The Benefits of Procurement Auctions: Competitive Pressure vs. Selection of Efficient Suppliers

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Abstract

We study the effects of the procurement mode on the quantity of regional train services and the procurement price in Germany. We exploit a 1996 reform that allowed regional rail agencies to use procurement auctions. A reduced-form analysis shows that using procurement auctions rather than directly awarding the contracts to the incumbent increased the service frequency by 12-16%, and decreased the procurement price of a train kilometer by 20-25%. Adopting a structural auction framework, we confirm that auctions reduce prices (though only by 15-16%). We also find that auctions substantially reduce markups, and select more efficient suppliers, thereby reducing costs.

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1 Introduction

The nature of public procurement has changed dramatically over the last decades. Until the nineteen eighties, state-owned companies provided a wide range of goods and services. Most importantly, network industries such as electricity, gas, water, railways and postal services were state monopolies in many countries. The wave of privatization and deregulation in the nineteen eighties led to institutional change all over the world. The retreat of the state and the introduction of competition were supposed to foster efficiency and help to reduce taxes. Yet, early enthusiasm for privatization and liberalization has given way to a more critical assessment of policies introducing competition in the public domain. Reasonable arguments can be made for privatization and competition, but the efficiency-enhancing effects of these measures cannot be taken for granted.

We focus on the effects of competition in public procurement. This is an important topic because public procurement amounts to approximately 13% of GDP on average in OECD countries (OECD 2013, p.18). In addition, competitive and non-competitive modes are both used in the public procurement of goods and services. Yet it is not clear which of the two modes is superior. There are at least two theoretical reasons why using competitive procedures rather than awarding contracts directly might lower procurement costs. First, competition puts pressure on firms to submit lower bids. Second, procurement auctions help to select efficient suppliers.[1]

However, the literature has cast serious doubts on the functioning of competitive procurement. First, it is not obvious that the potential benefits of competitive procurement will materialize. The desirable effects of competition on prices may be absent if firms collude or bid conservatively because they are afraid of the winner's curse in a common value framework. Second, competitive procurement may have substantial downsides. Whenever quality is non-verifiable and price competition is unlimited, it is plausible to suspect that low prices come at the cost of low quality. This study will deal with a case where the first concern will turn out

[1] Also, it has sometimes been argued that an obligation to use competitive procurement can help to fight corruption (e.g., Chong et al. 2014) or "passive" waste (Bandiera et al. 2009).

not to be valid. In our example, competitive procurement has strong beneficial effects on prices and on the supply of services (in quantitative terms). We also argue, much more tentatively, that there are no strong reasons to believe that these positive effects mirror quality reductions in the case at hand.

Specifically, this paper analyzes the effects of competition on the procurement of passenger railway services by public agencies in Germany. Many European countries have gradually liberalized the sector since the nineteen nineties. As a result, competitive procurement now coexists with direct award procedures, sometimes even within countries. Germany is a case in point. In January 1996, the German *Regionalisierungsgesetz* ("Regionalization Law") came into effect. This law stipulates that state agencies are responsible for the assignment of public funds to individual lines; and it gives them the freedom to procure the services by awarding the contract directly to the dominant supplier, *DB Regio*, or via auctions. The law was part of a policy to expand public transportation and, in particular regional rail transportation. In the period under investigation (1994-2004), the funds for regional passenger transportation increased substantially, resulting in a drastic increase of the supply of railway services. There is widespread agreement that regional passenger transportation developed positively in the period under consideration, but it is less clear whether this was due to the introduction of competition or merely to the inflow of additional funds.

The German setting provides a unique opportunity to compare the performance of lines procured competitively with those awarded directly. The central empirical issue is whether these different types of lines are comparable. Agencies were free to select lines for procurement auctions. Thus, the choice of procurement mode is not random. We address this important issue by collecting rich information on the frequency of service on the lines before and after the introduction of the reform to characterize the choice of procurement mode. A key concern is that, in ways unobserved to us, agencies might have selected lines that would have grown most with auctions. Selection based on expected growth has an important testable implication: auctioned lines would have lower service levels prior to the reform than directly awarded lines, all else equal. A regression of procurement mode on various observables shows that regional passenger service agencies used auctions predominantly on remote lines that were not very

frequently served before the reform. However, once we condition on observed characteristics, we find no difference in the pre-reform frequency of service between lines to be auctioned and lines that were directly awarded to the incumbent. This finding suggests selection was not based on the expected growth of service on a line.

We find that, compared to directly awarded lines, procurement auctions increase the frequency of service by about 12-16%. Moreover, using an OLS regression, we show that winning bids in procurement auctions are about 20-25% lower than prices for directly awarded contracts.[2] Procurement auctions in the German regional passenger rail sector thus produced substantial gains in service, at a substantially lower price. An open question is whether the advantages of competitive procurement indeed come at the cost of lower quality, as one might expect. While we could not obtain adequate data to answer this question definitely, the limited evidence we have provides no reason for the conjecture that competitively procured lines are plagued by systematically lower quality than directly awarded lines.

Auctions can reduce prices by forcing bidders to ask for lower markups to deliver a service, or by selecting providers who have lower costs of providing a service. Understanding which of the two channels operates is important. If auctions lower markups without picking a more efficient firm than the incumbent, this does not merely redistribute rents from suppliers to agencies: It also increases welfare because agencies are likely to choose a quantity that is higher and thereby closer to the optimum.[3] If auctions select a more efficient supplier, welfare increases further, because any quantity can be produced at lower costs.

We therefore go on to analyze the relative importance of the two channels. We recover the distribution of bidders' costs in an auction framework. Specifically, we estimate a structural model of the distribution of the lowest bids in the procurement auctions. We use this to recover bidders' costs in a second step, using the first order-condition for optimal bidding behavior (see Guerre et al., 2000). Due to data limitations – we only observe winning bids and, in some cases, the number of bidders, not their identity – our structural models is rather simple. We assume an independent private value environment and cannot account for collusion, endoge-

[2] We cannot use a difference-in-difference approach for procurement prices because such prices were only introduced after the reform.

[3] For details, see Section 5.1.

nous entry (Krasnokutskaya and Seim 2011, Athey et al. 2011) or unobserved heterogeneity (Krasnokutskaya 2011). Still, we believe that at least some of these limitations might not be too serious.[4]

We have no direct measures of the incumbent's costs when contracts are awarded directly, but we estimate upper and lower bounds. Using these bounds, we can also obtain some idea about the relative contributions of markup reduction from competitive pressure and cost reduction from selection of efficient suppliers. We estimate that auctions reduced the price of rail service from 8.23 EUR to 6.98 EUR per kilometer, or by 1.25 EUR. Using the upper bound on incumbent costs for directly awarded contracts, we find that procurement auctions reduced the average cost of providing the service from 7.53 EUR to 6.68 EUR, or by 85 Cents. Costs thus responded substantially to auctions, explaining around 70 percent of the price response to auctions. The absolute markup decreases from 70 Cents to 30 Cents, or by 40 Cents. Even in this scenario, the markup response to auctions explains around 30 percent of the price response. Using the lower bound on incumbent costs for directly awarded contracts instead, we find that the cost does not respond to the procurement mode, so that the price reduction is entirely explained by a reduction in markups from 20.6 to 4.3%.

The remainder of the paper is organized as follows. Section 2 provides a review of related literature, and Section 3 discusses the institutional background. In Section 4, we describe the data and provide the first results of our regression analysis. Section 5 introduces a structural model, the results of which are discussed in Section 6. Section 7 concludes.

2 Related Literature

Our paper contributes to a rapidly growing literature on the performance of public procurement. We focus on the part of the literature that analyzes the effects of competition.[5] In addition, our paper provides insights on the success of reforms in the railway sector, an important example of a network industry. We thus provide a short summary of the literature on both issues.

[4] In particular, our reduced form analysis shows that procurement prices are much lower with competitive procurement than without. This suggests that collusion and/or common values are not very important in the industry under observation.

[5] Another broadly related strand of literature deals with how the procurement prices paid by government agencies are affected by corruption (active waste) and inefficiency (passive waste); see, e.g., Bandiera et al. 2009.

The literature has focused on the advantages and disadvantages of competitive mechanisms, and it has identified circumstances under which competitive procurement is called for. Bulow and Klemperer (1996) give general conditions under which adding a competitor to an optimal sales mechanism with n buyers improves the outcome for the seller, and, in particular, auctions $(n > 1)$ are preferable to negotiations $(n = 1)$ with a single buyer. Applied to a procurement context, the result identifies circumstances under which, from the perspective of the agency, competitive procurement is favorable to negotiations with a single supplier, no matter how cleverly these negotiations are designed. On a related note, Armstrong and Sappington (2006) identify the beneficial effects of competition for the buyer, the *rent-reducing effect* from increasing competitive pressure on bidders and the *sampling effect* from improved bidder selection; these two effects are the motivation for our structural analysis in Section 5.

There are several theoretical reasons why a price-reducing effect of competition need not necessarily arise. With common or affiliated values, it is well-known that, because of fear of the winner's curse, rational bidders will bid less aggressively when the number of bidders increases. As a result, bids are not necessarily decreasing in the number of firms, and not even necessarily lower with competitive bidding than with direct negotiations with a single supplier.[6] Empirical evidence supports this idea.[7] Collusion is another reason why potential price advantages from competitive procurement might not materialize.[8] While collusion between bidders does not necessarily prevent the selection of the efficient supplier, it reduces competitive pressure.

Some papers have gone futher, identifying actual disadvantages of competitive procedures. For instance, Manelli and Vincent (1995) have highlighted the potential disadvantages of auctions when the buyer has preferences for unverifiable quality; such disadvantages are also a common concern of procurement agencies. Similarly, while the empirical analysis of Decarolis (2014) identifies cost reductions through the use of competitive procurement auctions, he also finds that these cost reductions are partly compensated by costs of renegotiation and increases

[6]See, for instance, the examples of Wilson (1992) for the first-price sealed-bid sales auctions, and the analysis of Bulow and Klemperer (2002) for ascending bid auctions.

[7]For instance, using data from highway procurement in New Jersey, Hong and Shum (2002) argue that procurement costs are lowest with three bidders, so that unlimited competition is not necessarily advantageous for the agency. Even with independent values, by taking the endogeneity of entry into account, Li and Zheng (2009) show that increases in the number of potential bidders increased procurement costs in the case of Texas highway lawn mowing auctions.

[8]See Mc Afee and Mac Millan (1992) for a theoretical analysis of bidding rings in auctions.

in project completion times. To solve problems related to unverifiable quality, Calzolari and Spagnolo (2009) and Albano et al. (2017) have advocated competitive procedures that give discretion to the buyer to take past performance into account and thus exploit reputation effects. On a related note, Coviello et al. (2018) have applied a regression discontinuity design to Italian procurement data, showing that discretion tends to lead to repeated interactions between the same buyers and suppliers. They also provide (mixed) evidence on the relation between discretion and quality.[9]

Some authors have taken a positive rather than a normative approach, trying to identify the circumstances under which auctions are more likely to be chosen. For instance, Bajari et al. (2009) show that buyers are less inclined to use formal procurement auctions when the number of potential bidders is low, when projects are complex and when sellers are reputable and experienced. Chong et al. (2014) identify a similar role of complexity with French procurement data.

