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DISCUSSION PAPER

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# Collusion Through Market Sharing Agreements: Evidence from Quebec's Road Paving Market

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# Collusion Through Market Sharing Agreements: Evidence from Quebec's Road Paving Market*

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**Abstract**

I study a case of market sharing agreements to provide evidence of coordination between colluding firms on the degree to which they compete against each other (henceforth referred to as head-to-head competition) and their bidding behavior. I also quantify the impact that coordinating head-to-head competition has on procurement costs. My focus is on the two largest firms bidding in provincial road paving procurement auctions in Quebec between 2007 and 2015. I use the police investigation into collusion and corruption in the Quebec construction industry launched in October 2009 to capture the end of this cartel. I find that after this date, the two suspected firms i) were more likely to bid in the same auction and ii) submitted significantly lower bids when they competed in the same auction. A structural model of entry and bidding shows that if the firms had kept competing head-to-head at the same rate as in the collusive period but had stopped colluding on bids, bids would have increased by about 3.86% with respect to the competitive scenario observed after the police investigation began. This finding suggests that there were additional procurement costs associated with firms coordinating on the degree of head-to-head competition.

**JEL classification**: D44, H57, L22, L74.
**Keywords**: Auction; Bidding ring; Collusion; Public procurement.

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# 1 Introduction

Researchers have devoted considerable attention to the study of price collusion (see for instance Porter and Zona, 1993, 1999; Bajari and Ye, 2003; Kawai and Nakabayashi, 2018; Clark et al., 2018). Yet less attention has been paid on the impact that other types of coordination have on prices. One of these other types of coordination between firms consists in adjusting the degree to which they compete against one another (henceforth referred to as head-to-head competition). In a market for differentiated products, for example, there can be collusion between firms not only on prices but also on the sets of products that these firms offer in an effort to lessen competition and share the market amongst themselves (Sullivan, 2017). In the same way, in procurement auctions firms can collude by coordinating their participation in auctions.

In this paper, I study a case of market sharing agreements i) to find evidence of coordination between firms on the degree of head-to-head competition and evidence of coordination on bids and ii) to quantify the impact that coordinating head-to-head competition has on procurement costs. I focus on two firms alleged to have reached market sharing agreements in the road paving procurement market in the Canadian province of Quebec.

In the market for provincial road paving contracts awarded by the Quebec Ministry of Transportation between 2007 and 2015, these two firms are the largest in terms of both the number of asphalt plants that they own and the number of contracts that they won. The *Commission of Inquiry on the Awarding and Management of Public Contracts in the Construction Industry* (henceforth referred to as the Commission), which investigated collusive practices in the construction industry, has provided evidence that these two firms coordinated i) their degree of head-to-head competition and ii) their bids once they decided to compete head-to-head.[1,2]

[1] See Charbonneau and Lachance (2015), p.531

[2] **Legal disclaimer:** This paper analyzes market sharing agreements from a strictly economic point of view. It is based on the analysis of publicly available contracts, testimony transcripts, and the final report from the Commission. Begun in 2015, the investigations of these allegations by the Canadian Competition Bureau are still ongoing. Newspapers have reported that the Canadian Competition Bureau obtained search warrants to investigate these firms. See Lévesque (2015).

In the road paving procurement market, firms face considerable transportation costs because they must bring asphalt from their plants to paving project locations. This means that there are two margins on which firms can coordinate head-to-head competition. First, colluding firms can coordinate relative to the location of their asphalt plants. To avoid head-to-head competition, they can place these asphalt plants at a certain distance from one another. Second, they can decide to avoid head-to-head competition when they are close to the paving project location by alternating their participation in the auctions. Both margins allow colluding firms to coordinate the degree of head-to-head competition and thus share the market amongst themselves.

My empirical analysis is based on an original dataset for paving contracts awarded between 2007 and 2015. I constructed the dataset using publicly available contracts listed on the official tendering website of the Quebec government (*Système Électronique d'Appel d'Offres*, *SEAO*). These contracts contain information on the auction outcomes (indicating both winning and losing bids) and on the number and the identities of the participants in every auction. The auctions are first-price (lowest price) sealed bid auctions. I expand the auction data by providing information on the geographic location of the asphalt plants that I obtained from the Quebec Ministry of Transportation.

To begin the analysis, I use the start of the police investigations into collusion and corruption in the Quebec construction industry launched in October 2009 to capture the end of this cartel. The beginning of these investigations predated by two years the Commission and this makes it possible to identify a pre-October 2009 (suspected collusive) period and post-October 2009 (competitive) period in the dataset. In this way, it is possible to test whether there were significant changes between the two periods in i) the degree of head-to-head competition (the probability that the two suspected firms bid on the same contract) and in ii) the level of bids.

A descriptive analysis shows that head-to-head competition increases by about 8% between the pre-investigation and post-investigation periods, and that the bids of the two cartel firms conditional on bidding decrease by about 15.43% of the value of the contract. I do not find a significant change in terms of the location of the firms' asphalt plants. The lack of significant changes in the location of the asphalt plants is probably due to the

availability of a relatively short sample period. For construction firms, where to locate an asphalt plant is typically a long-run decision.

To find causal evidence that the observed differences in head-to-head competition and bidding were driven by the start of the police investigation, I use a difference-in-difference design that compares the outcomes of *treated* auctions with the outcomes of a control group of auctions. A *treated* auction is one in which the two cartel firms could have potentially competed. I describe an auction as *potentially competitive* if the asphalt plants of the two cartel firms were close enough to the paving project location in order for both of them to have participated in the auction and to have bid competitively. I choose a radius of 100 kilometers around the paving project location. This choice is justified by the average distance of firms bidding in these procurement contracts.

The results show that the increase in the probability of head-to-head competition was significantly greater in the potentially competitive auctions than in the control group of auctions. Finally, the average winning bid decreased by 13% after the start of the investigation in the potentially competitive auctions than in the control group of auctions. Given that the average value of contracts was about C$2 million before the start of the investigation, this means that the average winning bid was C$260,000 higher during this period. Back-of-the-envelope calculations indicate the savings for the Quebec Ministry of Transportation to be C$14.3 million per year after the end of the cartel.

The descriptive analysis fails to distinguish between the impact that avoiding head-to-head competition has on procurement costs and the impact that coordinating bids has on these costs. It is important to determine which part of the decrease in procurement costs should be attributed to coordination on bids and which part should be attributed to coordination on head-to-head competition. In a cartel that does not include all the firms in the market, the two types of coordination have a different impact on procurement costs.

To quantify the extent to which restricting head-to-head competition increased procurement costs, I use a structural model of entry and bidding that allows for the existence of asymmetric bidders in the assumed competitive period, that is, the period after the start of the investigation into collusion. I consider a counterfactual scenario in which

firms continue to compete head-to-head at the same rate as in the collusive period, but submit competitive bids. In this counterfactual scenario, the average bid would have been 3.86% higher than the average bid observed in the competitive period. Thus there are extra procurement costs associated with this type of coordination. About 30% of the average bid increase observed before the start of the police investigation is due to firms coordinating the degree of head-to-head competition. The remaining 70% is due to firms coordinating bids.

Colluding firms avoid head-to-head competition for various reasons. First, the magnitude of the entry cost, that is those costs incurred by firms when they submit a bid. Second, in avoiding head-to-head competition, colluding firms face a less aggressive bidding strategy from bidders that are not part of the cartel. The bidding strategy in first-price auctions depends in fact on the number of bidders. Finally, when colluding firms avoid head-to-head competition, the bidder in the cartel with the lowest cost does not have to worry about preventing another cartel member from cheating. Thus the cartel firm with the lowest cost can bid less aggressively (Marshall and Marx, 2007).

This study is among the first to show that multiplant firms acting in multiple markets can share the market by colluding not only to set prices but also to determine the degree of head-to-head competition. Sullivan (2017) was the first to empirically analyze coordination on the degree of head-to-head competition in the US ice cream industry. In Sullivan (2017), the degree of head-to-head competition is represented by the extent to which firms produce the same varieties of ice cream. In my study, the degree of head-to-head competition is represented by the extent to which firms compete against one another in auctions. However, my study differs from Sullivan (2017) in several ways. First, I use an exogenous event to capture the end of the coordination on the degree of head-to-head competition between firms. This event was the starting point for a series of investigations into collusion and corruption in the Quebec construction industry. Similarly, Clark et al. (2018) show that this event affected the bidding behavior of colluding firms in the city of Montreal. Second, my study analyzes a market with different characteristics. In the road paving market colluding firms have two ways to avoid head-to-head competition: they can collude to determine the locations of their asphalt plants and they can decide whether or

not to participate in the same auction when their asphalt plants are fairly close to the location of the paving project. Sullivan (2017) does not investigate whether firms sell ice cream in different supermarkets, which would be equivalent to colluding on the location of the asphalt plants. Finally, I identify several possible drivers of collusion on the degree of head-to-head competition.

This study contributes to the empirical literature on multimarket contact and collusion. Following Bernheim and Whinston (1990), empirical studies have shown that the higher the frequency of interactions, the greater the likelihood of collusion; but to the best of my knowledge no empirical study has taken into account the degree of competition between multimarket firms as a strategic choice of these firms. Belleflamme and Bloch (2004) is the first theoretical study that endogenizes multimarket contact. Belleflamme and Bloch (2004) establish that firms can implement market sharing agreements by colluding to determine the degree of head-to-head competition (the number of contacts between firms).[3]

This study also extends the empirical literature on collusion in public procurement auctions (Porter and Zona, 1993, 1999; Pesendorfer, 2000; Bajari and Ye, 2003; Asker, 2010; Conley and Decarolis, 2016; Kawai and Nakabayashi, 2018; Clark et al., 2018; Chassang et al., 2019; Chassang and Ortner, 2019). The studies most closely related to mine are Porter and Zona (1999), Pesendorfer (2000) and Clark et al. (2018). Porter and Zona (1999) provide a statistical test to determine the presence of collusion acting through territorial allocation or through complementary bidding, and they find evidence of the latter form of collusion in the Ohio school milk market. Pesendorfer (2000) compares a cartel based on market sharing agreements and a cartel based on sidepayments, but he does not investigate the participation behavior of firms in the cartel. Clark et al. (2018) focus on municipal asphalt contracts for asphalt awarded by the two biggest cities in the Canadian province of Quebec, examining an all-inclusive cartel and the impact that the entry deterrence of firms outside the cartel had on bids. In this study, I empirically test

[3]The theoretical predictions in Bernheim and Whinston (1990) have been tested in various industries: Pilloff (1999) tests them for the banking industry, Jans and Rosenbaum (1997) for the cement industry, and Evans and Kessides (1994) and Ciliberto and Williams (2014) for the airline industry. The most relevant study of multimarket contact and collusive behavior in procurement auctions is Gupta (2001).

for the causal impact of the police investigation on the participation behavior of cartel firms, quantifying the impact that coordinating the participation behavior had on bids. In addition, I examine the *ex post* procurement performance (see for instance Decarolis and Palumbo, 2015; Coviello et al., 2017; Giuffrida and Rovigatti, 2018). In particular, I analyze the final amount paid by the Quebec Ministry of Transportation once a paving project had been completed to verify whether greater competition had unintended consequences on the *ex post* procurement performance. After colluding firms stop coordinating, they may accept a larger degree of head-to-head competition and submit more aggressive bids at the time of the awarding of a contract. Yet when executing the project, they may incur cost overruns that increase the final procurement costs forecast at the time of the signing of the contract. This pattern is not, however, observed in the data. Thus competition effectively improves the overall procurement costs.

The remainder of the study is structured as follows. Section 2 describes the publicity requirements and the adjudication process for the auctions together with a description of the cartel allegations faced by paving companies. Section 3 presents the data and summary statistics for all the firms in the market and for the two cartel firms analyzed. Section 4 examines whether the increase in head-to-head competition and the decrease in bids of the cartel firms observed between the collusive and the competitive periods could be attributed to the start of the police investigation. Section 5 introduces the structural model of entry and bidding used to quantify the extent to which avoiding head-to-head competition increased bids. Section 6 draws some general conclusions.

# 2 Institutional background and the investigation into collusion

## 2.1 Publicity requirements and adjudication process

According to the *Act Respecting Contracting by Public Bodies* (in French *Loi sur Les Contrats des Organismes Publics*), construction contracts awarded by ministerial bodies with an estimated value above C$100,000 must be publicly advertised on the Quebec

government's electronic tendering website (*SEAO*). These contracts must also be awarded through an open auction. Only Quebec firms or firms coming from a province that has a commercial agreement with the province of Quebec are allowed to bid.[4]

Contracts are awarded through open tenders using the mechanism of first-price sealed bid auctions where the firm with the lowest bid wins. For the type of activities involved, such as transportation and production of asphalt, a contract has multiple tasks and each firm participating in an auction has to bid a unitary price for the quantities indicated by the Ministry for each task.[5] The final bid is the sum of the products of the price and the quantities for each of the tasks described in the contract. Each bid has to meet conformability and admissibility requirements. One of the conformability requirements is the submission of a warranty that should be equal to either 5% or 10% of the submitted bid.

The winning bid is usually equal to the amount for which the contract is signed. The only cases in which the contract amount is different from the final amount are those contracts where, at the time of the awarding, the Ministry asks for the renegotiation of the contract and the bidder agrees with the renegotiation. Finally, there is no reserve price in these auctions.

## 2.2 The investigations into collusion

On October 15, 2009, a TV program called *Enquête* reported that collusion was widespread in the construction industry in Quebec, especially in the City of Montreal. According to the report, collusive practices inflated the amounts paid for public works by about 30% in the city of Montreal.[6] Following this report, a police operation called *Opération Marteau*

[4]The electronic tendering website has published calls for tender for the award of ministerial contracts since February 2005. For municipalities, it has been mandatory to publish calls for tender on the *SEAO* only since April 2011.

