KONKURRANSE·TILSYNET
Norwegian Competition Authority

Rapport 5/2023
Vedtak: 2019-3

Bidding Competition in the Norwegian Market for Road Maintenance

Malin Arve, Armando J. Garcia Pires, og Frode Skjeret

Prosjektet har mottatt midler fra det alminnelige prisreguleringsfondet.

Journal of Transport Economics and Policy, Volume 56, Part 4, October 2022, pp. 464–487

Bidding Competition in the Norwegian Market for Road Maintenance

Malin Arve, Armando J. Garcia Pires, and Frode Skjeret

Address for correspondence: Armando J. Garcia Pires, Centre for Applied Research at NHH — SNF, Helleveien 30, 5045 Bergen (armando.pires@snf.no).

Abstract

This paper provides an empirical analysis of the effect of competition for road maintenance contracts in 'thin' markets (markets with few participants). We study competition in public procurement auctions for road maintenance in Norway, and look to the effects of entry on prices. We provide evidence of a positive impact of entry on bid prices. This entry effect comes on top of the general effect of the number of bidders in the market. We show that the number of bidders is positively affected by the size of the auction.

Final version: March 2022

1.0 Introduction

In this paper, we investigate competition in public procurement auctions for road maintenance in Norway. First, we apply a model explaining bidding behaviour intended to estimate whether the entry of firms in the Norwegian road maintenance regional markets has a structural impact on bidding behaviour beyond competition effects. Second, we analyse how the size of contracts affects the number of bidders. The paper focuses on periodic routine contracts for asphalt work, a relatively homogeneous group of tenders.

General auction theory (Klemperer, 1999) indicates that more competition in a market leads to lower prices. This implies that the entry of a new firm into a specific market would lead to lower prices through increased competitive pressure. However, this result assumes a competitive market. The market for road maintenance has from one side a history of collusion; from the other side, even when collusion is absent, this market is characterised by oligopolistic structures with very few actors —that is, *thin* markets.

There are several examples of collusion in road construction markets. In Norway, the two largest road construction firms, NCC and Veidekke, were convicted of operating a cartel from 1996 to 2009. Employees at the two firms met in secret to divide the market between them and agreed on bidding prices in the procurement auctions (Konkurransetilsynet, 2013). Another example of collusion occurred in Sweden, involving NCC, Skanska, Peab Asfalt, and Vägverket Produktion (Bergman *et al.*, 2020). These firms were convicted of sharing Swedish regional markets for road asphalt work (Konkurrensverket, 2009). A third example took place in 2013 and involved municipalities in Finland. The District Court of Helsinki fined several municipalities a total of €60 million for damages resulting from a cartel in the Finnish asphalt paving market (Joenpolvi, 2015).

Even when collusion is absent, the road construction/maintenance market is often characterised by having few participants — that is, *thin* markets. In thin markets, firms may exploit market power without engaging in illegal collusive behaviour. For example, dominant firms can engage in demand reduction behaviour in order to reduce bidding prices. See Weber (1997) for an illustration of such behaviour in the US Federal Communications Commission (FCC) auctions. In multi-unit auctions, Ausubel *et al.* (2004) show that demand reduction generally leads to inefficiencies, but the ranking of auction formats by revenue and efficiency is ambiguous. In procurement markets, the equivalent to demand reduction is supply reduction, but this would have the same effects in terms of revenue and efficiency.

In markets with a high risk of collusion or, more generally, in markets with a low level of competition (thin markets), entry might have stronger effects than in very competitive markets. Accordingly, when a new firm enters a cartelised market or one market with low competition, the ability of incumbent firms to continue to bid high prices may be reduced significantly. Although in some cases this new entrant might be less efficient than the incumbent firms, it can offer lower prices than those of the incumbents to succeed in entering the market. It is well known that the likelihood of maintaining a cartel falls as the number of firms in the market increases (Ivaldi *et al.*, 2007). More generally, an entry would stimulate competition in the market, which would lead to lower prices.

In the period that we are studying, no cartel has been identified in the Norwegian road maintenance market. However, this market, as we will see later when analysing our data, has very few competitors — that is, it is a *thin* market. Therefore, instead of focusing on whether the Norwegian market for road maintenance is characterised by collusion, we focus on the effect of entry (that is, increasing competition), ignoring the reasons for the weak competition in this market.

Consistent with competition economics and the theoretical model that we develop, we find that the number of potential bidders present in a regional market impacts the prices negatively, suggesting that entry leads to structural changes beyond the standard competition effect of destabilising the market power of incumbent firms. We also find that the size of the project (as measured in tonnes of asphalt) has a positive impact on the number of bidders. These results have clear policy implications. First, they show the well-known effects of competition on consumer surplus and social welfare because more competition (that is, entry) leads to lower prices. Second, they show the benefits of larger auctions because they prompt more firms to enter the auction. This is particularly relevant for the Norwegian road maintenance market since Norwegian authorities tend to divide contracts into smaller auctions for different parts of the same project.[1]

The remainder of the paper is organised as follows. In Section 2, we make a short review of the literature in the field. In Section 3, we present a theoretical model to inform our empirical strategy. In Section 4, we describe the data and institutional background in the Norwegian road maintenance market. In Section 5, we describe our econometric strategy and present our results. We conclude in Section 6 by discussing our findings.

2.0 Literature Review

As discussed in Section 1, the main contribution of this paper is to study the effects of entry on auctions. A closer look on both the theoretical and empirical literature on auctions shows that the effects of entry on bid prices has not been much studied (see, for instance, Hendricks and Paarsch, 1995; Laffont, 1997; Gugler *et al*., 2015). This is even more surprising since procurement auctions in construction and maintenance markets have been studied extensively. We review this literature in this section.

Jofre-Bonet and Pesendorfer (2003) study Californian highway procurement auctions using a parametric model. They find evidence of capacity constraints in repeated auctions, since previously won uncompleted contracts reduce the probability of winning further contracts. Krasnokutskaya (2011) studies Michigan highway procurement auctions to recover the distribution of bidders' private information when unobserved auction heterogeneity is present. She finds that private information is estimated to account for 34 per cent of the variation in bidders' costs in Michigan highway procurement auctions.

Balat (2013) analyses road construction in California resulting from the American Recovery and Reinvestment Act. For that purpose, he develops a dynamic auction model that allows for project heterogeneity and endogenous auction participation. He shows that the American Recovery and Reinvestment Act increased prices instead of increasing road construction. Groeger (2014) also considers repeated auctions in the context of construction procurement. He finds significant synergies in terms of cost savings for firms that enter into contracts of the same type.

[1] However, we acknowledge that the overall policy also needs to take into account smaller firms who may not have the capacity to bid for very large contracts.

In turn, Athey *et al*. (2011) and Krasnokutskaya and Seim (2011) look at endogenous participation in auctions. Athey *et al*. (2011) use data from the US Forest Service timber auctions, and compare bidding patterns in sealed bid and open auctions. They show that sealed auctions attract more small bidders and shift the allocation towards these bidders. Krasnokutskaya and Seim (2011) study highway procurement auctions subject to California's Small Business Preference programme. They present evidence that participation responses significantly alter the assessment of preferential treatment policies.

Gugler *et al*. (2015), in turn, study the effects of the 2008 economic crisis on firms' bidding behaviour and markups in sealed bid auctions from Austrian construction procurements. They find that the crisis had a significant impact on bid prices. In particular, markups of all bids submitted decreased by 1.5 percentage points, while markups of winning bids decreased by 3.3 percentage points.

