Discussion Paper No. 17-035

Competition, Collusion and Spatial Sales Patterns – Theory and Evidence

Matthias Hunold, Kai Hüschelrath, Ulrich Laitenberger, and Johannes Muthers

ZEW

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

Discussion Paper No. 17-035

Competition, Collusion and Spatial Sales Patterns – Theory and Evidence

Matthias Hunold, Kai Hüschelrath,
Ulrich Laitenberger, and Johannes Muthers

Competition, collusion and spatial sales patterns - theory and evidence*

Matthias Hunold†, Kai Hüschelrath‡, Ulrich Laitenberger§ and Johannes Muthers¶

September 26, 2017

Abstract

We study competition in markets with significant transport costs and capacity constraints. We compare the cases of price competition and coordination in a theoretical model and find that when firms compete, they more often serve more distant customers that are closer to plants of competitors. By means of a rich micro-level data set of the cement industry in Germany, we provide empirical evidence in support of this result. Controlling for other potentially confounding factors, such as the number of production plants and demand, we find that the transport distances between suppliers and customers were on average significantly lower in cartel years than in non-cartel years.

JEL classification: K21, L11, L41, L61
Keywords: Capacity constraints, cartel, cement, transport costs.

*We are grateful to Cartel Damage Claims (CDC), Brussels for providing us with the data set. Hüschelrath was involved in a study of cartel damage estimations which was financially supported by CDC. The study is published in German (K. Hüschelrath, N. Leheyda, K. Müller, and T. Veith (2012), Schadensermittlung und Schadensersatz bei Hardcore-Kartellen: Ökonomische Methoden und rechtlicher Rahmen, Baden-Baden). The present paper is the result of a separate research project. We thank Toker Doganoglu, Joe Harrington and Shiva Shekhar for valuable comments.

†Düsseldorf Institute for Competition Economics (DICE) at the Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf, Germany; E-Mail: hunold@dice.hhu.de.

‡ZEW Centre for European Economic Research, MaCCI Mannheim Centre for Competition and Innovation and University of Mannheim, L7,1, D-68161 Mannheim, Germany; E-Mail: hueschelrath@zew.de.

§Télécom ParisTech, Département Sciences économiques et sociales, 46 Rue Barrault, 75013 Paris, France, and ZEW as above; E-Mail: laitenberger@enst.fr.

¶University of Würzburg, Sanderring 2, 97070 Würzburg; E-Mail: johannes.muthers@uni-wuerzburg.de.

1 Introduction

It is well established in the literature that cartels between competitors typically lead to excessive prices and can also result in excess capacities. However, little is known about the spatial pattern of sales. In this article we therefore study how competition affects which customers firms serve in markets with significant transport costs and capacity constraints. Our results help to better understand the competitive process and provide hints for distinguishing competition and coordination when analyzing market data in competition policy cases.

We start by formally comparing the market outcomes with price competition and coordination. Consider that customers are located evenly on a line and that each of two symmetric suppliers is located at one end. The products are homogeneous and the only differentiation is due to location and thus transport costs. Cost minimization implies that all customers are served by the respectively closest firm. Absent capacity constraints, price competition yields this efficient allocation. Similarly, if the two firms coordinate and maximize joint profits, the transport costs are also minimized, albeit customers have to pay higher prices. By contrast, if the firms are capacity constrained and compete in prices, an inefficient allocation can arise in equilibrium. Consider the situation that each firm cannot serve the whole market on its own, but has capacity to serve more than half of the market, such that each firm can serve all the customers closest to it and an efficient allocation is clearly feasible. However, price competition turns out to be chaotic as firms cannot anticipate the exact prices of their capacity constrained competitors. This strategic uncertainty regularly yields situations where the more distant firm makes the more attractive offer to a customer, which results in inefficient allocations.

If firms compete, there is a non-monotonic relationship between the average transport distance and the degree of excess capacity. When capacity is very scarce, firms are effectively local monopolists and the average transport distances are low. Without capacity constraints, fierce competition yields limit prices for each customer at the costs of the second most efficient firm, such that again the cheapest supplier wins the contract. For intermediate capacities, however, the average transport distance varies in the degree of overcapacity. Instead, theory predicts that there should not be such a variation if there is a well-organized cartel. The pattern that significant changes in the supply-demand balance are not accompanied by changes in the average transport distances is therefore indicative of coordination among the firms with intermediate levels of capacity.

In order to test our theory, we empirically investigate the allocation of customers to suppliers in the cement industry in Germany between 1993 and 2005. The cement industry is suitable for several reasons. Transport costs typically constitute a significant part of the cement price as cement is heavy and, due to scale economies, there is a limited number of cement production plants. The production capacity is limited by several factors, in particular the capacity of clinker kilns, which constitute costly long term investments. Demand for cement largely depends on the demand of the construction industry, which tends to be volatile and largely exogenous to the cement price. Indeed, the cement industry in Germany exhibited significant overcapacities in most of the investigated time-frame. Moreover, the industry had been cartelized during the first part of our observation period. There is a clear cut after the German competition authority (Bundeskartellamt) raided 30 cement producers in 2002, based on hints it had received out of the construction industry.[1] We therefore compare the allocation of customers in the cartel period of 1993 to 2002 with that in the period following the cartel breakdown.

We use a rich data set with transactions of 36 cement customers in Germany from January 1993 to December 2005. Controlling for other potentially confounding factors, such as the number of production plants and demand, we find that during the cartel period the transport distances between suppliers and customers were on average significantly lower than in the later period of competition. This provides strong empirical support of our theoretical finding that competing firms serve more distant customers in areas that are closer to their competitors' production sites. Moreover, we test the theoretical prediction that an increase in overcapacities increases transport distances. We provide empirical evidence for this result using variation in construction demand to compare different capacity levels relative to demand. Insofar as the excess capacity is a result of a cartel period, the finding of higher transport distances points to a novel inefficiency caused by cartelization.

We continue with a discussion of the related literature in the next section and present the theoretical model in section 3. In section 4 we provide empirical evidence on the relationship between transport distances and the mode of competition using data of the cement industry in Germany. We conclude in section 5 where we relate our theoretical and empirical findings and discuss implications for competition policy.

2 Related literature

This article contributes to several strands of the existing theoretical and empirical literature.

There is a well-known literature based on Bertrand (1883) – Edgeworth (1925) that analyzes price competition in case of capacity constraints – and does so mostly for homogeneous products. A prominent example is Acemoglu et al. (2009). There are a few articles which introduce differentiation in the context of capacity constrained price competition, notably Canoy (1996); Sinitsyn (2007); Somogyi (2016); Boccard and Wauthy (2016). Canoy investigates the case of increasing marginal costs in a framework with differentiated products. However, he does not allow for customer specific costs and customer specific prices. Somogyi considers Bertrand-Edgeworth competition in case of substantial horizontal product differentiation in a standard Hotelling setting. Boccard and Wauthy focus on less strong product differentiation in a similar Hotelling setting. Somogyi uses a logit demand specification and shows that pure-strategy equilibria exist for small and large overcapacities, but only mixed-strategy equilibria for intermediate capacity levels. For some of these models equilibria with mixed-price strategies over a finite support exist (Boccard and Wauthy (2016); Sinitsyn (2007); Somogyi (2016)). This appears to be due to the combination of uniform prices and demand functions which, given the specified form of customer heterogeneity, have interior local optima as best responses.[2] Overall,

[1] See the Bundeskartellamt's press release "Bundeskartellamt imposes fines totalling 660 million Euro on companies in the cement sector on account of cartel agreements", April 14 2003, last accessed September 2017.

[2] In a related vein, some work has considered heterogeneous customers in models with different cus-

these contributions appear to be mostly methodological and partly still preliminary. The probably most closely related theory contribution is our companion article Hunold and Muthers (2017). In that article we consider a simplified model with only four customers to study price differentiation and subcontracting when firms compete. Different from that article, we contribute in the present article with a comparison between competition and coordination in a model with a continuum of customers and a general cost structure. Additionally, we develop hypotheses and provide empirical evidence in their support by using a rich data set of the cement industry in Germany.

