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DISCUSSION PAPER

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# Complementary Bidding and the Collusive Arrangement: Evidence from an Antitrust Investigation

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# Complementary bidding and the collusive arrangement: Evidence from an antitrust investigation*

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**Abstract**

Tied bids attract antitrust scrutiny and so cartel members may leave a gap between the winning bid and other bids. The gap cannot be too large though, since then the winner could increase its bid and profits. We present causal empirical evidence from a procurement cartel that bidding involves both clustering and a gap around the winning bid. We support these results with information from testimony of cartel participants that explain how both patterns arise naturally as part of an arrangement featuring complementary bidding. Based on these findings, we develop an easy-to-implement screen for collusive arrangements featuring complementary bidding.

**JEL codes**: L22, L74, D44, H57

**Keywords**: Auction; Bidding ring; Collusion; Complementary bidding; Clustered bids; Missing bids; Public procurement

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# 1 Introduction

Collusion involves groups of firms that explicitly agree on coordinating prices, thereby earning higher profits at the expense of consumers. This behaviour led former EU commissioner Mario Monti to describe cartels as "cancers on the open market economy."[1] Since a sizeable share of investigated cartels arise in public procurement auctions and since procurement represents an important component of total general government expenditures (on average 30% in OECD countries in 2015, OECD, 2017), bidding rings impose a significant cost on taxpayers. Understanding the functioning of bidding rings and identifying patterns and behaviour associated with them is therefore of importance for antitrust authorities. Many authorities have started to take into consideration behaviours linked with collusion to guide their searches for suspicious bidding patterns. For example, instances of high correlation in the residuals of the bidding function (Bajari and Ye, 2003) and low bid variance across auctions (Froeb et al., 1993; Harrington, 2008; Abrantes-Metz et al., 2006) are thought to imply coordinated efforts of industry participants and are being used to provide guidance about which markets antitrust authorities should target for investigation with their limited resources.

Clustering of bids within auctions, especially of the two lowest bids, has also been suggested as indicative of collusion.[2] More precisely, tied or almost tied bids are thought to be collusive markers. As pointed out in McAffee and McMillan (1992) when cartel members are unable to make cash transfers, they can submit identical bids and use the seller as their randomization device to determine allocation. Chassang and Ortner (2019) remark that almost tied bids arise since an optimal collusion scheme is equivalent to a bidding game in a complete information setting.

In the presence of antitrust oversight, cartel members may try to avoid submitting tied bids by ensuring that a gap is left between the winning bid and all other losing bids. Such behaviour has been documented in cartels operating in Switzerland, where large gaps were left between winning and losing bids (see Imhof et al., 2018). However, the gap cannot not be too large, since this would imply that the designated winner could have increased its bid and therefore its profits (Ortner et al., 2020 and Chassang et al., 2020).

In this paper, we present causal empirical evidence from an actual procurement cartel that bidding involves a high degree of clustering, but also a gap around the winning bid. We support these results with information from testimony of alleged participants in the cartels that explain how both patterns arise naturally together as part of a cartel arrangement featuring complementary bidding. Finally, based on these findings, we develop a simple and easy-to-implement screen for a collusive arrangement featuring complementary bidding.

[1] See press release on the website of the European Commission: Speech/00/295.

[2] See for instance Porter and Zona (1993), Marshall and Marx (2007), and Harrington (2008), and also Feinstein et al. (1985), LaCasse (1995), and Ishii (2009).

Our study is centered on the construction industry in Montreal, where the existence of cartels in some sectors was discovered in October 2009, following an investigation by a news show, *Enquête*, that shed light on collusive practices in this industry, namely bid-rigging, complementary bidding, and market-sharing agreements. Immediately after the show, the Quebec government launched a police investigation called *Opération Marteau* and then a formal inquiry, known as the Charbonneau Commission, in order to verify the reported allegations.[3]

Our empirical analysis examines bidding data from calls for tender in Montreal's asphalt industry, one of the industries suspected of being collusive. We study the distribution of bid differences (the difference between a given bid and the next most competitive bid), which capture bidders' margins of victory or defeat. Bid differences are negative when the bidder won the auction, and positive otherwise. We start by calculating bid differences during the infringement period and find a low mass at zero and a significant mass of bid differences just to the right and left of zero, suggesting the existence of isolated winning bids and bid clustering. Together these two forces generate what appear to be twin peaks centered around zero in the distribution of bid differences.