There is also a large literature looking at the effects of contracting out road maintenance on costs for the public coffers (in opposition to in-house).[2] The empirical evidence from many countries suggests that contracting out road maintenance has reduced costs substantially (see Yarmukhamedov *et al*., 2020). The range of cost reductions has been estimated at 10–20 per cent in Canada (Sultana *et al*., 2013), 20–30 per cent in Australia (Lyon and Dwyer, 2011), and 8–27 per cent in Sweden (Arnek, 2002; Yarmukhamedov *et al*., 2020). In addition, Yarmukhamedov *et al*. (2020) provide evidence from the Swedish road maintenance market that even when contracting out was adopted, the state-owned maintenance provider continued to be considerably more expensive than its private counterparts.[3] In the case of Norway, Odeck (2014) shows that the move to a competitive agency reduced cost overruns. However, overruns remain prevalent among smaller projects.

3.0 Theoretical Model

In this section, we develop a theoretical framework to guide our empirical analysis. We adapt the textbook model of a first-price auction (see, for instance, Krishna, 2002: chapter 2.3) to a procurement setting; that is, instead of bidders having a valuation for the good and bidding to buy the good for the price they bid, in a procurement setting the bidders have costs for producing the good and bid to provide the good at the price they bid.

Formally, we assume that there are n firms who can provide a good. The cost of firm i for providing the good is denoted c_i. Costs are identically and independently distributed according to the uniform distribution on the support $[0,1]$.[4]

[2] Related to this literature is the literature on the cost of road infrastructure. See, for instance, Nash and Sansom (2001), Nash and Matthews (2005), Link (2014), and Ricardo-AEA (2014). Our focus differs from this literature because we take road use as given and focus on the competitive tendering process; asking what drives prices, in particular entry.

[3] The data that we have in this study refers to road maintenance contracts that are contracted out — that is, we do not focus on the question of in-house versus contracting out of activities. On this issue, see Levin and Tadelis (2010), Gonçalves and Gomes (2012), and Yarmukhamedov *et al*. (2020). We also do not analyse the costs of road wear. On this see, for instance, Gonçalves and Gomes (2012), Heike (2014), and Nilsson *et al*. (2020).

[4] The uniform distribution is chosen for simplicity. The model gives similar results for a general distribution function.

3.1 Competitive bidding

In a competitive environment, each bidder will choose a bid strategy b that maximises the firm's expected profit (its likelihood of winning times the profit when it wins):

$$\max_b Prob(winning)(b - c_i).$$

The solution concept is the symmetric Nash equilibrium and straightforward computations[5] gives the following equilibrium bidding strategy $b(c_i)$:

$$b^c(c_i) = c_i + \frac{1 - c_i}{n}.$$

The expected profit of a firm in this equilibrium is:

$$\Pi^c(c_i) = \frac{(1 - c_i)^n}{n},$$

and the ex-ante[6] expected profit is:

$$E[\Pi^c(c_i)] = \frac{1}{n(n+1)}.$$

The bidding strategy approaches marginal cost and expected profits approaches zero as the number of participants, n, increases.

3.2 Non-competitive bidding

Assume for a moment that the market is not competitive. This implies that the firms set higher margins than in the competitive bidding equilibrium.

Assume that bidding in this non-competitive environment consists of setting a margin α (where $\alpha > 1$) in the bidding process so that the bidding strategy looks like:[7]

$$b^{nc}(c_i) = c_i + \alpha\frac{1 - c_i}{n}.$$

This yields an expected profit, $\Pi^{nc}(c_i)$, of:

$$\alpha\frac{(1 - c_i)^n}{n} \geqslant \Pi^c(c_i) = \frac{(1 - c_i)^n}{n}.$$

This bidding strategy is sustainable if and only if the discounted sum of present and future gains from this strategy are larger than the present and future gains from deviating and reverting to the competitive bidding strategy in future tenders (Tirole, 1988: Chapter 6; Ivaldi *et al.*, 2007).

It can be shown[8] that such a non-competitive equilibrium is sustainable if and only if:

$$(1 - \delta)\left[1 - \left(\frac{n-1}{n-\alpha}\right)^{n-1}\right] + \delta\frac{\alpha - 1}{(n+1)} \geqslant 0,$$

[5]The details of these computations can be found in Appendix A1.

[6]The expected profit before the firm learns its realisation of the cost parameter.

[7]We would get a similar result in a model where we assume that firms bid according to the monopoly bidding strategy $b^m(c_i) = 1$.

[8]See Appendix A2 for the details.

where $\delta \in (0,1)$ denotes the discount factor. This condition may hold if δ is large enough or if n is small enough. Thus, this condition will hold in a 'thin' market given that firms are patient enough.

3.3 Implications of entry

For the empirical estimation, we are interested in how entry affects the firms' bidding strategy. If the number of firms increase from n to $n+1$, competitive bidding will go from:

$$c_i + \frac{1-c_i}{n}$$

to:

$$c_i + \frac{1-c_i}{n+1}.$$

Thus, the bidding strategy decreases by:

$$\Delta^c = \frac{1-c_i}{n(n+1)}.$$

In case of non-competitive bidding, entry may or may not lead to cooperation of higher margins breaking down.[9]

If cooperation does not break down — that is, $n+1$ also satisfies the condition above and the entrant plays according to the non-competitive bidding strategy — then entry leads to bidding going from:

$$c_i + \alpha\frac{1-c_i}{n}$$

to:

$$c_i + \alpha\frac{1-c_i}{n+1}.$$

Thus, the bidding strategy decreases by:

$$\alpha\frac{1-c_i}{n(n+1)} > \Delta^c.$$

If cooperation breaks down upon entry, bidding goes from:

$$c_i + \alpha\frac{1-c_i}{n}$$

to:

$$c_i + \frac{1-c_i}{n+1}.$$

[9] Alternatively, we could assume that the entrant never acts non-competitively and that cooperation always breaks down. In that case, only the second part of the analysis above applies, but the result regarding the effect of entry remains the same.

Thus, the bidding strategy decreases by:

$$(\alpha - 1)\frac{1 - c_i}{n} + \Delta^c > \Delta^c.$$

Regardless of whether cooperation breaks down or not, the theoretical model shows that we should expect entry to have a larger effect in a non-competitive environment than in a competitive environment. This suggests that entry in a thin market — that is, where cooperation is more likely to occur — should have a larger (negative) effect. We will test this empirically in our econometric model.

3.4 What affects entry?

The theoretical framework developed in this section gives us testable empirical implications to study what affects bidding strategies in the market for road maintenance contracts. However, the model developed assumes that n firms have entered the market. It does not explain why these firms have decided to enter the market. To study that, we need to take one step back. If a firm enters a market it may expect to earn the ex-ante expected profits, $E[\Pi(c_i)]$, but there might be entry costs (see, for instance, Dimitri *et al.*, 2006: Chapter 11). A firm will only enter if the ex-ante expected profits are net of any entry costs; that is:

$$E[\Pi(c_i)] - K \geqslant 0,$$

where K represents the entry costs.

If the contracts available on the market are large, the expected profits are large (compared to smaller contracts) and it becomes more attractive to enter the market — that is, the entry condition described in the previous paragraph holds.

On the other hand, to compete for a public contract the firm needs both to have the capacity to handle the administrative part of bidding and to have (or to be investing in) the capacity required to handle such contracts. These are part of the entry costs in the description above and are presumably larger for large contracts. Risk aversion or the financial structure of the firm might also increase the entry costs. It is therefore an empirical question whether the number of bidders is positively or negatively related to the size of the contract. We also address this question in our empirical analysis.

4.0 Data and Institutional Background

The Norwegian Public Roads Administration (NPRA) has a sectoral responsibility to follow up national tasks for the entire road transport system. Importantly for our analysis, the NPRA is the authority overseeing national roads, and is responsible for building, operating, and maintaining national roads.[10] The operational tasks related to this responsibility are delegated to five regional divisions: Middle (Midt), North (Nord), South (Sør), West (Vest), and East (Øst). The geographical regions are shown in Figure 1.