Another related theoretical literature is that on the efficiency of competition and cartels. Benoit and Krishna (1987) as well as Davidson and Deneckere (1990) have shown that in a dynamic game firms generally carry excess capacity in equilibrium in order to sustain higher collusive prices. Similarly, Fershtman and Gandal (1994) have shown that firms may build up excessive capacity in anticipation of a price cartel in which the rents are allocated in proportion to capacity shares. They have demonstrated that building capacities non-cooperatively can lead to lower profits in the subsequent price cartel, but may overall nevertheless decrease social welfare. Also in our model cartels may lead to inefficiently high capacity levels. However, our focus is different as we compare the spatial customer allocation in the cases of competition and coordination for given capacity levels. The derived insights can be used in competition policy to assess by means of market data on transport distances and customer allocations whether firms are competing or coordinating. As regards efficiency effects of cartels, Asker (2010) has analyzed a bidding cartel of stamp dealers and identified an inefficiency that stems from the coordination problem in the cartel which leads to overbidding. Overall, this strand of the literature points to additional inefficiencies caused by cartels. In contrast to this, we point out an inefficiency that arises when symmetric firms compete and do not coordinate their sales activities.

There are various economic studies of the cement industry which largely focus on investment behavior and environmental aspects (Salvo, 2010a; Ryan, 2012; Miller et al., 2017; Perez-Saiz, 2015). More closely related is a study of the cement industry in the US Southwest from 1983 to 2003 by Miller and Osborne (2014). They use a structural model to analyze aggregate market data on annual regional sales and production quantities as well as revenues and argue that transportation costs around \$ 0.46 per tonne-mile rationalize the data. In addition, Miller and Osborne find that isolated plants obtain higher ex-works prices[3] from nearby customers. Our study complements the study of Miller and Osborne as we can specifically test our theoretical predictions about transport distances by means of a rich customer data set that includes identified periods of collusion and competition.

There are several studies of the cement cartel that lasted until 2002 in Germany. Blum (2007) discusses the functioning and impact of the cartel in the eastern part of Germany. Friederiszick and Röller (2010) quantify the damage caused by the cartel due to elevated prices. A few other studies have also used parts of the transaction data which we use in the present article. Hüschelrath and Veith (2011) study pricing patterns during

tomer segments where mixed-strategy price equilibria result, see Sinitsyn (2008, 2009), which is in line with the Varian (1980) model of sales.

[3]This means prices before transport costs.

and after the cartel; Hüschelrath and Veith (2014) investigate the workability of cartel screening methods, and Harrington et al. (2015, 2016) investigate internal and external factors respectively destabilizing the cartel.

Cement cartels in Finland, Norway and Poland have also been documented quite in detail in the literature. Regarding the legal Norwegian cement cartel, Röller and Steen (2006) report that the three firms decided to allocate the domestic market according to the capacity shares of the firms. This incentivized the firms to heavily invest in their capacity, eventually leading to high overcapacity and to the demise of the cartel. This made an industry-wide merger necessary to restore profitability. Bejger (2011) report that the Polish cement firms fixed allocations according to historical shares. As regards the legal cartel in Finland, Hyytinen et al. (2014) report that the allocation was based on territories which minimized the transport costs. The central plant supplied the center and north-centric region by rail, while the remaining plants, which were located at the coast, supplied the east and western parts of Finland.

3 Model

Set-up

There are two symmetric firms. Firm L is located at the left end of a line, and firm R at the right end of this line. In between, customers of mass one are distributed uniformly. Each customer has unit demand and a willingness to pay of v. Firms incur location specific transport costs $C(x)$, where x is the *distance* between firm and customer location on the line. Transportation costs are increasing in distance with $C(y) \geq C(x)$ for all $y > x$. Assuming $v > C(1)$ ensures that all customers are contestable.

Example. A simple form of costs that fulfills the above conditions are linear transportation costs, as usually assumed in the Hotelling framework. In the Hotelling specification increasing costs are captured by the parameter t with $C(x) = tx$. The above contestability assumption, $v > C(1)$, becomes $v > t$.

In the context of cement it is appropriate to think of these costs as mainly the physical transportation costs. In general these costs could also be the costs for adapting a product, or service, to the needs and wishes of a customer. Interpreting costs as mainly adaption costs is suitable for example in industries where customer specific supplies are common, like in the supply chain of the automobile industry and in case of specialized consulting services.

Both firms have limited capacities. We focus on the symmetric case that each firm has a capacity of k, such that a mass k of customers can be served by each firm. If a firm has more demand than it can serve, efficient rationing takes place. We describe rationing in more detail below.

We assume that the firms are able to price discriminate by location. For the cement industry this is typically the case, as the price is set for each customer / construction site for which the location is typically known. Formally the pricing of firm i is a function $p^i(x)$ of the distance between firm and customer. Firms set prices (price functions) simultaneously. The resulting market allocation does not only depend on the prices, but also on capacities as a firm may be unable to serve all customers for which it has charged the lowest price with its capacity.

Rationing

Each customer attempts to buy from the firm with the lowest price if that price is not above the willingness to pay of v. If more customers demand the good from a firm than it can serve, these customers are rationed such that consumer surplus is maximized. More precisely:

1. If one firm charges lower prices to all customers than the other firm and does not have capacity to serve all customers, we assume that the customers are allocated to firms so that consumer surplus is maximized. In other words, those customers with the best outside option are rationed.

2. If point 1. does not yield a unique allocation, the profit of the firm which has the binding capacity constraint is maximized (this essentially means cost minimization).

While this is not the only rationing rule possible, we consider this rule appropriate for the following reasons:

- The rationing rule corresponds to the usual efficient rationing (as, for instance, used by Kreps et al. (1983)) in that the customers with the highest willingness to pay are served first. A difference is, however, that the willingness to pay is endogenous in that it depends on the (higher) prices charged by the other firm. These may differ across customers, and so does the additional surplus for a customer from purchasing at the low-price firm.

- The rationing rule gears at achieving efficiencies, in particular for equilibria in which the firm's prices weakly increase in the costs of serving each customer. Our results of inefficiencies in the competitive equilibrium are thus particularly robust.

- At least for the case of uniform prices ($p^j(x) = p^i$), other rationing rules yield the same outcome. In particular, the firm with lower prices would also choose to serve the closest three customers, as this minimizes the transportation costs.

- The rationing rule is the natural outcome if the customers can coordinate their purchases: They will reject the offer that yields the lowest customer surplus. This occurs, for instance, if interim-contracts with side payments among the customers are allowed. It would also occur if there is only one customer.

- Similarly, if a firm has to compensate a customer to which it made an offer that it cannot fulfill, this might also incentivize the firm to ration according to the customer's net utility from this contract. More generally, in a repeated game firms may at least partially internalize the customers' willingness to pay, which again supports the employed rationing rule.

In the next sections we solve the price game for Nash equilibria, taking the rationing rule into account. We focus on the symmetric equilibria. We start by characterizing symmetric Nash equilibria for the case without capacity constraints. We then solve the symmetric mixed strategy Nash-equilibrium in differentiated prices when each firm has an intermediate level of capacity with $1 > k > 1/2$.

3.1 Competition without capacity constraints

Suppose that each firm has capacity to serve all the customers. As a consequence, for each customer the two firms face Bertrand competition with asymmetric costs. It is thus an equilibrium in pure strategies that each firm sets the price for each customer equal to the highest marginal costs of the two firms for serving that customer, and that the customer buys the good from the firm with the lower marginal costs. This is again efficient in that all customers are served by the closest firm with the lowest transport costs. Each firm serves customers from its location up to the location of the customer at 0.5. The firms make the same profit, which for firm L is computed as $\int_0^{0.5} C(1-x) - C(x)dx$. Consumer surplus is given by $\int_0^1 \{v - \min(C(x), C(1-x)\} \, dx$.