To provide causal evidence that clustering and isolated winning bids were part of the collusive arrangement, we adopt a difference-in-difference approach in which we compare the extent of winning-bid isolation and clustering in Montreal's asphalt industry before and after the police investigation to patterns over the same time span in Quebec City, whose asphalt industry has not been the subject of collusion allegations. More specifically we use distributional regression techniques (see Fortin et al., 2021, and Chernozhukov et al., 2013) to compare the distribution of bid differences in Montreal and Quebec City before and after the investigation. Our findings provide causal evidence that the collusive arrangement featured isolated winning bids and clustering. The pattern of isolated winning bids and bid clustering (the twin peaks in the distribution of bid differences) observed during the infringement period disappears in Montreal after the start of the police investigation and is much less pronounced in Quebec City.

Interviews from the news program and testimony from the Commission help us to understand how these bid patterns are associated with a collusive scheme. The cartel arrangement involved market segmentation and complementary bidding. Representatives from each of the cartel firms would get together to decide which of them would be assigned a given contract as a function on the firms' production capacities and their plant locations. The designated winner would then organize the bidding for the contract by contacting

[3]**Legal disclaimer:** This paper analyses the alleged cartel case strictly from an economic point of view. We base our understanding of the facts mostly on data obtained from the municipal clerk's office through access to information requests, through transcripts of testimony from the Charbonneau Commission, and the testimony presented in the *Enquête* broadcast. The investigation into, and prosecution of, firms involved in the alleged conspiracy is ongoing. The allegations have not been proven in a court of justice. However, for the purpose of this analysis, we take these facts as established.

the other cartel members and giving instructions on complementary bidding.[4] According to the Enquête news program, complementary bids were submitted in order to provide the appearance of competition. Using coded language to avoid detection, the designated winner would provide guidance as to what should be the complementary bids. The winner would then have incentive to bid just below the lowest bid leaving only a small margin between the assigned lowest losing bid and its bid to avoid detection and in case there were any errors during the bid submission process.

This testimonial evidence is consistent with cartel behaviour described in Chassang et al. (2020) and in Ortner et al. (2020). They find isolated winning bids in their sample of Japanese procurement auctions, but they also point out that bids are somewhat clustered with a large mass of bids within 2% of the winning bid. They explain that firms instructed to provide complementary losing bids should be incentivized not to undercut the designated winner, and that losing bidders should bid just above the designated winner so that the latter has no incentive to raise its bid. This leads to clustering of bids. Regarding isolated bids, the authors propose two possible collusive explanations. First, if the possibility of antitrust scrutiny is added to the framework just described, and if highly clustered (and, in particular, identical) bids attract antitrust scrutiny, then the cartel could want to ensure that identical or nearly-identical bids are not submitted. Second, isolated winning bids may facilitate the assignment of the contract to the designated winner, thereby improving allocative efficiency. They point out that isolation of winning bids can guarantee that the designated winner comes away with the contract in cases where precise bids cannot be assigned to losers and/or if bids can be perturbed by small trembles. Our empirical findings can be viewed as providing causal and testimonial evidence in support of these arguments.

It is also related to the model proposed in LaCasse (1995). Her's is a model of a first-price sealed-bid auction in which an all-inclusive cartel decides whether to rig bids in the face of antitrust oversight. Firms endogenously choose whether or not to collude, knowing there is some chance their conspiracy will be detected. This knowledge influences the form that the collusive arrangement takes. LaCasse shows that the chosen arrangement has two features that line up with behaviour described in the testimony. First, the frequency of identical bids should be very low, since these identify collusion. Second, losing bids give the appearance of competition, but are derived from a truncated bid distribution, since they must be higher than the designated winning bid. Together these yield the bimodal pattern we observe.