The observation that procurement decisions depend on project characteristics suggests that a comparison of different procurement modes needs to take the potential endogeneity of the decision into account. Such issues also come up in the related decision between cost-plus and fixed price contracts, as discussed by Gagnepain and Ivaldi (2010) using data from the French public transportation sector.[10]

Our paper confirms the logic of Bulow and Klemperer (1996) that, from a buyer's point of view, auctions are preferable to negotiations, if we loosely interpret "auctions" as mechanisms where the buyer directly deals with only one supplier, whereas "negotiations" refer to competitive mechanisms where the buyer receives at least one offer, no matter whether a formal competitive tender is used or not.[11] Moreover, our analysis suggests that the beneficial effect reflects the sampling effect of Armstrong and Sappington (2006) as well as the rent-reducing

[9]More peripherally related to our analysis of a fairly straightforward service, Bajari and Tadelis (2001) have extended Goldberg (1977) to emphasize that the necessity of ex-post adaptations of a project may limit the usefulness of competitive procurement mechanisms for complex goods; see Bajari et al. (2009) for a related empirical analysis. Herweg and Schmidt (2017) argue that, in such settings, participants in auctions will withhold useful knowledge on necessary design adaptations and that they will invest less into identifying possible adaptations than with negotiations.

[10]In a related paper on this industry, Gagnepain et al. (2013) analyze a model where the type of the contract (cost-plus or fixed-price) can be renegotiated. They find substantial welfare costs of renegotiation.

[11]Chong et al. (2016) provide evidence that public buyers frequently ask for offers from different buyers multiple offers, even when they are not using formal competitive tenders.

effect. The more skeptical perspective on competition provided by taking into account collusion or common-value components is not confirmed, in the latter case in contrast with the above-mentioned observations of Hong and Shum (2002). Contrary to some previous studies, anecdotal and descriptive evidence do not suggest substantial adverse effects of competition on quality, cost overruns, etc. either. Our relatively positive – though incomplete – assessment of competition may well relate to the simplicity of the service under consideration, which makes it easy to specify the buyer's needs and monitor the fulfillment of contractual obligations. Finally, we should remark that, even though the evidence on the effects of competitive procurement in the literature is not unambiguously positive, our study is by no means an outlier (see for instance the results for the bus industry below or a wider study on Turkish procurement by Onur et al.(2012)).

Railway Reforms: The paper also contributes to a literature on the evaluation of the railway reforms introduced in Europe in the nineteen nineties. Several papers deal with the efficiency effects of various reforms in an international context on an aggregate level (Cantos et al. 1999, Friebel et al. 2010), emphasizing the role of cross-country institutional differences. Friebel et al. (2010) identify positive efficiency effects of deregulation. Other authors resort to before-and-after comparisons in individual countries. For instance, Cowie (2002) and Pollitt and Smith (2001) analyze the outcomes of the U.K. reform, coming to more positive conclusions than the political debate in Britain. would suggest. In any event, the institutional differences between Germany and Britain are massive, so that it would be inadequate to jump to quick conclusions from the experiences of one of these countries to the other one. For instance, in Germany, contrary to the U.K., competition for the market was introduced gradually and concerned only regional passenger transportation.[12]

Contrary to these contributions, our paper allows the comparison of different institutions within one country, without relying on a before-and-after comparison. Also, it focuses on a specific aspect of the reform (competitive procurement) which has been important in several other countries as well.[13] It shares this feature with Lalive and Schmutzler (2008a) who use a

[12]Other important differences concern the role of the network owner and the pricing flexibility of operators.

[13]The most prominent examples are the United Kingdom and Sweden, but several other European countries have followed suit.

difference-in-difference approach to establish a positive relation between competition and the frequency of service for a small subsample of the one we use in the current paper. Lalive and Schmutzler (2008a) considered only Baden-Württemberg, one of the 16 German states. Moreover, the present paper differs substantially from its precursor in at least three important dimensions. First, based on reduced form models, we discuss the problem of endogeneity of procurement choice. Second, because we now have procurement price data, we can identify that the previously found positive relation between competition and frequency of service reflects a negative relation between competition and procurement prices. Third, with our structural model, we can now obtain estimates of the effects of competition on cost and mark-ups.

Within-country analyses of the German regional passenger railway sector have also been carried out by Hunold and Wolf (2013) and Weiergräber and Wolf (2021). The former study asks how the subsidy level, the number of bidders and the incumbent's winning chances depend on auction design.[14] The latter study disentangles cost advantages from informational advantages as sources of incumbency advantages. Neither of these papers analyzes the effects of competition. Beyond the railway sector, there is a substantial amount of (descriptive) evidence on competitive tendering in the bus industry, as surveyed by Hensher and Wallis (2005). The results are mixed, with reports of substantial efficiency gains in the early phase of the deregulation in London (White 2000), but essentially no effects in Italy (Boitani and Cambini 2006). Amaral et al. (2008) relate more successful competitive procedures in London than in France to differences in the design of the competition mechanisms.

3 Regional Passenger Railways in Germany

In most European countries, integrated state monopolies controlled the railways until the early nineteen nineties.[15] In West Germany, *Deutsche Bundesbahn* owned most of the infrastructure and was the dominant operator for passenger and freight services. In addition, there were several minor railroad companies (*NE-operators*) that were typically also vertically integrated and carried out freight and/or passenger transportation on small networks. In East Germany,

[14] On a related note, Lalive and Schmutzler (2008b) analyze the determinants of entry into the market.

[15] This purely descriptive section has considerable overlap with Lalive and Schmutzler (2008a); see there for additional details.

Deutsche Reichsbahn was the integrated operator of the railway system.

In response to the EU-directive 91/440, a major railway reform became effective in Germany on January 1, 1994. *Deutsche Bahn AG* became the successor of *Deutsche Bundesbahn* and *Deutsche Reichsbahn.* In addition, the reform had several elements that are important for our analysis.

3.1 Financing

Before the reform, the railway system created large deficits. Local passenger transportation was responsible for a large part of this deficit, but as the central government took over the total deficit ex post, it was impossible to attribute the costs to specific lines. The reform changed the approach to financing passenger services radically. Whereas long-distance transportation was expected to be profitable after the reform, it was continued to be taken for granted that the revenues from passenger service did not suffice to cover costs on the local passenger lines. Our analysis deals exclusively with these non-profitable local passenger railway services. Procurement of these services now relies on contracts specifying the expected service level and the payments from the state to the railway companies ex ante. Starting in 1996, the federal state distributed a total of about 5-7 billion Euros per year to the 16 states, mainly to finance the services. The responsibility for the use of these funds (the so-called *Regionalisierungsmittel*) was assigned to the states. The funds were so generous that they allowed the agencies to expand regional passenger railway services.

3.2 Industry Structure

As a prerequisite for the introduction of competition, *Deutsche Bahn AG* was divided into two upstream subsidiaries (*DB Netz* for the network and *DB Station & Service* for the stations) and three downstream subsidiaries (*DB Regio* for regional passenger transportation, *DB Reise und Touristik* for long-distance passenger services and *DB Cargo* for freight). Thus, a move into the direction of vertical separation took place. Railway companies (including *DB Regio*) that want to use the network of *DB Netz* pay access charges determined by *DB Netz.* These access charges, which vary across lines, are an important cost component for the railway operators,

which also influence the prices that agencies pay. In our analysis, we will therefore use them to construct procurement prices on directly awarded lines.

Even after the reform, *DB Regio* stands out as the most visible player in the industry. Its institutional ties with *Deutsche Bahn AG* and its various subsidiaries give it a unique position within the industry, which result in various asymmetries. When competitive procurement was introduced, *DB Regio* started out as the incumbent. It benefited from informational advantages and economies of size and scope resulting from its experience and its large network (see Weiergräber and Wolf 2021). The overall effects of these asymmetries are not clear-cut. For instance, one should note that its connection to *DB Reise und Touristik* as monopolistic supplier of long-distance services might imply opportunity costs of providing regional train services on such lines, which could work against its presumed cost advantages in the provision of railway services. In most of our analysis, we therefore treat all firms as symmetric.

3.3 Auctions vs. Direct Awards of Contracts

After the reform, the 16 states created agencies organizing the procurement process. These agencies were equipped with a fixed budget for the procurement of railway services, but they have considerable freedom in the way they procure services. The crucial distinction is whether agencies used a competitive procedure or directly awarded the line to the incumbent.

Throughout the period under consideration, direct awards of the contract to the incumbent supplier remained the dominant mode of procurement. Long-term contracts between the agencies and *DB Regio* covered a large majority of the regional passenger services. These contracts specified the expected service level over a period of 10-15 years and the payments to *DB Regio*. Also, the contracts typically contained a roadmap for the introduction of competitive procurement.

Competitive procurement usually involved a bidding procedure in which firms asked for transfer payments to carry out railway services. The successful bidder received his required transfer and obtained the franchise. In the simplest and most common case, the agency specified the frequency of service and detailed requirements about the verifiable aspects of the expected service quality. The specifications included the rolling stock, the prices charged to cus-

tomers, etc.[16] The contracts were usually awarded in a first-price sealed-bid auction, where the bids corresponded to the procurement prices.[17] In exceptional cases, the agencies used multi-dimensional auctions where the bidders obtained scores for verifiable aspects of quality as well as for low prices.[18] We do not have reliable data on the instances in which the agencies applied scoring rules. We therefore have to treat the possibility of such rules as unobserved heterogeneity. If, contrary to our perception, our data set included a substantial number of instances where non-price components played an important role in the procurement process, then the large price effects of competitive procurement should be interpreted as a lower bound for the effects that purely price-based auctions would have had on procurement prices, as an emphasis on quality would tend to soften price competition.[19]

The extent to which competitive procurement was used varied considerably across agencies. In the period under consideration, agencies were essentially free to determine the procurement mode for any of the lines they served.[20] However, it became a common practice that the agency and the incumbent negotiated on which lines should be opened to competition during the lifetime of the contract.[21]

3.4 Types of Contracts

Contracts in our sample are heterogeneous in several dimensions. First, contracts differ according to the treatment of fare revenues. In *net contracts*, the train operator receives the revenues (and thus has an incentive to increase it), and the agency only pays the difference between costs and revenues. In *gross contracts*, the agency receives the revenues, whereas the operator

[16] Regional public transport organisations (Verkehrsverbünde) decide on timetables, prices etc. on a large part of the network. This limits the freedom of railway operators to set prices. Similar restrictions apply to rolling stock which is usually tightly specified (Brenck and Peter 2007).

[17] This differs from textbook models of competition for the market (Viscusi et al. 2000). In those models, instead of the subsidy, contractors bid the price they want to charge to consumers and the lowest bid wins (Demsetz 1968).

[18] See Che (1993) for a formal analysis of such auctions. However, the role of the quality dimension is often not made absolutely clear ex ante, so that the mechanism corresponds to a beauty contest.

[19] Moreover, price competition could be softened by mechanisms such as the average scoring rule of Dini et al. (2006) that do not give credits for price reductions below a certain level.

[20] This right has been challenged both by national courts and the EU. This is leading to a clearer move into the direction of more competition (Brenck and Peter 2007).