We summarize the equilibrium characteristics in the following proposition.

Proposition 1. *If firms compete without capacity constraints, transportation costs are minimized and each firm serves its closest customers up to a distance of* $1/2$*. Prices decrease from both ends of the unit line (*$x = 0$ *and* $x = 1$*) towards the center (*$x = 1/2$*).*

3.2 Competition with capacity constraints

Non-existence of a pure strategy equilibrium

Suppose each firm can only serve at most k customers and both firms set prices as if there were no capacity constraints, as discussed in the previous subsection. Is this an equilibrium? For each firm, the candidate equilibrium prices charged to customers that have a distance to the firm that exceeds 0.5 equal the firm's costs of supplying those customers. Hence, there is no incentive to undercut these prices. Similarly, there is no incentive to reduce the prices for the customers at a distance of less than 0.5 as these customers are already buying from the firm.

In view of the other firm's capacity constraint, the now potentially profitable deviation is to charge all customers the highest possible price of v. All customers prefer to buy from the other firm at the lower prices which range between $C(1/2)$ and $C(1)$. However, as the other firm only has capacity to serve $k < 1$ customers, $1 - k$ customers end up buying from the deviating firm at a price of v. Given the rationing rules, the customers closest to the deviating firm are rationed as the prices of the other firm are largest for these customers. The profit of the deviating firm is thus $v \cdot (1 - k) - C(1 - k)$. This is larger than the pure strategy candidate profit[4] of $\int_0^{0.5} C(1-x) - C(x)dx$ if

$$v \cdot (1-k) - C(1-k) > \int_0^{0.5} C(1-x) - C(x)dx$$
$$\Leftrightarrow v > \frac{C(1-k) + \int_0^{0.5} C(1-x) - C(x)dx}{1-k} \equiv \tilde{v}.$$

With linear costs t per unit of distance, as in the Hotelling framework, the latter condition reduces to $v > t\frac{1.25-k}{1-k}$. The above condition for a profitable deviation is more restrictive than the contestability assumption $v > C(1) = t$. Moreover, a higher valuation v is necessary to fulfill the condition when the level of overcapacity, k, is larger.

Mixed strategy equilibria

We now focus on the case that $v > \tilde{v}$, such that no pure strategy equilibria exist and solve the price game for symmetric mixed strategy Nash equilibria. Such an equilibrium is defined by a symmetric pair of joint distribution functions over the prices of each firm. We proceed by first postulating that both firms play uniform prices and derive the corresponding distribution functions. We later derive a parameter range in which firms indeed play uniform prices albeit they could charge different prices for each customer.

Note that if both firms play uniform price vectors, there cannot be mass points. If either firm would have a mass point in the symmetric equilibrium at any price, the best response of the other firm would be to put zero probability at that price. This contradicts symmetry and implies that in any symmetric equilibrium with uniform prices both firms play prices without mass points in a closed interval between the lowest price, denoted by $\underline{p}$, and the maximal price v. With uniform price vectors in mixed strategy equilibrium, only two basic outcomes are possible: either one firm has the lowest price for all customers or both firms have identical prices. In the mixed strategy equilibrium the later outcome turns out to not occur almost surely as both firms play prices from atomless distributions and mix independently. The case that one firm offers a lower price to all customers is thus the outcome which occurs almost surely. In this case the capacity constraint is always binding and the rationing rule determines the customer allocation. The efficient rationing rule ensures that the firm with the lower price serves its closest customers up to the customer at distance k, which equals the capacity limit of the firm. This occurs because there is a unit mass and thus the mass of customer located up to a distance of x from a firm is just x.

Thus we can write the expected profit of a firm depending on the price distribution chosen be the other firm. We do this exemplary for firm L:

[4]There are, however, potentially equilibria with even lower prices, in which firms set prices below costs for customer that are closer to the competitor. We exclude those equilibria as it is usual in the literature on asymmetric Bertrand competition. In these cases, deviations to the high price level of v are even more profitable.

$$
\begin{aligned}
\pi_L^e(p^L) =& \left(1-F^R(p^L)\right)\int_0^k p^L - C(x)dx + F^R(p^L)\int_0^{1-k} p^L - C(x)dx \\
=& p^L k - \int_0^k C(x)dx + F^R(p^L)\left(-p^L(2k-1) + \int_{1-k}^k C(x)dx\right)
\end{aligned}
$$

As there are no mass points, the expected profit for each price (p^L) must be equal to the profit at a price of v, which is given by

$$
\pi_L^e(v) = v\,(1-k) - \int_0^{1-k} C(x)dx.
$$

We can derive the equilibrium distribution $F^R(p^L)$ for each price by equating $\pi_L^e(p^L) = \pi_L^e(v)$,

$$
p^L k - \int_0^k C(x)dx + F^R(p^L)\left(-p^L(2k-1) + \int_{1-k}^k C(x)dx\right) = v\,(1-k) - \int_0^{1-k} C(x)dx,
$$

which yields

$$
F^R(p^L) = \frac{p^L k - v\,(1-k) - \int_{1-k}^k C(x)dx}{p^L(2k-1) - \int_{1-k}^k C(x)dx}. \tag{1}
$$

The lowest price that will be played, $\underline{p}$, is the price that yields the same profit as $\pi_L^e(v)$ and is weakly below any price of firm R with certainty:

$$
p^L k - \int_0^k C(x)dx = v\,(1-k) - \int_0^{1-k} C(x)dx,
$$

$$
p^L k = v\,(1-k) + \int_{1-k}^k C(x)dx,
$$

$$
\underline{p} = \frac{v\,(1-k) + \int_{1-k}^k C(x)dx}{k}. \tag{2}
$$

Proposition 2. *In the symmetric mixed strategy equilibrium with uniform prices, both firms play atomless prices according to the atomless distribution function defined in 1 and mix over the interval $\underline{p}$, defined in 2, to v. In the equilibrium, almost surely either one of the two firms sets lower price than the other firm and serves customers up to its capacity limit, starting with the closest customers.*

This result is obtained in richer model but similar to Hunold and Muthers (2017), where mixed strategy equilibria in weakly increasing prices in distance are obtained in a simple setting with linear costs and only four customers. The average transportation distance depends on the capacity in the markets. There are two groups of customers in equilibrium. First, customers that are located close to a firm and will always be served by the closest firm. Second, customers that are located between firms and will always be served by the firm with the lowest price. The size of the first group is given by $2 \cdot (1-k)$ as each firm always serves the closest customers for which the other firm does not have capacity, and the size of the second group is the remainder of $2k-1$. The average transportation distance for customers of group 1 depends on the capacities of the more distant firm for each customer.

Both firms have the lowest price with equal probability, thus the transportation distance for the second group is the average distance to the two firms. This average distance is 0.5 for any customer on the line between the two firms.

Overall the average distance is thus

$$2\int_0^{1-k} x dx + 0.5(1-2(1-k)) = (1-k)^2 + k - 0.5 = 1 - 2k + k^2 + k - 0.5 = 0.5 - k + k^2 \quad (3)$$

The derivative with respect to k of the average distance is: $-1+2k$, which is positive, as by assumption $k > 0.5$.

To check that uniform prices are indeed an equilibrium, we derive the conditions for which the best-response to a uniform price vector by the competitor is a to charge identical prices to all customers.

Consider firm L which is facing firm R that plays uniform price vectors according to the distribution function derived above. Firm L could deviate with any price, the distribution function F_R is defined such that L is indifferent over changing all prices simultaneously and in the same way.