[5]The Ministry of Transportation has different regional departments (one for each Quebec administrative region) that each year check the status of the roads under their administration and submit their request to the central administration. The central administration then looks at the priorities and fills in the final plan (contracts to award, whether to use an open or restricted auction according to the value of the contract). Thus the location of the paving project is subject to the priorities of the Ministry and its budget constraints.

[6]See *Enquête*, Radio Canada (2009).

was launched by the Quebec government to investigate allegations of collusion, corruption and possible relationships between firms and organized crime.

Two years later, the *Commission of Inquiry on the Awarding and Management of Public Contracts in the Construction Industry* was created on October 19, 2011 to analyze the allegations of collusion and corruption in the various sectors of the construction industry. The Commission's mandate was to find evidence of collusion and corruption in the construction industry and to make recommendations on the awarding and management of public contracts. After completing its investigation, the Commission issued a final report in November 2015.[7]

In the final report, a whole chapter was dedicated to contracts awarded by the Ministry of Transportation of Quebec. The report provided evidence of a market segmentation scheme based on the locations of the asphalt plants of two firms (firm A and firm B in my analysis). These two firms agreed on sharing the market by putting asphalt plants far away from each other. Since the distance of a firm's closest asphalt plant to the paving project location is a major cost factor affecting competition in this industry, the two firms avoided competing against each other.[8]

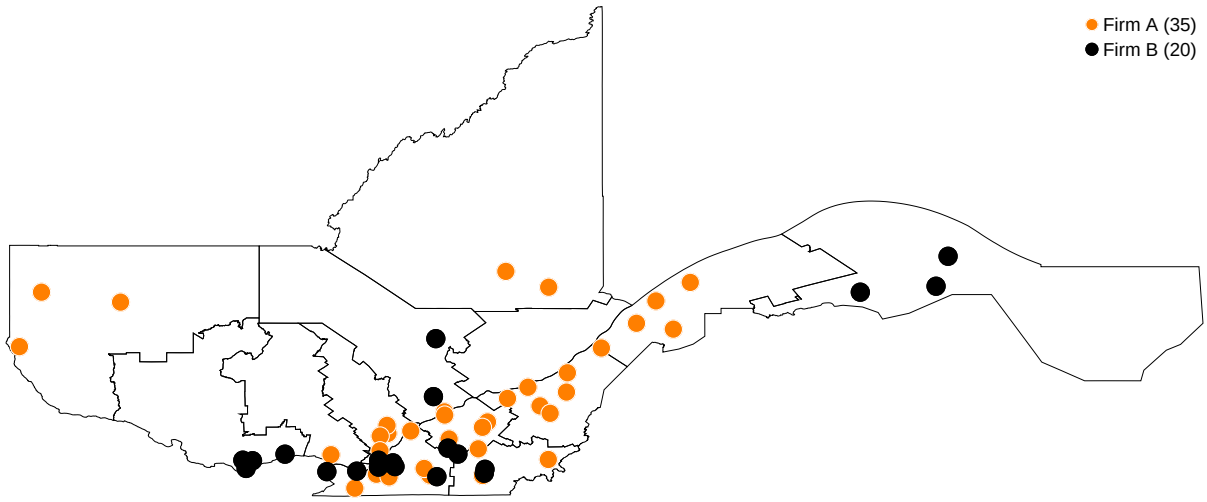
Figure 1 shows the distribution of the asphalt plants of firms A and B as they appeared in 2006 (one year before the start of the sample) in each administrative region of Quebec. In four of these regions we observe plants owned by firm A as well as plants owned by firm B; and in most of the remaining regions, the distribution of the plants belonging to the two firms is such that they are too far away from each other to make competition between the firms possible. Since we do not observe significant changes in the number of asphalt plants owned by the two firms and in the distances between these plants, it is impossible to determine whether these firms coordinated their plant location choices or whether these firms were simply geographically differentiating.[9]

[7]See Charbonneau and Lachance (2015).

[8]An executive of firm A admitted the existence of a market sharing agreement with firm B. The two firms coordinated their participation and their bidding behavior in open auctions administered by the Ministry of Transportation of Quebec. See Bédard (2014), pp. 20-24.

[9]The map in Figure 1 does not show the entire province of Quebec. I have excluded in my analysis the two most northern regions of the province where there are few inhabitants and few viable roads. These regions have a low population density of less than 1 inhabitant per $km^2$. Figure A.3 in Appendix A.4 shows the Canadian province of Quebec and its location in Canada.

Figure 1: Geographic map of asphalt plants of firms A and B for all Quebec administrative regions in 2006




Since 2015, the Bureau has focused its attention on 18 firms (among those, firms A and B) suspected of having shared the market, having allocated territories and having rigged the bids between 1982 and 2011 in the road paving market. Some firms' plants were searched in March 2015. The name of the firms involved were not publicly released, but newspapers reported that firms A and B were among them.[10] According to newspapers, the Canadian Competition Bureau affirmed that the cartel was active in five administrative regions. Four of these five administrative regions are regions where firms A and B had at least one plant and where their plants were close to each other.[11]

# 3 Data and summary statistics

The dataset includes contracts above C$100,000 awarded by the Ministry of Transportation of Quebec through open auctions between 2007 and 2015. The Quebec Ministry of Transportation awarded road paving contracts for a total value of C$1.46 billion between 2007 and 2015 through the process of calls for tenders with an yearly average of C$162 million. The database is obtained by merging two different datasets. The first is obtained by scraping the contracts from the Official Tendering website of the Quebec

[10] See Lévesque (2015).

[11] Table A.1 in Appendix A.1 shows that for the other 16 firms involved in the searches, the number of times they bid with either firm A or firm B (or both) did not increase. In Table A.2 I run a difference-in-difference where I put all suspected firms in the treatment group and observe that if firms A and B are removed from the sample, I obtain a non-significant drop in the winning bids.

government. The second is obtained by downloading data on all contracts awarded by the Quebec public administration in the open data website of the Quebec government. This second dataset allows me to verify whether the contracts included paving as a principal component of the construction work.[12]

A total of 751 contracts were kept. These contracts include the description of the job, the name of firms participating and their bids, the code identifying the type of job, the location of the job, the date when the contract was published and the date of the award of the contract. A nice feature of these data is that both winning bid and losing bids are reported together with the identity of the firms participating in the auction. On the other hand, the dataset includes only an interval of the *ex ante* estimated value of the contract because the precise value is confidential information. In the descriptive and structural analysis, I use the mean value of the contract. It is the mean of the upper and lower bounds of the interval indicating the value of the contract.

I augmented the auction data with asphalt plant data. The Ministry of Transportation issued (in 2005, 2006, 2008, 2010 and 2014) a detailed map showing not only the location of the asphalt plants of each firm but also the main shareholders of the firm together with the total number of plants owned by each firm. With this additional information, I compute the distance between the location of the paving project and the closest asphalt plant of each firm.[13]

Table 1 reports summary statistics for the pre-investigation (2007-2009) and post-investigation (2010-2015) periods. There are 86 different firms bidding in at least one auction and 51 firms winning at least one auction. Auctions receive on average three bids. There is a substantial number of auctions with one bidder, equal to 13.3% of the number of contracts in the dataset. The maximum number of bidders is equal to 9, and 72.4% of auctions in the dataset have between 2 and 4 bidders. The number of bidders does not change substantially in the two time periods considered. From the table we can observe a decline in the average and winning bids between the two periods considered, while the mean value of the contracts is approximately constant around C$2 million.

[12]https://www.donneesquebec.ca/recherche/fr/dataset/systeme-electronique-dappel-doffres-seao. Since the open data begin in 2009, I cannot verify the scraped data for 2008 and 2007.

[13]More details on the data cleaning process are in Appendix C.1.

Table 1: Summary statistics for pre-investigation and post-investigation period.

| | Pre (2007-2009) | Post (2010-2015) |
|---|---|---|
| Number of firms | 58 | 73 |
| Number of winning firms | 36 | 45 |
| Total contracts awarded | 194 | 557 |
| Total value contracts (C$ millions) | 392.10 | 1064.14 |
| Total value contracts by year (C$ millions) | 130.70 | 177.36 |
| Mean value contract (C$ millions) | 2.02 | 1.91 |
| Average number of bidders | 3.04 | 2.95 |
| Average bid (C$ millions) | 1.60 | 1.27 |
| Average bid (% value contract) | 84.51 | 76.88 |
| Average winning bid (C$ millions) | 1.46 | 1.16 |
| Average win bid value (% value contract) | 81.34 | 72.08 |

Notes: *Pre (2007-2009)* is the period before the start of the police investigation (October 2009). *Post (2010-2015)* is the period after the start of the police investigation (October 2009). *Number of firms* indicates the number of firms bidding in at least one auction. *Number of winning firms* indicates the number of firms winning at least one auction. *Total value of contracts awarded (C$ million)* indicates the total value of contracts (C$ millions) awarded in the period expressed as the sum of all mean values of the contracts. *Total value of contracts awarded by year (C$ million)* indicates the average total value of contracts (C$ millions) awarded by year. *Average value of contract* indicates the average value (C$ millions) of a contract. *Average number of bidders* indicates the average number of bidders in an auction. *Average bid (C$ million)* is the average bid expressed in C$ millions. *Average bid (% value contract)* indicates the average bid expressed in % of the value of the contract. *Average winning bid (C$ million)* indicates the average winning bid expressed in C$ millions. *Average winning bid (% value contract)* indicates the average winning bid expressed in % of the value of the contract.

## 3.1 Firms

In the road paving market, a firm's location is a key strategic decision given that transportation is a relevant component of costs in this industry; firms have to produce asphalt and transfer it to the place where the job is undertaken.[14]This characteristic makes competition in this market localized. Multiplant firms are thus more likely to win ministerial contracts than firms with a small number of plants. Each firm also faces capacity constraints: a firm cannot afford more than a certain amount of work within a certain period of time.

[14]Bajari and Ye (2003) underline the importance of transportation costs in these types of industries in the analysis of seal-coating contracts.

Table 2 shows summary statistics for the ten firms with the highest participation rates in the market. The market is characterized by firms that bid occasionally and firms that own multiple plants and bid in many auctions. Since paving projects can be located across the whole province of Quebec, owning more plants allows a firm to have higher participation rates. There are only 9 firms bidding in more than 50 auctions, and only 4 bidding in more than 100 (including firms A and B). Firm A is the leading firm in the market and owned twice the number of plants of firm B in 2006. Firms A and B have the highest participation rates in the market. For the 76 firms with the lowest participation rates, the average participation rate is only 1%. These firms win, on average, 24% of the auctions in which they participate in.

Table 2: Descriptive statistics of firms bidding in Quebec road paving contracts (2007-2015).

| ID Firm | Participation (%) | Win/Participation (%) | Distance (km) | Plants |
|---|---|---|---|---|
| A | 70.57 | 48.68 | 38.69 | 41 |
| B | 45.01 | 31.07 | 45.02 | 21 |
| C | 17.98 | 38.52 | 51.14 | 9 |
| D | 21.57 | 40.12 | 42.85 | 6 |
| E | 12.52 | 32.98 | 44.94 | 6 |
| F | 12.92 | 28.87 | 30.19 | 6 |
| G | 11.45 | 13.95 | 44.23 | 3 |
| H | 8.26 | 25.81 | 38.53 | 10 |
| I | 7.19 | 14.81 | 49.70 | 3 |
| L | 6.52 | 10.20 | 45.17 | 1 |

Notes: *ID Firm* indicates an anonymous identifier replacing the actual name of a firm in the dataset. *Participation rate (%)* indicates the number of contracts in which a given firm participates over total contracts. *Win/Participation (%)* indicates the total number of contracts won over the total participation rate of a firm. *Distance (km)* represents the average distance of the firm from the project location of the auction. *Plants* indicates the number of asphalt plants for each firm in 2006 for the whole province of Quebec.

## 3.2 Cartel firms' statistics

Table 3 shows summary statistics for firms A and B for the periods pre-October 2009 and post-October 2009. Firm A has a higher participation rate than firm B over the whole sample period. The internal division of the aggregate market shares seems to correspond until 2009 to what the executive of firm A testified in front of the Commission, that is, a division of 2/3 and 1/3 for the collusive years. I observe that the % of head-to-head competition out of total contracts increases by about 8% while the reduction in bids of firms A and B when they compete head-to-head is 15.43% of the mean value of the contract in the period post-October 2009.

Table 3: Summary statistics for firms A and B for pre-investigation and post-investigation periods

| | Pre (2007-2009) | Post (2010-2015) |
|---|---|---|
| Participation firm A | 65.46 | 72.35 |
| Participation firm B | 42.27 | 45.96 |
| Market share A | 24.71 | 38.73 |
| Market share B | 16.72 | 11.94 |
| Number asphalt plants A | 35.00 | 36.00 |
| Number asphalt plants B | 20.00 | 25.00 |
| Head head (% total contracts) | 23.20 | 31.24 |
| Average bid (% value) when head-to-head | 88.87 | 73.44 |

Notes: *Pre (2007-2009)* refers to the period before the start of the police investigations (*Operation Marteau*). *Post (2010-2015)* refers to the period after the start of the police investigations. *Participation firm* refers to the percentage of contracts out of total contracts where cartel firms participate. *Market share firm* refers to the market share of the cartel firm as percentage of total value in the period. The total value in the period is calculated summing all the winning bids. *Head-to-head competition (% total contracts)* is the percentage of contracts where firms A and B both participate out of total contracts. *Average bid (% value) when head-to-head* is the average bid expressed in % of the mean value of the contract for those contracts where firms A and B are both bidding.

From Figures 2 and 3 we can observe on the map that the increase in the % head-to-head competition for firms A and B is higher in regions where plants of both firms are close to each other.[15]

[15]The location of asphalt plants in Figure 2 represents the one observed in 2006, while the location of asphalt plants in Figure 3 represents the one observed in 2015.