Following European and national laws on public procurement,[11] all contracts for road maintenance in Norway are subject to competitive bidding and formal tender procedures.

[10] Information is available at www.vegvesen.no.

[11] Directives 2014/23/EU, 2014/24/EU, and 2014/25/EU. In national law: Lov om offentlige anskaffelser.

Figure 1
NPRA's Five Regions of Norway: North (Blue), Middle (Green), East (Orange), South (Red), and West (Purple).

This means that all prospective road maintenance entities that meet a certain set of qualification criteria are eligible to bid for these contracts. Based on the call for tender and the submitted bids, the NPRA will award the contract to the bidder that best fits the criteria in the call for tender.

This paper uses a unique data set, including details from all calls for tender (or competitions) for road maintenance in Norway from the NPRA for the period 2008–18. All of these tenders are awarded based solely on price as a selection criterion. In addition to the data from the NPRA, we have collected data on price indexes, regional population, and lengths of roads by counties from Statistics Norway. In total, there are 1,017 calls for tender during this period. Given that, on average, approximately three bids are submitted for each call for tender, this amounts to a total of 2,881 bid observations. Table 1 shows the distributions of these calls for tender across time and regions.[12]

Table 2 presents summary statistics for our data set. In total, there are 24 distinct firms active in our data set. However, only 18 of these were awarded a contract during the period

[12]Note that although Table 1 only shows the distributions of these calls and the location of the work required at the regional level, the data set also includes location information at the county level. There were 17 counties in Norway during this period. In 2020 the number of counties was reduced to 11, but this has no impact on the regional markets in this study.

Table 1
Distribution of Calls for Tender Across Time and Regions

Region	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
Middle	10	15	11	10	10	11	12	15	10	16	14
North	20	15	20	20	17	13	12	13	16	13	16
South	47	30	33	25	24	20	25	20	15	17	14
West	16	30	20	18	19	17	15	17	12	13	15
East	26	30	27	28	23	19	20	18	19	18	18
Total	119	120	111	101	93	80	84	83	72	77	77

Table 2
Summary Statistics for Explained and Explanatory Variables

	Mean	*Min*	*Max*	*S.d.*
Price per tonne (NOK)	1.09	1	3	0.28
Bidders	3.26	1	7	1.10
Rate	0.73	0	1	0.21
Tonnes	24,572	1,317	88,479	15,522
Density	3.22	1	6	1.31
Contracts	8.99	5	15	2.05
Rounds	1.38	1	4	0.58

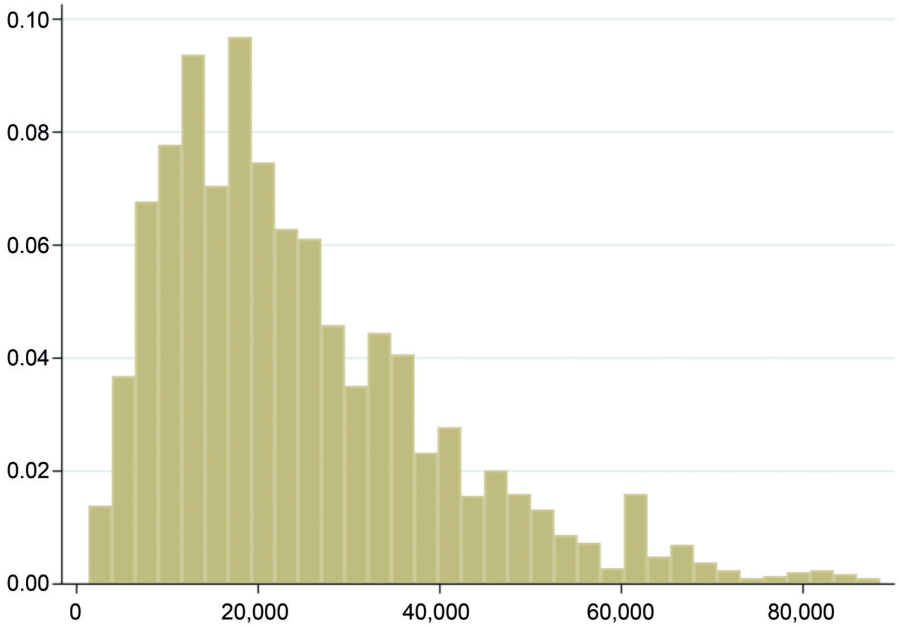
2008–18. Compared with similar markets outside Scandinavia (Johansson *et al.*, 2019; De Silva *et al.*, 2020), there are relatively few competitors in the Norwegian markets. The mean of bidders per project is about three, with a minimum of one and a maximum of seven. All the projects in the data set are relatively homogeneous in terms of size (see Figure 2). In fact, 31.9 per cent of the projects require somewhere between 15,000 and 25,000 tonnes of asphalt. All projects relate to similar, and relatively standardised and homogeneous, road maintenance work.

The data set also includes information about the date of the call to tender,[13] the number of submitted bids for each (bidders), the identity of the bidders, the individual bids (price, measured in Norwegian kroner (NOK), per tonne of asphalt),[14] and the estimated size of the project (measured in tonnes of asphalt). The participation rate in each auction (rate) is the actual number of participants bidding in an auction divided by potential participants (measured as the number of participants operating in the market); density is measured as the population divided by the area (km^2), the number of contracts per bid (contract), and which round of competition the particular auction belongs to (rounds).

[13]The data set includes both dates for the publication of the call for tender and the deadline for submitting bids.

[14]Rather than adjusting prices according to the general price level in the period, we use the construction cost index for road construction. We observe that the evolution of the cost index for road construction differs from the changes in the general price level in Norway (see Appendix B). This may be explained partially by changes in the international supply of bitumen and changes in the requirements from the NPRA.

Figure 2
Histogram of Estimated Tonnes of Asphalt Specified in the Calls for Tender in the Data Set. The Bars are Scaled so that the Sum of Their Heights Equals One.



The NPRA announces several blocks of calls to tender simultaneously, and this occurs in several rounds at least twice a year, but sometimes three or four times. This implies that in the first round of calls to tender, the firms can anticipate that there will be more contracts and competition later in the same year, whereas this becomes more uncertain for later rounds.

5.0 Econometric Framework and Results

In this section, we analyse what factors may explain prices in road maintenance regional markets in Norway. As argued above, our main focus is on the effects of entry. This exercise can cast some light on mechanisms that can strengthen competition in auction markets for road maintenance.

5.1 Impact of competition and entry

In this section, we design a model intended to analyse empirically the factors affecting the price of road maintenance in regional markets in Norway. In contrast to most other European or US markets, the Norwegian asphalt market is very thin — that is, it has very few players (Johansson *et al.*, 2019). As outlined in the introduction, the market also has a history of collusion. The number of firms involved in regional markets, and number of firms taking part in individual auctions within regional markets, is therefore included in the model. In addition, the impact of entry is estimated using a dummy variable.