For any customer that is so close that it is served with certainty by firm L (0 to $1-k$) there is no incentive to lower the price. Would it make sense to increase the price? By increasing the price the allocation is unaffected as long as the price is below the competitor's. Whenever the price is above the competitors, for just this customer, the rationing rule applies as R is still at its capacity limit.

Proposition 3. *The symmetric equilibrium in uniform prices exists whenever the transport costs are not too large.*

Proof. See Annex 5.

In summary this establishes that for a certain parameter range we have mixed strategy equilibria in uniform prices. Compared to standard models of competition, a surprising consequence of the uncertainty in the mixed strategy equilibrium is that transport costs are not minimized by competition. In the mixed strategy equilibrium in uniform prices (including transportation costs), indeed, some customers that are located in the middle of the unit interval are almost surely served by the more distant firm. The size of this transport inefficiency increases in k, as can be seen in equation (3). □

3.3 Market outcome when firms coordinate

If firms coordinate and maximize joint profits, they can achieve higher prices than possible with competition. Moreover, the competitive equilibrium characterized above features strategic uncertainty. A result of this uncertainty is an inefficient allocation of suppliers and customers and thus too high transportation cost. Reducing costs by minimizing transport distances is thus another incentive for firms to coordinate. A simple way to coordinate would be to agree on non-overlapping local markets that are exclusively served by one of the firms. In our model firms could agree to only serve customers that have a distance of less than 0.5 to the firm. This agreement minimizes transportation costs.

In that case each firm could simply charge the customers closest to its plant monopoly prices of v.

Considering that firms have overcapacities ($k > 0.5$), the average transport distance is 0.25 in case of successful coordination, and $0.5 - k + k^2$ in the competitive mixed strategy equilibrium, thus depending on the degree of overcapacity. The average transport distance is larger by $0.25 + k\,(k - 1)$ with competition. This difference is 0 for $k = 0.5$ and increases in k until capacities are sufficiently large such that a pure strategy equilibrium with a transport distance minimizing allocation is the unique outcome.

Indeed, in case of the German cement cartel a local market delineation was observed. We discuss the case in more detail below in section 4.1.

3.4 Hypotheses for the empirical analysis

Our theoretical model predicts that in case of overcapacities the average transportation distance in case of competition between firms is higher than if firms coordinate – as in case of a cartel. Moreover, our model predicts that the level of overcapacities affects the transportation distances if firms compete.

If firms compete, the average transportation distance increases in the level of overcapacities. The economic intuition for this fact is that mis-coordination is worse if each firm has larger capacities. With larger capacities, even more inefficient allocations of customers to firms materialize as, in addition to its close-by customers, each firm is able to serve a larger number of more distant customers with higher transportation costs.

If firms coordinate, they have incentives to minimize transportation costs. This might be achieved by agreeing to allocate customers to firms based on location and transport distances. For instance, one strategy of the cement cartel in Germany was that firms focus on their customer bases and avoid "advancing" competition for customers of other firms (see subsection 4.1). As a prediction for the empirical analysis, we thus expect that a cartel is associated with lower transportation distances and that in case of a cartel there is no effect (or at least a lower effect) of an increase in overcapacity on the way markets are shared and thus on transport patterns.

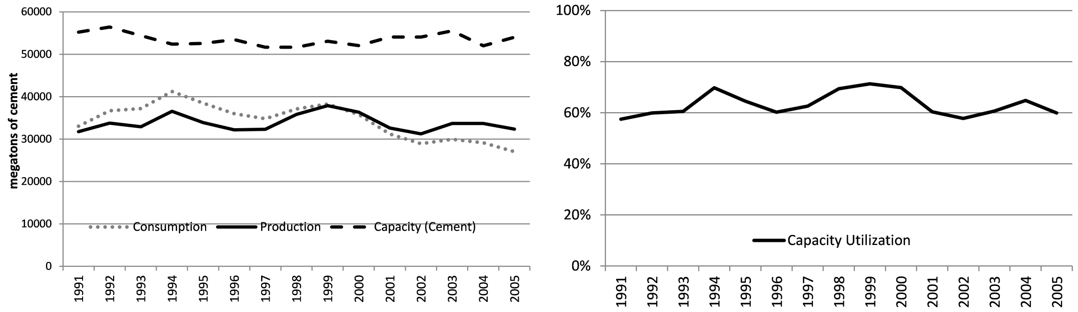
In summary, our theory yields the following hypotheses. *In an industry with capacity constraints, but overall excess capacity and spatial competition:*

H1. *Transport distances are larger if there is competition instead of coordinated firm behavior as in case of a cartel.*

H2. *An increase in capacity relative to demand increases transportation distances if firms compete, but has no effect on the transportation distances if firms coordinate.*

The theoretical predictions could be used as an marker for cartels in practice. To test our hypotheses, we continue with an econometric analysis of the cement industry in Germany, which has a verified period of cartelization.

Figure 1: Cement capacity, production, demand and capacity utilization



Source: German Cement Association, Friederiszick and Röller (2002) and own calculations.

4 Empirical analysis

We now test the hypotheses developed in the previous section, in particular how transport distances differ between states of competition and cartelization, and how they depend on regional variation in capacity utilization. For this, we use data of cement customers in Germany in the years 1993 to 2005. We exploit variations in supply and demand as well as the fact that there was a cement cartel in Germany until 2002. We start with a description of the cement industry in Germany which shows that the industry fits our model very well because of its significant transport costs, customer specific pricing, and industry wide overcapacities (4.1). Subsequently, we present the data set in subsection 4.2 and describe the econometric model and main results in subsection 4.3.

4.1 Background

The cement industry. Cement is a substance that sets and hardens independently, and can bind other materials together. The most common use for cement is in the production of concrete. The costs of transporting cement from the production plant to the customer location are a significant fraction of the overall cement production costs. According to our data, the transportation cost amounts to on average more than 20 percent of the ex-work price for shippings in Germany during the period of competition which is consistent with Friederiszick and Röller (2002).[5]

Substantial excess cement production capacity existed in Germany since the beginning of the 1980s when the capacity utilization declined from 85 percent to 50 percent within five years (see Friederiszick and Röller (2002)). Domestic cement consumption increased in the early 1990s – driven by a construction boom after the reunification of Germany in 1990. However, the boom was rather short term and the cement capacity remained at a high level (cf Figure 1). As a consequence, the average utilization rate during the 1990's remained at levels below 70 percent, with a slightly lower value of 65 percent in Eastern Germany (Friederiszick and Röller (2002)).

[5]Friederiszick and Röller (2002) report that the cost of transporting cement by truck over a distance of 100km (ca. 62 miles) amount to more than 20 percent of production cost. Miller and Osborne (2014) report an average transport distance of 122 miles for cement in the US Southwest and estimate transport costs of about \$ 56 and ex-works prices of about \$ 77, which amounts to even more significant transport costs.

The cement cartel. At least since the early 1990s, the largest six cement companies in Germany – Dyckerhoff, HeidelbergCement, Lafarge Zement, Readymix, Schwenk Zement and Holcim (Deutschland) – were involved in a cartel agreement that divided up the German cement market by a regional quota system. The 'backbone' of the cartel was the division of Germany into four large regions: North, South, West and East. For every region, one market leader was nominated. The quota system was partially applied to smaller sub-regions within the four major regions.[6] The cement producers also discussed to avoid "advancing competition", but rather focus on established market shares and customer bases.[7] This is consistent with our theoretical predictions of cartel behavior and competition in such an industry.

The cartel lasted until 2002. During that time there were two major developments that challenged the stability of the cartel. First, a source of instability arose by low-priced imports into Germany from cement manufacturers in countries such as the Czech Republic, Poland, and Slovakia (see Harrington et al. (2016)). These alternative sources of cement supply for German customers presented a possibly serious challenge to the cement cartel until the mid of the 1990's. Second, demand for cement from construction activities in East Germany fell significantly below expectations (see Harrington et al. (2015)). The resulting underutilization of production capacities induced one of the cartel members - Readymix - to deviate from the collusive agreement, which ultimately led to the breakdown of the cartel in February 2002. In late 2003, HeidelbergCement revealed plans to acquire Readymix; however, the acquisition did not take place as a merger control clearance seemed unlikely.[8] In September 2004 Cemex, a Mexican company which was then new to cement production in Germany, announced plans to acquire Readymix and did so in March 2005.