[21] The most competition-friendly authority (LVS in Schleswig-Holstein) signed a long-term contract in 2003, according to which the last part of the network will be opened to competition in 2014, 20 years after the railway reform. (See *http://www.premiumpresse.de/bahn-und-land-schleswig-holstein-unterzeichnen-verkehrsvertrag-PR156817.html*, visited July 4, 2011.

receives a cost compensation (but carries the cost risk). In our data set, 67 % of competitive lines were procured in net contracts. The grand contracts with *DB Regio* were usually net contracts.[22] We take this asymmetry between competition and directly awarded contracts into account in our estimation. Second, there are fixed price contracts and cost plus contracts. According to Brenck and Peter (2007), in a sample of contracts analyzed by Borrmann (2003) which contains many of our contracts, 40% of the contracts were fixed-price, whereas the rest contained cost-pass-through clauses for costs on which the operator has little influence, such as energy costs and infrastructure charges. Moreover, the contracts typically contained dynamic adjustment formulas, at least for access charges. Such provisions reduce the need for renegotiation. Further, the contracts typically described detailed provisions for renegotiations (Brenck and Peter 2007). Finally, the contracts contained various incentive elements to deal with quality issues, including sanctions and bonus payments (Brenck and Peter 2007) that are applicable for verified violations of quality standards.[23]

3.5 Evolution of the Market

As a result of the introduction of competitive procurement, the market share of *DB Regio*'s competitors grew substantially. In 1994, the *NE-operators* had a market share of 3% (based on train-km); in 2004, the share was 12% (Brenck and Peter 2007). However, these figures understate the dynamics of competition: On lines with competitive procurement, the *NE-operators* won more often than *DB Regio*. (See also Table 1.)

There were several distinct types of competitors. First, there are the above-mentioned pre-reform *NE-operators*. Starting from their old infrastructure, they often expanded their operations onto the network of *Deutsche Bahn* where they only provided the downstream services. Second, some companies expanded their activities from other modes of public transportation into the railroad sector. Third, some new companies emerged. Fourth, some railway operators resulted from joint ventures between several companies, in some cases including *DB Regio*. Finally, foreign firms such as *Connex*, *Arriva* and *Abellio* entered the market.

[22] According to private communication with Felix Berschin (Nahverkehrsberatung Heidelberg), the state of Hessen is an exception.

[23] Obviously, such measures cannot prevent shirking on non-veraifiable aspects of quality.

4 Does Competitive Procurement Work?

In this section, we first describe our data (Section 4.1). Thereafter, we provide regression results to show that competition increased the frequency of service and lowered procurement prices. In Section 4.2, we deal with the selection problem that competitively procured lines may differ from directly awarded lines. Section 4.3 identifies a positive effect of competition on quantity and a negative effect on procurement prices. Section 4.4 provides some descriptive evidence on quality, suggesting that quality on auctioned lines was not systematically lower than on directly awarded lines.

4.1 Description of data

Our data contains information regarding service frequency on 559 railway lines in Germany. We now provide background information and descriptive statistics on this data.

The empirical analysis uses information on our main dependent variables, service quantity and procurement prices. Following Lalive and Schmutzler (2008a), we used the *frequency of service,* the ratio between train kilometers per year (tkm) and the length of a line (lkm), as a quantity measure.[24] The division of the network into different lines follows the 2004 timetable.[25] We hand counted all information on frequency of service from time-tables. Frequency of service is available for 1994, before the reform, and for 2004, several years after the reform.

We compiled detailed data on whether a segment of a train line was competitively procured or not. In the vast majority of cases, we attributed the competitive status to a line whenever the agency used a procurement auction to select the operator. However, the definition of a competitive line was slightly broader.[26] Most lines were procured using only one procurement mode. A few lines had a mixed procurement mode, with a small number of competitively

[24]Thus, the frequency of service corresponds to the average number of trains per year on each kilometer of tracks.

[25]In some cases, we had to make small adjustments to avoid double-counting of trains.

[26]We define a competitive line as in Lalive and Schmutzler 2008a, Definition 1. Thus, apart from lines that were auctioned in an open tender procedure, our treatment group contains the following types of lines: (i) Services were procured in invitation procedures on the basis of offers from at least two firms that were approached directly by the agency; (ii) Apart from the incumbent, at least one firm offered a contract to the agency without having been asked to do so. (iii) A competitor took over the infrastructure and the task of running services from *DB Regio* for a symbolic price (see Lalive and Schmutzler (2008) for examples).

procured trains from neighboring lines. We classified a line as competitive ("auctioned") if at least 20% of the services were procured competitively, and as non-competitive ("directly awarded") if less than 20% of the services were procured competitively.[27]

The incumbent, *DB Regio*, also won a considerable number of procurement auctions. We defined these lines as competitive, even though the operator is the incumbent. A few small lines were awarded directly to other companies than *DB Regio*. We included information on who operated the line, the incumbent or entrants, as a control variable in our regression.[28]

Obtaining information on procurement prices was difficult. We were able to get information on the winning bid for 64 of the 139 competitively procured lines in the sample.[29] We have studied whether these lines represent a selected sample but, conditional on the observed line characteristics, we did not find any differences between the lines with price data and lines without price data.[30]

The prices of contracts awarded directly to *DB Regio* are publicly available, but only quoted at the state level. We constructed individual line-specific estimates of the price as follows. We assume that the incumbent negotiates a price to cover costs and guarantee a positive markup. Rail service providers face two costs. First, operators pay access fees to the network owner, *DB Netz*, which varied considerably across lines in the period under consideration, even within the regions served by one agency. *DB Netz* charged a standard price on some lines. The *Regionalfaktor* (regional factor) captures the factor by which the access price on a specific line is inflated above this standard price. Regional factors were high on remote lines with low density of service.[31] Second, operators incur costs of providing the service, e.g. energy, rolling stock, labor. Absent direct information on these costs, we assume that they varied across German

[27]The vast majority of the lines either has no competitively procured services or only competitively procured services. Note that the fuzzy treatment status on a few lines introduces a small amount of measurement error, dampening our estimates of the effect of competitive procurement.

[28]In analogy to our definition of competitive lines, we define a line as operated by *DB Regio* if at most 20% of the services were run by competitors.

[29]For 41 of these lines, we also have data on the number of bidders; we use these lines for the structural model. The data were supplied by Felix Berschin from Nahverkehrsberatung Südwest in Heidelberg, a consulting firm that is specialized in regional passenger train services.

[30]We have also explored another source of data on prices. The official source of the European Union, the databank *Tender Electronic Daily*, contains useful information on which lines were grouped together in a particular auction and what the overall volume of the contract is. However, this source only provides procurement price data in a small number of cases.

[31]This is supposed to help the network owner to recover fixed costs.

states, but not within them. We observed the state-level average price in the directly awarded contracts, and the regional factor for almost all lines. Using these two pieces of information, we reconstructed the prices of directly awarded contracts to match state-level average prices, as we show in Appendix A.[32]

Apart from these basic variables, we added further controls, corresponding to the geographical line characteristics and to properties of the contract. We used the distance to the nearest city with at least 100,000 inhabitants as a measure of remoteness.[33] Moreover, we included the number of inhabitants of the largest and the second-biggest city served by the line in 1994, again as proxies for demand along the lines. Finally, we use information on whether a gross revenue contract or a net revenue contract was applied.

To complement our analysis, we collected information on the quality of services from several large agencies. These data cover a more recent period than our main regression analysis of the effects of competition on quantities and prices. We looked into punctuality and train cancellations (verifiable quality); one agency also carries out a more general quality monitoring of the competitively procured railway lines (that also captures customer opinions and thus addresses non-verifiable aspects to some extent). Unfortunately, however, these data are not only incomplete, they also are not available on the basis of individual lines.

4.2 Choice of Procurement Mode

Agencies could choose between using auctions (competitive procurement) and directly awarding contracts to procure railway services. We have no inside information on the determinants of the procurement decision. However, it seems likely that attitudes towards risk and the size of the expected service growth due to competitive procurement should be important for this decision. Attitudes towards risk could matter because auctions were never tested in Germany before its regional rail market opened up in 1996, so that agencies had no prior experience with procurement auctions. Risk-averse agencies should be expected to choose lines for competitive procurement that are not too important, so as to limit any damage due to a failed auction.

Our reduced-form analysis contrasts frequency of service and procurement price on two

[32] We are grateful to *DB Netz* for providing us with information on the access charges.

[33] We measure the distance as the length of the shortest connecting passenger railway line.

different groups of lines. The treated lines are those defined to be competitive (see Section 3.3). As discussed there, most of these lines were selected by the agency to have their services procured via an auction between 1994 and 2004. Therefore, we also refer to these lines as *auctioned lines*. By contrast, *directly awarded lines* are those selected by the agency to always have their services directly awarded to the incumbent DB Regio between 1994 and 2004. Table 1 displays procurement prices, frequency of service, and line characteristics of all railway lines in our sample. Panel A shows the average price and frequency of service from 2004, after the 1996 reform that opened up the regional rail sector; in addition, it shows the average number of bidders. Panel B shows frequency of service information in 1994, before the railway reform. To repeat, procurement prices did not exist at the time. Procurement prices in 2004 were significantly lower on lines with procurement auctions, compared to directly awarded lines. Interestingly, the frequency of service was lower on auctioned lines, compared to directly awarded lines. However, this was already the case before the reform: As Panel C shows, lines that were procured competitively were more remote and thus less important than directly awarded lines. Auctioned lines were 27 percentage points less likely to have electric traction, 8.4 km further away from the next city, and the populations of the biggest and second-biggest city along the line were smaller.

Our reduced form analysis measures effects of procurement mode on service frequency in a difference-in-differences design (DiD). A standard assessment of the validity of the DiD is to test for parallel trends in frequency of service. We cannot implement a test of parallel trends, as we do not have any data on frequency of service before 1994. To address the key identification challenge, we propose an alternative test for selection based on expected service growth. If agencies selected lines with higher unobserved growth, a part of the effect that we attribute to competitive procurement would just reflect selection. Unfortunately, it is not possible to assess this concern directly, as we would need information on service growth along auctioned lines in the hypothetical case that they had been directly awarded instead. Note, however, that lines with large growth will have a high service level after the reform, and a low service level before the reform. Therefore, if agencies really select lines based on large growth, then the service level prior to the reform, observable for all lines, should be lower for auctioned lines than for

Table 1: Summary statistics

Variable	Directly awarded lines		Auctioned lines		Difference	
A. Outcomes 2004						
Price[a]	8.6988	(0.0617)	6.7236	(0.1784)	1.9752***	(0.1888)
Frequency	19295.1	(696.2)	17358.49	(1001.8)	1936.65	(1220.0)
Number of bidders[b]			4.6098	(0.2633)		
B. Outcomes 1994						
Price	NA		NA		NA	
Frequency	15696.55	(626.1)	11533.34	(651.2)	4163.20***	(903.4)
C. Controls (not time varying)						
Electric traction	0.5238	(0.0244)	0.2518	(0.0369)	0.2720***	(0.0442)
Distance to city (km)	15.5286	(1.2875)	23.9640	(3.0165)	-8.4355**	(3.2798)
Track length	60.0190	(2.2771)	59.8058	(4.1089)	0.2132	(4.6977)
Population largest city	474,351	(36,016)	225,469	(29,539)	248,882***	(46,580)
Pop 2nd largest city	83,741	(7,748)	47,783	(6.539)	35,959***	(10,138)
Regional factor	1.1249	(0.0118)	1.1954	(0.0270)	-0.0705**	(0.0295)
Type of contract (net revenues)	0.9167	(0.0135)	0.8273	(0.0322)	0.0893**	(0.0349)
Number of observations	420		139			

Notes: Summary statistics for directly awarded and auctioned lines. Standard errors are shown in the columns beside the coefficients. Differences are tested against zero using a t-test. *** (**, *) stands for significance at the 1% (5%, 10%) level.

