(0.025)***
RPLANT	-0.049	-0.053	-0.047	-0.049
	(0.023)***	(0.023)***	(0.039)	(0.041)
CAPU		0.007		-0.013
		(0.031)		(0.037)
CAPUC		0.087		0.089
		(0.028)***		(0.027)***
MRBID	0.149	0.149	0.148	0.163
	(0.005)***	(0.005)***	(0.005)***	(0.005)***
LNLENGTH	0.164	0.169	0.164	0.168
	(0.018)***	(0.018)***	(0.018)***	(0.018)***
LNADT	0.120	0.122	0.119	0.121
	(0.009)***	(0.009)***	(0.009)***	(0.009)***
VST	0.122	0.104	0.123	0.049
	(0.029)***	(0.030)***	(0.029)***	(0.031)***
VV	-0.042	-0.052	-0.037	-0.048
	(0.027)	(0.027)*	(0.028)	(0.028)*
VSK	-0.087	-0.080	-0.083	-0.078
	(0.041)**	(0.040)**	(0.041)**	(0.040)*
VSO	-0.143	-0.147	-0.140	-0.145
	(0.033)***	(0.033)***	(0.034)***	(0.034)***
CONST	-2.400	-2.459	-2.395	-2.444
	(0.219)	(0.218)	(0.222)	(0.220)
FIRM DUMMIES	NO	NO	YES	YES
$\bar{R}^2$	0.81	0.82	0.81	0.82
F - statistic	455.68	398.88	234.80	223.15
DF	2096	2089	2086	2079
N	2107	2102	2107	2102

a. Dependent variable is $LNRBID$.

b. The reference region is VMN, Mälardalen.

c. Firm dummies for the ten largest firms in the market are included in columns (3) and (4).

d. White's heteroskedasticity-robust standard errors in parenthesis.

e. ***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

Table A.5. Estimates on bid-submission decisions and bid levels

	(1)	(2)	(3)	(4)
LNDRT	0.018	-0.290	0.018	-0.328
	(0.006)***	(0.062)***	(0.006)***	(0.069)***
LNDRTC	0.364	0.192	0.368	-0.001
	(0.039)***	(0.129)***	(0.039)***	(0.159)
RPLANT	-0.024	1.188	-0.024	1.185
	(0.010)***	(0.106)***	(0.010)***	(0.122)***
CAPU			-0.049	1.300
			(0.013)***	(0.079)***
CAPUC			0.039	4.530
			(0.025)	(0.277)***
INVIT		2.725		2.616
		(0.131)***		(0.132)***
F14	0.012	0.159	0.036	0.014
	(0.022)	(0.100)	(0.022)	(0.110)
F21	0.008	0.228	-0.023	0.340
	(0.014)	(0.103)**	(0.015)	(0.116)***
F26	-0.035	2.337	-0.013	2.104
	(0.012)***	(0.161)***	(0.012)	(0.188)***
F30	0.030	0.507	0.029	0.418
	(0.015)**	(0.100)***	(0.014)**	(0.109)***
F33	0.009	0.138	0.032	0.162
	(0.012)	(0.098)	(0.013)**	(0.103)
F37	-0.019	0.254	0.08	-0.068
	(0.017)	(0.085)***	(0.017)	(0.095)
F43	-0.008	2.054	0.008	1.878
	(0.014)	(0.096)***	(0.014)	(0.115)***
F44	-0.030	2.173	-0.013	1.892
	(0.012)**	(0.155)***	(0.012)	(0.179)***
F50	-0.023	1.364	-0.015	1.327
	(0.010)**	(0.096)***	(0.010)	(0.104)***
F55	-0.015	1.835	0.004	1.547
	(0.011)	(0.088)***	(0.011)	(0.098)***
HECKMANS λ	-0.005		-0.014	
	(0.005)		(0.005)***	
CONST	-0.004	-4.101	-0.007	-4.498
	(0.185)	(0.579)***	(0.184)***	(0.697)***
AUCTION DUMMIES	YES	YES	YES	YES
Log pseudolikelihood	-87.59		270.01	
Wald Chi^2	1550000		1650000	
Censored obs.	7031		7019	
Uncensored obs.	2786		2781	
N	9817		9800	