Figure 2: % head-to-head competition out of total contracts and plant location of firms A and B by Quebec administrative regions (pre-investigation period, 2007-2009)

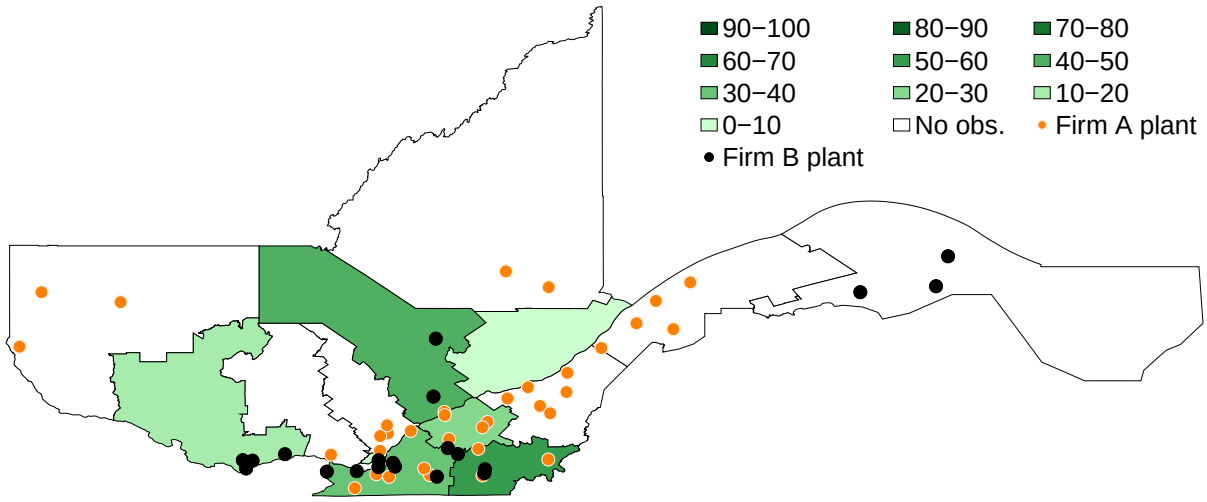
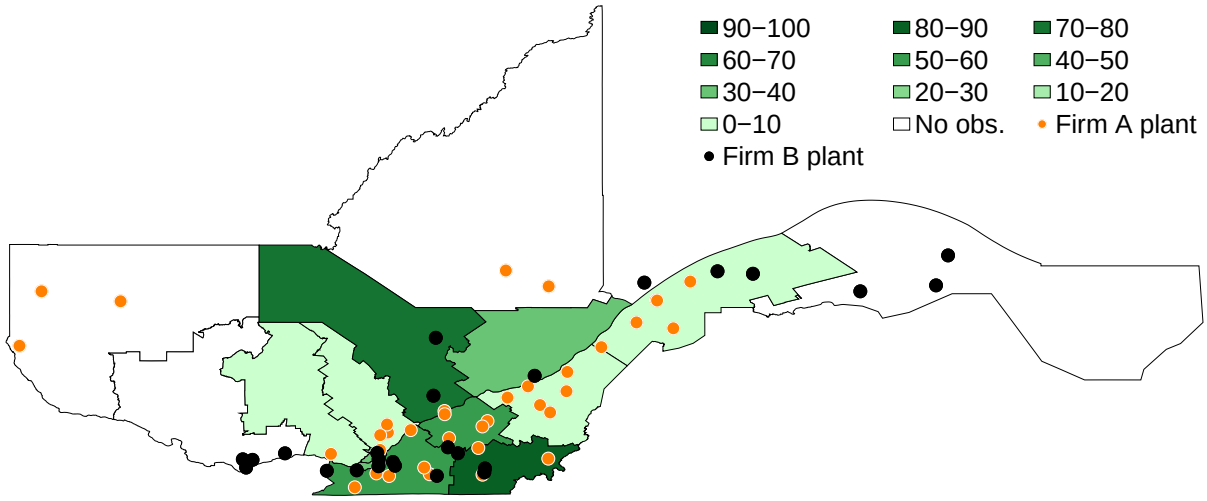



Figure 3: % head-to-head competition out of total contracts and plant location of firms A and B by Quebec administrative regions (post-investigation, 2010-2015)




From the descriptive statistics, the following facts can be observed:

- An increase in the % of head-to-head competition after the start of the investigation,
- An increase in the % of head-to-head competition in those administrative regions of Quebec where both firms had at least one asphalt plant at the beginning of the sample period considered,
- A decrease in bids of cartel firms when they compete head-to-head (15.43% of the mean value of the contracts).

The increase in head-to-head competition and the decrease in bids could have also been driven by other factors different from the police investigation. To account for this, in the next section I propose a difference-in-difference design to identify whether the start of the police investigation had a causal effect on the increase in the degree of head-to-head competition and the drop in bids submitted by firms A and B.

# 4 Descriptive analysis

## 4.1 Identification strategy

I identify the causal effect of the end of the cartel on the two main outcomes analyzed, that is, the probability of head-to-head competition and the bids submitted by firms A and B when they compete head-to-head. I want to establish whether the increase in head-to-head competition and the decrease in bids were caused by the police investigation.

To capture the effect, I employ a difference-in-difference strategy. I compare two different groups of auctions, a "treated" and "control" group to analyze significant changes in the probability of head-to-head competition between the two cartel firms and their bids. I define the treated group of auctions in terms of potential competition i) at the bidding stage, and ii) at the participation stage. Thus, I define an auction as potentially "competitive" if the two cartel firms are located within a 100 km radius around the paving project awarded with the auction. I chose a radius of 100 km because it reflects the average distance that firms participating in these auctions have to cover to reach the paving project location. The average distance of participating firms in the dataset is 45 km and the average distance of participating firms in the treated group of auctions is 41 km. Interestingly, the median distance of participating firms is 35 km and is identical to the median distance of participating firms in the treated group of auctions.[16]

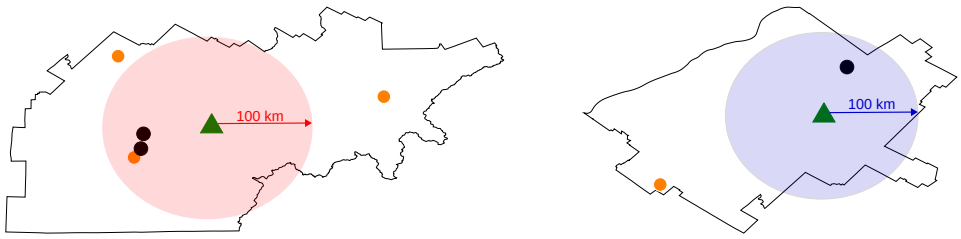
Figure 4 shows examples of my identification strategy. it shows the location of firm A (orange circle), the location of firm B (black circle) and the location of the paving project (green triangle). The boundaries represent the boundaries of an administrative region

[16]In Appendix B.3 I show that the results are robust i) to the choice of a radius of 90 km (Tables B.9 and B.10), ii) to the choice of a radius of 110 km (Tables B.11 and B.12).

in Quebec. Since the plant location could be itself a strategic choice of firms, I cannot exploit the location of a firm in a given administrative region. Using the radius allows me to overcome this endogeneity problem.

Figure 4a shows one case of treated auctions. Both cartel firms have at least one plant located within a 100 km radius around the paving project awarded with the auction. Figure 4b shows a case of an auction in the control group in which one of the cartel firms is located outside a 100 km radius around the project.

Figure 4: Location of the paving project (green triangle), of firms A (orange circle) and B (black circles) in an administrative region of Quebec




(a) Treated auction (b) Control auction

## 4.2 Head-to-head competition

Table 4 reports the probability of head-to-head competition for the two groups of auctions (treated and control). There is a lower probability of head-to-head competition for projects considered in the control group of auctions. Since I built my empirical strategy on the identification of treated auctions as the ones with higher potential competition between cartel firms, in the control group the probability of head-to-head competition for the cartel firms is close to 0. The two groups are thus not comparable on this dimension. On the other hand, observing a higher gap in the difference between the two groups in the probability of head-to-head competition after the start of the police investigation could signal that the investigation affected the participation behavior of cartel firms in those auctions in which they could be potential competitors. The difference between the two groups increases from 0.35 to 0.45.

Table 5 reports instead the average number of bids from cartel firms in an auction. Consistently with Table 4, the average number of cartel bids in the treated auctions relative to the control group of auctions increase after the start of the police investigation.

Table 4: Probability head-to-head

| | Pre | Post | Post-Pre |
|---|---|---|---|
| TreatedAuction=1 | 0.354 | 0.470 | 0.115 |
| TreatedAuction=0 | 0.000 | 0.016 | 0.016 |
| Post-Pre | 0.354 | 0.454 | 0.100 |

Table 5: Number of cartel bids

| | Pre | Post | Post-Pre |
|---|---|---|---|
| TreatedAuction=1 | 1.260 | 1.396 | 0.136 |
| TreatedAuction=0 | 0.731 | 0.782 | 0.051 |
| Post-Pre | 0.528 | 0.613 | 0.085 |

Next, I investigate whether these results are robust to the inclusion of other contract characteristics. The econometric specification is the following:

$$Y_a = \beta_0 + \beta_1 TreatedAuction_a \times Post_a + \beta_2 TreatedAuction_a + \beta_3 Post_a + \beta_4 Z_a + \epsilon_a \quad (1)$$

where $Y_a$ is the measure of head-to-head competition (the number of cartel bids in an auction). The variable *TreatedAuction* is equal to 1 if the two cartel firms are located within a 100 km radius around the project, 0 otherwise. The variable *Post* indicates whether the auction was published after October 2009, and $Z_a$ represents a set of auction characteristics: i) the number of potential cartel bidders (firms A and B); ii) the number of potential bidders outside the cartel (firms other than A and B); iii) a proxy for the demand, that is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year; iv) dummies identifying the administrative region of project location of the auction, the year of publication of the auction and the value of the auction's project. Capacity constraints could be also another potential confounding factor. That is why I include a variable that represents the highest level of free capacity of cartel firms in a given region and year to control for possible capacity constraints.

Since one of the contract characteristics is the number of potential bidders (cartel and non-cartel bidders), I need to identify a set of potential participants for which I do not have data. Thus, I rely on a proxy for potential competition at the participation stage. Unlike Li and Zheng (2009), the dataset does not provide any information on the number of firms that downloaded the call for tender on the electronic tendering website. I define a firm as a potential participant if it has ever bid in an auction nearby. I associate nearby auctions with the smallest geographic unit I can identify for the paving project. This

geographic unit is the regional county municipality, in French *municipalité régionale de comté* (from now on MRC). A MRC is a supra-local type of regional municipality and it groups different municipalities. If a firm has bid at any time in any auction in a given MRC, the firm is considered a potential participant.[17]

Table 6: Diff-in-diff for the number of cartel bids in an auction and probability of head-to-head competition

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | prob.head-to-head | prob.head-to-head | nbr.cartel bids | nbr.cartel bids |
| TreatedAuction×Post | 0.0999 | 0.222*** | 0.0847 | 0.231** |
| | (0.0817) | (0.0510) | (0.138) | (0.116) |
| TreatedAuction | 0.354*** | -0.0377 | 0.528*** | -0.0169 |
| | (0.0628) | (0.0491) | (0.114) | (0.115) |
| Post | 0.0155 | -0.0222 | 0.0510 | -0.0585 |
| | (0.0112) | (0.110) | (0.0949) | (0.161) |
| N potential cartel bidders | | 0.0970*** | | 0.262*** |
| | | (0.0287) | | (0.0548) |
| N potential non-cartel bidders | | -0.00556 | | -0.0302* |
| | | (0.00971) | | (0.0173) |
| Free capacity of cartel firms (%) | | -0.000164 | | -0.000573 |
| | | (0.000424) | | (0.000822) |
| Demand (%) | | -0.000403 | | -0.00114 |
| | | (0.000524) | | (0.00104) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Size project effects | No | Yes | No | Yes |
| Observations | 751 | 751 | 751 | 751 |
| R-squared | 0.209 | 0.479 | 0.202 | 0.494 |
| Average Outcome Treated Pre | 0.354 | 0.354 | 1.260 | 1.260 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *nbr. cartel bids* indicates the number of cartel bids in an auction. *prob head-to-head* is a binary variable indicating whether both cartel firms (firms A and B) bid in the auction. *Post* is a dummy equal to 1 if the contract is published after October 2009. *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Free capacity of cartel firms (%)* is the highest level of free capacity (%) of cartel firms in a given administrative region and year. *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), at 5% (**), and at 1% (***).

[17]This procedure is similar to that of Athey et al. (2011) and Conley and Decarolis (2016).

Table 6 reports the results of the estimation of equation 1. After the start of the police investigation, the number of cartel bids increases by about 0.22 with respect to the control group of auctions, once I control for contract characteristics. The increase is about 63% of the average outcome observed in the pre-investigation period in the treated group. The results are similar if I consider as outcome the number of cartel bids in an auction.[18]

## 4.3 Bids

In the last part of the descriptive analysis, I show the impact of the police investigations on bids. The bids are expressed in % of the mean value of the contract. Table 7 and Table 8 report the results for the treated and control group of auctions. On average, bids decrease in the treated group of auctions by about 11.29% and winning bids decrease by about 13.11% of the contract value. In the control group of auctions, the bids on average remain at the same level between the two periods considered.