[a] Number of observations is 64; [b] number of observations is 41.

Source: Own calculations.

directly awarded lines. A test for selection based on growth compares pre-reform service levels, conditional on line characteristics. In Appendix B, we explain this idea in more detail.

Implementing this idea, Table 2, column (1), explains log service frequency in 1994 with the subsequent procurement status. Lines that were subsequently procured competitively were served 19 percent (21 log points)[34] less frequently than lines to be directly awarded in the future. Lower frequency of service is consistent with both risk aversion and selection based on gains. To differentiate between these two explanations, Column (3) adds exogenous characteristics of lines such as technical aspects (electrification, length), proxies for demand (distance to next city in km, population in the largest and second largest city along the line), and determinants of operating costs (regional factor, identity of operator) as control variables. Electrification, remoteness, and size of the second-largest city explain frequency of service in 1994. This second estimation shows that auctioned lines were not less frequently served than directly awarded lines. Agencies did not systematically select lines with high unobserved growth potential to be auctioned. Agencies selected relatively unimportant lines, and we will explore below whether

[34]The change in percent is $\exp(\beta) - 1$, where β is the estimated coefficient.

auctions were more effective on such lines.

Table 2: Determinants of quantities in 1994

	(1)	(2)	(3)	(4)
Auctioned	-0.214**	(0.097)	0.062	(0.098)
Electric traction			0.328***	(0.049)
Distance to city (km)			-0.004***	(0.001)
Log track length			-0.094	(0.061)
Log pop largest city			0.047	(0.038)
Log pop 2nd largest city			0.120***	(0.028)
Regional factor			-0.087	(0.085)
Incumbent			0.112	(0.099)
Net revenue contracts			-0.093	(0.069)
Constant	9.399***	(0.087)	9.060***	(0.294)
Adjusted R-squared	0.016		0.337	
Number of observations	559		559	

Notes: Results from OLS estimations. In columns (1) and (3), the dependent variable is the logarithm of the quantity in 1994. Standard errors are clustered (on agencies) and are shown in the columns beside the coefficients. *** (**, *) stands for significance at the 1% (5%, 10%) level.
Source: Own calculations.

Table 3 shows the results of a linear probability analysis of the choice of procurement mode.[35] Column (1) provides a baseline analysis that explains procurement choice with frequency of service in 1994. Results clearly suggest that auctioned lines were less frequently served before the railway reform. Column (3) adds background information on the lines and the markets that are served. We control only for time-invariant characteristics and population in 1994 because contemporaneous time-varying characteristics are endogenous. Results now indicate that the frequency of service in 1994 no longer predicts procurement mode in 2004. This result testifies to the quality of the available line characteristics, and it means that there are no time-invariant unobserved characteristics of lines that are correlated with frequency of service and determine procurement choice. Which characteristics matter for procurement choice? Column (3) shows that electrified lines are much less likely to be procured competitively. Importantly, Column (5) adds agency-specific fixed effects.[36] These are not reported directly in

[35]Moffitt (1999) argues that linear probability models are more convenient and often just as accurate as probit and logit. We use linear probability also because some agencies do not auction any lines. Probit – assuming that the probability of seeing a line auctioned is never exactly zero – automatically discards lines procured by these agencies. We believe that this is not justified since agencies may very well end up never procuring lines for reasons modeled within our framework. Results are, however, not sensitive to discarding lines procured by agencies who never opt for auction.

[36]In terms of the model, these effects reflect the heterogeneity of agencies with respect to the cost of carrying out auctions.

the table, but it is clear that they matter. The F-statistic indicates that they are significant with a p-value of less than 1%. Moreover, we now find that lines with net revenue contracts are less likely to be procured competitively.

Table 3: Determinants of procurement mode

	(1)	(2)	(3)	(4)	(5)	(6)
Log frequency	-0.081**	(0.035)	-0.009	(0.024)	0.005	(0.031)
Electric traction			-0.163***	(0.059)	-0.143**	(0.056)
Distance to city (km)			-0.000	(0.001)	0.001	(0.001)
Log track length			0.029	(0.025)	-0.020	(0.033)
Log pop largest city			-0.034	(0.023)	-0.015	(0.029)
Log pop 2nd largest city			0.001	(0.017)	0.015	(0.019)
Regional factor			0.025	(0.083)	-0.010	(0.182)
Net revenue contracts			-0.213	(0.186)	-0.751***	(0.076)
Constant	1.006***	(0.336)	0.627**	(0.288)	1.596***	(0.341)
Agency fixed effects	No		No		Yes	
Adjusted R-squared	0.016		0.074		0.251	
Number of observations	559		559		559	

Notes: Results from OLS estimations. The dependent variable is 1 if the regional passenger line was procured by auction and it is 0 if the line was procured by negotiation with the incumbent Deutsche Bahn. Standard errors are clustered (on agencies) and are shown in the columns beside the coefficients. *** (**, *) stands for significance at the 1% (5%, 10%) level.
Source: Own calculations.

4.3 The Effects of Competition on Service Frequency and Procurement Price

The results of Section 4.2 suggest that the selection of the procurement mode is based on observables, so that we can think of the lines as being randomly assigned conditional on observables. We therefore now use regressions of quantities and prices on procurement status and observables to identify the effects of competition. Table 4 shows the results from our model on quantities. Column (1) presents the results of a difference-in-difference model that explains growth in service frequency with procurement status. On lines that were competitively procured in 2004 the frequency of service grew 16.0 percent more than if these lines had been awarded directly. Column (3) adds line characteristics since the procurement mode reflects differences with respect to characteristics (see Table 1). After conditioning on line characteristics, we find that auctions increased the frequency of service by 12.4 percent compared to direct awards. Column (5) provides estimates of the effects of competition, explaining the level of service in

2004 with line characteristics and the level of service in 1994. The results in levels indicate that auctions increased service by 14.1 percent, which is very much in line with our result in column (3). Column (7) presents estimates that allow the effect of competition to vary with observed characteristics.[37] Auctions increased service by 15.6 percent on the line with average characteristics, slightly higher than in column (5) that does not contain interaction terms, although not significant.[38] Auctions increased quantity less on lines served frequently already in 1994, and more strongly on lines where the largest city had a large population in 1994.

Table 4: Determinants of quantities in 2004

	Growth in quantity				Quantity in 2004			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Auctioned	0.148***	(0.040)	0.117*	(0.062)	0.132**	(0.057)	0.145	(0.114)
Electric traction			-0.080*	(0.040)	-0.004	(0.036)	0.008	(0.039)
Distance to city (km)			0.000	(0.001)	-0.001	(0.001)	-0.001	(0.001)
Log track length			-0.060***	(0.022)	-0.082***	(0.015)	-0.063***	(0.023)
Log pop largest city			0.012	(0.021)	0.023	(0.017)	0.005	(0.013)
Log pop 2nd largest city			-0.003	(0.014)	0.025*	(0.013)	0.018	(0.012)
Regional factor			-0.247***	(0.076)	-0.267***	(0.075)	-0.191**	(0.071)
Incumbent			-0.044	(0.055)	-0.018	(0.043)	0.008	(0.049)
Net revenue contracts			0.052	(0.046)	0.031	(0.041)	0.024	(0.019)
Log frequency					0.768***	(0.026)	0.790***	(0.034)
Auction *								
log frequency							-0.144**	(0.068)
el. tract.							-0.007	(0.081)
dist. to city							0.001	(0.002)
log length							-0.074	(0.061)
log pop larg. city							0.070*	(0.037)
log pop 2nd larg. city							0.042	(0.039)
incumbent							-0.070	(0.047)
regional factor							-0.182	(0.206)
net rev. contr.							0.041	(0.104)
Constant	0.246***	(0.022)	0.732***	(0.145)	2.835***	(0.295)	2.567***	(0.347)
Adjusted R-squared	0.029		0.064		0.761		0.763	
Number of observations	559		559		559		559	

Notes: Results from OLS estimations. In columns (1) and (3), the dependent variable is the growth of quantity between 1994 and 2004; in columns (5) and (7) the dependent variable is the logarithm of quantity in 2004. Observations are from the pooled sample of all lines. Standard errors are clustered (on agencies) and are shown in the columns besides the coefficients. *** (**, *) stands for significance at the 1% (5%, 10%) level.
Source: Own calculations.

Table 5 displays our reduced-form analysis of the effects of competition on procurement

[37] We mean deviate all line characteristics before forming interactions. The main effect of competition refers to the line with average characteristics, i.e. zeros for all interaction terms.

[38] This lack of significance reflects the reduction in the degrees of freedoms coming from including too many interaction terms. Significance reoccurs in a regression where we only include the main interaction terms (with log frequency and log population of the largest city).

prices in 2004.[39] Column (1) indicates that auctioning the service reduced the price by 24.3 percent. Column (3), adding service frequency in 1994 and line characteristics, indicates that auctions reduced the procurement price by 21.7 percent, very similar to the estimates in column (1). Column (5) presents estimates that allow price effects to vary with line characteristics. Auctions lowered price by 25.5 percent for the line with average characteristics. Price effects differed with respect to the regional factor. Procurement prices on lines with high regional factor were high for directly awarded contracts, but no different than on other lines with auctions.

Table 5: Determinants of directly awarded and auctioned prices

	(1)	(2)	(3)	(4)	(5)	(6)
Auctioned	-0.278***	(0.050)	-0.244***	(0.050)	-0.295***	(0.062)
Log frequency			-0.031**	(0.015)	-0.030*	(0.015)
Electric traction			0.057**	(0.023)	0.068**	(0.026)
Distance to city (km)			-0.001	(0.000)	-0.001**	(0.000)
Log track length			-0.013	(0.014)	-0.009	(0.011)
Log pop largest city			-0.005	(0.009)	-0.007	(0.008)
Log pop 2nd largest city			-0.009	(0.008)	-0.005	(0.010)
Regional factor			0.213***	(0.047)	0.248***	(0.039)
Incumbent			0.053	(0.051)	0.046	(0.047)
Net revenue contracts			0.033	(0.042)	-0.003	(0.030)
Auction * log frequency					-0.017	(0.076)
Auction * el. tract.					-0.137	(0.082)
Auction * dist. to city					0.000	(0.002)
Auction * log length					-0.014	(0.043)
Auction * log pop largest city					-0.016	(0.053)
Auction * log pop 2nd largest city					-0.056	(0.073)
Auction * incumbent					0.020	(0.065)
Auction * regional factor					-0.330***	(0.088)
Auction * net revenue contracts					0.037	(0.070)
Constant	2.153***	(0.034)	2.220***	(0.165)	2.188***	(0.155)
Adjusted R-squared	0.254		0.351		0.397	
Number of observations	484		484		484	

Notes: Results from OLS estimations. Dependent variable is the logarithm of price. Observations are from the pooled sample of all lines. Standard errors are clustered (on agencies) and are shown in the columns besides the coefficients. *** (**, *) stands for significance at the 1% (5%, 10%) level.
Source: Own calculations.