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

b. Dependent variable in the bid-level estimations is $LNRBID$.

c. Columns (1) and (3) present the bid-level estimations and columns (2) and (4) the submisission estimations.

d. White's heteroskedasticity-robust standard errors in parenthesis.

e. ***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

f. A total of 74 observations are lost in the estimations due to collinearity among some of the auction dummies.

Table A.6. 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	−0.122	0.520
(14, 26)	16	0.068	0.803	(37, 43)	20	0.011	0.965
(14, 43)	13	−0.258	0.394	(37, 44)	27	−0.640***	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	−0.684***	0.000	(43, 55)	17	−0.260	0.314
(26, 43)	32	−0.278	0.127	(44, 50)	18	0.241	0.337
(26, 44)	55	0.381***	0.004	(44, 55)	27	−0.673***	0.000
(26, 50)	17	0.632***	0.007	(50, 55)	10	−0.249	0.489

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.7. 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)	28	−0.189	0.334
(8, 44)	12	−0.147	0.649	(26, 55)	34	−0.283	0.106
(14, 26)	20	0.469**	0.037	(30, 44)	11	−0.064	0.853
(14, 43)	19	0.291	0.226	(43, 44)	33	0.040	0.823
(14, 44)	22	0.179	0.425	(43, 50)	22	−0.221	0.324
(14, 50)	16	0.638***	0.008	(43, 55)	27	−0.791***	0.000
(14, 55)	21	−0.738***	0.000	(44, 50)	27	−0.002	0.993
(26, 30)	11	0.018	0.958	(44, 55)	35	−0.435***	0.009
(26, 43)	33	−0.220	0.218	(50, 55)	24	0.086	0.697
(26, 44)	43	0.377***	0.013				

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.8. 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	0.357**	0.045
(26, 44)	41	0.426***	0.006	(43, 55)	34	−0.455***	0.007
(26, 50)	37	−0.307	0.065	(44, 50)	37	−0.452***	0.005
(26, 55)	40	−0.372**	0.018	(44, 55)	40	−0.302	0.058
(43, 44)	35	−0.203	0.243	(50, 55)	37	0.005	0.978

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.9. Year 1995: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(14, 26)	17	−0.010	0.978	(30, 50)	18	−0.177	0.484
(14, 43)	17	−0.034	0.896	(30, 55)	20	−0.517**	0.020
(14, 44)	17	−0.292	0.256	(37, 43)	13	−0.209	0.494
(14, 50)	14	−0.363	0.203	(37, 44)	13	0.429	0.144
(14, 55)	17	−0.105	0.687	(37, 55)	13	0.319	0.289
(19, 26)	10	−0.067	0.855	(43, 44)	67	−0.070	0.571
(19, 55)	10	−0.394	0.260	(43, 49)	13	−0.599**	0.031
(26, 30)	20	−0.320	0.169	(43, 50)	58	0.038	0.780
(26, 37)	13	0.566**	0.044	(43, 55)	66	−0.272**	0.027
(26, 43)	67	−0.339***	0.005	(44, 49)	14	−0.675***	0.008
(26, 44)	73	0.254**	0.030	(44, 50)	61	0.072	0.584
(26, 49)	13	−0.445	0.128	(44, 55)	72	−0.230**	0.052
(26, 50)	63	−0.340***	0.006	(49, 50)	12	−0.252	0.430
(26, 55)	73	−0.073	0.540	(49, 55)	14	0.147	0.615
(30, 43)	20	0.379	0.099	(50, 55)	62	0.042	0.747
(30, 44)	20	−0.337	0.146				