Table 7: Bids as % of the value of the contract

| | Pre | Post | Post-Pre |
|---|---|---|---|
| TreatedAuction=1 | 86.680 | 75.391 | -11.289 |
| TreatedAuction=0 | 79.756 | 81.588 | 1.831 |
| Post-Pre | 6.923 | -6.197 | -13.120 |

Table 8: Winning bids as % of the value of the contract

| | Pre | Post | Post-Pre |
|---|---|---|---|
| TreatedAuction=1 | 83.137 | 70.027 | -13.110 |
| TreatedAuction=0 | 77.932 | 75.940 | -1.993 |
| Post-Pre | 5.205 | -5.913 | -11.118 |

I investigate whether these results are robust with the inclusion of other contract and bidder characteristics. The econometric specification is the following:

$$Bid_{ia} = \beta_0 + \beta_1 TreatedAuction_a \times Post_a + \beta_2 TreatedAuction_a + \beta_3 Post_a + \beta_4 X_{ia} + \beta_5 Z_a + \epsilon_{ia} \quad (2)$$

where $Bid_{ia}$ is the bid submitted by firm $i$ in auction $a$ (as% of the mean value of the contract). The variable *TreatedAuction* is equal to 1 if both cartel firms are within a

[18]Tables A.5 and A.6 in Appendix A.3 report the results for the test of the common trend assumption for the two groups of auctions considered. If I interact the dummy variable indicating the treated group of auctions with a linear trend (*Year*), I reject the parallel trend assumption. On the other hand, if I interact the dummy variable indicating the treated group of auctions with year dummies, I cannot reject the hypothesis that the coefficient of *Treated×2008* is equal to the coefficient of *Treated×2009*.

radius of 100 km around the paving project awarded with auction $a$, 0 otherwise. The variable *Post* indicates whether the auction was published after October 2009, while the variables $X_{ia}$ and $Z_a$ represent respectively bidder and contract characteristics. Bidder characteristics are i) capacity, ii) distance of the closest asphalt plant from the project location, iii) the value of contracts won up to auction $a$ in a given administrative region and year. Contract characteristics are the number of potential cartel and non-cartel bidders, demand and the dummies related to the year of publication of the auction and related to the location of the auction (administrative region).

Table 9 reports the results. Columns 1-3 report the estimates for bids (winning and losing bids), and columns 4-6 report the estimates only for winning bids. In all the different specifications there is a negative and significant coefficient for the treated group of auctions compared to the control group, in line with what we found in Table 7 and Table 8. The bids in the treated group of auctions decrease by about 14.8% of the mean estimated value of the contract compared to auctions in the control group. The decrease in bids represents 15% of the average bid observed in the pre-investigation period in the treated group of auctions. The observed decrease in the bids is robust to the inclusion of relevant cost factors of firms, such as their distance from the project (in km) and their capacity. The decline in bids is also robust to other contract characteristics, such as the number of contracts awarded in a given administrative region and year and the number of potential competitors. For the average bids, there seems to be a significant impact of the number of contracts previously won by a given firm. This variable represents firm's economies of scale (the more contracts a firm wins in a region, the lower they will bid in the following contracts). The winning bids decrease by about 13% of the value of the contract. [19]

[19] Table A.7 reports the tests for the presence of a linear common trend for the two groups of auctions before the start of the investigation. The null hypothesis of a linear common trend in the pre-investigation period for the treated and control groups of auctions is only weakly rejected if we consider all bids but it is not rejected if we consider only the winning bids.

Table 9: Diff-in-diff for bids over value of the contract (%)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -13.12** | -14.77** | -11.12** | -12.93** |
| | (5.550) | (5.929) | (5.076) | (5.623) |
| TreatedAuction | 6.923 | 12.81** | 5.205 | 12.41** |
| | (4.334) | (4.999) | (4.227) | (5.027) |
| Post | 1.831 | 11.07 | -1.993 | 9.116 |
| | (4.623) | (7.961) | (3.799) | (6.389) |
| Distance (km) | | 0.0364** | | 0.0356 |
| | | (0.0175) | | (0.0245) |
| Capacity (%) | | 0.0237 | | 0.0196 |
| | | (0.0381) | | (0.0769) |
| Value firm region (%) | | -0.110* | | 0.00534 |
| | | (0.0563) | | (0.113) |
| N potential cartel bidders | | -6.713** | | -3.924 |
| | | (2.963) | | (2.642) |
| N potential non-cartel bidders | | 0.543 | | -0.306 |
| | | (0.970) | | (0.843) |
| Demand (%) | | 0.0818* | | 0.0151 |
| | | (0.0468) | | (0.0463) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 2,230 | 2,230 | 751 | 751 |
| R-squared | 0.0186 | 0.0522 | 0.0267 | 0.0554 |
| Average Outcome Treated Pre | 86.68 | 86.68 | 83.14 | 83.14 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether auction $a$ was published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of the total value of contracts won up to auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over the total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Considering the average value of a contract equal to C$2 million, firms in the treated group of auctions are winning by submitting bids that are about C$260,000 lower than

those observed in the pre-investigation period. This implies an average saving for the public administration of about C$14.3 million per year after the investigation started.

Appendix B.1 shows several robustness checks. In Table B.1 I replicate Table 9 using the upper bound of the interval identifying the estimated value of the contract as a measure to normalize bids. In Table B.2 I exclude auctions with only one bidder. In Table B.3 I control for the number of actual bidders, instead of the number of potential bidders. Finally, in Table B.4 I include firm fixed effects. The decrease in bids is even stronger if we include in the treated group of auctions only those auctions where firm A and firm B compete head-to-head (Table B.5) and if we only consider in the treated group only the bids of firms A and B when they compete head-to-head (Table B.6).

## 4.4 Other outcomes

The investigation could have also impacted other variables. In this section, we investigate other auction-level outcomes such as i) the number of bids excluding firms A and B (in other words, the number of non-cartel bids), ii) the probability that an auction has only one bidder, iii) the probability that firms other than A and B win the auction. In particular, one bidder auctions are a sign of lack of competition (*The Economist*, 2016). Table 10 shows that after the investigation, the probability of observing auctions with one bidder goes down significantly while the probability the number of bidders outside the cartel significantly increases.

Another important dimension that I want to investigate is the ex-post procurement performance. Once a cartel stop coordinating bids and participation behavior in auctions, firms previously in the cartel could adjust their behavior by delaying the end of paving projects and thus incurring in cost overruns. Table 10 shows that this is not the case in the auctions I analyze (column 5). On the other hand, we find that firms complete projects related to treated auctions faster after the start of the police investigation (column 4).

Table 10: Diff-in-diff for additional outcomes at the auction level (%)

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Dep.Variable | nbr. non-cartel bids | 1-bidder auction | prob. non-cartel win | delays | overrun |
| TreatedAuction×Post | 0.748*** | -0.126** | 0.0194 | -219.4** | 1.904 |
| | (0.143) | (0.0554) | (0.0678) | (100.9) | (1.859) |
| TreatedAuction | -0.368** | 0.0372 | 0.0958* | 107.6 | -1.397 |
| | (0.153) | (0.0542) | (0.0570) | (109.4) | (1.789) |
| Post | -0.723** | 0.188 | -0.237* | -608.8*** | -13.67*** |
| | (0.312) | (0.119) | (0.133) | (133.8) | (2.470) |
| N potential cartel bidders | -0.185* | 0.00717 | -0.112** | | |
| | (0.0944) | (0.0450) | (0.0473) | | |
| N potential non-cartel bidders | 0.225*** | -0.0184** | 0.0401*** | | |
| | (0.0329) | (0.00913) | (0.0102) | | |
| Demand (%) | -0.00368*** | 0.000763** | -0.000135 | | |
| | (0.00117) | (0.000319) | (0.000571) | | |
| Admin Region effects | Yes | Yes | Yes | Yes | Yes |
| Year effects | Yes | Yes | Yes | Yes | Yes |
| Size project effects | Yes | Yes | Yes | Yes | No |
| Observations | 751 | 751 | 751 | 534 | 567 |
| R-squared | 0.636 | 0.300 | 0.230 | 0.496 | 0.273 |
| Average Outcome Treated Pre | 1.921 | 0.0472 | 0.559 | 1187 | 1.533 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether auction $a$ was published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. *Delays* are expressed as the difference between the day when the contract has been signed and the date of termination. *Overrun* is the difference between the amount at which the contract is signed and the final amount paid by the Quebec Ministry of Transportation, expressed as % of the amount at which the contract is signed. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

# 5 The effect of the increase in head-to-head competition on bids

The results presented in the previous section show that head-to-head competition increased and bids decreased after the start of the police investigation in the Quebec construction industry. The econometric model was not capable of capturing whether the higher level of the bids observed before the start of the investigation was due to firms A

and B avoiding head-to-head competition or coordinating bids. Determining which part of the higher procurement costs should be attributed to coordination on bids and which part should be attributed to coordination on head-to-head competition is important. In a cartel that does not include all the firms in the market, the two types of coordination can have a different impact on procurement costs.

To quantify the extent to which restricting head-to-head competition increased procurement costs, I propose two approaches: a reduced form and a structural one. To determine the impact that coordination on the degree of head-to-head competition has on bids, I mimic a situation in which the two firms suspected of collusion compete head-to-head at the same rate as under the collusive regime observed before October 2009.

## 5.1 Reduced-form approach

In Table 11 I estimate a model in which I exclude all auctions awarded in MRCs where one of the two cartel firms participated for the first time after the start of the investigation. For example, suppose that firm A was the only bidder in the MRC of Montreal until October 2009. If firm B started bidding in Montreal after October 2009, I drop the auctions in Montreal in which firm B bids. The results obtained are almost identical to those observed in Table 9. This implies that the effect of coordination on the degree of head-to-head competition is on average smaller relative to the effect of coordination on bids.

The reduced-form approach presents different issues. First, it considers the decision of firms to participate in an auction as exogenous. Second, in some of the MRCs both cartel firms were already active bidders in the period pre-investigation but they simply competed head-to-head to a lower extent. This second aspect cannot be captured with a reduced-form approach. Finally, an additional reason is related to the entry effect established by Li and Zheng (2009). They show that the probability of entry decreases with the number of potential bidders. Thus bids do not always decrease with an increase in competition because bidders are more willing to participate when facing a lower number of potential opponents.

Table 11: Diff-in-diff for bids over value of the contract (%)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -13.85** | -14.21** | -10.97** | -12.47** |
| | (5.693) | (6.083) | (5.171) | (5.729) |
| TreatedAuction | 6.923 | 10.47** | 5.205 | 10.73** |
| | (4.335) | (4.893) | (4.228) | (5.056) |
| Post | 2.455 | 10.84 | -1.699 | 9.120 |
| | (4.715) | (8.212) | (3.841) | (6.696) |
| Distance (km) | | 0.0485** | | 0.0342 |
| | | (0.0194) | | (0.0262) |
| Capacity (%) | | 0.0123 | | 0.0267 |
| | | (0.0387) | | (0.0824) |
| Value firm region (%) | | -0.0875 | | 0.00306 |
| | | (0.0572) | | (0.129) |
| N potential cartel bidders | | -3.890 | | -0.941 |
| | | (2.440) | | (2.323) |
| N potential non-cartel bidders | | -0.496 | | -1.016 |
| | | (0.953) | | (0.837) |
| Demand (%) | | 0.0616 | | -0.00297 |
| | | (0.0472) | | (0.0465) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 1,906 | 1,906 | 678 | 678 |
| R-squared | 0.0203 | 0.0493 | 0.0247 | 0.0538 |
| Average Outcome Treated Pre | 86.68 | 86.68 | 83.14 | 83.14 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether auction $a$ was published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over the total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

## 5.2 Structural model of entry and bidding

To make the participation decision of firms endogenous, I employ a structural model of entry in auctions and bidding that models the entry decision and bidding behavior as

endogenous. I can simulate a counterfactual scenario in which firms A and B coordinate the degree of head-to-head competition and do not coordinate their bids. While in the data there is a scenario in which firms coordinate the degree of head-to-head competition and bids (the period before the start of the police investigation) and a scenario in which firms A and B do not coordinate the degree of head-to-head competition and bids (the period after the start of the police investigation), the scenario in which firms A and B coordinate only the degree of head-to-head competition is not observed.

To identify the effect of coordination on the degree of head-to-head competition on bids, I use a model of entry in an auctions and bidding that strictly follows Athey et al. (2011) and Gugler et al. (2015). The model is based on the following assumptions. First, the model has two steps: the individual decision of each firm to participate in an auction (step 1) and the decision on the bid level once the firm decides to participate (step 2). In line with the firm statistics presented in Table 2, the model allows for the existence of asymmetric bidders, since there are differences between the two cartel firms and, more generally, between almost every firm in terms of participation behavior and the number of asphalt plants they own in the province of Quebec. I adopt a parametric assumption on the bid distribution. I assume, again strictly following Athey et al. (2011) and Gugler et al. (2015), that bids are distributed according to a Weibull distribution. With asymmetric bidders and given the nature of the counterfactual experiment, putting parametric assumptions on the bid distribution makes the estimation of counterfactual bids easier. Finally, the model is estimated using auctions from the competitive period, i.e. the period after October 2009, and I assume independent private costs.

### 5.2.1 The model

The model can be characterized as a two-stage game. In the first stage, firms choose whether or not to participate in the auction. In the second stage, only firms that decided to participate in the first stage bid in the auction. The preparation of the bid is a costly activity. Each bidder willing to participate in an auction has to pay a submission warranty; and, before submitting the final bid, each firm has to estimate the price offered for each

task in the contract (the price per ton of asphalt or the transportation cost of asphalt, for example).

Participation and bidding are independent activities because the participation stage only determines at the bidding stage the number of firms effectively participating. Since the model is characterized by a two stage game, it is solved by backward induction. For the bidding process, a standard first-price sealed-bid auction setting is adopted. Bidders are risk neutral and each bidder $i$ draws his own private cost $c_i$ for completing the project from his own distribution $F_i(.)$. At the bidding stage, participating firms already know how many bidders $n$ they face out of a set of potential bidders $N$, and each bidder maximizes its own profit:

$$\pi_i(c_i, b_i, n) = (b_i - c_i) \prod_{j \in n \setminus i} [1 - F_j(b_j^{-1}(b_i); n)] \tag{3}$$

where $1 - F_j(b_j^{-1}(b); n) = 1 - G_j(b; n)$ is the probability that $j$ will bid higher than $b$ and the inverse bidding strategy $b_j^{-1}(b)$ is equal to the cost of player $j$, called $c_j$. Maximizing with respect to $b_i$, we can find the first-order condition of the problem, which is the following:

$$\frac{1}{b_i - c_i} = \sum_{j \in n \setminus i} \frac{g_j(b_i; n)}{(1 - G_j(b_i; n)} \tag{4}$$

The asymmetric equilibrium bidding is characterized by the following equation:

$$b_i(c_i, n) = c_i + \frac{1}{\sum_{j \in n \setminus i} \frac{g_j(b_i; n)}{(1 - G_j(b_i; n)}} \tag{5}$$

which depends on the firm's own cost and the opponents' bid distribution and density of bids.