4.2 Data set and descriptive statistics

The raw data was collected by the Brussels-based law firm Cartel Damage Claims (CDC). The data consists of about 500,000 market transactions from 36 smaller and larger customers of German cement producers from January 1993 to December 2005. Market transactions include information on product types, dates of purchases, delivered quantities, cancellations, rebates, early payment discounts, free-of-charge deliveries as well as locations of the cement plants and unloading points. We added information on all cement plants located in Germany and near the German border in neighboring countries. The data contains 220 unloading points of the 36 customers, which are either permanent (such as a concrete plant) or temporary (such as a construction site).[9] For each of these unloading points, we calculated the number of plants and independent cement producers located within a radius of 150 km road distance in each year. This yields measures of local supply concentration. Based on the geographical information for both cement plants and

[6]For further information on the German cement cartel, see for instance Blum (2007); Friederiszick and Röller (2010); Hüschelrath and Veith (2011, 2014).

[7]See the judgment VI-2a Kart 2 – 6/08, 6 June 2009 of the higher regional court (OLG) Düsseldorf, par 130 and 131.

[8]See "Operation Skunk bremst Heidelcement", Die Welt, November 3 2003, (last accessed September 2017).

[9]Unloading points are defined on the ZIP code level

unloading points, we also calculated the road distances for all possible plant-unloading-point relations. We subsequently aggregated transactions to observations which consist of the quantity shipped by several cement plants[10] (located in Germany) to one of the customers' unloading point in one specific year. We restrict our analysis to one specific cement type called 'CEM I' (Standard Portland Cement) which accounts for almost 80 percent of all available transactions. We account only for shippings from German plants.[11] This leaves us with almost 1,300 observations at the customer - unloading-point - year level.

Table 1: Descriptive statistics of yearly shippings per customer-unloading-point (quantity-weighted)

	Cartel period		Post Cartel Period		Overall	
Road distance (km)	92.21	(58.44)	119.72	(102.09)	98.37	(71.53)
Plant rank	3.48	(3.23)	5.41	(6.82)	3.91	(4.38)
Constr. employment	94.00	(8.83)	79.75	(14.92)	90.12	(12.55)
Customer size (year)	0.10	(0.10)	0.16	(0.18)	0.11	(0.12)
Plants in 150km	7.33	(5.00)	7.11	(4.48)	7.28	(4.89)
HHI (0-100)	28.93	(15.37)	30.88	(16.76)	29.37	(15.71)
Next plant	54.05	(33.68)	50.53	(32.96)	53.26	(33.55)
RMX plant in 150km	0.28	(0.45)	0.27	(0.44)	0.28	(0.45)
East	0.26	(0.44)	0.28	(0.45)	0.26	(0.44)
West	0.31	(0.46)	0.28	(0.45)	0.31	(0.46)
North	0.10	(0.30)	0.05	(0.23)	0.09	(0.28)
South	0.33	(0.47)	0.38	(0.49)	0.34	(0.47)
PC	0.00	(0.00)	1.00	(0.00)	0.22	(0.42)
Observations	916		382		1298	

Table 1 shows descriptive statistics of the data set. The "cartel period" is January 1993 to February 2002 and the "post-cartel period" runs from March 2002 to December 2005.[12] In order to capture changes in supply relationships, we calculate the average shipment distance (in km) between the cement plant and the customer's unloading point for each year. Table 1 shows that in the period after the cartel broke down the average transport distance is almost 30km higher. As the distance can fluctuate due to changes in the positions of both unloading points and customers, we also calculate the rank of the delivering plant relative to the unloading point: the plant nearest to the unloading point has rank 1, the second nearest rank 2 etc. Similar to the distance, also the rank is higher in the period after the cartel broke down.

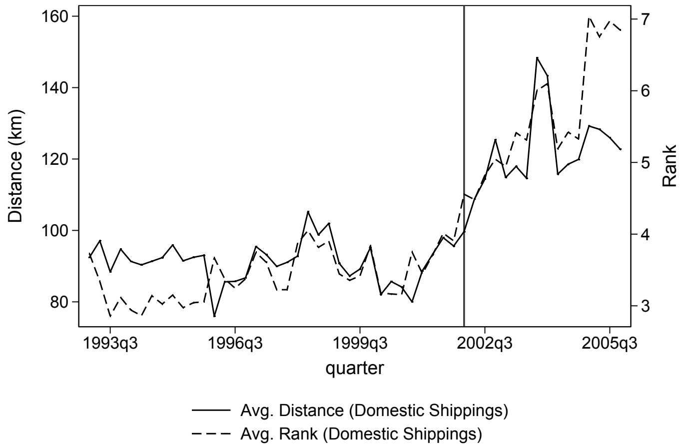
In terms of the development of capacity utilization, plant level data is unfortunately unavailable. However, as the oven capacity is relatively constant during the observation period and we also control for the local number of plants, we approximate variations in capacity utilization by variations in the local cement demand, measured by the number of workers in construction in the county (comparable to NUTS3-level) of the unloading point in a given year. This information is available from 1996 onward. In order to sort

[10]In 63% of the observations the deliveries came from one plant only, and in only 20 percent of the other cases the quantity share of the biggest supplier was below 80 percent. In such cases we built the quantity-weighted average.

[11]This restriction is done as production cost is more comparable inside Germany. Shippings within Germany account in our data set for more than 94 percent of the sold CEM I quantity.

[12]We split the shippings in the year 2002 t in separate observations for the cartel and post cartel period.

Figure 2: Average distance from unloading point to cement plant and rank of plant over time



out size effects, we normalize the number of workers by the respective value in 1996 and multiply it by 100. While during the years 1996 and 2001 the number of workers were on average at 94 percent of the level of 1996, the respective mean after the cartel break down is 78 percent. There is substantial variation between counties as reflected by the high standard deviation of 13 percent.

To control for the size of the customers, we calculate the total quantity shipped to the respective customer by aggregating across purchases of all cement types and locations. The average of this variable in the data set is 142,541 thousand tons per year.[13]

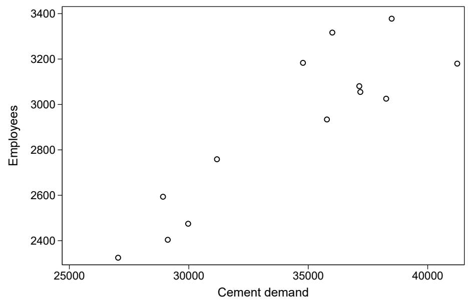
To account for differences in the regional supply structure, we include the number of cement plants and a plant-based HHI for a radius of 150 km road distance around the customers' unloading points. The number of cement plants around the unloading points after the cartel breakdown is 3% lower while concentration increased by 7% (note however, that the locations of some of the unloading points also vary over time). It is interesting to note that the minimum distance to the nearest cement plant decreased from about 54 to 51 km. Other things equal, this suggests that distances should have rather decreased than increased. Finally, to investigate in a robustness analysis how the presence of the firm that deviated from the cartel affected transport routes, we also measure whether this firm ("Readymix") has a plant in 150km distance to the unloading point, which is the case in 28 percent of the cases.[14]

As an initial examination of distances during and after the cartel, Figure 2 plots the average distance and rank of all (quantity weighted) shipments from domestic plants. Please note that the average distance and rank do not differ much in their development over time, suggesting that changes in the position of unloading points or closures of cement plants are unlikely to drive the results. The figure further shows that both average distance and rank were rather stable during the cartel but increased substantially after the cartel

[13]As some of the 36 customers have several unloading points, they appear more often within one year in the data set. The reported average has an upward bias. Taking into account every customer only once for each year, the average is 31,461 thousand tons per year.