To capture potential heterogeneity across agencies with respect to procurement behavior, we also carried out our main regressions with agency fixed effects (available on request as supplementary material. The price regressions are quite similar to those in the regressions we have in the main text. In particular, the competition effects are of similar size and significance. One difference is that the substantial positive price effect of the regional factor disappears once

[39] We cannot use a difference-in-difference approach to estimate the effects on prices, because procurement prices did not exist in 1994 (see Section 3.1).

agency dummies are used. This is not surprising as regional factors vary substantially across agencies. The role of agency fixed effects is more substantial for the quantity regressions. After controlling for agencies, the main regression coefficients captured in columns (3) and (5) both decrease. However, the effect is much less pronounced in column (5), where we control for log frequency in 1994. This suggests the following interpretation. Agencies where the frequency of service is high tend to be more inclined to used competitive procurement, explaining why the coefficient in column (3) is lower with agency dummies than without (and insignificant). However, there is no strong tendency for agencies with high quantity changes between 1994 and 2004 to use more competitive procurement, which is why the difference in the competition coefficients in columns (5) in the regressions with and without agency controls is small.

4.4 Potential Pitfalls of Competition

As indicated in the introduction, one may be concerned that our analysis overstates the beneficial effects of competition. High ticket prices, low service quality, renegotiation and winner's curse are potential problems of bidding competition in the railway sector. However, we find very little evidence that these problems were severe in the case at hand.

Ticket prices: If operators could have set ticket prices freely after having been awarded a competitive contract, they might have bid low procurement prices, but then charged high ticket prices. However, in the period under consideration, competing through ticket prices was not an allowable option for the operators as ticket prices were coordinated by agencies.[40]

Quality: A more relevant issue is that bidders in procurement auctions might have reduced quality to save on costs, so as to submit more aggressive bids. Ideally we would have addressed this concern with a difference-in-difference approach as in Section 4.3. Unfortunately, we do not have detailed line-level quality data, not even on verifiable and easily measurable aspects of quality such as train cancellations and punctuality. However, the limited information we have suggests that, while quality problems are an issue in the industry, they are not more frequent on auctioned lines than on directly awarded lines.

First, agencies are clearly aware of the potential quality problem. Whether auctioned or

[40]The German Monopoly Commission has discussed this fact critically at several occasions. e.g., Monopolkommission 2009.

awarded directly, contracts contain detailed quality provisions. These provisions are enforced with punishments if violations can be verified.[41]

Second, a few agencies have begun to publish quality data. This admittedly imperfect, purely descriptive evidence does not support the view that competition reduces quality. For instance, several agencies have collected punctuality data on their entire network. They report punctuality at an intermediate level of aggregation, with a typical data point referring to a subnetwork of lines. The subnetworks differ with respect to operators. Table 6 provides unweighted averages of the punctuality measures for the subnetworks of *DB Regio* and all other operators, respectively.[42] For each agency, we reported this number for the year which was closest to the end of the time period we investigated in our regression analysis (2004). As *DB Regio* was the operator on the vast majority of directly awarded lines in the period under consideration, whereas competitors had a high market share on the competitively procured lines, an adverse effect of competitive procurement should show up in a quality advantage of *DB Regio*. However, *DB Regio* trains were not more punctual than those of the competitors. Even in the two states where *DB Regio* had better punctuality values than the competitors, this mainly reflects the fact that we are showing unweighted averages: The values for the grand contracts under which most trains were procured with *DB Regio* were 95.37 for Baden-Württemberg and 93.52 for Thüringen and thus much lower than the average values of *DB Regio*.

An even smaller group of agencies provided data on the percentage of train cancellation for the above-mentioned subnetworks. Table 7 presents unweighted averages of these subnetworks. In Hessen and Brandenburg, there were indeed more train cancellations for "other" operators than for DB Regio. However, in the largest German state (Nordrhein-Westfalen) *DB Regio* cancelled a higher fraction of their trains than the competitors. Thus again there was no systematic quality advantage of *DB Regio*.

Taken together, the two tables do not provide support for the view that there is an adverse effect of auctions on reliability (punctuality and cancellations). Information on other quality cri-

[41] As a recent example, in 2010 the Bavarian agency BEG fined the operators for delays and other quality problems with a total of 24 Million Euros. *DB Regio* whose contracts were mostly awarded non-competitively had to pay 84% of these fines.

[42] The number refers to the percentage of trains that arrived on time. The precise definition of "arriving on time" varies across agencies. Usually, it applies to trains with less than six minutes delay.

Table 6: Punctuality of trains

State / Agency / Year / Operator	Baden-Württemberg NVBW 2008	Schleswig-Holstein LVS 2010	Thüringen NASA 2009	Hessen RMV 2004	Nordrhein-Westfalen NRW 2009
DB Regio	96.79	84.96	95.60	92.10	88.00
Others	95.20	94.60	94.06	98.91	91.47
Difference (DB Regio - Others)	1.59	-9.64	1.54	-6.81	-3.47

Notes: Punctuality statistics for several states. The table presents the unweighted average of punctuality measures for different sub-networks within the state. Here punctuality refers to the percentage of trains arriving in time at the final destination. For clarity, we chose the most recent available figures for each state.
Sources: Klingel, Bernd, "Aktuelle Entwicklungen Im SPNV - Bericht Der NVBW," 2013, p.8-10; RMV, 2010, "Qualitätsbericht 2009," June, p.7; Kompetenzcenter ITF NRW 2015, "Qualitätsbericht SPNV Nordrhein-Westfahlen 2014," p.54-55.
NRW = NWL, VRR, NVR

Table 7: Train cancelations

State / Agency / Year / Operator	Hessen RMV 2009	Berlin-Brandenburg VBB 2012	Nordrhein-Westfalen NRW (NWL, VRR, NVR) 2007
DB Regio	0.52	0.88	1.65
Others	3.62	1.51	0.73
Difference (Others - DB Regio)	3.1	0.63	-0.92

Note: This table shows the percentage of cancelled trains in three states.
Sources: RMW, 2010, "Qualitätsbericht 2009," June, p.12; VBB 2013, "Verbundbericht 2013," June, p.30; Kompetenzcenter ITF NRW 2015, "Qualitätsbericht SPNV Nordrhein-Westfahlen 2014," p.54-55.

teria is rare. However, the Bavarian agency (BEG) carries out yearly quality rankings based on cleanliness, the quality of passenger information and complaint management, the functionality of the equipment, and the service orientation of staff.[43] The most complete ranking (from 2015) investigated 27 subnetworks. The top 5 networks were operated by competitors of *DB Regio*; whereas 8 of the 10 networks on rank 6-15 and 8 of the 12 networks on rank 16-27 were run by *DB Regio*. If anything, therefore, this ranking suggests a slight advantage of the competitors compared to *DB Regio*. However, these quality rankings are less useful for our purposes, as they only concern competitively procured sub-networks. Thus, the observation that competitors do not offer lower quality than *DB Regio* does not rule out that all companies supply lower quality than they would have absent competition.

Renegotiation: An often raised concern with competitive procurement contracts is the pos-

[43] See http://beg.bahnland-bayern.de/qualitaetssicherung/qualitaetsranking, visited on February 9, 2016.

sibility of renegotiation. Large-scale problems apparently have been quite rare in the industry. The only frequently cited example concerns the line Hamburg-Westerland, where the lowest bidder *Nord-Ostsee-Bahn* demanded additional payments after the contract was awarded. A possible reason why these events are quite rare is that the contractual rules often state precise conditions for renegotiations (see Section 3.4).

Winner's curse: While rational bidders adjust their behavior to a common-value setting by bidding conservatively, naive bidders will bid low when receiving overly positive cost or demand signals. In an industry with a substantial amount of entry by inexperienced firms, naive bidding may indeed be a problem. Again, in the period under consideration there was one highly publicized case where a new firm went bankrupt very soon, but this was largely due to very special circumstances.[44]

Patronage: If quality was a big problem on the competitive lines, one would expect to see less growth in patronage on these lines than on-the non-competitive lines. If anything, the opposite seems to be true. For instance, *Allianz Pro Schiene*, a lobbying organisation supporting "safe and environmentally friendly rail transportation" published a list of 15 railway lines that were particularly successful in attracting passengers in the first 10-15 years after the railway reform. The majority of these lines were classified as competitive in our sample; in several cases, patronage increased by a factor of two to three or even higher.[45]

All told, there does not seem to be any evidence, quantitative or anecdotal, to support the view that competition in the German regional railway sector was accompanied by serious downsides.

5 Structural Analysis of Auction Prices

To refine the above analysis, we now introduce a simple structural model. Because of data limitations, we use the simplification of an independent private value setting without collusion.[46]

[44] After *DB Fernverkehr* decided with short notice to stop serving the line Hamburg-Flensburg, the state agency searched for alternative solutions in an informal ad-hoc procedure. A newly founded company, *Flex AG* made an unrealistic offer and went bankrupt a year later.

[45] See https://www.allianz-pro-schiene.de/presse/pressemitteilungen/2009-2009-47/, visited February 18, 2017.

[46] The analysis of the previous section shows that competition increases quantities and reduces price, so that collusion does not appear to be a central issue. Moreover, though we cannot strictly rule out that there is a common value element in the auction, fear of the winner's curse does not appear to keep bidders from submitting fairly low

In Section 5.1 we first formulate a theoretical model; in Section 5.2 we describe the empirical approach that is based on this model.

5.1 Theoretical Framework

This section introduces a simple theoretical framework explaining procurement choice and price and quantity decisions. This framework allows us to estimate structural parameters and to carry out counterfactual calculations.

For simplicity, we suppose that costs on any given railway line are independent of the quantity supplied on other (in particular, neighboring) lines. Moreover, we assume that costs are linear in quantity on any line; thereby ruling out a decisive rule of capacity constraints. We suppose there are K ex-ante homogeneous firms (an incumbent and potential entrants): All costs are drawn independently from the same distribution on the positive real numbers. We write c for the mean of the cost distribution; in particular, it is the expected cost of the incumbent, c_I.[47] Dropping line indices for simplicity and denoting the frequency of service of the line as q and the procurement price as p, we suppose the agency has an objective function $\left(s\sqrt{q} - pq\right)$ for some $s > 0$, which we refer to as (agency) surplus. The term $s\sqrt{q}$ in this function (gross surplus) is supposed to capture two effects. First, improvements in public transportation will generate direct benefits for the users (consumer surplus): Consumers take the train more often, and they can choose more convenient trains. Second, substitution from road to rail goes along with reductions in pollution and accidents (Luechinger, Lalive, and Schmutzler 2018). The term pq captures total payments to the operator; p is the price paid by the agency. On lines supplied by the incumbent, he cares about profits, which are given as $(p - c_I)\, q$. Given the exogenous characteristics of a line, prices can be determined either in an auction or in a direct award procedure.

First suppose the agency uses a first-prize procurement auction. The (surplus-maximizing) agency specifies a fixed quantity q. After having observed this quantity, the firms simultaneously cast bids that correspond to the price at which they are prepared to supply each unit of quantity.

bids.

[47] While there are reasons why the incumbent may have lower costs (for instance, experience or scale advantages), there are also reasons why entrants might have lower costs (for instance, less rigid employment contracts). We thus opted for a symmetric treatment.

The successful firm has to supply a quantity q announced by the agency at the submitted price. Suppose $N \leq K$ firms participate in the auction, where N is common knowledge. Denote the expectation of the lowest cost as $c_{(1)}$ and the expectation of the second-lowest cost as $c_{(2)}$. In the Nash equilibrium of the auction, the expected absolute markup is $m = c_{(2)} - c_{(1)}$ and the expected costs are $c_{(1)}$. Therefore, the expected price paid by the agency is $p_A = c_{(2)}$.