At the entry stage, a potential bidder $i$ decides whether or not to enter in the auction. Each bidder enters the auction if its expected profits from entering are higher than its entry costs. In other words,

$$\Pi_i(p) = \sum_{n \subset N} \pi_i(n) Pr[n | i \in n] \geq K_i \tag{6}$$

where $K_i$ is the entry cost, $\pi_i(n)$ is the *ex ante* markup from the auction, and $Pr[n|i \in n]$ is the probability that $n$ bidders out of $N$ potential bidders enter the auction if bidder $i$ enters. Although the model is more flexible since it allows for asymmetric bidders and for bidder-specific entry costs, the asymmetric participation equilibrium exists, but it need not be unique. The result has been established by Li and Zhang (2015) who discuss this problem in detail. In my model, I assume that the participation probabilities come from a unique equilibrium.

### 5.2.2 Identification

As in Guerre et al. (2000) (GPV), it is possible to directly identify the cost $c_i$ of each bidder from the observed bids and their distribution. Here, I apply a parametric version of GPV. In an auction with a set of contract characteristics $Z$, number of potential cartel bidders $N_c$, number of potential bidders outside the cartel $N_{nc}$, number of actual bidders in the cartel $n_c$ and those outside the cartel $n_{nc}$, the estimated cost of bidder i with characteristics X is given by

$$\hat{c}_i = b_i - \frac{1}{\sum_{j \in N \setminus i} \frac{\hat{g}_j(b_i|X,Z,N_c,N_{nc},n_c,n_{nc})}{(1-\hat{G}_j(b_i|X,Z,N_c,N_{nc},n_c,n_{nc})}} \tag{7}$$

The participation probability $p_i$ is directly identifiable from the data. Owing to the variation in the number of potential bidders (both in the cartel and outside the cartel), entry costs are also identifiable. I estimate these costs to check whether the relevance of these entry costs explains the reluctance of head-to-head competition in the collusive period. To do so, I find an expression for the expected profits through the estimation of the participation probabilities of each firm and the repeated simulations of auction outcomes in which each firm participates as in Athey et al. (2011).

### 5.2.3 Estimation

In the first stage, firms decide whether or not to participate in the auction. The participation decision is a binary choice variable that takes value 1 if equation (6) is satisfied. The distribution of bidders' participation is binomial. This binomial distribution has a

parametric (logit) specification that allows estimating the predicted participation of each firm:

$$p_i(X, Z, N_c, N_{nc}) = \frac{exp(\alpha_1 X + \alpha_2 Z + \alpha_3 N_c + \alpha_4 N_{nc})}{1 + exp(\alpha_1 X + \alpha_2 Z + \alpha_3 N_c + \alpha_4 N_{nc})} \tag{8}$$

With the logit estimation, I can obtain the predicted probabilities of participation for each firm in each auction. With these probabilities, I simulate 1000 times the participation behavior in a given contract. The participation of potential bidders in an auction is simulated 1000 times using individual predicted participation probabilities for each potential bidder. Thus, 1000 new samples of auctions are obtained.

At the subsequent bidding stage, participants choose their bid $b_i$ which is dependent on their cost $c_i$ given the number of bidders entering the auction $n \subseteq N$. Costs are estimated through the method proposed by Guerre et al. (2000) with parametric assumptions on the distribution of bids. As in Athey et al. (2011), a Weibull distribution has been chosen for bids:

$$G_i(b_i|X, Z, N_c, N_{nc}, n_c, n_{nc}) = 1 - \exp\left(-\frac{b_i}{\lambda_i(X, Z, N_c, N_{nc}, n_c, n_{nc})}\right)^{\rho_i(X,Z,N_c,N_{nc},n_c,n_{nc})} \tag{9}$$

where the parameters of the distribution $\lambda_i$ and $\rho_i$ depend on a set of bidder characteristics, auction characteristics and the number of potential and actual bidders in the cartel and outside the cartel. These two parameters are linearized and estimated through maximum likelihood.

Given the 1000 different samples of auctions obtained and the estimated bid distribution parameters, for each participation draw we can find the empirical distribution and density of bids for each bidder in order to recover the estimated cost $\hat{c}_i$ given by

$$\hat{c}_i = b_i - \frac{1}{\sum_{j \in n \setminus i} \frac{\hat{g}_j(b_i|X,Z,N_c,N_{nc},n_c,n_{nc})}{(1-\hat{G}_j(b_i|X,Z,N_c,N_{nc},n_c,n_{nc}))}} \tag{10}$$

with empirical distribution $\hat{F}_i(\hat{c}_i|X, Z, N_c, N_{nc}, n_c, n_{nc})$. The variables representing the bidder characteristics are the capacity, the value of contracts won by the firm in a given administrative region up to the auction, and the firm's own distance from the paving project. The set of contract characteristics include dummies for year of publication of the

auction, dummies identifying the administrative region of location of the paving project of auction $a$, and the value of contracts awarded up to auction $a$ in a given region and year. The number of potential bidders in the cartel is defined as the number of bidders (firms A and B) bidding at least once in the post-investigation period in a given MRC where the paving project is located. The number of potential non cartel bidders is the number of bidders other than firms A and B bidding at least once in the whole post-investigation period in a given MRC where the paving project is located.

### 5.2.4 Results

Table 12 reports the estimates of the parameters in equation 8 using the observed bidder participation. The capacity, contracts won and the firm's own distance enter the participation decision in the expected way. The higher the occupied capacity, the lower is the probability of participating in an auction. The higher the distance from the project, the lower is the probability of participation. The higher the value of contracts won (a proxy capturing economies of scale), the higher is the participation probability. In addition, the probability of participation is negatively influenced by the number of potential non-cartel bidders. This effect is similar to the one found in Li and Zheng (2009), who estimate a negative relationship between the number of potential and actual bidders in the auction. The number of potential cartel bidders is not significantly correlated with the probability of participation.

Table 12 reports also the estimates of bid parameters $\lambda_i$ (the scale of distribution) and $\rho_i$ (the shape of the distribution). The only significant parameters for the scale of the distribution are the demand and number of potential and actual bidders. If the value of contracts awarded in a given administrative region and year is higher, firms bid higher. This might be due to the fact that the higher the number of awarded contracts, the more firms are likely to reach their capacity constraints. The negative coefficient of the number of potential cartel bidders shows that if firms A and B are potential competitors, the competitive pressure is higher, causing bids to be lower. The number of actual cartel bids is another factor influencing the bid distribution. If both cartel firms bid in the auction, there is a downward pressure on bids (as expected).

Table 12: Determinants of entry and parameters of the bid distribution

| Dep.Variable | entry | $\lambda$ | $\rho$ |
|---|---|---|---|
| Distance (km) | -0.0150*** | 0.0301 | 0.00129 |
| | (0.00101) | (0.0208) | (0.00153) |
| Capacity (%) | -0.000861 | 0.00571 | -0.00230 |
| | (0.00180) | (0.0416) | (0.00299) |
| Value firm region (%) | 0.0590*** | -0.125 | 0.00423 |
| | (0.00572) | (0.0813) | (0.00599) |
| N potential cartel bidders | -0.0512 | -10.93*** | -0.187 |
| | (0.109) | (2.416) | (0.214) |
| N potential non-cartel bidders | -0.241*** | 1.969*** | 0.0647 |
| | (0.0307) | (0.692) | (0.0525) |
| actual cartel bidders | | -4.174** | -0.255 |
| | | (1.898) | (0.164) |
| actual non-cartel bidders | | 0.479 | 0.169* |
| | | (1.029) | (0.0911) |
| Demand (%) | -0.0100*** | 0.123*** | 0.000925 |
| | (0.00145) | (0.0344) | (0.00286) |
| Admin Region effects | Yes | Yes | Yes |
| Year effects | Yes | Yes | Yes |
| Size project effects | Yes | No | No |
| Observations | 3,351 | 1,553 | 1,553 |
| Pseudo $R^2$ | 0.2110 | | |
| Log-pseudolikelihood | | -7431.4414 | |

Notes: Standard errors in parentheses. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* represents the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*).*N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *n cartel bidders* is the number of cartel bidders (firms A and B) bidding in the auction. *n non-cartel bidders* is the number of bidders (other than firms A and B) bidding in the auction. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Finally, I estimate entry costs. I take an average of firms' profits across simulations of each contract and multiply these profits by the probability of participation found by estimating equation (6). The median participation cost is 14% of the average bid. The relevance of these entry costs is one of the factors motivating coordination on the degree of head-to-head competition between cartel firms.

### 5.2.5 Counterfactual: The relative importance of coordinating head-to-head competition with respect to coordinating bids

As counterfactual experiment, I simulate an unobserved scenario where firms collude on the degree at which they compete head-to-head. In this way, I establish what would have been the price effect if firms were allowed only to collude on the degree of head-to-head competition. To implement this counterfactual scenario, I use the participation probabilities of the cartel firms observed in the pre-investigation period, assuming that firms outside the cartel keep the same participation probabilities they had in the competitive period. Then, I simulate competitive bidding under this alternative scenario.

When I use the participation probabilities of cartel firms in the pre-investigation period, I have to consider one issue. The baseline estimation of the previous section computes the participation probabilities that are firm-auction specific. For the counterfactual, in order to find the participation probability in the pre-investigation period, I use the empirical frequencies of participation of these two firms at the MRC level.

The steps for the estimation of the counterfactual experiment are as follows:

- For cartel firms, I compute the empirical frequencies in the pre-investigation period (2007-2009) in a given MRC.
- I leave the participation probabilities of firms not in the cartel as those estimated in the competitive period.
- I simulate participation in 1000 replications of a contract.
- I keep the parameters of the bid distribution equal to those estimated in the competitive period.

- I adjust the number of potential cartel bidders and actual cartel bidders to that observed in the collusive period.

- I attach all draws and find the counterfactual average bid as the mean of all average bids in the different 1000 draws.

The 1000 samples produce a counterfactual average bid of 79.54% of the mean value of the contract. The counterfactual average bid is 3.86% higher with respect to the average bid that was estimated from the actual data. The effect of the coordination on the degree of head-to-head competition is low if compared to the effect on prices of coordination in bids. It accounts for 30% of the overall effect of collusion on bids. The small magnitude of this effect could be due to two factors going in opposite directions. With fewer potential bidders, the competition effect suggests that prices should increase, since bidding is less aggressive. However, there is an entry effect going in the opposite direction. Because of this second effect, bidders would be more willing to participate when they face fewer potential rivals (Li and Zheng, 2009).

## 5.3 Discussion

In the structural exercise, I found that the effect of coordinating head-to-head competition accounts for a small part of the average increase in bids observed in the collusive period. This pattern could be at odds with the fact that, in principle, the two effects should not be different. I explain why colluding firms prefer to coordinate the degree of head-to-head competition rather than coordinating on bids.

### 5.3.1 Entry costs

The entry costs are the costs incurred by firms when they prepare the submission of a bid. Through the structural model, the median entry cost is estimated to be 14% of the average bid. Part of these entry costs comes from the fact that the Quebec Ministry of Transportation requires all bidders willing to participate in an auction to submit 5 or 10% of the submission as warranty. The submission warranty is a real cost for firms, as it is money frozen for a certain period of time.

### 5.3.2 Bidding behavior of bidders not in the cartel

Bidders not in the cartel respond to realized competition. In a cartel that does not include all firms in the market, colluding firms could potentially prefer to avoid head-to-head competition because the designated winner within the cartel faces in expectation a less aggressive bidding strategy by the firms outside the cartel. Suppose that we observe an auction in which there are three potential bidders: two bidders are in the ring and one bidder is outside the ring. If the two colluding firms avoid head-to-head competition, the one firm in the ring designated to participate in the auction faces less aggressive bidding by the bidder outside the ring compared to the case in which both firms in the ring participate in the auction.

To support this idea, Table 13 shows the relationship between bids and the number of bidders in an auction. The relationship is negative and significant if I consider all bids and also if I consider only the bids of firms different from A and B. All bidders, and in particular bidders other than firms A and B, respond to realized competition.

### 5.3.3 Bid coordination is weaker than the bid selection mechanism

Marshall and Marx (2007) have shown that, in first-price auctions, a bidding ring can suppress competition from other firms in the ring if the ring is able to control ring members' bids (what they call a *bid selection mechanism*). By avoiding head-to-head competition, firms in the cartel implement the strongest case of bid selection mechanism. On the other hand, a ring that relies on a bid coordination mechanism does not have the ability to perfectly control all ring members' bids. That is why in this mechanism the bidder in the ring with the lowest cost should bid aggressively not to let a ring member with the lowest cost cheat on the agreement.

Given all the possible reasons that make colluding firms choose to avoid head-to-head competition with respect to coordinating bids, it is not rational for them to avoid head-to-head competition in every auction. If colluding firms avoided competing against each other in every auction, this would clearly be a red flag for collusion. In this particular case, for antitrust authorities, it is easy to understand that firms coordinate their participation

behavior, ruling out the possibility that they do not compete in an auction for other reasons, such as capacity constraints. In some parts of Quebec, for example, the two firms are so close to each other that it is suspicious if they decide to avoid competing against each other. In one administrative region, for example, the two firms are located only 3 km away from each other. In that region, it is difficult to avoid head-to-head competition in every auction.