[14]This is to rule out that higher distances in the years after the cartel break down are caused by extraordinary retaliation measures against the deviating producer, which could consist of other producers shipping cement over long distances into the "home markets" of the former cartel deviator.

Figure 3: Cement consumption and construction employment 1993-2005



Sources: German Statistical Office, Regional Statistical Offices and own calculations.

breakdown.

Please note that cement consumption and our (local) proxy variable for demand, the number of workers in construction, are highly correlated (Figure 3).

As later analysis will reveal, the post-cartel increase in the transport distances is robust to taking account of changes in the local market structure. However, we will see that there is a more nuanced post-cartel relationship between the transport distances and local capacity utilization, as measured by our demand proxy.

4.3 Econometric model and estimation results

We estimate the following reduced form linear model:

$$y_{c,u,t} = \beta_1' X_{c,u,t} + \beta_2 PC_t + \beta_3 PC_t \cdot Z_{c,u,t} + \varepsilon_u + \epsilon_{c,u,t}. \tag{4}$$

As the dependent variable, $y_{c,s,t}$, we use alternatively the distance between the delivering cement plant and the unloading point as well as the rank of the delivering plant (with the nearest plant having rank 1).[15] Subscript c is an index for the customers, u for the unloading point and t for the year. Vector X includes characteristics of the (customer-related) unloading points and their surrounding market structures. PC is an indicator variable with value 1 if the delivery was invoiced after the cartel breakdown in February 2002. Vector Z consists of market structure variables which we interact with the PC indicator variable to test whether the impact of these factors on the distance (or rank) changes over time. Finally, we eliminate local time-constant unobserved heterogeneity by the inclusion of unloading points fixed effects ε_u. The standard errors are clustered at the unloading point level and robust to heteroscedasticity.

Table 2 contains the main regression results, for both the distance in km to the delivering plant and the rank as dependent variables. The significantly positive coefficient of the post cartel indicator PC confirms that both the distance to the delivering plant and its rank are higher after the cartel breakdown. With respect to other control variables, we see that there are positive correlations of distance with the number of plants in 150km distance and customer size. However, the respective coefficients are not significantly different from zero. Only for our measure of local plant ownership concentration (HHI) we

[15] In case of shippings from multiple plants in the same months we use the quantity-weighted average rank.

see that an increase leads to lower transport distance, which might be explained by a firm minimizing shipping cost over its own plants.

Table 2: Main regression results

	Distance		Rank	
	(1)	(2)	(3)	(4)
Plants in 150km	0.32	1.50	0.42	0.49
	(0.08)	(0.36)	(1.39)	(1.57)
HHI (0-100)	-0.71**	-0.75**	-0.03**	-0.03**
	(-2.12)	(-2.19)	(-2.39)	(-2.42)
Customer size (year)	22.34	9.55	-2.44	-3.19
	(0.63)	(0.27)	(-1.08)	(-1.35)
PC	28.42***		1.90***	
	(3.64)		(2.74)	
Year before cartel collapse (2001)		1.42		0.04
		(0.42)		(0.15)
Year of cartel collapse (2002)		13.95**		1.41**
		(2.10)		(2.29)
Years after cartel collapse		35.73***		2.27***
		(3.72)		(2.82)
Constant	119.92***	114.25***	2.22	1.84
	(3.84)	(3.65)	(1.05)	(0.84)
Obs.	1298	1298	1298	1298
R^2	0.01	0.03	0.04	0.04
Within R^2	0.07	0.07	0.04	0.05

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

We analyze the time structure of the post cartel effect with the specifications in columns 2 and 4. We find no increase in rank and distance in the year before the breakdown while there is indeed a slight increase in the year the cartel ended. However, we observe the strongest effect in terms of magnitude and significance in the years after the breakdown. We take this as an indication that the rise in distances was not related to a short-run fight of suppliers for new customers, but due to the reversion to competition in times of underutilization of capacity.

In a related vein, we have specifically analyzed the alternative hypothesis that higher transport distances could have resulted from retaliatory actions that consisted of long distance shippings to customers of the the defecting cartel member. For this we include an indicator variable that takes on the value of 1 if a plant of the cement producer Readymix is within 150km (about 93 miles) to the unloading point, and 0 otherwise. We interact this indicator with the post-cartel (PC) indicator. The regressions show that the presence of the deviating firm is not a good predictor for the the increase in distances, as the interaction term is not significantly different from zero. The respective results can be found in Table 4 of annex II. We have thus not found empirical support for the alternative hypothesis that retaliatory measures in relation to firm that deviated from the cartel agreement explain the increase in distance.

Overall the theoretical and empirical results point to an inefficiency that arises if firms compete with spatial differentiation and overcapacities. The cost increase can be approximately quantified as we have estimates for the additional distance in kilometers and for the transport cost per km. The estimated additional transport distance under competition is about 30km (ca. 19 miles). To compute the additional costs, we use estimates on incremental costs for transporting cement from Friederiszick and Röller (2002). The additional transport costs amount to about 3 Euros.[16] For comparison, estimates for the overcharge of cement customers due to the cement cartel captured in our data set are in the order of 15 Euros,[17] with average cement prices during the cartel of about 78 Euros.[18] This is consistent with our theory that the cartel overcharge of a well functioning cartel is higher than the associated transport cost inefficiency. At the same time it is noteworthy that the estimated additional transport in case of competition are substantial.

We now test the hypothesis how capacity utilization affects distance. For this, we include in Table 3 our proxy variable for demand and – controlling for the number of plants around a customer – for capacity utilization. As mentioned before, this data is only available from 1996 on. To make findings comparable to prior results, we report the same specifications as in Table 2 in column (1) and (4) for the restricted data set and do not find qualitative differences. In columns (2) and (4) we include the proxy variable and do not find an effect that is significant at common confidence levels. When distinguishing between the cartel and post cartel phase by introducing an interaction term in column (3) and (6), one can see that the post cartel indicator PC is still positively significant, while the interaction term of PC and the demand proxy is significantly negative. This shows that while in general the breakdown of the cartel is associated with an increase in distances, this increase is lower in areas where demand (and thus capacity utilization) declined less.

[16]More precisely, their report contains a table of Fiederer et al (1994), p. 88. In this table, incremental freight costs for 30 tonne-km are around 4,8 Deutsche Mark (about 2.45 Euros nominally or 3.09 Euros in prices of 2010).

[17]See Hüschelrath et al. (2016), fixed effects regressions, in terms of 2010 prices.

[18]This is the quantity-weighted average of transaction prices during the cartel period in terms of 2010 prices according to our data. We did not control for different cement types and differences across regions.