Motivated by our findings, we propose a screen for a collusive arrangement featuring complementary bidding. Note that our results so far were based on a difference-in-differences setup that requires data from one or more control markets and being able to identify the beginning or end of collusive activity. Authorities interested in screening for

[4] See paragraphs 997-1009 ad 1060-1100 of Gilles Théberge's testimony from the Charbonneau Commission, May 23rd 2013, Théberge (2013a).

collusion will not necessarily have access to such data. We therefore propose a screen that is based only on data from the suspect calls for tender, and leverages the fact that losing bids are not informative about the existence of a cartel (see Ortner et al. (2020) and LaCasse (1995)) and can be thought of as being allocated randomly provided they are inferior to the designated winning bid. Based on this intuition, we construct a new set of bid differences, this time excluding the winning bid. The distribution of these bid differences does not feature the twin peaks of the original bid difference distribution (containing winning bids). The screen is based on a distributional regression with an indicator for whether the bid difference is from the original distribution, or the new one with winning bids excluded. The null hypothesis is that the coefficient on this indicator should be zero in a neighborhood around zero. We reject the null when we run our screen on calls for tender from Montreal during the cartel. To evaluate the performance of our screen we repeat the exercise for three other samples: (i) Montreal post, (ii) Quebec pre, and (iii) Quebec post. In each case, there is no reason to suspect that collusion was taking place and so the null should not be rejected. This is the case and so we conclude that our screen is a useful tool for detecting a collusive arrangement featuring complementary bidding.

This paper relates to the literature on the detection of cartels in procurement auctions. In addition to the papers mentioned above see also Porter and Zona (1999), Pesendorfer (2000), Conley and Decarolis (2016), Aryal and Gabrielli (2013), Marmer et al. (2016), Schurter (2017), Chassang and Ortner (2019), Kawai and Nakabayashi (2021), and Kawai et al. (2021). Kawai and Nakabayashi document clustering of the lowest bids and associate this with collusion. However, the setting is different. In their context, auctions involve multiple bidding rounds (re-bidding), and they find that the order of the lowest bids in the first round is maintained even in the second, although the second lowest bidder in the first round lost only marginally. We are the first paper to provide causal and testimonial evidence showing a small degree of isolation of the winning bids as part of a collusive strategy.

This study also relates to the literature on explicit cartels and their functioning.[5] See for instance Roeller and Steen (2006), Asker (2010), Genesove and Mullin (2001), Clark and Houde (2013), Chilet (2018), Igami and Sugaya (2018), and Byrne and deRoos (2019).[6] Relative to these papers, here we provide new evidence on the role of complementary bidding. The Quebec construction cartels were studied by Clark et al. (2018). The focus in that paper is on the entry-deterrence activities of the cartel and not on complementary bidding.

The paper is structured as follows. In the next section we discuss the adjudication process of the contracts, the police investigation and the special Commission appointed

[5]Ross (2004) reviews cartels in Canada.

[6]A separate literature studies tacit coordination. See for instance Slade (1987), Slade (1992), Miller and Weinberg (2017), and Ciliberto and Williams (2014).

by the Quebec government to examine collusion and corruption in Quebec's construction industry. Section 3 presents a framework for understanding how clustering of bids and isolated winning bids could coexist as part of a collusive arrangement. Section 4 describes the data. In Section 5 we present descriptive evidence motivating our empirical analysis, which is laid out in Section 6. Section 7 discusses the small test that we provide. Finally, Section 8 concludes.

# 2 The markets and the investigation

In this section we describe the markets, the adjudication process, the police investigation and the Commission established to learn more about corruption and collusion in the construction industry in Quebec. Further details can be found in Clark et al. (2018).

## 2.1 The markets

The focus of the analysis is on municipal contracts for the procurement of asphalt in Montreal and Quebec City. Montreal is made up of 19 boroughs, while Quebec is composed of six boroughs.[7] When procuring asphalt, each borough in Montreal makes predictions about the amount required for the maintenance of their roads for the coming year. Due to the weather conditions, most contracts are awarded for the spring and summer seasons. There were eleven different asphalt types ordered in Montreal, and slightly fewer in Quebec City. In each of the 19 boroughs of Montreal there can be one auction per asphalt type. So every year there can be up to 209 contracts awarded in Montreal. Submissions are invited for all boroughs requiring asphalt simultaneously. Quebec City operates differently, using a single auction per borough, combining all asphalt types. As a result, there are more calls for tender in Montreal than in Quebec City.