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.10. 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	0.531***	0.001
(26, 43)	36	0.478***	0.003	(43, 50)	33	0.014	0.433
(26, 44)	43	0.601***	0.000	(43, 55)	32	−0.367**	0.039
(26, 50)	39	−0.473***	0.002	(44, 50)	39	−0.343**	0.033
(26, 55)	39	−0.435***	0.006	(44, 55)	40	−0.193	0.234
(37, 43)	10	−0.249	0.489	(50, 55)	35	−0.096	0.585
(37, 44)	10	−0.139	0.701				

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.11. Year 1997: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(14, 26)	10	−0.661**	0.038	(37, 44)	12	−0.350	0.265
(14, 44)	10	−0.636**	0.048	(37, 55)	11	0.227	0.502
(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	0.553***	0.000	(44, 50)	28	−0.524***	0.004
(26, 50)	28	−0.686***	0.000	(44, 55)	39	−0.351**	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 ** denote significance at the 1 and 5 percent level, respectively.

Table A.12. 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	-0.256^{**}	0.034
(21, 33)	17	−0.304	0.236	(30, 44)	12	−0.455	0.138
(21, 44)	19	0.768^{***}	0.000	(30, 55)	11	−0.509	0.110
(21, 55)	21	−0.309	0.173	(37, 44)	30	-0.070	0.713
(26, 30)	12	−0.308	0.331	(37, 55)	21	−0.382	0.088
(26, 33)	56	-0.404^{***}	0.002	(44, 49)	11	−0.364	0.272
(26, 37)	31	−0.223	0.227	(44, 50)	66	-0.423^{***}	0.000
(26, 44)	76	0.449^{***}	0.000	(49, 55)	12	0.294	0.354
(26, 49)	12	0.000	1.000				

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.13. 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	−0.179	0.425

Table A.14. 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)	51	0.040	0.779
(21, 33)	16	−0.462	0.072	(30, 44)	10	−0.552	0.098
(21, 44)	21	−0.283	0.214	(33, 44)	47	−0.210	0.157
(21, 55)	20	0.006	0.980	(33, 55)	46	−0.266	0.074
(26, 33)	46	−0.030	0.856	(34, 44)	14	-0.714^{***}	0.004
(26, 34)	14	0.284	0.326	(37, 44)	11	−0.200	0.555
(26, 37)	11	−0.491	0.125	(44, 55)	52	−0.119	0.400
(26, 44)	61	−0.145	0.266				

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.15. Year 2001: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(21, 26)	12	−0.720	0.008	(26, 55)	36	−0.297	0.079
(21, 33)	10	−0.285	0.425	(33, 35)	14	−0.407	0.149
(21, 44)	12	0.518	0.085	(33, 37)	19	0.221	0.363
(21, 55)	12	0.224	0.485	(33, 44)	30	−0.181	0.339
(25, 26)	10	-0.758^{**}	0.011	(33, 55)	26	-0.654^{***}	0.000
(25, 44)	10	0.164	0.652	(35, 44)	14	−0.420	0.135
(25, 55)	10	0.176	0.627	(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	−0.229	0.140	(44, 55)	36	0.265	0.119

a. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.16. Year 2002: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(26, 33)	14	0.209	0.474	(33, 44)	15	−0.246	0.376
(26, 37)	12	0.552	0.063	(33, 55)	13	−0.528	0.064
(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	−0.044	0.887	(44, 55)	10	0.423	0.150