Because our data set includes all the bidders for all the calls for tender, we define a firm as an entrant if this firm was not active in that region in the first year of our data set (2008), but starts bidding in that regional market at a later stage.[15]

To analyse empirically the factors affecting the price of road maintenance in regional markets in Norway, we estimate the following model on the logarithm of prices (bids) in call for tender i in region j in year t, $p_{i,j,t}$. We use available explanatory variables that have been found in the literature to have an impact on bids in procurement auctions for road work (Johansson *et al.*, 2019):

$$p_{i,j,t} = \alpha_0 + \beta_1 Bidders_{i,j,t} + \beta_2 Rate_{i,j,t} + \beta_3 BidRate_{i,j,t} + \beta_4 Tonnes_{i,j,t} + \beta_5 Density_{i,j,t} + \beta_6 Contracts_{j,t} + \beta_7 Rounds_{j,t} + \delta_j + \mu_i + \gamma_t + D_{j,t} + \varepsilon_{i,j,t}. \quad (1)$$

The parameter β_i measures the impact from the number of bidders participating actively in tender i in market j in the year t, which is denoted by $Bidders_{i,j,t}$. From theory (Klemperer, 1999; as well as our model in Section 3) and previous studies (Johansson *et al.*, 2019), we expect that the number of competitors will have a negative impact on prices because having more bidders increases the degree of competition. Note that all active firms in a particular region might not participate in all calls for tender.

$Rate_{i,j,t}$ captures the participation rate for the specific call i. It is defined as the number of bidders submitting a bid for call i divided by the total number of firms operating in a region j in a given year t. The parameter β_2 quantifies the impact of the share of bidders in one region participating in the call for tender i. For the same reasons as for β_1, this parameter is expected to be negative. Accordingly, the higher is the rate of auction participation, the greater is the competition, and the lower are the prices.

In turn, the variable $BidRate_{i,j,t}$ attempts to capture interaction effects between the number of bidders in a bid and the rate of participation in the same bid. Accordingly, we believe that not only is the potential number of bidders in a market important, but also the interaction with the actual number of bidders in a given bid.

The next variable is the size of the contract, as measured by the estimated tonnes of asphalt required ($Tonnes_{i,j,t}$). This variable is intended to capture economies of scale (following Link, 2006; Wheat, 2017; and Johansson *et al.*, 2019) — that is, a larger project might involve a lower price per tonne. This would be captured in β_4.

The population density ($Density_{j,t}$) in a region might influence the price of road work, either because it is less or more costly to provide services in more dense regions (β_5 would be negative), or because the outside option (that is, availability of other contracts) is bigger in more densely populated areas (β_5 would be positive). Costs can be lower in more dense regions because there are more suppliers of raw materials or, conversely, costs can be higher because wages or other constraints are higher in dense regions. In dense regions, roadwork must be done at night, when workers' wages are higher.

We control for the total number of calls for tender in region j in year t ($Contracts_{j,t}$). If there are few contracts in one region in a particular year, it would make it more important for the firms present in that region to win each individual call for tender and, thus, would increase the competitive pressure. Therefore, we would expect β_6 to be negative because

[15] We exclude entry by firms that never win any contracts from the analysis. Firms that were bidding for only some of the years, and have won two or fewer tenders during the period, have not been defined as entrants.

more contracts increase the size of the market and decrease the competitive pressure in that region.

In addition, we have the total number of rounds of calls for tender within a regional market in one year ($Rounds_{j,t}$). Usually, there are only one or two rounds within a year, but in some cases we have three or four rounds occurring. The impact from *Rounds* is picked up by the parameter β_7. The parameter δ_j is the fixed effect on the regional market j, μ_i is the fixed effect on firm i, and the parameter γ_t is the fixed effect in year t. Finally, the dummy variable $D_{j,t}$, which takes the value 1 after a firm has entered into a regional market (and zero before). If the parameter associated with $D_{j,t}$ is found to be significant, we have an indication of how the intensity of competition affects bidding behaviour, as described in our theoretical model in Section 3.

There are several threats to obtaining a consistent estimate of the effect of interest in the econometric model outlined above. Our strategy to tackle these issues is threefold. First, we use the theoretical model developed in Section 3 as a guide to our estimation strategy. This implies that the estimated coefficient identifies the effect of interest under the assumptions of the structural model and, therefore, it must be interpreted in these bounds (see, for instance, Reiss and Wolak, 2007; Chetty *et al*., 2009; Coles *et al*., 2012; Rust, 2014; Blundell, 2017). Second, we attempt to account for other confounding sources of variation such as costs of raw materials, costs of intermediary goods and transportation costs, using firm, regional and year fixed effects in the estimation of the model. Finally, we conduct several robustness tests in which we vary the estimator; we also use a GMM model to make sure that we arrive at a consistent estimate of the effect of interest.

Figure 3 shows that we have four regional entrants in our data set: NCC entered the market ‘North’ in 2015; YIT Norge entered the market ‘Middle’ in 2012; and Peab entered the market ‘South’ in 2013 and the market ‘East’ in 2011. In addition, Mesta left the markets ‘West’, ‘East’, ‘South’, ‘North’, and ‘Middle’ in 2011. No firm entered the market ‘West’ during the period of analysis, 2008–18.[16]

All variables used in the regression are logarithms of the original variable. Hence, the measured impact, β_i, can be interpreted as the percentage change in the explained variable as a result of a percentage change in the explained variable. The model is estimated using robust standard errors, where the error term is clustered on regional bidders.

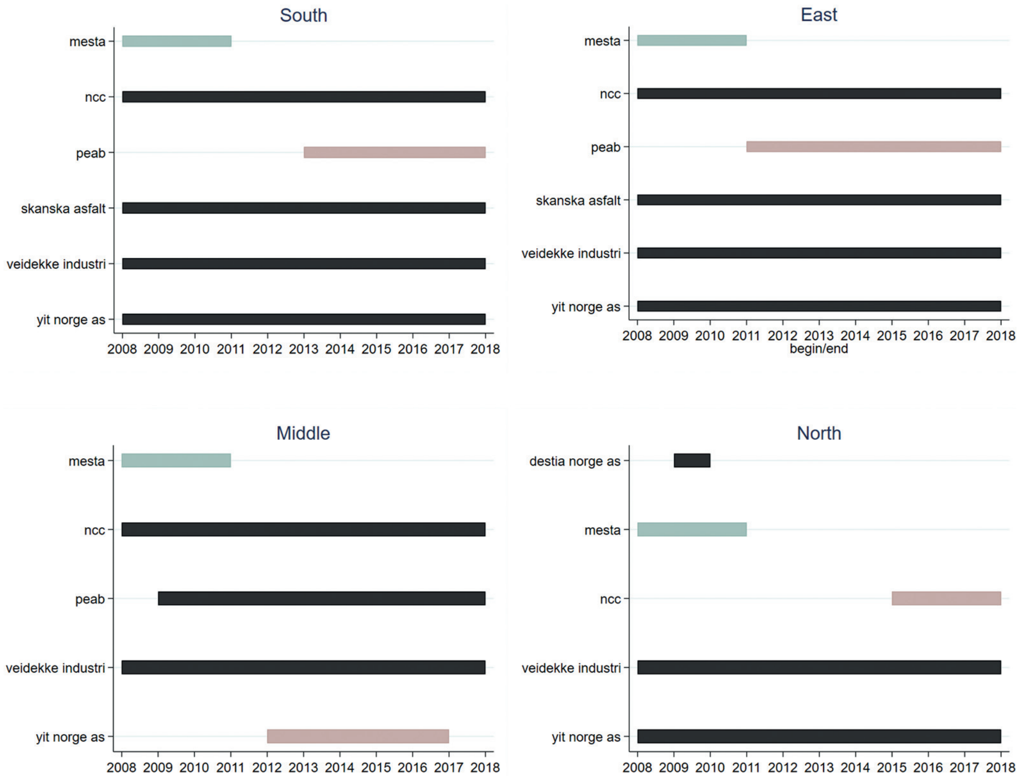
We run regressions for four versions of the econometric model in Table 3: Model 1 includes fixed effects on regions; in Model 2 we add firm fixed effects; Model 3 includes fixed effects on time (year); and Model 4 uses the GMM assumptions for the model without fixed effects.[17]

First, as expected, the number of bidders responding to a specific call, $Bidders_{i,j,t}$, has a negative impact on the price per tonne. Second, the participation rate for an individual call, $Rate_{i,j,t}$, impacts price per tonne positively in all models. Hence, when there is an increase in

[16]We have added an additional dummy variable for market exit. This variable is defined analogously to the entry variable. However, in the statistical analysis, it was found that the exit variable was not significant and, therefore, we do not show the results of this variable here. The reason why the exit variable is not significant might be because we have just one firm exiting the market (that is, too few observations) in our data set.