Firms propose bids with two components. First, firms submit a unit price per metric ton for each type of asphalt required. Second, firms submit a bid that matches the total unit price multiplied by the quantity required for each type of asphalt and to this they add their shipping costs and taxes. Auctions are first-price, sealed-bid and single-attribute (cost). This means that the firm offering the lowest bid wins the contract. In our empirical analysis we focus on raw bids without the transportation cost, because during our sample period there were changes to the way transport charges were calculated in Montreal and in Quebec City it is not possible to properly separate out transportation costs. For more details, see Appendix A.1. We also confirm in the Appendix that our results are qualitatively similar if we use instead total bids.

[7] Prior to 2010 Quebec City was composed of eight boroughs. In 2010, the boroughs of Quebec City were amalgamated.

## 2.2 The investigation into collusion

The *Commission of Inquiry on the Awarding and Management of Public Contracts in the Construction Industry* (known as the Charbonneau Commission) was established on October 11th 2011 to investigate allegations of collusion and corruption initially revealed in 2009 by Radio Canada and through the police investigation, Opération Marteau.[8] Testimony heard throughout the Commission substantiated the allegations of collusion in various construction-related industries in and around Montreal, including the asphalt industry in Montreal proper. According to testimony, collusion has existed in and around Montreal and for provincial contracts (with the Ministry of Transport) at least as far back as the 1980's.[9] Contracts involving asphalt, sewers, aqueducts and sidewalks were all affected.[10]

Testimony also revealed that, although less structured collusion had existed as far back as the 1980's, the cartel in Montreal's asphalt market was formed in 2000, by four of the dominant construction firms in Montreal (see Radio Canada (2013)). The firms coordinated (i) the quantity of asphalt to be produced by each member, (ii) the territory of each member, and (iii) the price of raw materials for the production of asphalt. Two other firms were added to the initial four, such that six firms actively participated in the market. All six were involved in the cartel.[11]

The collusive arrangement was characterized by market segmentation, complementary bidding and payoffs to bureaucrats. Prior to the allocation of contracts by the municipalities or the Ministry of Transport conspiring firms would acquire private information about the contracts from officials.[12]

The police task force, Opération Marteau, was launched on October 22nd 2009. The task force comprised 60 members and had support from the Competition Bureau of Canada, the Ministry of Transportation, the Régie du Bâtiment, and the Commission de la construction du Québec. In our empirical analysis we will assume that the police investigation and the Radio Canada news show caused collusive activity to cease and bidding to return to more competitive levels.

[8] The Commission's mandate was to: (i) examine the existence of schemes and, where appropriate, to paint a portrait of activities involving collusion and corruption in the provision and management of public contracts in the construction industry (including private organizations, government enterprises and municipalities) and to include any links with the financing of political parties, (ii) paint a picture of possible organized crime infiltration in the construction industry, and (iii) examine possible solutions and make recommendations establishing measures to identify, reduce and prevent collusion and corruption in awarding and managing public contracts in the construction industry. See https://www.ceic.gouv.qc.ca/la-commission/mandat.html.

[9] See paragraph 1118 of Piero Di Iorio's testimony from the Charbonneau Commission, November 26th 2012, Di Iorio, 2012.

[10] See paragraphs 788, 790, 804, 1038-1042 and 1134 of Gilles Théberge's testimony from the Charbonneau Commission, May 23rd 2013, Théberge (2013a).

[11] See paragraphs 575 and 677-696 of Gilles Théberge's testimony from the Charbonneau Commission, May 23rd 2013, Théberge (2013a).

[12] See paragraphs 684-686 and 724 of Jean Théoret's Testimony from the Charbonneau Commission, November 26th 2012, Théoret (2012).

# 3 Complementary bidding, isolated winning bids and clustered bidding

In this section we describe how isolated winning bids and clustered bidding can be part of a collusive arrangement featuring complementary bidding. As pointed out in Chassang et al. (2020), clustering will occur because firms designated to submit complementary losing bids should bid just above the assigned winner so that the latter has no incentive to raise its bid. The authors propose two potential explanations as to why winning bids might be isolated when collusion is involved. First, if nearly-identical bids attract antitrust scrutiny, then a cartel may want to prevent the submission of clustered bids. Second, isolated winning bids may make it easier to assign the contract to the designated winner and, in so doing, improve allocative efficiency. The authors argue that winning-bid isolation can help to secure the victory of the designated winner when exact bids cannot be assigned to losers and/or if small trembles can perturb bids. In their sample of procurement auctions from Japan, Chassang et al. (2020) find evidence that winning bids are isolated, but that at the same time bids are somewhat clustered with a large mass of bids within 2% of the winning bid.