Table 13: OLS estimation for bids as % of the mean value of the contract over the number of bidders

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | non cartel bids | non cartel bids |
| n cartel bidders | -4.924** | -4.110* | -5.698*** | -5.339** |
| | (2.165) | (2.267) | (2.168) | (2.271) |
| n non-cartel bidders | -0.538 | -0.588 | -0.353 | -0.0503 |
| | (1.087) | (1.558) | (1.162) | (1.766) |
| Distance (km) | | 0.0373** | | 0.0305 |
| | | (0.0177) | | (0.0199) |
| Capacity (%) | | 0.0243 | | 0.0342 |
| | | (0.0385) | | (0.0446) |
| Value firm region (%) | | -0.121** | | -0.159* |
| | | (0.0574) | | (0.0909) |
| Demand (%) | | 0.0832* | | 0.0877* |
| | | (0.0484) | | (0.0497) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 2,230 | 2,230 | 1,362 | 1,362 |
| R-squared | 0.00974 | 0.0431 | 0.0145 | 0.0521 |
| Average Outcome Pre | 84.51 | 84.51 | 83.95 | 83.95 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *n cartel bidders* is the number of cartel bidders (firms A and B) bidding in the auction. *n non-cartel bidders* is the number of bidders (other than firms A and B) bidding in the auction. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year. *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

# 6 Conclusion

Through the study of a case of market sharing agreements, I found evidence of coordination on the degree of head-to-head competition. I also quantified the extent to which avoiding head-to-head competition represents a cost for public procurement. I have analyzed the participation and bidding behavior in auctions of the two largest firms bidding in the provincial road paving procurement market in Quebec. Using the start of a police investigation into collusive behavior to capture the end of this cartel, I documented that the two suspect firms were more likely to compete head-to-head and submitted significantly lower bids after the police investigation was launched.

A structural model of entry and bidding with asymmetric bidders quantified the extent to which colluding on the degree of head-to-head competition increased bids. If the firms had kept competing head-to-head at the same rate as in the collusive period but had stopped colluding on bids, bids would have increased by about 3.86% with respect to the competitive scenario observed after the beginning of the police investigation.

This study is one of the first to document price and non-price collusion in a public procurement setting. I show that multiplant firms that potentially compete in multiple markets can share the market by i) avoiding competing against each other, and ii) fixing prices. The results also demonstrate that collusion on a dimension other than prices, such as the degree of head-to-head competition, is associated with higher procurement costs, although these costs are lower compared to a situation where firms collude on prices. Finally, I discuss several reasons why colluding firms may prefer to avoid head-to-head competition in a context of a cartel that does not include all the firms in a market.

Reducing the cost for submitting a bid could provide a solution to stimulate competition. The Ministry of Transportation, for example, requires all bidders to submit 5 or 10% of the submission as a warranty. This requirement makes entry costs high and gives an incentive to large firms to coordinate their respective decisions to participate in an auction. In addition, I demonstrate that antitrust authorities should investigate the participation behavior of firms: if firms that are not in the cartel respond to competition,

coordinating the participation behavior in auctions may be more likely to occur than coordinating bids.

Another policy implication of my work is related to procurement policies. In some countries, the need for a reduction in government expenditure has led to the creation of centralized procurement agencies that award big contracts by aggregating the demand of several public administrations. The centralization could give an incentive for multimarket firms to refrain from bidding in one auction, expecting the other firm to do the same in another auction. The implementation of market sharing agreements between firms becomes thus more likely. This point has also been raised in a recent paper by Atella and Decarolis (2019) in the context of multi-lot auctions for the procurement of medical devices.

A sudden switch from collusion to competition could potentially worsen the *ex post* procurement performance. After colluding firms stop coordinating, they may compete head-to-head to a larger extent and submit more aggressive bids at the time of the awarding of the contract. Yet when executing the project, they may incur cost overruns. These cost overruns increase the final procurement costs compared to the procurement costs forecast at the time of the signing of the contract. This pattern is not, however, observed in the data, reinforcing the assertion that stimulating competition through encouraging bidder participation provides a tool to achieve not only a better *ex ante*, but also a better *ex post* procurement performance.

This study comes with some caveats. First, the unavailability of precise estimated values of the contracts could partially bias the estimates of the difference-in-difference design for bids, although my results are robust to a different specification for the bids, as shown in Table B.1 in Appendix B.1. Second, the relatively short sample period of a few years makes it challenging to disentangle whether the geographic separation of asphalt plants observed in some administrative regions of Quebec for the two suspected firms could be associated with collusion rather than simple geographic differentiation. Although not directly identifiable as collusion because of the unavailability of additional years of data, such geographic differentiation does help multimarket firms to mitigate losses from the collapse of a cartel, as shown in other studies (Chilet, 2018).

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# Appendix A
# Additional tables and figures

## A.1 Other firms in the cartel?

The Canadian Competition Bureau is currently investigating 16 firms other than firms A and B. They are typically smaller firms.

Table A.1: Summary statistics for suspected firms other than firms A and B

| | Pre (2007-2009) | Post (2010-2015) |
|---|---|---|
| Number of bids per contract | 0.86 | 0.82 |
| Number of bids per contract (contracts with at least one cartel bid) | 0.89 | 0.81 |
| Average bid (% value) | 85.21 | 74.99 |
| Average bid (% value, contracts with at least one cartel bid) | 82.88 | 74.38 |

Notes: *Pre (2007-2009)* refers to the period before the start of the police investigations. *Post (2010-2015)* refers to the period after the start of the police investigations. *Number of bids per contract* is the average number of bids of the suspected firms other than firms A and B out of total contracts. *Number of bids per contract (contracts with at least one cartel bid)* is the average number of bids of the suspected firms other than firms A and B in contracts that received at least one bid from either firm A or firm B. *Average bid (% value)* is the average bid expressed in % of the mean value of the contract submitted by suspected firms other than firms A and B. *Average bid (% value, contracts with at least one cartel bid)* is the average bid expressed in % of the mean value of the contract submitted by the suspected firms other than firms A and B in those contracts that receive at least one cartel bid.

In Table A.2, I estimate a difference-in-difference by considering the suspected firms as the treated group and all other bidders in the control group. Firms A and B are excluded from the sample. While we observe a significant change in the average bid, the change in the winning bids is not significant.

Table A.2: Diff-in-diff for bids over mean value of contract (%). Sample restricted to other 16 suspected firms. Firms A and B are excluded.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| Suspects×Post | -8.042* | -8.872** | -4.124 | -7.671 |
| | (4.300) | (4.026) | (7.606) | (7.891) |
| Suspects | 2.258 | 3.414 | 3.154 | 4.829 |
| | (3.718) | (3.545) | (6.786) | (7.579) |
| Post | -2.179 | 5.807 | -5.046 | 8.330 |
| | (4.156) | (9.039) | (4.176) | (11.61) |
| Distance (km) | | 0.0332 | | 0.0662* |
| | | (0.0200) | | (0.0372) |
| Capacity (%) | | 0.0358 | | 0.0241 |
| | | (0.0430) | | (0.0883) |
| Value firm region (%) | | -0.173* | | -0.00996 |
| | | (0.0896) | | (0.175) |
| Demand (%) | | 0.0957** | | 0.00147 |
| | | (0.0445) | | (0.0547) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 1,362 | 1,362 | 388 | 388 |
| R-squared | 0.0129 | 0.0503 | 0.0115 | 0.0631 |
| Average Outcome Pre | 83.95 | 83.95 | 83.95 | 83.95 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether the auction $a$ is published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

## A.2 Territorial allocation

Coordinating head-to-head competition in the period before the start of the police investigation in the treated group of auctions includes two types of effects: i) colluding firms divide territories amongst themselves, and ii) colluding firms alternate their participation in territories where they are both "active" bidders. To find evidence of i), I examine the participation behavior in an MRC. In particular, I look at those MRCs where in the pre-investigation period only one of the two cartel firms bid. The outcome I consider is the number of cartel bids in an auction.

Table A.3 reports the statistics for the treated and control groups. By construction, in the treated and control groups, the average number of cartel bids is less than 1 in the pre-investigation period. In the treated group of auctions, there has been a 37% increase in the average number of cartel bids in the post-investigation period.

Table A.3: Number of cartel bids in an auction. Only MRCs with only one cartel firm actively bidding in the pre-investigation period are considered.

| | Pre | Post | Post-Pre |
|---|---|---|---|
| TreatedAuction=1 | 0.907 | 1.240 | 0.333 |
| TreatedAuction=0 | 0.849 | 0.833 | -0.016 |
| Post-Pre | 0.058 | 0.407 | 0.349 |

As in the previous subsection, I investigate whether these results are robust with the inclusion of other contract characteristics. The econometric specification is the following:

$$Y_a = \beta_0 + \beta_1 TreatedAuction_a \times Post_a + \beta_2 TreatedAuction_a + \beta_3 Post_a + \beta_4 Z_a + \epsilon_a \quad \text{(A.11)}$$

where $Y_a$ is now the number of cartel bids in auction $a$. The variable *TreatedAuction* is equal to 1 if the cartel firms are located within a 100 km radius around the project, 0 otherwise. The variable *Post* indicates if the auction was published after October 2009 and $Z_a$ represents auction characteristics as above. The interest relies on the coefficient $\beta_1$.

Table A.4 reports the results. The increase in the number of cartel bids in the treated with respect to the control group of auctions is about 0.35 in a model that does not account for contract characteristics (column 1). The inclusion of all contract characteristics does not change the results. The observed increase in the number of cartel bids in the treated group represents an increase by about 35% of the average number of cartel bids in the pre-investigation period in the treated group.

Table A.4: Diff-in-diff for the number of cartel bids in an auction. Only MRCs where only one of the cartel firms bid are considered.

| | (1) | (2) | (3) |
|---|---|---|---|
| Dep.Variable | nbr.cartel bids | nbr.cartel bids | nbr.cartel bids |
| TreatedAuction×Post | 0.349*** | 0.336*** | 0.315** |
| | (0.105) | (0.105) | (0.137) |
| TreatedAuction | 0.0579 | 0.00132 | -0.228* |
| | (0.0637) | (0.0782) | (0.119) |
| Post | -0.0157 | -0.0366 | -0.155 |
| | (0.0945) | (0.0923) | (0.194) |
| N potential cartel bidders | | 0.223*** | 0.156** |
| | | (0.0577) | (0.0714) |
| N potential non-cartel bidders | | -0.0208 | -0.0107 |
| | | (0.0173) | (0.0251) |
| Free capacity of cartel firms (%) | | -0.000172 | 0.000259 |
| | | (0.00126) | (0.00117) |
| Demand (%) | | -0.000772 | -0.000515 |
| | | (0.00148) | (0.00149) |
| Admin Region effects | No | No | Yes |
| Year effects | No | No | Yes |
| Size project effects | No | No | Yes |
| Observations | 345 | 345 | 345 |
| R-squared | 0.127 | 0.166 | 0.374 |
| Average Outcome Treated Pre | 0.907 | 0.907 | 0.907 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *TreatedAuction*Year* represents the interaction between *TreatedAuction* and a linear trend (*Year*). *Post* is a dummy equal to 1 if the contract was published after October 2009. *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Free capacity of cartel firms (%)* is the highest level of free capacity of cartel firms in a given administrative region and year. *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10%(*), 5% (**), 1%(***) $p < .01$.

## A.3 Test common trend

Figure A.1: Average probability of head-to-head competition by year.

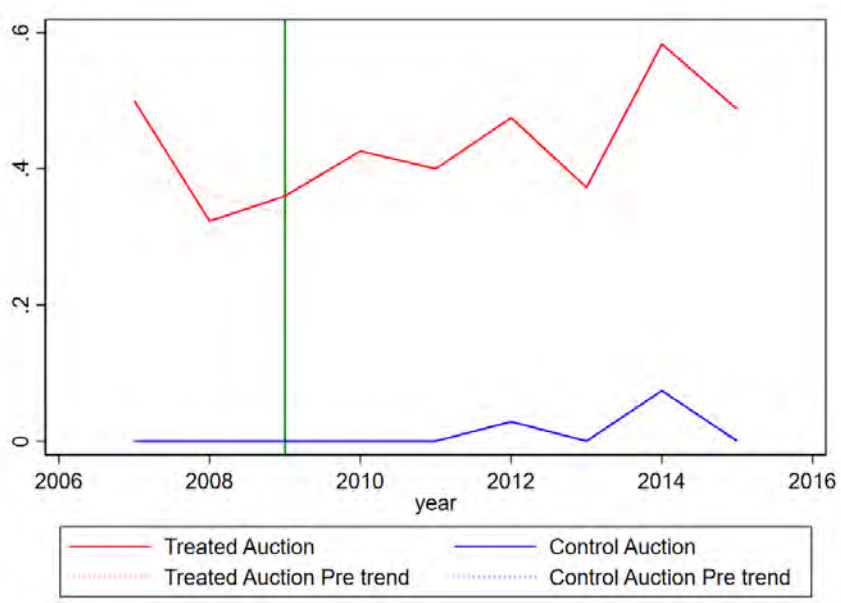


Table A.5: Test of common trend for the probability of head-to-head competition.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | prob.head-to-head | prob.head-to-head | prob.head-to-head | prob.head-to-head |
| TreatedAuction×2008 | | | 0.247** | 0.116 |
| | | | (0.0982) | (0.0865) |
| TreatedAuction×2009 | | | 0.284** | 0.207** |
| | | | (0.126) | (0.0855) |
| TreatedAuction×Year | 0.000176*** | 8.89e-05** | | |
| | (3.16e-05) | (3.77e-05) | | |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Size project effects | No | Yes | No | Yes |
| Observations | 194 | 194 | 194 | 194 |
| R-squared | 0.159 | 0.353 | 0.0950 | 0.354 |
| Average Outcome Treated Pre | 0.354 | 0.354 | 0.354 | 0.354 |
| P-value | | | 0.802 | 0.214 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *TreatedAuction*Year* represents the interaction between *TreatedAuction* and a linear trend (*Year*). *TreatedAuction×2008* represents the interaction between *TreatedAuction* and a dummy equal to 1 if the auction was published in 2008. *TreatedAuction×2009* represents the interaction between *TreatedAuction* and a dummy equal to 1 if the auction was published in 2009. *p-value* is the p-value resulting from testing the equality of coefficients of *TreatedAuction×2008* and *TreatedAuction×2009*. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Figure A.2: Average number of cartel bids (bids of firms A and B) in an auction by year.