Second, we consider directly awarded lines. We do not model the negotiation mechanism between agency and supplier explicitly. We merely assume that the incumbent and the agency both expect the resulting price to be $p_N = m_N c$ for some $m_N > 1$, that is, higher than the expected average cost. Again, all variables can be line-specific.

Anticipating these prices p_M for the given procurement mode M, a risk-neutral agency therefore chooses q so as to maximize the expectation of

$$W_M \equiv s\sqrt{q} - p_M q. \tag{1}$$

The first-order conditions of this problem determine quantities as $q = \frac{s^2}{4p_M^2}$. Clearly, a reduction in the procurement price p_M and an increase in the surplus parameter s increase quantity. For the empirical analysis, we note that the values of s and the respective cost terms for auctions and directly awarded contracts, $c_{(2)}$ and $m_N c$ are identified by the model from price and quantity observations.

For an agency that is concerned about total welfare rather than consumer welfare net of transfer prices, the term p_M in the objective function would have to be replaced by marginal costs. In situations where the procurement price p_M lies above the marginal cost, the agency who chooses according to (1) will therefore choose a quantity that is lower than the one that maximizes total welfare for given costs. The competitive pressure resulting from auctions alleviates this problem.

5.2 Estimation

We now discuss how we recover the distribution of costs among firms who bid on auctioned lines. The approach has two steps. We first estimate the distribution of bids. We then recover

the distribution of bidders' costs in a second step by using the first order-condition for optimal bidding behavior (see Guerre, Perrigne and Vuong, 2000). We then use these estimation results to predict prices on lines that were auctioned under the assumption that they had been directly awarded instead, and other counterfactual scenarios.

Estimation of winning bids For the bidding model, we assume that each contract is procured with a standard first-price sealed bid auction. We assume that each contract is independent of the other contracts and we do not allow for dynamic or simultaneous strategic considerations by bidders. Bidders are risk neutral and symmetric. They know the number of bidders[48] and their own costs c_i, which are independent and private. We denote the distribution of bidders' costs as $F(\cdot|X)$, and assume that bidders' costs are independent conditional on observable auction characteristics X. Given these assumptions, one can write the distribution of bids as $G(\cdot|X)$. We assume that, conditional on the observable auction characteristics X, the (log) bids are drawn from a Weibull distribution, with c.d.f.

$$G(b_i|X) = 1 - \exp\left\{ - \left(\frac{b_i}{\lambda^{bids}(X)} \right)^{\rho^{bids}(X)} \right\}, \tag{2}$$

where b_i is the bid of bidder i, X is a set of line characteristics X known to the econometrician and the bidders, $\lambda^{bids}(X)$ is the scale and $\rho^{bids}(X)$ is the shape of the Weibull distribution. We parameterize the scale as $\lambda^{bids}(X) = \lambda_0^{bids} + \lambda_X^{bids} X$ and the shape $\rho^{bids}(X) = \rho_0^{bids}$ to be constant. As we observe (log) winning bids only, we use the density of the first-order statistic of a Weibull distribution, which is

$$h(b_{[1]}) = \frac{N!}{(N-1)!}(1 - G(b))^{(N-1)} g(b), \tag{3}$$

[48] We assume that entry into the auctions is fixed and the number of potential bidders is equal to the number of participating bidders. Thus, our model does not allow for endogenous entry as for example the analysis on highway procurement in Krasnokutskaya and Seim (2011). Our main reason for this assumption is the lack of appropriate data. We only observe winning bids and the number of bidders, but not their identity. That does not allow us to estimate an econometrically more challenging model to identify entry cost.

where $b_{[1]}$ is the winning bid, G is the distribution function of the bids and g its density function.[49,50,51]

Determinants of prices in directly awarded contracts As argued above, the procurement price is equal to $c + y$, for some $y > 0$ when the contract is awarded directly. We assume that, conditional on the observable auction characteristics X, (log) prices for directly awarded contracts also follow a Weibull distribution, with c.d.f.

$$G(p_{negs}|X) = 1 - \exp\left\{ - \left(\frac{p_{negs}}{\lambda^{negs}(X)} \right)^{\rho^{negs}(X)} \right\}, \tag{4}$$

where p_{negs} is the price on lines with directly awarded contracts. We again parameterize the scale as $\lambda^{negs}(X) = \lambda_0^{negs} + \lambda_X^{negs} X$ and the shape $\rho^{negs}(X) = \rho_0^{negs}$ to be constant. This enables us to predict prices for directly awarded contracts. However, we cannot back out marginal cost in this case, as without information on y we are not able to identify and recover c.

Likelihood We estimate the parameters of the model, $(\lambda^{bids}, \rho^{bids}, \lambda^{negs}, \rho^{negs})$, by maximum likelihood. With our assumptions regarding the distribution of the bids, we can form the likelihood for observed auctioned prices as well as observed prices of direct contracts. As our sample of auctions is relatively small, we combine the two samples for estimation. This, additionally, reduces the variance of our estimates. The likelihood has then two components and can be written as

$$l = d \times h(b_{[1]}) + (1 - d) \times g(p_{negs}), \tag{5}$$

where d is equal to one for the sample with winning bids and zero otherwise. For the estimations, we implement the log likelihood for the log winning bid and the log prices for directly awarded contracts and interact the variables X with a dummy variable for auctioned lines. This allows the influence of line characteristics to be different on auctioned lines and those awarded directly.

[49] See for example, David and Nagaraja (2004) for more information on order statistics.

[50] In contrast to the theoretical model, the Weibull distribution does not have a finite upper bound. We follow Athey, Levin and Seira (2011) and truncate the very upper tail of the estimated distribution.

[51] We do not model (to the econometrician) unobserved cost heterogeneity. As there is only one observation per auction, it is not possible to identify this heterogeneity non-parametrically (see Krasnokutskaya 2011).

Recovering marginal cost: We can recover the distribution of costs with information on the distribution of winning bids and the number of bidders. Following Guerre, Perrigne and Vuong (2000), the first order condition for i's bidding problem is

$$c_i \equiv b_i - \frac{1}{N-1}\frac{1-G(b_i;X)}{g(b_i;X)}, \tag{6}$$

where $G(b;X) = F(b_j^{-1}(b;X))$ is the probability that j will bid less than b and $b_j^{-1}(b;X) = c_j$; $g(b_i;X)$ is the density function. This formulation provides the basis for estimating bidders' cost distributions. It also reflects that, in equilibrium, bidders use a markup strategy and bid their values minus a shading factor that depends on the equilibrium behavior of opponents.

Assuming bidders behave as predicted by the theoretical auction model, the distribution $F(\cdot|X)$ is identified from the distribution of observed winning bids.[52] Bidders' costs are then directly derived from equation (6). As we do not observe all bids, we back out marginal cost and calculate markups for winning bids only.[53] To back out marginal cost, we apply (6) to the observations from the auctioned lines, only.

Predictions To predict winning bids in-sample and out-of-sample, we calculate the expectation of the first-order statistic of a Weibull distribution, i.e.,

$$\hat{b}_{[1]} \equiv \mathbb{E}[b_{[1]}] = N\hat{\lambda}(X)\left(\frac{1}{N}\right)^{\left(\frac{1}{\hat{\rho}(X)}+1\right)}\Gamma\left(\frac{1}{\hat{\rho}(X)}+1\right), \tag{7}$$

where $\mathbb{E}[b_{[1]}]$ is the expected winning bid, Γ the gamma function, and $\hat{\lambda}(X)$ and $\hat{\rho}(X)$ are the estimated scale and shape of the Weibull distribution.[54] We may also predict the mean prices of directly awarded contracts by calculating the mean value of the Weibull distribution as

$$\hat{p}_{negs} \equiv \mathbb{E}[p_{negs}] = \hat{\lambda}(X)\Gamma\left(\frac{1}{\hat{\rho}(X)}+1\right), \tag{8}$$

where $\mathbb{E}[p_{negs}]$ is the expected (log) price for directly awarded contracts.

[52] For a discussion on identification in first-price auctions, see Athey and Haile (2006).

[53] Once we have estimated the distribution function G and the density function g of the Weibull distribution, we are able to predict winning bids, but in principle also mean bids or any other order statistics.

[54] For the calculation of the expectation, see Appendix D.

Approximation of incumbent's cost To obtain an estimate for the incumbents' costs on lines where the contract was awarded directly, we use two approaches. The first approach gives us an upper bound for this cost, the second one provides a lower bound. The first approach starts from the symmetry assumption that the expected cost of the incumbent is the same as the expected cost of any other bidder. We cannot directly estimate this expected cost, as we have no explicit model of the underlying procurement mechanism. Instead of this expected cost, we therefore choose the winning bid in a second-price auction with two bidders. In expectation this winning bid corresponds to the expected cost of the bidder with the second lowest bid. The cost of the second bidder is the highest cost in the two-bidder case and thus higher than the expected average cost of the two bidders. Given the symmetry assumption, it is thus an upper bound for the incumbent's average cost.[55]

For our second approach, we use equation (6) to recover the incumbent's cost in auctions where the incumbent participated and won. We then regress these cost draws on line characteristics using OLS[56] and make predictions for all auctioned lines. We assume that, controlling for line characteristics, the incumbent is as efficient on auctioned lines where this firm has won and on those where it has not. As the lines where the incumbent has won will be those where he has particularly low costs, this approach underestimates costs on average lines and will therefore exaggerate markups.[57]

5.3 Discussion: Asymmetries

Our structural model assumes symmetry between incumbent and entrants. This is obviously a simplification. As emphasized by Weiergräber and Wolf (2021), it appears likely that *DB Regio* has cost advantages as well as more precise information (concerning passenger behavior and ticket revenue). They show theoretically how such asymmetries affect bidding behavior in a complex way, with different effects in gross revenue and in net revenue auctions. In the former case, the incumbent's cost advantage means that she is a stronger bidder. Compared to

[55] This would still remain true under asymmetry provided the incumbent faces lower expected average cost than the remaining firms.

[56] The estimation results are shown in Table D1 in Appendix C.

[57] In principle, we can extend both approaches to directly awarded lines. We however have to make further (out-of-sample) assumptions on the behavior of incumbents and other bidders.

the symmetric case, this translates into more aggressive bidding behavior of the entrant and less aggressive behavior of the incumbent, resulting in inefficiencies. The informational advantage of the incumbent matters only in net auctions. In contrast with the case of gross auctions, if the incumbent's informational advantage is the only source of asymmetry, this will lead the entrant to bid less aggressively, as she is more wary of the winner's curse. The net effect of omitting both types of asymmetries in the analysis is unclear. The empirical analysis of the authors suggests, however, that the informational effects dominate, leading to higher winning probability of the incumbent. It is hard to say how not admitting either type of asymmetry biases our results on the effects of using competitive rather than non-competitive procedures, though a casual application of the ideas of Weiergräber and Wolf (2021) might suggest that the effects of competition become weaker when asymmetries are taken into account. The results of our structural model below at least suggests that the overall effects of competition are similar (though somewhat lower) in the structural estimation as in the reduced-form estimations above.