This is related to the model developed by LaCasse (1995) of collusion in first-price sealed-bid auctions subject to antitrust oversight. Firms can choose whether or not to collude, knowing that the antitrust authority can detect collusive behavior upon investigation. The possibility of antitrust oversight affects the likelihood that collusion arises and the form that it takes. In particular, if identical bids attract antitrust scrutiny, then the cartel will avoid this sort of bidding. LaCasse proposes a bid rotation scheme featuring an incentive-compatible communication mechanism for determining bidding. The mechanism assigns to the designated winner a bid that maximizes expected cartel profits and to other cartel members bids below that level. The designated winner's bid must be close to the second highest bid in order to avoid leaving money on the table. Together these features generate a bimodal distribution of bid differences.

These explanations provide a framework for understanding why bids within an auction can feature both clustering and isolated winning bids. Moreover, they are consistent with testimonial evidence from the Charbonneau Commission and the *Enquête* news report. According to these sources, after having acquired confidential information about the contracts from officials of the municipality, firms' representatives then met to establish the winner of the contract and to settle on complementary bids to be submitted by the designated losers. This decision was based on attributing a certain amount of the overall work to each firm and was a function of location and distance to particular jobs. Trying to understand the arrangement, the president of the Charbonneau Commission interrogated a former high ranking executive at a Montreal construction company, Gilles Theberge, asking:

*Do I understand correctly that it is the location, that it is not only the volume that it is determined for who will supply the City in asphalt, but also the location where the work was to be done?*[13]

To which Gilles Theberge responded in the affirmative, and elaborated:

*We filled the orders as they came, we filled them in groups, we filled that particular order in accordance with a participant that had say 40 000 tons, he was sure to have at least 40 000 tons, another 30 000 tons, another 10 000 tons. So then just based on transportation, we knew roughly how many each would have in volume.*[14]

These sources also make clear that complementary bidding was part of the collusive arrangement. The designated winner was responsible for managing the bids that each of the other firms had to submit in the auction, giving instructions to the other cartel members about the level of their complementary bid:

*Well, one has to enter a complementary bid as well when you want to bid. You cannot just withdraw them for the sake of withdrawing them. At calls for tender, you have to bid, we submit a complementary bid.*[15]

These complementary bids must be different from the winning bid in order to avoid antitrust scrutiny as captured by the following statement from the Report of the anticollusion Unit at the Ministry of Transportation of Quebec (Duschesneau, 2011):

*The following elements might reveal collusion: competitors submit identical offers or the offers increase by constant amount*[16]

Therefore, to mimic a competitive environment and avoid detection, the winner should bid just below the lowest losing bid. This generated clustered bidding:

*Well, the designated winner had to give each the starting number. Well, the bid amount that he had to enter, including taxes.*[17]

Sometimes, worried that their conversations might be overheard, the participants would employ a coded vocabulary when communicating. For instance, the specified winner would

[13] Translated from *Est-ce que je comprends que c'est le lieu où, que c'est non seulement la tonne qui était où s'en était rendu à qui pour fournir la Ville en asphalte, mais aussi le lieu d'où se tenait les travaux?* Paragraph 1084 of Théberge (2013b).

[14] Translated from *On les a remplies comme tel, on les a remplies en groupe, on a rempli cette soumission-là en étant, en étant d'accord avec un participant avait quoi quarante mille (40 000) tonnes, il était sûr d'avoir au moins quarante mille (40 000) tonnes, l'autre trente mille (30 000) tonnes, l'autre dix mille (10 000) tonnes. Ça fait que juste avec les questions de transport, on savait combien à peu près chacun aurait de tonnes.* Paragraph 1081 of Théberge (2013b).

[15] Translated from *Bien il faut rentrer, il faut rentrer une soumission de complaisance aussi quand tu veux soumissionner. Il ne faut pas juste retirer des soumissions pour retirer. Les appels d'offres il faut soumissionner, on remplit une soumission de complaisance.* Paragraph 1075 of Théberge (2013b).