Table 3: Regression results with demand proxy

	Distance			Rank		
	(1)	(2)	(3)	(4)	(5)	(6)
PC	33.53***	24.52***	207.18***	2.05**	1.45*	8.93***
	(3.69)	(2.83)	(3.67)	(2.47)	(1.68)	(3.27)
Plants in 150km	-6.98	-5.61	-6.60	-0.13	-0.04	-0.08
	(-1.38)	(-1.15)	(-1.37)	(-0.37)	(-0.12)	(-0.24)
HHI (0-100)	-1.40***	-1.35***	-1.15***	-0.06***	-0.05***	-0.05**
	(-3.95)	(-3.90)	(-3.35)	(-2.84)	(-2.75)	(-2.31)
Customer size (year)	66.76	44.82	47.00	-1.19	-2.67	-2.58
	(1.46)	(0.99)	(1.06)	(-0.43)	(-0.93)	(-0.91)
Constr. employment		-0.72	0.66**		-0.05**	0.01
		(-1.58)	(2.03)		(-2.01)	(0.41)
PC=1 × Constr. employment			-2.05***			-0.08***
			(-3.29)			(-2.94)
Constant	178.74***	236.76***	108.80**	6.80**	10.71***	5.46
	(4.34)	(4.01)	(1.99)	(2.42)	(2.88)	(1.45)
Obs.	925	925	925	925	925	925
R^2	0.09	0.09	0.15	0.02	0.03	0.04
Within R^2	0.10	0.11	0.14	0.05	0.05	0.07

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5 Conclusion

We have studied the spatial pattern of sales in an industry with significant transport costs and capacity constraints. When firms compete, there is a non-monotonic relationship between the average transport distance in case of competition and the degree of excess capacity. When firms are highly capacity constrained, they are effectively local monopolists and the average transport distances are low. For intermediate capacities, however, the average transport distance generally increases in the degree of overcapacity, until there are no more capacity constraints. Absent capacity constraints, however, fierce competition yields prices that are essentially at marginal costs, such that again the cheapest supplier wins the contract. A stylized fact of this analysis is that the average transport distance should vary in the degree of overcapacity if there is capacity-constrained competition, but not if there is a well-organized cartel. When firms are capacity constrained at an intermediate level, the pattern that significant changes in the supply-demand balance are not accompanied by changes in the average distance of transportation is therefore indicative of coordination among the firms.

We have empirically investigated the allocation of customers to suppliers in the cement industry in Germany from 1993 to 2005, which had been cartelized in part of our observation period. Controlling for other potentially confounding factors, such as the number of production plants and demand, we have shown that during the cartel period the average transport distances between suppliers and customers were on average significantly lower than in the later period of competition. This provides strong empirical support of our theoretical finding that competing firms serve more distant customers in areas that are closer to their competitors' production sites.

The results of this exercise help to better understand the competitive process and provides hints for distinguishing competition and coordination when analyzing market data. This can be relevant for competition policy cases in industries which feature homogeneous products with significant transport costs for which location or customer based price discrimination is relevant. This not only concerns cartel prosecution, but also merger control. For instance, in the assessment of the merger M.7009 HOLCIM / CEMEX WEST in 2014 the European Commission took the past cartel behavior in the German and European cement industry into account and investigated whether the relevant cement markets exhibited signs of coordinated behavior the cement producers. In its analysis, the European Commission even referred to a Bertrand-Edgeworth model, which – given the economic literature of that time – did not take both capacity constraints and location specific costs into account.[19] The result of the present article is that in such a case, one could also analyze average transport distances. For instance, one could study whether – other things equal – average transport distances have again decreased in the years up to the merger control assessment. This would indicate coordinated behavior of the cement producers.

There is plenty of scope for further analyses. For instance, a more structural estimation approach that takes the Bertrand-Edgeworth model framework into account seems desirable. Moreover, reformulating the model to allow for more than two firms and simulating the effects of mergers in such a setting appears to be of major interest.

References

Acemoglu, D., Bimpikis, K., and Ozdaglar, A., "Price and capacity competition." *Games and Economic Behavior*, Vol. 66 (2009), pp. 1–26.

Armstrong, M. and Vickers, J., "Competitive Price Discrimination." *The RAND Journal of Economics*, Vol. 32 (2001), pp. 579–605.

Asker, J., "A Study of the Internal Organization of a Bidding Cartel." *The American Economic Review*, Vol. 100 (2010), pp. 724–762.

Baake, P., Oechssler, J., and Schenk, C., "Explaining cross-supplies." *Journal of Economics*, Vol. 70 (1999), pp. 37–60.

Bejger, S., "Polish cement industry cartel-preliminary examination of collusion existence." *Business & Economic Horizons*, Vol. 4 (2011).

Benoit, J.-P. and Krishna, V., "Dynamic duopoly: Prices and quantities." *The review of economic studies*, Vol. 54 (1987), pp. 23–35.

Bertrand, J., "Théorie des richesses: revue des théories mathématiques de la richesse sociale par Léon Walras et reserches sur les principes mathématiques de la richesses par Augustin Cournot." *Journal des Savantes*, (1883), pp. 499–508.

[19]See the European Commission decision M.7009 HOLCIM / CEMEX WEST, fn. 195.

Blum, U., “The East German Cement Cartel: Cartel Efficiency and Cartel Policy after Economic Transformation.” *Eastern European Economics*, Vol. 45 (2007), pp. 5–28.

Boccard, N. and Wauthy, X., “On the Nature of Equilibria when Bertrand meets Edgeworth on Hotelling’s Main Street.” (2016), mimeo.

Canoy, M., “Product differentiation in a Bertrand–Edgeworth duopoly.” *Journal of Economic Theory*, Vol. 70 (1996), pp. 158–179.

Dasgupta, P. and Maskin, E., “The existence of equilibrium in discontinuous economic games, I: Theory.” *The Review of Economic Studies*, Vol. 53 (1986), pp. 1–26.

Davidson, C. and Deneckere, R. J., “Excess Capacity and Collusion.” *International Economic Review*, Vol. 31 (1990), pp. 521–41.

Edgeworth, F. Y., “The pure theory of monopoly.” *Edgeworth, Papers relating to Political Economy*, Vol. 1 (1925), pp. 111–142.

Fershtman, C. and Gandal, N., “Disadvantageous semicollusion.” *International Journal of Industrial Organization*, Vol. 12 (1994), pp. 141–154.

Friederiszick, H. and Röller, L.-H., “Lokale Märkte unter Gobalisierungsdruck. Eine industrieökonomische Studie zur deutschen Zementindustrie.” *RACR Studie 01*, (2002), on behalf of the German Ministry of Economics and Labour.

Friederiszick, H. and Röller, L.-H., “Quantification of Harm in Damages Actions for Antitrust Infringements: Insights from German Cartel Cases.” *Journal of Competition Law and Economics*, Vol. 6 (2010), pp. 595–618.

Harder, J., “End of the crisis in the German cement industry.” *Onestone Consultig Group Report*, Vol. 59 (2006), pp. 42–53.

Harrington, J. E., Hüschelrath, K., and Laitenberger, U., “Rent sharing to control noncartel supply in the German cement market.” *ZEW Discussion Paper No. 16-025, Mannheim.*, (2016).

Harrington, J. E., Hüschelrath, K., Laitenberger, U., and Smuda, F., “The discontent cartel member and cartel collapse: The case of the German cement cartel.” *International Journal of Industrial Organization*, Vol. 42 (2015), pp. 106–119.

Hüschelrath, K. and Veith, T., “The Impact of Cartelization on Pricing Dynamics.” *ZEW Discussion Paper*, (2011).

Hüschelrath, K. and Veith, T., “Cartel Detection in Procurement Markets.” *Managerial and Decision Economics*, Vol. 35 (2014), pp. 404–422.

Huff, N., “Horizontal Subcontracting in Procurement Auctions.” *All Dissertations*, (2012), 917.

Hunold, M. and Muthers, J., “Capacity constraints, price discrimination, inefficient competition and subcontracting.” *DICE Discussion Paper*, (2017).

Hüschelrath, K., Müller, K., and Veith, T., "Estimating damages from price-fixing: the value of transaction data." *European Journal of Law and Economics*, Vol. 41 (2016), pp. 509–535.

Hyytinen, A., Steen, F., and Toivanen, O., "Anatomy of Cartel Contracts." *Katholieke Universiteit Leuven, FEB Research Report MSI_1231*, (2014).

Kamien, M. I., Li, L., and Samet, D., "Bertrand Competition with Subcontracting." *RAND Journal of Economics*, Vol. 20 (1989), pp. 553–567.

Kreps, D. M., Scheinkman, J. A., et al., "Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes." *Bell Journal of Economics*, Vol. 14 (1983), pp. 326–337.

Marion, J., "Sourcing from the Enemy: Horizontal Subcontracting in Highway Procurement." *The Journal of Industrial Economics*, Vol. 63 (2015), pp. 100–128.