[17]The GMM estimator is a large-sample estimator. However, our sample is not sufficiently large to use fixed effects on regions, firms and years; hence we omit the inclusion of these fixed effects when estimating Model 4.

Figure 3
Firms in the Regional Markets Across the Sample Period



the number of bidders actively bidding for a specific contract as a share of all firms in that particular market, prices increase. This result may seem surprising; we discuss it next when analysing the interaction term between $Bidders_{i,j,t}$ and $Rate_{i,j,t}$.

We can see that the interaction effect between $Bidders_{i,j,t}$ and $Rate_{i,j,t}$ is negative. Because the direct effect of $Rate_{i,j,t}$ is negative, as we have just observed, we have to examine the marginal effects of this variable to understand the full impact of $Rate_{i,j,t}$ on prices (see Brambor *et al*., 2006). This is shown in Figure 4. The left-hand panel illustrates how the price per tonne falls as the number of bidders increases in individual auctions. The right-hand panel shows that the price per tonne falls as the participation rate increases, given the level of bidders.

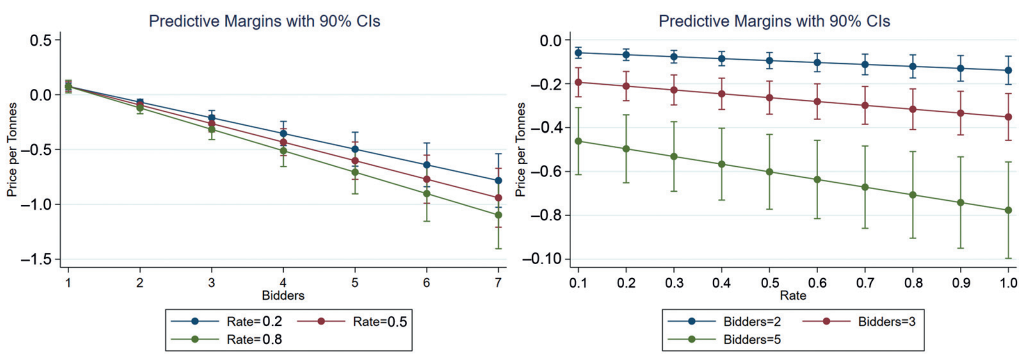
The left-hand panel in Figure 4 shows that irrespective of the participation rate for the particular call, the price per tonne falls significantly with the number of bidders. In the right-hand panel, we see that the impact of the participation rate on price per tonne is also negative, especially if the number of bidders is relatively high. This impact falls as the number of bidders falls. That is, as either: (i) the number of potential bidders increases in a market; or (ii) the participation rate of the potential bidders increases, as price per tonne falls. The first impact reflects the fact that intensity of competition — measured by the number of bidders — reduces prices. The second impact also relates to the number

Table 3
Regression Results for the Entry Model

	(1) Price per tonne (b/se)	(2) Price per tonne (b/se)	(3) Price per tonne (b/se)	(4) Price per tonne (b/se) GMM
Bidders	−0.196***	−0.194***	−0.116***	−0.239***
	(0.025)	(0.025)	(0.027)	(0.022)
Rate	0.149***	0.149***	0.078**	0.192***
	(0.030)	(0.030)	(0.032)	(0.028)
Bidders × Rate	−0.090***	−0.094***	−0.090***	−0.076***
	(0.022)	(0.022)	(0.023)	(0.022)
Tonnes	−0.140***	−0.143***	−0.144***	−0.131***
	(0.007)	(0.007)	(0.007)	(0.008)
Density	0.042***	0.042***	0.040***	0.033***
	(0.003)	(0.004)	(0.004)	(0.004)
Contracts	−0.076***	−0.070***	−0.012	−0.042***
	(0.019)	(0.020)	(0.025)	(0.015)
Rounds	−0.048***	−0.052***	−0.078***	−0.057***
	(0.010)	(0.010)	(0.011)	(0.011)
$D_{j,t}$	0.009	0.003	−0.035***	0.048***
	(0.010)	(0.010)	(0.013)	(0.008)
Constant	1.790***	1.803***	1.560***	1.686***
	(0.113)	(0.114)	(0.122)	(0.098)
Region FE	Yes	Yes	Yes	
Firms FE		Yes	Yes	
Year FE			Yes	
r2	0.355	0.371	0.408	
N	2,608	2,608	2,608	2,608

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 4
Marginal Effects of Participation Rate and Bidders



Note: The figure shows the marginal effects for Model 3, with all fixed effects. The left-hand panel shows the effect of the number of bidders, given the participation rate. The right-hand panel shows the effect of the participation rate, given the number of bidders. Cis = confidence intervals.

of competitors, not directly, but via the participation rate in the auctions. Again, as the intensity of competition — measured using the participation rate — increases, the prices fall. Thus, the number of bidding firms reduces the price in auctions.

The variable $Tonnes_{i,j,t}$, measuring the size of the individual projects, shows that larger auctions have a negative impact on the price per tonne. This is as expected because, as the size of the project increases, economies of scale become more important as the average and marginal costs fall. Similar effects have been found in studies in Sweden and Denmark (Johansson *et al.*, 2019). Two effects are most likely at play. First, as the size of a project increases, overhead costs are spread on a larger base of construction costs. Second, many of the larger projects are located in regions with less need for additional work requirements, such as building auxiliary bridges and tunnels for completion of the project.[18]

The variable $Density_{j,t}$ impacts price per tonne positively; that is, as the population density increases, the price per tonne increases. This contrasts with the findings of a Swedish study (Johansson *et al.*, 2019), in which there is a negative relationship between these two variables. We believe this difference is because we have introduced regional fixed effects. Therefore, the regional fixed effects already take into account regional differences in population density. In addition to the impact of regional fixed effects, there is a positive impact from population density in counties; that is, we observe that counties with large cities — or higher population densities in general — have a higher price per tonne. This might be related to the cost of living and regional price index effects. Alternatively, costs might be higher in dense regions because wages can be higher. For example, as we mentioned above, in dense regions, road works must be performed at night. In Norway, state labour regulations require that remuneration is higher per hour for working at night.

$Rounds_{i,j,t}$ denotes the number of calls for tender in a particular regional market in one year. As the number of calls for tender increases, the price per tonne falls. This might indicate that costs are reduced when a firm works on a project in which it has previous experience. This seems natural, as the firm already has all the work infrastructure in place.

The number of contracts in each regional market impacts price per tonne negatively — that is, prices per tonne are lower in large markets.[19] This is consistent with the idea that industry price indexes are lower in larger markets (measured by an economic activity indicator, such as regional/local GDP) after adjusting for transport costs. The economic geography literature usually refers to this as *market potential* (see Krugman, 1991). Alternatively, more contracts in a region allow firms to exploit larger economies of scale.

As to the dummy for market entry, we find that this is statistically negative for all models. Hence, as a new firm enters into the regional market, we find that this negatively impacts the prices submitted in the auctions. This implies that beyond the effect of increased competition captured by the number of bidders in the market, the entry of a new competitor has a structural effect on prices in these markets. This has policy implications in that stimulating more competition and increased entry in these markets should lead to

[18]We tested for a quadratic relationship between tonnes and prices per tonne. However, this impact was non-significant and was removed from the analysis.