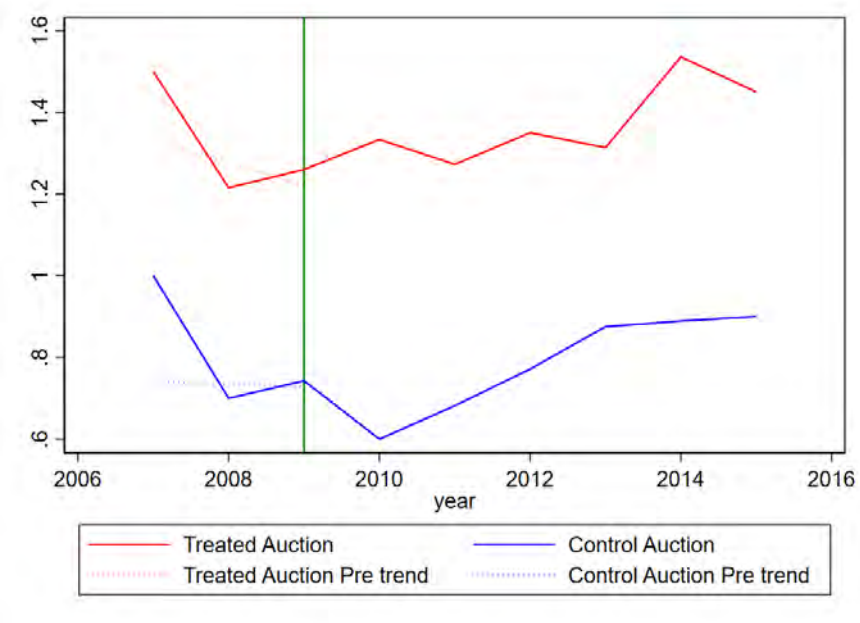


Table A.6: Test of common trend for the number of cartel bids in an auction.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variables | nbr.cartel bids | nbr.cartel bids | nbr.cartel bids | nbr.cartel bids |
| TreatedAuction×2008 | | | 0.367** | 0.667*** |
| | | | (0.168) | (0.169) |
| TreatedAuction×2009 | | | 0.412** | 0.609*** |
| | | | (0.175) | (0.150) |
| TreatedAuction×Year | 0.000263*** | 0.000254*** | | |
| | (5.72e-05) | (7.75e-05) | | |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Size project effects | No | Yes | No | Yes |
| Observations | 194 | 194 | 194 | 194 |
| R-squared | 0.166 | 0.475 | 0.0956 | 0.492 |
| Average Outcome Treated Pre | 1.260 | 1.260 | 1.260 | 1.260 |
| P-value | | | 0.841 | 0.708 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *TreatedAuction*Year* represents the interaction between *TreatedAuction* and a linear trend (*Year*). *TreatedAuction×2008* represents the interaction between *TreatedAuction* and a dummy equal to 1 if the auction was published in 2008. *TreatedAuction×2009* represents the interaction between *TreatedAuction* and a dummy equal to 1 if the auction was published in 2009. *p-value* is the p-value resulting from testing the equality of coefficients of *TreatedAuction*2008* and *TreatedAuction*2009*. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Table A.7: Test common trend for bids over mean value of the contract (%).

| VARIABLES | (1) all bids | (2) all bids | (3) winning bids | (4) winning bids |
|---|---|---|---|---|
| TreatedAuction×Year | 0.00345 | 0.00729* | 0.00259 | 0.00670 |
| | (0.00218) | (0.00386) | (0.00213) | (0.00458) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 589 | 589 | 194 | 194 |
| R-squared | 0.00964 | 0.0716 | 0.00628 | 0.0829 |
| Average Outcome Treated Pre | 86.68 | 86.68 | 83.14 | 83.14 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *TreatedAuction*× *Year* represents the interaction between *TreatedAuction* and a linear trend ( *Year*). Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

## A.4 Other figures

Figure A.3: Map of Canada (left) and of the Canadian province of Quebec (right)

(a) Canada

(b) Quebec

# Appendix B
# Robustness

## B.1 Bids

Table B.1: Diff-in-diff for bids over upper bound of the value of the contract (%).

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -10.38** | -11.82** | -9.030** | -9.975** |
| | (4.240) | (4.669) | (3.977) | (4.446) |
| TreatedAuction | 6.431** | 11.81*** | 5.259 | 10.69*** |
| | (3.161) | (3.825) | (3.234) | (3.880) |
| Post | 1.796 | 7.150 | -1.014 | 5.479 |
| | (3.470) | (6.390) | (2.894) | (5.171) |
| Distance (km) | | 0.0305** | | 0.0382* |
| | | (0.0141) | | (0.0196) |
| Capacity (%) | | 0.00817 | | 0.0256 |
| | | (0.0294) | | (0.0609) |
| Value firm region (%) | | -0.0671 | | -0.0119 |
| | | (0.0450) | | (0.0908) |
| N potential cartel bidders | | -6.225** | | -3.456 |
| | | (2.425) | | (2.103) |
| N potential non-cartel bidders | | 0.312 | | -0.318 |
| | | (0.755) | | (0.671) |
| Demand (%) | | 0.0703* | | 0.0177 |
| | | (0.0369) | | (0.0353) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 2,230 | 2,230 | 751 | 751 |
| R-squared | 0.0166 | 0.0517 | 0.0236 | 0.0540 |
| Average Outcome Treated Pre | 60.66 | 60.66 | 58.56 | 58.56 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether the auction $a$ is published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to the auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Table B.2: Diff-in-diff for bids over mean value of the contract. Auctions with only one bidder are excluded (%)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -13.83** | -14.66** | -10.60* | -11.49* |
| | (5.968) | (6.147) | (5.703) | (5.933) |
| TreatedAuction | 6.715 | 11.87** | 4.586 | 9.965* |
| | (4.502) | (5.247) | (4.507) | (5.274) |
| Post | 2.472 | 10.45 | -2.988 | 5.996 |
| | (5.030) | (8.196) | (4.216) | (6.788) |
| Distance (km) | | 0.0336* | | 0.0291 |
| | | (0.0181) | | (0.0280) |
| Capacity (%) | | 0.0294 | | 0.0447 |
| | | (0.0381) | | (0.0858) |
| Value firm region (%) | | -0.122** | | -0.0499 |
| | | (0.0580) | | (0.136) |
| N potential cartel bidders | | -7.263** | | -4.941* |
| | | (3.096) | | (2.775) |
| N potential non-cartel bidders | | 0.784 | | 0.475 |
| | | (1.005) | | (0.910) |
| Demand (%) | | 0.0847* | | 0.0243 |
| | | (0.0479) | | (0.0475) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 2,130 | 2,130 | 651 | 651 |
| R-squared | 0.0202 | 0.0573 | 0.0327 | 0.0626 |
| Average Outcome Treated Pre | 86.65 | 86.65 | 82.86 | 82.86 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether the auction $a$ is published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to the auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Table B.3: Diff-in-diff for bids over mean value of the contract controlling for realized competition (%)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -13.12** | -13.36** | -11.12** | -10.88* |
| | (5.550) | (6.157) | (5.076) | (5.837) |
| TreatedAuction | 6.923 | 11.21** | 5.205 | 10.99** |
| | (4.334) | (5.050) | (4.227) | (4.995) |
| Post | 1.831 | 9.631 | -1.993 | 7.565 |
| | (4.623) | (7.795) | (3.799) | (6.297) |
| Distance (km) | | 0.0339* | | 0.0307 |
| | | (0.0180) | | (0.0255) |
| Capacity (%) | | 0.0229 | | 0.0294 |
| | | (0.0385) | | (0.0779) |
| Value firm region (%) | | -0.117** | | -0.0255 |
| | | (0.0578) | | (0.117) |
| n cartel bidders | | -3.903* | | -3.567 |
| | | (2.312) | | (2.237) |
| n non-cartel bidders | | -0.0793 | | -1.690 |
| | | (1.568) | | (1.310) |
| Demand (%) | | 0.0852* | | 0.0110 |
| | | (0.0484) | | (0.0470) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 2,230 | 2,230 | 751 | 751 |
| R-squared | 0.0186 | 0.0493 | 0.0267 | 0.0570 |
| Average Outcome Treated Pre | 86.68 | 86.68 | 83.14 | 83.14 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether the auction $a$ is published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to the auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *n cartel bidders* is the number of cartel bidders (firms A and B) bidding in the auction. *n non-cartel bidders* is the number of bidders (other than firms A and B) bidding in the auction. *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Table B.4: Diff-in-diff for bids over mean value of the contract controlling for firm effects (%)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -13.12** | -13.68** | -11.12** | -11.53* |
| | (5.550) | (6.097) | (5.076) | (6.401) |
| TreatedAuction | 6.923 | 13.32** | 5.205 | 11.07* |
| | (4.334) | (5.319) | (4.227) | (6.124) |
| Post | 1.831 | 10.81 | -1.993 | 6.243 |
| | (4.623) | (7.964) | (3.799) | (7.452) |
| Distance (km) | | 0.0344 | | 0.0485 |
| | | (0.0212) | | (0.0350) |
| Capacity (%) | | 0.0136 | | -0.00840 |
| | | (0.0376) | | (0.0828) |
| Value firm region (%) | | -0.0466 | | 0.0267 |
| | | (0.0592) | | (0.128) |
| N potential cartel bidders | | -7.137** | | -2.025 |
| | | (3.096) | | (3.378) |
| N potential non-cartel bidders | | 0.550 | | -0.710 |
| | | (0.989) | | (0.904) |
| Demand (%) | | 0.0771 | | 0.0308 |
| | | (0.0484) | | (0.0513) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Firm effects | No | Yes | No | Yes |
| Observations | 2,230 | 2,230 | 751 | 751 |
| R-squared | 0.0186 | 0.0900 | 0.0267 | 0.117 |
| Average Outcome Treated Pre | 86.68 | 86.68 | 83.14 | 83.14 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether the auction $a$ was published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to the auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Table B.5: Diff-in-diff for bids over mean value of the contract (%). Treatment sample only includes auctions where firms A and B compete head-to-head.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -16.15** | -20.22** | -14.89** | -15.70** |
| | (7.375) | (8.822) | (6.623) | (7.773) |
| TreatedAuction | 7.612 | 14.79 | 6.626 | 10.25 |
| | (6.135) | (9.686) | (5.722) | (8.460) |
| Post | 1.831 | 13.74 | -1.993 | 10.90 |
| | (4.628) | (9.397) | (3.806) | (7.933) |
| Distance (km) | | 0.0207 | | -0.0153 |
| | | (0.0199) | | (0.0373) |
| Capacity (%) | | 0.0422 | | -0.0624 |
| | | (0.0563) | | (0.114) |
| Value firm region (%) | | -0.153* | | 0.0423 |
| | | (0.0841) | | (0.157) |
| N potential cartel bidders | | -5.513 | | -3.163 |
| | | (4.134) | | (4.261) |
| N potential non-cartel bidders | | 0.102 | | -1.007 |
| | | (1.270) | | (1.154) |
| Demand (%) | | 0.115* | | 0.102 |
| | | (0.0659) | | (0.0668) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 1,388 | 1,388 | 476 | 476 |
| R-squared | 0.0230 | 0.0680 | 0.0303 | 0.0707 |
| Average Outcome Treated Pre | 87.37 | 87.37 | 84.56 | 84.56 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether auction $a$ was published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over the total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Table B.6: Diff-in-diff for bids over mean value of the contract (%). Treatment sample only includes bids of firms A and B when they compete head-to-head.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -17.47** | -20.26** | -18.82*** | -19.53** |
| | (7.015) | (8.456) | (7.013) | (8.617) |
| TreatedAuction | 9.111 | 14.56 | 13.20** | 19.16* |
| | (5.724) | (9.011) | (5.949) | (10.19) |
| Post | 1.831 | 18.93** | -1.993 | 9.679 |
| | (4.630) | (9.382) | (3.810) | (11.92) |
| Distance (km) | | 0.0172 | | -0.0240 |
| | | (0.0220) | | (0.0396) |
| Capacity (%) | | 0.0505 | | -0.0697 |
| | | (0.0628) | | (0.139) |
| Value firm region (%) | | -0.129 | | 0.0832 |
| | | (0.0837) | | (0.172) |
| N potential cartel bidders | | -4.670 | | -1.226 |
| | | (4.139) | | (4.570) |
| N potential non-cartel bidders | | -0.251 | | -1.894 |
| | | (1.232) | | (1.333) |
| Demand (%) | | 0.0815 | | 0.0815 |
| | | (0.0588) | | (0.0806) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 1,011 | 1,011 | 386 | 386 |
| R-squared | 0.0209 | 0.0729 | 0.0275 | 0.0909 |
| Average Outcome Treated Pre | 88.87 | 88.87 | 91.13 | 91.13 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether auction $a$ was published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over the total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

## B.2 Different clustering of the standard errors

Table B.7: Diff-in-diff for the number of cartel bids in an auction and probability of head-to-head competition. Standard errors clustered by administrative region in parentheses.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | prob.head-to-head | prob.head-to-head | nbr.cartel bids | nbr.cartel bids |
| TreatedAuction×Post | 0.0999 | 0.222*** | 0.0847 | 0.231* |
| | (0.0647) | (0.0365) | (0.124) | (0.119) |
| TreatedAuction | 0.354*** | -0.0377 | 0.528*** | -0.0169 |
| | (0.0831) | (0.0475) | (0.147) | (0.184) |
| Post | 0.0155* | -0.0222 | 0.0510 | -0.0585 |
| | (0.00783) | (0.0905) | (0.0919) | (0.144) |
| N potential cartel bidders | | 0.0970*** | | 0.262*** |
| | | (0.0305) | | (0.0779) |
| N potential non-cartel bidders | | -0.00556 | | -0.0302* |
| | | (0.00980) | | (0.0153) |
| Free capacity of cartel firms (%) | | -0.000164 | | -0.000573 |
| | | (0.000260) | | (0.00106) |
| Demand (%) | | -0.000403 | | -0.00114 |
| | | (0.000379) | | (0.00110) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Size project effects | No | Yes | No | Yes |
| Observations | 751 | 751 | 751 | 751 |
| R-squared | 0.209 | 0.479 | 0.202 | 0.494 |
| Average Outcome Treated Pre | 0.354 | 0.354 | 1.260 | 1.260 |

Notes: Standard errors clustered by Quebec administrative region in parentheses. *nbr cartel bids* indicates the number of cartel bids in an auction. *prob head-to-head* is a binary variable indicating whether both cartel firms (firms A and B) bid in the auction. *Post* is a dummy equal to 1 if the contract was published after October 2009. *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Free capacity of cartel firms (%)* is the highest level of free capacity (%) of cartel firms in a given administrative region and year. *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), at the 5% (**), and at the 1% (***).