6 How Do Auctions Reduce Prices?

In the following, we present the empirical implications of our structural model. Section 6.1 explains how we deal with the number of bidders. In Section 6.2, we redo the counterfactual analysis of Section 4.3 and replace the reduced form price estimations for auctioned lines by estimations based on the structural model. In Section 6.3, we investigate the contributions of competitive pressure and selection to the overall price effect of competition.

6.1 Predicted Entry

Before we carry out the counterfactual analysis, we also require an estimate for the number of bidders that would have participated in the bidding process if a directly awarded line had been procured competitively. We run a Poisson regression with the number of bidders as the dependent variable and line characteristics as well as fixed effects for states as explanatory variables. Table 8 shows how the number of bidders depends on the control variables. Significant controls are the electrification dummy, line length and the population variables; log frequency is almost

significant. Interestingly, net revenue contracts are associated with a lower number of bidders, which fits well with the results of Weiergräber and Wolf (2021). The estimations are based on the small sample of auctions for which the number of bidders is available; we use them to predict this number on the remaining sample as well as to predict the number of bidders that would compete on in the hypothetical case of an auction on directly awarded lines.

Table 8: Determinants of the number of bidders

	(1)	(2)
Incumbent	0.035	(0.067)
Net revenue contracts	-0.549***	(0.108)
log frequency	0.104	(0.064)
Electric traction	0.099*	(0.057)
Distance to city (km)	0.000	(0.002)
Log track length	0.071**	(0.028)
Log pop largest city	0.055***	(0.017)
Log pop 2nd largest city	-0.162***	(0.047)
Regional factor	0.226	(0.183)
Constant	0.679	(0.801)
Dummy variables for federal states	yes	
Log likelihood	-69.180798	
Number of observations	41	

Notes: Results from MLE estimations. The dependent variables is the number of bidders and the estimated coefficients are from a Poisson model; Standard errors are clustered (on agency) are shown in parentheses besides the coefficients. $***$ ($**$, $*$) stands for significance at the 1% (5%, 10%) level.
Source: Own calculations.

When we calculate the average number of participating firms predicted by the Poisson model for the auctioned lines, we obtain a value of 4.6341. This is slightly larger than the average number of participating firms based on the observations, which is equal to 4.6098 (see Table 1). We also use this model to predict the entry of firms if directly awarded lines had been auctioned. The Poisson model predicts that on average, 4.2905 bidders would have competed in that case. This number is slightly smaller than we obtained for auctioned lines.

6.2 The Effects of Competition on Prices

We now investigate how prices and quantities would have evolved under different regimes. First, we would like to know how winning bids and quantities would have looked like if auctions had taken place on directly awarded lines. Second, we estimate hypothetical prices for directly awarded contracts on auctioned lines. For that purpose, we present estimated parameters of the

likelihood (5).

Table 9 presents the results of the price models. It shows the estimates for the scale parameter λ and the estimate for the shape parameter ρ. Column (1) shows determinants of prices of directly awarded contracts; column (3) the deviations for auctioned prices. The relation between the control variables and the shape parameter of the Weibull distribution is generally plausible. For instance, as one would expect, on directly awarded lines the regional factor has a substantial positive effect on the price. This effect is essentially wiped out on auctioned lines. This is consistent with the notion that auctions have a particularly strong price-reducing effect on less attractive lines where the regional factor is high. It is also interesting to note that the prices of direct contracts are particularly high for electrified lines. This is plausible in view of the opportunity costs for *Deutsche Bahn*: Lines that are electrified are often used for long-distance passenger and freight trains, so that *Deutsche Bahn* will be reluctant to accept a large number of regional passenger trains without substantial payments.

Table 9: Determinants of prices for auctions and directly awarded contracts

	Directly Awarded		Deviation for Auctioned	
	(1)	(2)	(3)	(4)
Constant (scale λ)	2.348***	(0.198)	-0.019	(0.046)
Log frequency	-0.039**	(0.018)	-0.025	(0.038)
Electric traction	0.079**	(0.035)	-0.142**	(0.059)
Distance to city (km)	-0.001**	(0.001)	0.001	(0.001)
Log track length	-0.015	(0.014)	0.043	(0.028)
Log pop largest city	-0.004	(0.012)	-0.003	(0.033)
Log pop 2nd largest city	-0.011	(0.011)	0.012	(0.030)
Regional factor	0.201***	(0.050)	-0.205***	(0.068)
Incumbent	0.066	(0.059)	-0.093**	(0.047)
Net revenue contracts	0.046	(0.033)	0.036	(0.048)
Constant (shape ρ)	16.123***	(1.346)		
Log likelihood	241.9455			
Number of observations	484			

Notes: Results from MLE estimations. The dependent variable is the logarithm of price and the coefficients describe the scale parameter λ and shape parameter ρ of the Weibull model. Column (1) shows determinants of the prices of directly awarded contracts; column (3) the deviations for auctioned prices. Standard errors are clustered (on agency) are shown in parentheses besides the coefficients. $***$ ($**$, $*$) stands for significance at the 1% (5%, 10%) level.
Source: Own calculations.

Using these new price estimates, we obtain that, on auctioned lines, prices were 15.2% lower than if contracts had been awarded directly (see Table 10). Moreover, on directly awarded lines, prices would have been 16.0% lower if competitive procurement had been used. These results

are somewhat lower than those obtained in the reduced form analysis as we also control for participation and allow for non-linear effects.

Table 10: Comparison of predicted quantities and prices

	Mean quantities			Mean prices		
	Direct Awards	Auctions	Difference	Direct Awards	Auctions	Difference
in levels	(1)	(2)	(3)	(4)	(5)	(6)
Directly awarded lines	18651.12	20901.27	-2250.15***	8.5196	7.1600	1.3596***
	(612.0)	(676.5)	(137.1)	(0.0263)	(0.0260)	(0.0370)
Auctioned lines	14230.53	16417.09	-2186.56***	8.2325	6.9846	1.2479***
	(678.1)	(773.1)	(188.5)	(0.0460)	(0.0452)	(0.0645)

Notes: Results based on OLS and MLE estimations in Tables 4 and 9. Mean predicted values in levels are shown. Standard errors are shown below the mean values. *** (**, *) stands for significance at the 1% (5%, 10%) level. Source: Own calculations.

6.3 Competitive Pressure vs. More Efficient Suppliers

So far, the analysis has established that competition increases the frequency of service and reduces procurement prices, but it has not uncovered the sources of these effects. As we argued before, the price reductions could potentially reflect increasing competitive pressure as well as a tendency for more efficient suppliers to win the auction (which would correspond to lower costs). We now analyze to which extent these two channels are responsible for the reduction in procurement prices. Table 11 provides information on mean estimated cost and markups on auctioned lines. We distinguish between auctioned and directly awarded contracts on auctioned lines in Panel A and on directly awarded lines in Panel B. We first concentrate on Panel A and later discuss the results from Panel B, which are not qualitatively different from the results in Panel A.

In Column (1), we calculate cost as well as absolute and relative markups using the auction model. The absolute markups is 0.3034 and the relative markup is 4.3174.[58] To obtain an estimate of incumbents' cost under directly awarded contracts and to calculate markups, we employ the two different approaches outlined in Section 5.2. The first one provides a lower bound of the markup; the second one provides an upper bound.

[58] Absolute markups are the difference between prices and costs, and relative markups are calculated using the standard Lerner index, i.e., (price - cost)/price. Here and elsewhere, we calculate markups for individual lines and then take the average. This is obviously not the same as calculating the markup using average prices and costs.

In the first approach, we assume two bidders in the structural model and use the resulting winning bid as an upper bound for the incumbent's cost under direct contract award. In the IPV setting, the expectation of this bid is equal to the marginal costs of the second lowest bidder. Based on marginal costs, we then calculate absolute and relative markups. Our results are presented in columns (2) and (3) of Panel A of Table 11. The upper bound for expected costs (the estimated cost of the second-lowest bidder in a two-bidder auction) is 7.5330. The corresponding lower bound for the markup under direct contract award is 8.4798%. We now use this lower bound of the estimated markup to capture the pure effect of competitive pressure on prices on auctioned lines.

To this end, we assume hypothetically that costs remain at the pre-competitive level of 7.5330, whereas relative markups fall from 8.4798% to 4.3174%, which is the predicted markup using auctions. The resulting hypothetical prices after the fall of markups are 7.8729. Thus, even in this scenario competitive pressure on procurement prices is that they fall from 8.2325 to 7.8729. This would amount to 28.8 of the total effect of competition on prices (the drop from 8.2325 to 6.9846; see Table 10). Thus, even if we take a conservative approach to estimating the markups under directly awarded contracts, the potential for competition to reduce them still appears to be quite substantial. In particular, competitive pressure (as opposed to cost reduction) is responsible for about 30% of the price reduction that occurred on auctioned lines.

As an alternative, we also present an upper bound for the estimated markups in directly awarded contracts in columns (4) and (5) of Table 11. We back out costs using the first order condition of optimal bidding of the incumbent, and we predict them out of sample for directly awarded lines. In the auction sample, estimated costs are 6.6812 Euro on the auctioned lines and 6.5301 Euro on the directly awarded lines. With this approach, which underestimates costs under direct award, the cost-reducing effect disappears and the entire price effect is due to the markup reduction from 20.5806% to 4.3174%.

In Panel B of Table 11, we repeat the above exercise for directly awarded lines. Table 10 reports that prices would drop from 8.5196 Euro under direct awards to 7.1600 Euro under auctions. The upper bound for expected costs is now 7.7846 Euro, the corresponding lower bound for the mark-up under direct awards is 8.6129 %. Applying the same procedure with an

Table 11: Comparison of estimated cost and markups

	Auctions	Direct awards	Difference	Direct awards	Difference
		Upper cost bound		Lower cost bound	
	(1)	(2)	(3)	(4)	(5)
			(2)-(1)		(4)-(1)
Panel A. auctioned lines (n=139)					
Price	6.9846	8.2325	1.2479***	8.2325	1.2479***
	(0.0452)	(0.0460)	(0.0645)	(0.0460)	(0.0645)
Costs	6.6812	7.5330	0.8518***	6.5301	- 0.1512***
	(0.0415)	(0.0403)	(0.0579)	(0.0339)	(0.0536)
Absolute markups	0.3034	0.6995	0.3961***	1.7025	1.3991***
	(0.0063)	(0.0056)	(0.0085)	(0.0291)	(0.0298)
Relative markups	4.3174	8.4798	4.1624***	20.5806	16.2632***
	(0.0221)	(0.0211)	(0.0744)	(0.0776)	(0.3011)
Panel B. directly awarded lines (n=420)					
Price	7.1600	8.5196	1.3596***	8.5196	1.3596***
	(0.02599)	(0.0263)	(0.0645)	(0.0263)	(0.0645)
Costs	6.8642	7.7846	0.9203***	6.4826	- 0.3816***
	(0.0240)	(0.0230)	(0.0333)	(0.0173)	(0.0296)
Absolute markups	0.2936	0.7351	0.4415***	2.0370	1.1663***
	(0.0031)	(0.0033)	(0.0045)	(0.0327)	(0.0343)
Relative markups	4.0807	8.6129	4.5323***	23.6041	19.5419***
	(0.0334)	(0.0116)	(0.0354)	(0.3173)	(0.3191)

Notes: Results based on MLE estimations in Table 9. Mean predicted values in levels for auctioned lines are shown. Absolute markups are price - cost; relative markups are in % and the Lerner index, i.e., (price - cost)/price multiplied by 100. *** (**, *) stands for significance at the 1% (5%, 10%) level.
Source: Own calculations.

upper and a lower bound for cost as above we obtain similar results also for directly awarded lines. Again, we first suppose costs remain at the pre-competitive level of 7.846 Euro, whereas relative markups fall from 8.1629% to 4.0807%, which is the predicted markup using auctions. The resulting hypothetical prices after the fall of the markup are 8.1798 Euro. Thus, the minimal effect of competitive pressure is that procurement prices fall from 8.5196 to 8.1798 Euro. This would amount to a cost reduction of 25.0% of the total effect of competition (the drop from 8.5196 to 7.1600).