[19]As a consistency check, we ran regressions removing the largest region (East), and removing the Northern region. The results are similar to those documented in Table 3. However, the significance levels fall owing to the reduction in observations in the regressions. Tables with these results are found in Appendix C.

significant structural changes to competition, and be beneficial for consumer surplus and social welfare.

5.2 Number of bidders

Another interesting question is whether the size of contracts affects the number of firms participating in auctions. As explained in Section 3.4, on the one hand, firms may regard large contracts as more lucrative, simply because larger contracts aid in filling order books. On the other hand, firms may consider larger contracts significantly more complex to administer, financially riskier, or simply too large for a firm to take on. To analyse these aspects empirically in the Norwegian market for asphalt, we study how the size of the contracts, measured in tonnes, affects the number of firms submitting bids in the NPRA's auctions in this market. We include a categorical variable for the market where the auction took place because we observe a significant difference in the number of bidders participating in auctions in the different markets organised by the NPRA. The equation used in the analysis is:

$$Bidders_j = Tonnes_j + RegionalMarket + \varepsilon, \tag{2}$$

where *Bidders* is the number of bidders in a given auction, *Tonnes* is as above in equations (1) and (2), and *Regional Market* is a dummy variable for the different regional markets (North, South, Middle, West, and East).

We use four count-data models to analyse the relationship between the number of firms participating in an auction and the size of the auctioned contracts.[20] All models are documented in Table 4.

First, we see that the size of the projects has a statistically significant positive impact on the number of bidders. This is true irrespective of what model is chosen. Hence, in our data set, larger contracts increase the number of bidders in a given auction.

In our view, this has clear policy implications, in particular, that the Norwegian road authorities should consider running larger auctions. This contrasts with the current policy, under which individual projects are usually divided into smaller contracts. However, the downside of larger contracts is that they can preclude the entrance of small contractors. At present, the market has few participants, and they are all large. At the same time, in road maintenance markets, a firm needs to be big to be competitive. Therefore, it is not clear if smaller contracts promote entry. In the period that we have analysed, despite smaller contracts, we do not observe the entrance of many small competitors.

[20]When analysing count data, the Poisson model or negative binomial regression analysis is often used. However, our data set does not fit well with the assumptions underlying these models. The Poisson model assumes equidispersed data — that is, the mean equals the variance of the explained variable. In many cases, data are over-dispersed — that is, $mean(x) < var(x)$. The opposite is true in our data set, $mean(x) > var(x)$ — that is, the data are under-dispersed. Therefore, we use four models, differing with respect to what extent the data fit the assumption underlying the model. One model, following Harris *et al*. (2012), is particularly suited to handling under-dispersed data (the generalised Poisson model). In Table 4, we document the results from running the four models, including an ordinary Poisson model on the left and a Poisson model with robust standard errors in the second column. Then, we run a generalised linear model using Stata's glm-routine (with family = binomial and link = logit). Finally, to the right, we estimate the generalised Poisson model (following Harris *et al*., 2012), which is expected to produce the most reliable results.

Table 4
Regression Results: Number of Bidders

	(1) Bidders (b/se)	(2) Bidders (b/se)	(3) Bidders (b/se)	(4) Bidders (b/se)
Tonnes	0.026**	0.026***	0.047***	0.026***
	(0.013)	(0.007)	(0.013)	(0.007)
Middle	Baseline			
North	−0.197***	−0.197***	−0.292***	−0.223***
	(0.076)	(0.037)	(0.059)	(0.040)
South	0.050	0.050	0.088	0.031
	(0.067)	(0.034)	(0.057)	(0.036)
West	0.138**	0.138***	0.238***	0.127***
	(0.070)	(0.036)	(0.061)	(0.038)
East	0.269***	0.269***	0.484***	0.307***
	(0.063)	(0.036)	(0.065)	(0.033)
Constant	0.909***	0.909***	−0.617***	0.909***
	(0.069)	(0.036)	(0.061)	(0.038)

Notes: The symbols *, **, and *** denote that $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.
The results are based on four count-data models: Model 1: Poisson model; Model 2: Poisson model with robust standard errors; Model 3: generalised linear model; and Model 4: generalised Poisson model.

In addition, we find that the number of bidders is significantly higher in the Eastern and Western regional markets, and significantly lower in the Northern region. This is identical to what we found in the analyses above and from the descriptive statistics. We also observe that both the traditional Poisson and robust Poisson models produce results that are highly similar to the generalised Poisson model. Hence, the particular assumptions on the data analysed seem to be unimportant to the results that we find, and this observation can be regarded as a test for robustness.

6.0 Discussion and Conclusion

In the above sections, we have empirically analysed the Norwegian market for the maintenance of national roads. First, we construct a model explaining bidding behaviour, using a range of explanatory variables expected to determine bid levels, controlling for effects related to years, firms, and regional markets. Our analysis suggests, consistent with theory, that the number of bidders in the market negatively influences prices. This provides evidence that competition is an important factor in thin markets, such as the one that we analyse. Furthermore, the number of potential bidders, which is observable to other bidders, seems to be more important than the number of actual bidders in a specific competition for a contract, which is unobservable to other bidders at the time of submitting their bid.

In addition, entry into regional markets affects the bidding behaviour. We find that a firm entering a new market significantly reduces the average bid.[21] This suggests that

[21] Firm entry also negatively impacts our other measures of prices and bids, but not at the same level of significance.

entry has a structural impact on regional competition and reduces prices beyond the simple competition effect of a larger number of bidders. This result indicates to the regional authorities and the NPRA the positive impact of promoting entry.

Finally, we show that the size of projects has a positive impact on the number of entries in an auction. This has clear policy implications for the Norwegian road maintenance market. In this market, projects are usually divided into smaller projects, thereby reducing the size of each auction. Our results indicate that competition and therefore prices would be significantly more favourable if the Norwegian authorities opted instead for a larger auction for each project.

References

Arnek, M. (2002): 'Empirical essays on procurement and regulation', doctoral thesis, Uppsala University.

Athey, S., J. Levin, and E. Seira (2011): 'Comparing open and sealed bid auctions: evidence from timber auctions', *The Quarterly Journal of Economics*, 126, 207–57.

Ausubel, L. M., P. Cramton, and P. Milgrom (2004): 'The clock-proxy auction: a practical combinatorial auction design', in P. Cramton, Y. Shoham, and R. Steinberg (eds), *Combinatorial Auctions*, MIT Press, Cambridge.

Balat, J. (2013): 'Highway procurement and the stimulus package: identification and estimation of dynamic auctions with unobserved heterogeneity', working paper.

Bergman, M. A., J. Lundberg, S. Lundberg, and J. Y. Stake (2020): 'Interactions across firms and bid rigging', *Review of Industrial Organization*, 56, 107–30.

Blundell, R. (2017): 'What have we learned from structural models?', *American Economic Review*, 107, 287–92.

Brambor, T., W. Clark, and M. Golder (2006): 'Understanding interaction models: improving empirical analyses', *Political Analysis*, 14, 63–82.

Chetty, R., A. Looney, and K. Kroft (2009): 'Salience and taxation: theory and evidence', *American Economic Review*, 99, 1145–77.

Coles, J. L., L. L. Michael, and J. F. Meschke (2012): 'Structural models and endogeneity in corporate finance: the link between managerial ownership and corporate performance', *Journal of Financial Economics*, 103, 149–68.

De Silva, D. G., T. P. Hubbard, and G. Kosmopoulou (2020): 'An evaluation of a bidder training program', *International Journal of Industrial Organization*, 72, Article 102661.