Table B.8: Diff-in-diff for bids over mean value of the contract (%). Standard errors clustered by administrative region in parentheses.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -13.12** | -14.77** | -11.12** | -12.93** |
| | (5.379) | (5.425) | (4.839) | (4.946) |
| TreatedAuction | 6.923* | 12.81** | 5.205 | 12.41** |
| | (3.314) | (4.825) | (4.215) | (5.356) |
| Post | 1.831 | 11.07* | -1.993 | 9.116* |
| | (2.810) | (6.134) | (2.309) | (4.777) |
| Distance (km) | | 0.0364* | | 0.0356 |
| | | (0.0179) | | (0.0285) |
| Capacity (%) | | 0.0237 | | 0.0196 |
| | | (0.0369) | | (0.0855) |
| Value firm region (%) | | -0.110 | | 0.00534 |
| | | (0.0636) | | (0.127) |
| N potential cartel bidders | | -6.713* | | -3.924 |
| | | (3.761) | | (2.949) |
| N potential non-cartel bidders | | 0.543 | | -0.306 |
| | | (1.331) | | (1.081) |
| Demand (%) | | 0.0818** | | 0.0151 |
| | | (0.0348) | | (0.0472) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 2,230 | 2,230 | 751 | 751 |
| R-squared | 0.0186 | 0.0522 | 0.0267 | 0.0554 |
| Average Outcome Treated Pre | 86.68 | 86.68 | 83.14 | 83.14 |

Notes: Standard errors clustered by Quebec administrative region in parentheses. *Post* indicates whether the auction $a$ was published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to the auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

## B.3 Identification strategy

- Both cartel firms are closer to the project than the furthest potential participant in the auction, and both are within a 90 km radius of the project location.

Table B.9: Diff-in-diff for the number of cartel bids in an auction and probability of head-to-head competition

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | prob.head-to-head | prob.head-to-head | nbr.cartel bids | nbr.cartel bids |
| TreatedAuction×Post | 0.117 | 0.236*** | 0.0675 | 0.218* |
| | (0.0817) | (0.0573) | (0.148) | (0.130) |
| TreatedAuction | 0.369*** | -0.00612 | 0.587*** | 0.0705 |
| | (0.0634) | (0.0570) | (0.129) | (0.130) |
| Post | 0.0140 | -0.0292 | 0.0731 | -0.0514 |
| | (0.00994) | (0.110) | (0.106) | (0.164) |
| N potential cartel bidders | | 0.0917*** | | 0.252*** |
| | | (0.0276) | | (0.0552) |
| N potential non-cartel bidders | | -0.00407 | | -0.0268 |
| | | (0.00975) | | (0.0171) |
| Free capacity of cartel firms (%) | | -0.000117 | | -0.000450 |
| | | (0.000423) | | (0.000792) |
| Demand (%) | | -0.000369 | | -0.00103 |
| | | (0.000517) | | (0.000990) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Size project effects | No | Yes | No | Yes |
| Observations | 751 | 751 | 751 | 751 |
| R-squared | 0.247 | 0.487 | 0.243 | 0.502 |
| Average Outcome Treated Pre | 0.369 | 0.369 | 1.295 | 1.295 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *nbr cartel bids* indicates the number of cartel bids in an auction. *prob head-to-head* is a binary variable indicating whether both cartel firms (firms A and B) bid in the auction. *Post* is a dummy equal to 1 if the contract was published after October 2009. *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Free capacity of cartel firms (%)* is the highest level of free capacity (%) of cartel firms in a given administrative region and year. *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

Table B.10: Diff-in-diff for bids over mean value of the contract (%)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -9.554* | -11.10* | -8.833* | -9.848* |
| | (5.574) | (6.007) | (5.090) | (5.565) |
| TreatedAuction | 2.820 | 7.039 | 2.090 | 7.071 |
| | (4.485) | (5.267) | (4.329) | (4.991) |
| Post | -0.866 | 8.414 | -3.810 | 6.453 |
| | (4.481) | (8.456) | (3.644) | (6.786) |
| Distance (km) | | 0.0358** | | 0.0357 |
| | | (0.0176) | | (0.0249) |
| Capacity (%) | | 0.0275 | | 0.0244 |
| | | (0.0383) | | (0.0754) |
| Value firm region (%) | | -0.117** | | -0.00643 |
| | | (0.0565) | | (0.111) |
| N potential cartel bidders | | -6.145** | | -3.341 |
| | | (3.020) | | (2.620) |
| N potential non-cartel bidders | | 0.424 | | -0.421 |
| | | (0.984) | | (0.848) |
| Demand (%) | | 0.0839* | | 0.0165 |
| | | (0.0468) | | (0.0463) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 2,230 | 2,230 | 751 | 751 |
| R-squared | 0.0179 | 0.0488 | 0.0276 | 0.0519 |
| Average Outcome Treated Pre | 85.47 | 85.47 | 82.12 | 82.12 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether the auction $a$ was published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to the auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), 1% (***) $p < .01$.

- Both cartel firms are closer to the project than the furthest potential participant in the auction, and both are within a 110 km radius of the project location.

Table B.11: Diff-in-diff for the number of cartel bids in an auction and probability of head-to-head competition

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep.Variable | prob.head-to-head | prob.head-to-head | nbr.cartel bids | nbr.cartel bids |
| TreatedAuction×Post | 0.108 | 0.190*** | 0.156 | 0.241** |
| | (0.0802) | (0.0461) | (0.138) | (0.120) |
| TreatedAuction | 0.324*** | -0.0651 | 0.412*** | -0.158 |
| | (0.0622) | (0.0416) | (0.113) | (0.116) |
| Post | 0.0118 | 0.00766 | 0.00516 | -0.0524 |
| | (0.00822) | (0.109) | (0.0887) | (0.160) |
| N potential cartel bidders | | 0.104*** | | 0.282*** |
| | | (0.0283) | | (0.0554) |
| N potential non-cartel bidders | | -0.00778 | | -0.0350** |
| | | (0.00987) | | (0.0173) |
| Free capacity of cartel firms (%) | | -0.000165 | | -0.000656 |
| | | (0.000427) | | (0.000810) |
| Demand (%) | | -0.000389 | | -0.00118 |
| | | (0.000520) | | (0.00102) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Size project effects | No | Yes | No | Yes |
| Observations | 751 | 751 | 751 | 751 |
| R-squared | 0.174 | 0.471 | 0.153 | 0.488 |
| Average Outcome Treated Pre | 0.324 | 0.324 | 1.194 | 1.194 |

Notes: Standard errors clustered by Quebec administrative region and year in parentheses. *nbr cartel bids* indicates the number of cartel bids in an auction. *prob head-to-head* is a binary variable indicating whether both cartel firms (firms A and B) bid in the auction. *Post* is a dummy equal to 1 if the contract is published after October 2009. *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Free capacity of cartel firms (%)* is the highest level of free capacity (%) of cartel firms in a given administrative region and year. *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10% (*), 5% (**), and 1% (***) $p < .01$.

Table B.12: Diff-in-diff for bids over mean value of the contract (%)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep. Variable | all bids | all bids | winning bids | winning bids |
| TreatedAuction×Post | -11.73* | -12.39* | -11.10* | -12.51* |
| | (6.665) | (7.126) | (6.260) | (6.893) |
| TreatedAuction | 4.387 | 7.800 | 3.997 | 9.069 |
| | (5.710) | (6.732) | (5.577) | (6.663) |
| Post | 1.397 | 9.885 | -1.455 | 9.343 |
| | (5.659) | (8.809) | (4.948) | (7.292) |
| Distance (km) | | 0.0365** | | 0.0354 |
| | | (0.0173) | | (0.0250) |
| Capacity (%) | | 0.0293 | | 0.0332 |
| | | (0.0380) | | (0.0756) |
| Value firm region (%) | | -0.119** | | -0.0137 |
| | | (0.0559) | | (0.111) |
| N potential cartel bidders | | -5.932* | | -3.308 |
| | | (3.046) | | (2.726) |
| N potential non-cartel bidders | | 0.383 | | -0.440 |
| | | (0.956) | | (0.822) |
| Demand (%) | | 0.0831* | | 0.0127 |
| | | (0.0465) | | (0.0456) |
| Admin Region effects | No | Yes | No | Yes |
| Year effects | No | Yes | No | Yes |
| Observations | 2,230 | 2,230 | 751 | 751 |
| R-squared | 0.0184 | 0.0493 | 0.0281 | 0.0538 |
| Average Outcome Treated Pre | 85.66 | 85.66 | 82.47 | 82.47 |

Notes. Standard errors clustered by Quebec administrative region and year in parentheses. *Post* indicates whether the auction $a$ is published after October 2009. *Distance (km)* is the driving distance between the project location and the firm's closest plant to the project. *Capacity (%)* is the percentage of total value of contracts won up to the auction $a$ over total value of contracts won in a given administrative region and year. *Value firm region (%)* is the total value of contracts won by the bidder up to auction $a$ over total value of contracts awarded in a given administrative region and year (in percentage). *N potential cartel bidders* is the number of cartel bidders (firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *N potential non-cartel bidders* is the number of bidders (other than firms A and B) bidding in at least one auction in a given MRC (*municipalité régionale de comté*). *Demand (%)* is the total value of contracts awarded up to auction $a$ as % of the total value of the contracts awarded in a given administrative region of Quebec and year. Significance at 10%(*), 5% (**), 1%(***) $p < .01$.

# Appendix C
# Data

## C.1 Dataset

Two sources were used to construct the dataset: the official tendering website of the Quebec government (SEAO) and data from the open data portal of the Quebec government.

On the tendering website, I open "Advanced search" to look for contract between 2007 and 2015 with the code identifying paving job (72131701). The name of the public buyer is *Ministère des Transports du Quèbec* and I choose contracts awarded and concluded. Then, I scrape these contracts.

I use the open dataset to obtain information on whether the job is focused mainly on paving. If not, the contract is eliminated from the dataset.

## C.2 Data cleaning

**Distance variable**: This variable represents the distance between the location of the project and the closest asphalt plant of each firm to the project. The location of the project is the first location announced in the contract. The location of the plant is found on the map given by the Ministry of Transport. From the addresses, I then construct a Python script that uses Google API to transform the addresses into coordinates (latitude and longitude). Then, using the STATA command globdist and georoute (georoute requires opening a HERE account), I find the shortest distance, the driving distance, and the time distance from the project.

## C.3 Definition of the variables used in the dataset

Table C.1: Definition of the main variables used in the dataset

| **Main outcomes** | | |
|---|---|---|
| **Variable** | **Definition** | **Notes** |
| Number of cartel bids | Number of cartel bids in an auction | Auction-level variable |
| Head-to-head competition | Probability that firms A and B bid in the same auction | Auction-level binary variable |
| Bid | Bid expressed as % of the mean value of the contract | Bidder and auction-level variable |
| **Bidder characteristics** | | |
| Capacity (%) | Total value of contracts won in a given administrative region and year up to auction $a$ as % of the total value of contracts won in a given administrative region and year | The value is the amount for which the contracts are signed. Bidder-auction specific |
| Value firm region (%) | Total value of contracts won in a given administrative region and year up to auction $a$ as % of the total amount of contracts awarded in a given administrative region and year | The value is the amount for which the contracts are signed. Bidder-auction specific |
| Distance (km) | Driving distance in km from the closest asphalt plant of the firm to the paving project location | STATA command georoute. For paving project location I use the first location in the call for tender. Bidder-auction specific |
| **Auction characteristics** | | |
| Treatment | Equal to 1 if both cartels are closer to the project than the furthest potential participant in the auction and both are within 100km of the auction | Auction-level binary variable |
| Post | Equal to 1 if the auction was published after 23rd October 2009 | Auction-level binary variable |
| n cartel bidders | Number of actual cartel bidders (firms A and B) | Auction specific variable |
| n non-cartel bidders | Number of actual non cartel bidders (different from firms A and B) | Auction specific variable |
| N potential cartel bidders | Number of potential cartel bidders (firms A and B). A firm is a potential bidder if it bids at least once in a given MRC | For a given MRC, there is one value of this variable |
| N potential non-cartel bidders | Number of potential bidders different from firms A and B. A firm is a potential bidder if it bids at least once in a given MRC. | For a given MRC, there is one value of this variable |
| Demand (%) | Total value of contracts awarded up to auction $a$ as % of the total value of contracts awarded in a given administrative region and year | The value of the contract is the amount for which the contracts are signed |
| Administrative region effects | Dummies for administrative region of location of the paving project | |
| Year effects | Dummies for year | |
| Size project effects | Dummies for project size | I use the upper bound of the value of the contract |

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