Matusui, A., "Consumer-benefited cartels under strategic capital investment competition." *International Journal of Industrial Organization*, Vol. 7 (1989), pp. 451–470.

Miller, N. H. and Osborne, M., "Spatial differentiation and price discrimination in the cement industry: evidence from a structural model." *The RAND Journal of Economics*, Vol. 45 (2014), pp. 221–247.

Miller, N. H., Osborne, M., and Sheu, G., "Pass-through in a concentrated industry: empirical evidence and regulatory implications." *The RAND Journal of Economics*, Vol. 48 (2017), pp. 69–93.

Normann, H.-T. and Tan, E. S., "Effects of different cartel policies: evidence from the German power-cable industry." *Industrial and Corporate Change*, Vol. 23 (2014), pp. 1037–1057.

Perez-Saiz, H., "Building new plants or entering by acquisition? Firm heterogeneity and entry barriers in the US cement industry." *The RAND Journal of Economics*, Vol. 46 (2015), pp. 625–649.

Röller, L.-H. and Steen, F., "On the workings of a cartel: Evidence from the Norwegian cement industry." *The American economic review*, Vol. 96 (2006), pp. 321–338.

Ryan, S. P., "The costs of environmental regulation in a concentrated industry." *Econometrica*, Vol. 80 (2012), pp. 1019–1061.

Salvo, A., "Inferring market power under the threat of entry: The case of the Brazilian cement industry." *The RAND Journal of Economics*, Vol. 41 (2010a), pp. 326–350.

Salvo, A., "Trade Flows in a Spatial Oligopoly: Gravity Fits Well, But What Does It Explain?" *Canadian Journal of Economics*, Vol. 43 (2010b), pp. 64–96.

Sinitsyn, M., "Equilibria in a Capacity-Constrained Differentiated Duopoly." Tech. rep., McGill University, Montréal (2007).

Sinitsyn, M., "Technical Note-Price Promotions in Asymmetric Duopolies with Heterogeneous Consumers." *Management Science*, Vol. 54 (2008), pp. 2081–2087.

Sinitsyn, M., "Price dispersion in duopolies with heterogeneous consumers." *International Journal of Industrial Organization*, Vol. 27 (2009), pp. 197–205.

Somogyi, R., "Bertrand-Edgeworth competition with substantial horizontal product differentiation." (2016), mimeo.

Spiegel, Y., "Horizontal Subcontracting." *RAND Journal of Economics*, Vol. 24 (1993), pp. 570–590.

Thisse, J. and Vives, X., "On the Strategic Choice of Spatial Price Policy." *American Economic Review*, Vol. 78 (1988), pp. 122–37.

Varian, H. R., "A model of sales." *The American Economic Review*, Vol. 70 (1980), pp. 651–659.

Annex I: Proofs

Proof of Proposition 3

Proof. Let us consider the decision of firm L, while R plays uniform prices according to the equilibrium distribution. We verify that every best response to a uniform price vector has prices that are non-decreasing in distance. First consider prices for two customers with locations x and y, where $y > x$. Suppose to the contrary that $p^L(x) > p^L(y)$, while the uniform price of R is p^R. In any case L would either strictly prefer to switch the prices for x and y or be indifferent. The case that x is served but not y cannot emerge, because R playing uniform prices implies that it cannot be that $p^R(x) > p^L(x)$ and $p^R(y) < p^L(y)$. Three other cases are conceivable, first, L serves both x and y, second, L servers neither x nor y, third, L serves only y but not x. Only in the third case switching the prices has an effect on profits and is strictly profitable. By switching prices, L can ensure that revenues are identical but costs are strictly lower. This establishes that it is always a best-response to uniform prices to play non-decreasing price vectors.

In the next step we derive the conditions under which uniform prices are best-responses to uniform prices. For this let us consider the marginal incentive to change prices given that the price order has weakly increasing prices. Again consider that R plays uniform prices p^R with the equilibrium price distribution for uniform prices. Since L plays weakly increasing prices and the price distribution of R is atomless, the realized price vectors almost surely cross once or less. That is either p^R is above or below all prices of L, or L has lower prices for all customers starting at the location of L up to a threshold customer after whom all more distant customers face lower prices from R than from L. Note that all customers between 0 and $1-k$ will be served by L with certainty as long as its prices are weakly increasing. Either the threshold customer lies in the interval $[0, 1-k)$, then R is at its capacity limit and by the rationing rule all customer in that interval are served by L as this maximizes consumer surplus and minimizes costs. If the threshold customer is $\in [1-k, 1]$ then L always serves at least all customers in the interval $[0, 1-k)$, even if L is at its capacity limit. As L serves customers in $[0, 1-k)$ independent of the price level, as long as the weakly increasing price order is maintained, L has a strict incentive to increase prices in that interval up to the price level at the border of that interval at $1-k$. Hence, all-best responses in weakly increasing prices have uniform prices in $[0, 1-k)$. Furthermore, as there is a marginal incentive to increase prices in that interval but the price distribution is derived such that there is no incentive to increase or decrease a uniform price vector, the average marginal profit of changing a uniform price is zero. Hence, the marginal incentive to change prices, neglecting that this can change the customer allocation through rationing, must be negative for at least some prices in the interval $[1-k, 1]$ starting from any weakly increasing price vector. Thus, if the marginal profit from increasing the $p^L(k)$ is negative, which is the most distant customer that is ever served by firm L in this context, then it is optimal to lower all prices in $[1-k, k]$ such that the order of increasing prices is just maintained; i.e. it is optimal to set a single uniform price in the whole interval $[0, k]$. Note that, given weakly increasing prices, customers in $(k, 1]$ are never served by L such that is also a best-response to charge the identical uniform price p^L in $[0, 1]$. A sufficient and necessary condition for an equilibrium in uniform prices is thus that there is no marginal incentive to increase $p^L(k)$ individually: $\frac{\partial}{\partial p^L(k)} \left[p^L(k) - C(k)\right] \left[1 - F^R(p^L(k))\right] = \left[1 - F^R(p^L(k))\right] - f^R(p^L(k)) \left[p^L(k) - C(k)\right] =$

$$\left[1 - \frac{p^L(k)k - v\,(1-k) - \int_{1-k}^{k} C(x)dx}{p^L(k)(k-(1-k)) - \int_{1-k}^{k} C(x)dx}\right] - f^R(p^L(k)) \left[p^L(k) - C(k)\right] < 0.$$

After simplifying this condition to

$$(2k-1)\left[vC(k) - p^L(k)^2\right] + \left(2p^L(k) - v - C(k)\right) \int_{1-k}^{k} C(x)dx < 0$$

it can be observed that it holds if costs are sufficiently low.

□

Annex II: Additional empirical results

Table 4: Robustness Check: Readymix

	Distance		Rank	
	(1)	(2)	(3)	(4)
PC	28.42***	21.13**	1.90***	1.83**
	(3.64)	(2.36)	(2.74)	(2.17)
Plants in 150km	0.32	2.26	0.42	0.43
	(0.08)	(0.53)	(1.39)	(1.44)
HHI (0-100)	-0.71**	-0.53	-0.03**	-0.03*
	(-2.12)	(-1.56)	(-2.39)	(-1.93)
Customer size (year)	22.34	21.21	-2.44	-2.45
	(0.63)	(0.63)	(-1.08)	(-1.10)
Readymix plant in 150km		-9.80*		0.45
		(-1.76)		(0.56)
PC=1 × Readymix plant in 150km		28.91		0.29
		(1.48)		(0.25)
Constant	119.92***	103.51***	2.22	1.96
	(3.84)	(3.19)	(1.05)	(0.94)
Obs.	1298	1298	1298	1298
R^2	0.01	0.02	0.04	0.04
Within R^2	0.07	0.08	0.04	0.04

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$