Dimitri, N., G. Piga, and G. Spagnolo (2006): *Handbook of Procurement*, Cambridge University Press, Cambridge.

Gonçalves, R. and A. Gomes (2012): 'Maintenance incentives in highway concession contracts', *Journal of Transport Economics and Policy*, 46, 99–122.

Groeger, J. R. (2014): 'A study of participation in dynamic auctions', *International Economic Review*, 55, 1129–54.

Gugler, K., M. Weichselbaumer, and C. Zulehner, (2015): 'Competition in the economic crisis: analysis of procurement auctions', *European Economic Review*, 73, 35–57.

Harris, T., Z. Yang, and J. W. Hardin (2012): 'Modeling underdispersed count data with generalized Poisson regression', *The Stata Journal*, 12, 736–47.

Heike, L. (2014): 'A cost function approach for measuring the marginal cost of road maintenance', *Journal of Transport Economics and Policy*, 48, 15–33.

Hendricks, K. and H. J. Paarsch (1995): 'A survey of recent empirical work concerning auctions', *Canadian Journal of Economics*, 28, 403–26.

Ivaldi, M., B. Jullien, P. Rey, P. Seabright, and J. Tirole (2007): 'The economics of tacit collusion: implications for merger control', *The Political Economy of Antitrust*, 282, 217–39.

Joenpolvi, K. (2015): 'Finnish asphalt and timber cartel damages cases', *Business Law International*, 16, 157.

Jofre-Bonet, M. and M. Pesendorfer (2003): 'Estimation of a dynamic auction game', *Econometrica*, 71, 1443–89.

Johansson, O., J.-E. Nilsson, and J. Nyström (2019): 'Does asphalt exhibit economies of scale?', mimeo, KTH Royal Institute of Technology, Stockholm.

Klemperer, P. (1999): 'Auction Theory: A Guide to the Literature', *Journal of Economic Surveys*, 13, 227–86.

Konkurransetilsynet (2013): 'V2013-3 — Veidekke ASA/Veidekke Industri AS og NCC AB. Report', Konkurransetilsynet.

Konkurrensverket (2009): 'Asfaltkartellen fälld i högsta instans. Report', Konkurrensverket.

Krasnokutskaya, E. (2011): 'Identification and estimation of auction models with unobserved heterogeneity', *The Review of Economic Studies*, 78, 293–327.

Krasnokutskaya, E. and K. Seim (2011): 'Bid preference programs and participation in highway procurement auctions', *American Economic Review*, 101, 2653–86.

Krishna, V. (2002): *Auction Theory*, Academic Press, San Diego.

Krugman, P. (1991): 'Increasing returns and economic geography', *Journal of Political Economy*, 99, 483–99.

Laffont, J.-J. (1997): 'Game theory and empirical economics: the case of auction data', *European Economic Review*, 41, 1–35.

Levin, J. and S. Tadelis (2010): 'Contracting for government services: theory and evidence from US cities', *Journal of Industrial Economics*, 58, 507–41.

Link, H. (2006): 'An econometric analysis of motorway renewal costs in Germany', *Transportation Research Part A: Policy and Practice*, 40, 19–34.

Link, H. (2014): 'A cost function approach for measuring the marginal cost of road maintenance', *Journal of Transport Economics and Policy*, 48, 15–33.

Lyon, B. and A. Dwyer (2011): 'Road maintenance: options for reform. Report', Infrastructure Partnerships Australia, Sidney.

Nash, C. and T. Sansom (2001): 'Pricing European transport systems: recent developments and evidence from case studies', *Journal of Transport Economics and Policy*, 35, 363–80.

Nash, C. and B. Matthews (2005): *Measuring the Marginal Social Cost of Transport*, Elsevier, Amsterdam.

Nilsson, J.-E., K. Svensson, and M. Haraldsson (2020): 'Estimating the marginal costs of road wear', *Transportation Research Part A: Policy and Practice*, 139, 455–71.

Odeck, J. (2014): 'Do reforms reduce the magnitudes of cost overruns in road projects? Statistical evidence from Norway', *Transportation Research Part A: Policy and Practice*, 65, 68–79.

Reiss, P. C. and F. A. Wolak (2007): 'Chapter 64: Structural econometric modeling: rationales and examples from industrial organization', *Handbook of Econometrics*, Elsevier, Amsterdam.

Ricardo-AEA (2014): 'Update of the handbook on external costs of transport: final report', Ricardo-AEA/R/ED57769.

Rust, J. (2014): 'The limits of inference with theory: a review of Wolpin (2013)', *Journal of Economic Literature*, 52, 820–50.

Sultana, M., A. Rahman, and S. Chowdhury (2013): 'A review of performance based maintenance of road infrastructure by contracting', *International Journal of Productivity and Performance Management*, 62, 276–92.

Tirole, J. (1988): *The Theory of Industrial Organization*, MIT Press, Cambridge, MA.

Weber, R. (1997): 'Making more from less: strategic demand, reduction in the FCC spectrum auctions', *Journal of Economics & Management Strategy*, 6, 529–48.

Wheat, P. E. (2017): 'Scale, quality, and efficiency in road maintenance: evidence for English local authorities', *Transport Policy*, 59, 46–53.

Yarmukhamedov, S., A. S. J. Smith, and J.-C. Thiebaud (2020): 'Competitive tendering, ownership, and cost efficiency in road maintenance services in Sweden: a panel data analysis', *Transportation Research Part A: Policy and Practice*, 136, 194–204.

Appendices

Appendix A1: Derivation of the symmetric Nash equilibrium bidding strategy

Let β be the symmetric bidding strategy of all the other firms. In a bidding competition with n firms, we can thus write that the probability of firm i (with cost c_i) to win with bidding strategy b is:

$$Prob(b < \beta(c_j), \forall j \neq i).$$

Since costs c_j are independent, this can be written as:

$$(Prob(b < \beta(c)))^{n-1},$$

where the subscript j is dropped because the cost parameters of all the $n-1$ competitors are drawn from the same probability distribution.

Imposing that the symmetric bidding strategy is (strictly) monotone allows us to rewrite $b < \beta(c)$ as $c > \beta^{-1}(b)$, and we finally obtain (by rearranging terms and using the definition of the cumulative density distribution of the uniform distribution, $F(c) = c$):

$$(Prob(c > \beta^{-1}(b)))^{n-1} = (1 - F(\beta^{-1}(b)))^{n-1} = (1 - \beta^{-1}(b))^{n-1}.$$

Define $G(c) = (1 - c)^{n-1}$. With this expression, we are now ready to write down firm i's optimisation problem:

$$\max_b G(\beta^{-1}(b))(b - c_i).$$

The associated first-order condition with respect to b is:

$$\frac{g(\beta^{-1}(b))}{\beta'(\beta^{-1}(b))}(b - c_i) + G(\beta^{-1}(b)) = 0,$$

where g is the probability density function associated with G. Using that in the symmetric equilibrium $b = \beta(c_i)$, this is equivalent to:

$$g(c_i)b(c_i) + G(c_i)b'(c_i) = c_i g(c_i).$$

Integrating both sides from c_i to 1 yields:

$$G(c_i)b(c_i) = \int_{c_i}^{1} xg(x)dx.$$

Integration by part and using the definition of G finally yields:

$$b(c_i) = c_i + \frac{1 - c_i}{n}.$$

The expected profit is thus:

$$\Pi^c(c_i) = G(c_i)(b(c_i) - c_i) = \frac{(1 - c_i)^n}{n},$$

and the ex-ante expected profit is:

$$E[\Pi^c(c_i)] = \int_0^1 \frac{(1 - x)^n}{n} dx = \frac{1}{n(n + 1)}.$$

Appendix A2: Derivation of the necessary and sufficient condition for a non-competitive bidding strategy to be sustainable

This bidding strategy is sustainable if and only if the discounted sum of present and future gains from this strategy are larger than the present and future gains from deviating and reverting to the competitive bidding strategy in future tenders. This can be written as:

$$\Pi^{nc}(c_i) + \sum_{\delta=1}^{\infty} \delta^t E[\Pi^{nc}(c_i)] \geqslant \Pi^{dev}(c_i) + \sum_{\delta=1}^{\infty} \delta^t E[\Pi^{c}(c_i)],$$

where δ is the discount factor and $\Pi^{dev}(c_i)$ is the expected profit from deviating from the cooperative bidding strategy, which we will now determine.