Table A.17. Region MÄLARDALEN: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(21, 26)	21	−0.036	0.876	(30, 50)	23	0.098	0.657
(21, 44)	22	0.060	0.789	(30, 55)	36	−0.553***	0.001
(21, 55)	21	−0.012	0.960	(43, 44)	34	0.218	0.215
(26, 30)	39	−0.305	0.059	(43, 50)	30	−0.323	0.866
(26, 43)	34	0.196	0.267	(43, 55)	30	−0.596***	0.000
(26, 44)	69	0.354***	0.003	(44, 49)	20	−0.793***	0.000
(26, 50)	30	−0.297	0.112	(44, 50)	30	−0.129	0.496
(26, 55)	62	0.154	0.231	(44, 55)	64	−0.117	0.358
(30, 43)	25	−0.035	0.867	(50, 55)	26	−0.092	0.655
(30, 44)	40	−0.471***	0.002				

a. Includes tests for 20 or more simultaneous bids.

b. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.18. Region STOCKHOLM: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(26, 30)	20	−0.107	0.654	(37, 43)	21	−0.252	0.271
(26, 37)	60	−0.034	0.795	(37, 44)	59	−0.371***	0.004
(26, 43)	30	0.540***	0.002	(37, 55)	35	−0.026	0.882
(26, 44)	88	0.272***	0.010	(43, 44)	30	0.386**	0.035
(26, 50)	20	−0.698***	0.001	(43, 55)	27	−0.723***	0.000
(26, 55)	54	−0.408***	0.002	(44, 50)	20	−0.716***	0.000
(30, 44)	20	0.591***	0.006	(44, 55)	34	−0.364***	0.007

a. Includes tests for 20 or more simultaneous bids.

b. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.19. Region SYD-OST: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(26, 37)	20	−0.402	0.079	(37, 44)	20	−0.313	0.179
(26, 44)	77	0.399***	0.000	(44, 50)	28	−0.168	0.394
(26, 50)	27	0.107	0.594	(44, 55)	70	−0.221	0.066
(26, 55)	69	0.009	0.941	(50, 55)	23	0.177	0.420

a. Includes tests for 20 or more simultaneous bids.

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

Table A.20. Region VÄST: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(14, 26)	64	−0.035	0.786	(26, 55)	198	−0.312***	0.000
(14, 43)	58	0.108	0.421	(33, 37)	29	0.164	0.395
(14, 44)	64	−0.061	0.631	(33, 44)	80	−0.212	0.059
(14, 50)	51	−0.160	0.263	(33, 55)	78	0.045	0.696
(14, 55)	58	−0.293**	0.026	(37, 43)	33	−0.161	0.372
(19, 26)	37	0.335**	0.043	(37, 44)	61	−0.550***	0.000
(19, 44)	33	0.673***	0.000	(37, 55)	52	0.067	0.635
(19, 50)	26	−0.590***	0.002	(43, 44)	101	−0.149	0.164
(19, 55)	33	−0.592***	0.000	(43, 50)	76	0.062	0.594
(26, 33)	82	−0.483***	0.000	(43, 55)	87	−0.456***	0.000
(26, 37)	64	−0.423***	0.000	(44, 50)	93	0.124	0.238
(26, 43)	105	−0.228**	0.019	(44, 55)	193	−0.243***	0.001
(26, 44)	215	0.251***	0.000	(50, 55)	90	−0.150	0.158
(26, 50)	96	−0.145	0.159				

a. Includes tests for 20 or more simultaneous bids.

b. *** and ** denote significance at the 1 and 5 percent level, respectively.

Table A.21. Region Skåne: Spearman's rank correlation coefficients

Firms	n	r_s	p-value	Firms	n	r_s	p-value
(26, 43)	40	−0.333**	0.036	(43, 50)	36	0.169	0.324
(26, 44)	63	0.164	0.200	(43, 55)	38	−0.351**	0.031
(26, 50)	39	−0.600***	0.000	(44, 50)	39	−0.011	0.945
(26, 55)	61	0.219	0.090	(44, 55)	61	−0.396***	0.002
(43, 44)	40	−0.343**	0.030	(50, 55)	37	−0.040	0.814

a. Includes tests for 20 or more simultaneous bids.

b. *** and ** denote significance at the 1 and 5 percent level, respectively.