7 Summary and Discussion

The reorganization of German railway passenger transportation after 1994 provides a unique setting for obtaining insights on the relative performance of two important institutions for public procurement, auctions and direct awards. At the same time, the analysis allows us to contribute to the evaluation of reforms in network industries such as railways that took place in many

European countries towards the end of the last century.

Our analysis indicates that auctions have been successful. According to our estimates, competitive procurement increased the frequency of service by 12-15%, and it reduced procurement prices by about 20%. Moreover, estimates from a structural auction model allow us to back out bidders' marginal costs and their markups. We find that markups decreased from between 8% and more than 20% to just above 4% when lines were auctioned rather than awarded directly. The analysis also suggests a potentially large effect from selection of more efficient bidders.

Our data are not sufficiently detailed to rule out the possibility that competition reduced procurement prices and increased quantities at the cost of lower quality. However, anecdotal and descriptive evidence does not suggest that competitively procured lines are plagued by more serious quality problems than those that were awarded directly. Nevertheless, a systematic investigation of the quality effects would be an interesting and challenging subject for an entirely new paper, assuming adequate data could be obtained.

These results contain several interesting implications. From the perspective of the agency, procurement auctions have substantial advantages over direct awards. Auctions should therefore be the preferred mode of procurement for regional rail service in a context like the one we study. The key impediment appears to be the willingness of the agency to set up the auction. Policies that support regional agencies in running the auctions (or make auctions compulsory) would therefore appear plausible.

There may be specific aspects of the market situation that fostered the positive effects of competition. Most importantly, the analysis concerned an early phase after the reform. At the time, there was substantial entry into the market, which limited the ability of suppliers to ask for high transfers in auctions. In the meantime, market consolidation may have reduced competition. Also, incumbency advantages may have become persistent.[59]

[59] Iossa and Waterson (2016) observe a tendency for incumbents to be selected in the London bus market in later rounds of procurement.

A Appendix: Procurement prices for directly awarded contracts

We now show how we constructed line-specific prices for directly awarded contracts from the average price in the agency and from information on line-specific access charges. We make the following assumptions. For each individual line $i = 1, ..., I$, the price charged by DB Regio is calculated using the costs of delivering the service plus markup. The cost has two components: The costs of using infrastructure and the costs of running the service (a total number $k_i = q_i l_i$ of train kilometers, where q_i is the frequency of service, and l_i is the length of the line in kilometers).

First, note that the costs of using infrastructure are the access charges that have to be paid to DB Netz. These costs differ across lines. We have detailed information on these access costs for each line. Let a_i be the access charge for a line. We calculated the detailed access prices for 504 out of the 551 lines, or 91%, of the lines observed in our sample (the percentage with information on access price is 92% on lines that were directly awarded to the incumbent). For the remaining 47 lines we could not match the start and end station with the data base providing information on access prices. We impute missing prices using linear regression.

Second, for simplicity, we suppose that the remaining costs of running the service, and the markup, are identical on the different lines but they differ across states (*Bundesländer*). Let x_j denote the sum of the remaining costs of running the service and an absolute markup charged by the incumbent, with $j = 1, ..., J$ indexing states. The resulting price of a directly awarded contract is

$$p_{i,D} = a_i + x_j.$$

We recover the line specific price for a directly awarded contract using information on $p_{j,D}$, the average price of a directly awarded contract by state j. We estimate x_j assuming that the average (frequency of service weighted) price of a directly awarded contract is identical to the price of the contract awarded directly at the state level. Let $b_{ij} = 1$ if line i is situated in state j,

and $b_{ij} = 0$ otherwise, and $\delta_i = 1$ if the line is auctioned, and $\delta_i = 0$ otherwise. It follows that

$$p_{j,D} = \frac{\sum_{i=1}^{I} b_{ij}(1-\delta_i)k_{i,D}p_{i,D}}{\sum_{i=1}^{I} b_{ij}(1-\delta_i)k_{i,D}}.$$

This means we can back out an estimate of the state specific price of running the service as

$$x_{j,D} = p_{j,D} - \frac{\sum_{i=1}^{I} b_{ij}(1-\delta_i)k_{i,D}a_i}{\sum_{i=1}^{I} b_{ij}(1-\delta_i)k_{i,D}}.$$

The resulting prices $p_{i,\delta}$ have a number of properties. First, the state average prices of directly awarded contracts match the quoted prices exactly. Second, the resulting price components match published sources well. The average total price of directly awarded contracts was 8.73 EUR per train kilometer, with the access charge amounting to 3.53 EUR on average. Thus, the access charge makes up 40% of the total price. This is consistent with LNVG (2010) who argue that infrastructure costs amount to about 40% of the costs of railway services.

B Selection on Unobserved Growth

This section discusses our test for selection based on unobserved growth. Let y_{it}^{δ} denote the potential service frequency along line i. $t = 1$ after the reform, and $t = 0$ before the reform. $\delta = 1$ if services along a line have been auctioned, and $\delta = 0$ otherwise. In $t = 0$, $\delta = 0$ for all lines, and we omit the super-script. In $t = 1$, a line is either auctioned, or awarded directly, so only one potential outcome exists. Also, let $y_{it} \equiv \delta y_{it}^{1} - (1 - \delta) y_{it}^{0}$ be the outcome we observe in our data.

For ease of exposition, we abstract from pure time effects, but include these in our empirical analysis. Service frequency prior to the reform is

$$y_{i0} = x_i' \alpha + \epsilon_{i0}$$

x_i has no time index, since line characteristics are time-invariant. ϵ_{i0} has mean zero.

Service frequency along auctioned lines after the reform is

$$y_{i1}^{1} = x_i' \beta + \epsilon_{i1}^{1}$$

where ϵ_{i1}^{1} has mean zero.

Thus, along auctioned lines, service growth is

$$\begin{aligned} y_{i1}^{1} - y_{i0} &= x_i'(\beta - \alpha) + \epsilon_{i1}^{1} - \epsilon_{i0} \\ &= x_i' \gamma + \epsilon_{i1}^{1} - \epsilon_{i0} \end{aligned}$$

Supposes agencies select based on positive expected service growth, so $\delta = I[x_i' \gamma + \epsilon_{i1}^{1} - \epsilon_{i0} > 0]$, where $I[A]$ is the indicator function that takes the value one if the condition A is true, and zero otherwise.[60] Auctioned lines are those with larger service growth if procured using auctions rather than direct awards.

[60] Note that agencies may use any threshold, not just 0, and the test remains valid. If agencies select on the gains to growth from auctions compared to direct awards, i.e. $\epsilon_{i1}^{1} - \epsilon_{i0} > \epsilon_{i1}^{0} - \epsilon_{i0} = \epsilon_{i1}^{1} > \epsilon_{i1}^{0}$, the test would not detect selection, as the selection condition does not involve service levels prior to the reform. But if there is persistence in unobserved service levels, as we find in our main estimates in section 4, selection based on service levels in period 1 would also show in period 0.

Our test for selection based on service growth focuses on the average unobserved component of service, prior to the reform. Among auctioned lines, this is

$$\begin{aligned} E[\epsilon_{i0}|\delta = 1] &= E[\epsilon_{i0}|x_i'\gamma + \epsilon_{i1}^1 - \epsilon_{i0} > 0] \\ &= E[\epsilon_{i0}|x_i'\gamma + \epsilon_{i1}^1 > \epsilon_{i0}] \end{aligned}$$

Among auctioned lines, the distribution of the unobserved component of pre-reform service levels, ϵ_{i0}, is truncated from above. Truncation from above will dampen the mean unobserved service level among lines chosen to be no larger than the population mean of zero. Truncation is stronger the smaller the effect of auctions on service frequency, $x_i'\gamma$, relative to the support of the distribution of service frequency.

For directly awarded lines, with $x_i'\gamma + \epsilon_{i1}^1 < \epsilon_{i0}$, ϵ_{i0} is truncated from below so the mean of ϵ_{i0} is positive. Truncation is weaker if $x_i'\gamma$ is smaller, contrary to auctions. Regardless of the size of $x_i'\gamma$, selection based on gains drives a wedge between the mean unobserved service component in the two groups of lines.

We test whether unobserved components of pre-reform service differ using this regression

$$y_{i0} = x_i'\alpha + \delta_i\eta + \nu_{i0}$$

where $\nu_{i0} = \epsilon_{i0} - D_i\eta$. The parameter η is a consistent estimator of $E[\epsilon_{i0}|x_i, \delta = 1] - E[\epsilon_{i0}|x_i, \delta = 0]$. A standard hypothesis test on η informs on the presence of selection based on unobserved service growth.

C Appendix: Results for auxiliary regression

Table D1 shows the estimation results, when we regress the incumbent's cost in auctions where the incumbent participated and won on line characteristics using OLS. From this regression, we make predictions for all auctioned lines.

Table D1: Determinants of the incumbent's cost

	(1)	(2)
Log frequency	-0.033	(0.022)
Electric traction	-0.038*	(0.020)
Distance to city (km)	0.000	(0.000)
Log track length	0.011	(0.013)
Log pop largest city	-0.007	(0.014)
Log pop 2nd largest city	0.004	(0.018)
Regional factor	-0.087**	(0.039)
Net revenue contracts	0.115***	(0.027)
Constant	2.160***	(0.255)
Adjusted R-squared	0.612	
Number of observations	23	

Notes: Results from OLS estimations. The dependent variables is incumbent's cost in auctions where the incumbent participated and won. Standard errors are clustered (on agency) are shown in parentheses besides the coefficients. $***$ ($**$, $*$) stands for significance at the 1% (5%, 10%) level.
Source: Own calculations.

D Appendix: Derivation of (7)

$$
\begin{aligned}
\mathbb{E}[b_{[1]}] &= \int_{-\infty}^{\infty} x f(x_{[1:n]})dx = \frac{n!}{(n-1)!}\int_{-\infty}^{\infty} x[1-F(x)]^{n-1}f(x)dx \\
&= n\int_{0}^{\infty} x\{\exp[-(x/\lambda)^{\rho}]\}^{n}(\frac{\rho}{\lambda})(\frac{x}{\lambda})^{\rho-1}dx \\
&= n\rho\int_{0}^{\infty}(\frac{x}{\lambda})^{\rho}\{\exp[-(x/\lambda)^{\rho}]\}^{n}dx = \text{ (integration by substitution)} \\
&= n\lambda\int_{0}^{\infty}(\frac{1}{n})^{(1/\rho+1)}y^{(1/\rho)}\exp(-y)dy \\
&= n\lambda\big(\frac{1}{n}\big)^{\big(1/\rho+1\big)}\Gamma\big(1/\rho+1\big) \text{ with } \Gamma(t) = \int_{0}^{\infty} x^{t-1}\exp(-x)dx \qquad (9)
\end{aligned}
$$

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