In fact, if everyone else bids according to $b^{nc}(c_j)$, then firm i's optimal bidding strategy solves:

$$\max_{b^{dev}} G\left(\frac{n}{n-\alpha}\left(b^{dev} - \frac{\alpha}{n}\right)\right)(b^{dev} - c_i),$$

where G is defined in Appendix A1. The first-order condition for this problem is:

$$\frac{n}{n-\alpha} g\left(\frac{n}{n-\alpha}\left(b^{dev} - \frac{\alpha}{n}\right)\right)(b^{dev} - c_i) + G\left(\frac{n}{n-\alpha}\left(b^{dev} - \frac{\alpha}{n}\right)\right) = 0.$$

Solving this yields $b^{dev}(c_i) = b^c(c_i)$. The optimal deviation is to revert to the competitive bidding strategy (any other deviation is less profitable). This deviation yields an expected profit of:

$$\frac{(n-1)^{n-1}(1-c_i)^n}{n(n-\alpha)^{n-1}}.$$

The necessary and sufficient condition for a non-competitive bidding strategy to be sustainable can thus be simplified to:

$$\frac{(1-c_i)^n}{n}\left[1 - \left(\frac{n-1}{n-\alpha}\right)^{n-1}\right] + \frac{\delta}{1-\delta}\frac{\alpha-1}{n(n+1)} \geqslant 0.$$

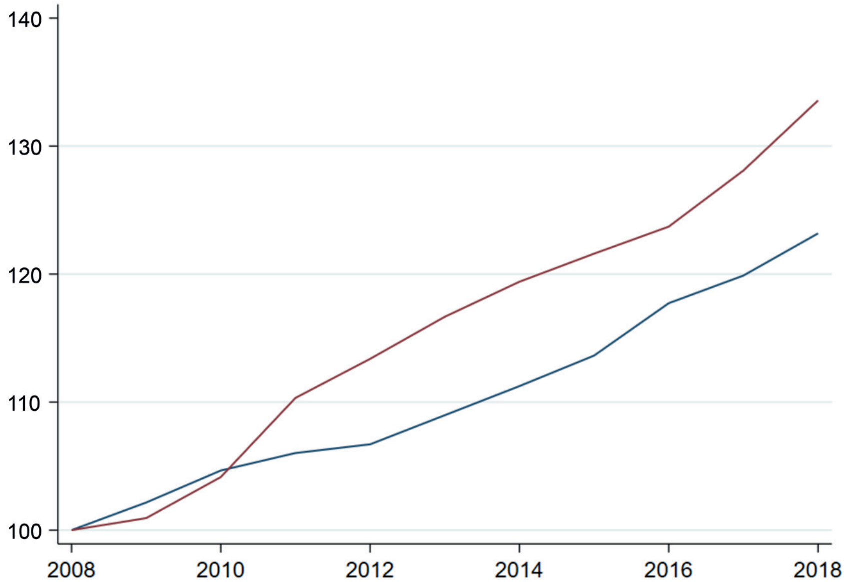
The first term is negative because $\alpha > 1$ and so if it holds for the lowest cost (highest profit) type, it holds for the other costs as well. This means that condition becomes:

$$(1-\delta)\left[1 - \left(\frac{n-1}{n-\alpha}\right)^{n-1}\right] + \delta\frac{\alpha-1}{(n+1)} \geqslant 0.$$

For δ high enough or n small enough (given the discount factor), this inequality holds.

Appendix B: Difference in the consumer price index and road construction cost index

Figure B1
Cost Indexes



Note: Consumer price index (blue line) and road construction cost index (red line). Data source: Statistics Norway.

Appendix C: Regression excluding regions

Table C1
Model 1 (Market Model): Factors Determining Bid Levels, Excluding the East Region

	(1) Price per tonne b/se	(2) Price per tonne b/se	(3) Price per tonne b/se	(4) Price per tonne b/se GMM
Bidders	−0.148***	−0.148***	−0.089***	−0.330***
	(0.026)	(0.026)	(0.029)	(0.025)
Rate	0.094***	0.097***	0.033	0.252***
	(0.035)	(0.036)	(0.037)	(0.035)
Bidders × Rate	−0.058*	−0.063*	−0.038	−0.029
	(0.032)	(0.032)	(0.033)	(0.032)
Tonnes	−0.121***	−0.121***	−0.122***	−0.130***
	(0.008)	(0.008)	(0.008)	(0.008)
Density	0.021***	0.019***	0.019***	−0.014***
	(0.005)	(0.005)	(0.005)	(0.005)
Contracts	−0.039*	−0.034*	0.016	−0.070***
	(0.020)	(0.021)	(0.026)	(0.016)
Rounds	−0.056***	−0.060***	−0.092***	−0.059***
	(0.012)	(0.012)	(0.013)	(0.013)
$D_{j,t}$	0.023**	0.016	−0.033**	−0.001
	(0.010)	(0.010)	(0.014)	(0.009)
Constant	1.470***	1.469***	1.281***	1.199***
	(0.125)	(0.125)	(0.134)	(0.097)
Region FE	Yes	Yes	Yes	
Firms FE		Yes	Yes	
Year FE			Yes	
r2	0.358	0.370	0.419	
N	1,826	1,825	1,825	1,826

Note: The symbols *, **, and *** denote that $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

Table C2
Model 1 (Market Model): Factors Determining Bid Levels, Excluding the North Region

	(1) Price per tonne b/se	(2) Price per tonne b/se	(3) Price per tonne b/se	(4) Price per tonne b/se GMM
Bidders	−0.168***	−0.159***	−0.109***	−0.017
	(0.027)	(0.027)	(0.030)	(0.020)
Rate	0.111***	0.104***	0.072**	−0.044
	(0.033)	(0.033)	(0.035)	(0.027)
Bidders × Rate	−0.065***	−0.065***	−0.074***	−0.062***
	(0.023)	(0.023)	(0.024)	(0.022)
Tonnes	−0.132***	−0.135***	−0.136***	−0.119***
	(0.008)	(0.008)	(0.008)	(0.008)
Density	0.044***	0.043***	0.041***	0.049***
	(0.003)	(0.004)	(0.004)	(0.004)
Contracts	−0.076***	−0.072***	−0.100***	−0.061***
	(0.020)	(0.020)	(0.025)	(0.014)
Rounds	−0.061***	−0.064***	−0.081***	−0.062***
	(0.010)	(0.010)	(0.011)	(0.010)
$D_{j,t}$	0.003	−0.003	−0.020	0.040***
	(0.010)	(0.010)	(0.014)	(0.008)
Constant	1.652***	1.662***	1.703***	1.199***
	(0.126)	(0.126)	(0.134)	(0.097)
Region FE	Yes	Yes	Yes	
Firms FE		Yes	Yes	
Year FE			Yes	
r2	0.291	0.310	0.347	
N	2,283	2,282	2,282	2,283

Note: The symbols *, **, and *** denote that $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.