[16] Translated from *Les éléments suivants peuvent révéler de la collusion : - Des concurrents présentent des offres identiques, ou bien les offres de prix des soumissionnaires augmentent par paliers réguliers.*

[17] Translated from *Bien, celui qui était gagnant devait remettre à chacun le départ. Bien, le numéro de la soumission qui devait rentrer, incluant les taxes.* Paragraphs 1139-1140 of Théberge (2013b).

claim to be organizing a round of golf. He would call other firms saying, for example, "we will start from the 4th hole and we will be 9 players." This meant that the complementary bids must be over $4 900 000 (4th = $4 000 000 and 9 players = $900 000). The specified winner would bid just below this threshold (Théberge, 2013b; *Enquête*, Radio Canada, 2009).

Testimony during the Charbonneau Commission also provides evidence of behaviour leading to isolated winning bids. Despite the incentive to bid as close to the next lowest bid as possible, the designated winner would, according to testimony, allow a small margin between the assigned lowest losing bid and its bid to guard against any mistake in the bidding When asked to describe the complementary bidding procedure Gilles Theberge responded:

*It was a custom like this. The others did not report their bids to me, me also I did not tell them my bid. Why should I have told my bid to him? If my bid was $2.310M, I would have told him: listen, you can submit $2.380M. I kept for myself a small margin in case the secretary made a mistake in typing, but never more than that.* (Théberge, 2013b).[18]

The result was a very small gap between the two lowest bids, that is, isolated winning bids.

In Sections 5 and 6 we provide causal evidence that the collusive arrangement involved isolated winning bids and clustered bidding.

# 4 Data

The dataset, described in Clark et al. (2018), consists of borough-level asphalt contracts for Montreal and Quebec City, obtained through access to information requests at the Municipal Clerk's office. The dataset covers procurement auctions from 2007 to 2013 for both cities.[19] The data contain information on all submitted bids (raw bids and transportation charges) and the identity of the winner. Addresses for all asphalt plants in Montreal and Quebec City were also collected from the Quebec Ministry of Transportation, and we gathered addresses of the central point of reception for each neighborhood in the two cities. Together these allow us to determine delivery distances for each tender. Capacity information is also available for Montreal. Finally, we also collected information on the price of crude oil, since this is the main input into the production of asphalt.[20]

[18]Translated from *C'était une coutume comme ça. Les autres ne me le donnaient pas, moi Je ne le donnais pas non plus. Pourquoi Je lui aurais donné mon prix? Lui, si ma soumission était 2,310 M$, Je lui disais, écoute, tu peux rentrer à 2,380 M$. Je me gardais un peu de marge en cas que sa secrétaire fasse une erreur en dactylographiant, mais il n'avait jamais plus que ça.*

[19]Additional information was collected in the Cahiers d'appels d'offres (Call for tender books).

[20]These data are from the website of Natural Resources Canada: http://www.nrcan.gc.ca/energy/crude-petroleum/4541. We take the average of all crude oils listed, and lag one period.

The dataset has information on 662 contracts. The median number of participants is 3 and the mean number of participants is 3.42. The mean winning raw bid is $68.73 per ton with a standard deviation of 10.32. Table 1 presents summary statistics for Montreal and Quebec City.[21] The winning bid in Montreal decreases after the start of the police investigation by $8 per ton, while in Quebec City it increases by $6 per ton. Before the start of the police investigation, there is a remarkable difference in the winning bid between the two municipalities equal to $18 per ton. This difference is equal to $4 per ton between 2010 and 2013. As documented in Clark et al. (2018), part of the cartel scheme in Montreal involved the deterrence of some firms from bidding in auctions. In Montreal, after the police investigation was launched, the number of firms bidding in these contracts increased from 6 to 9. This increase in the number of firms bidding drove the increase in the average number of bidders from 2.6 before the start of the police investigation to 3.6 after. In Quebec City, we observe that the average number of bidders is between 3 and 4 bidders in both periods. The number of firms bidding in at least one auction in Quebec decreased from 7 to 6.

Table 1: Descriptive statistics for Montreal and Quebec City

| Year | $ awarded (millions) | Nbr contracts | | Nbr bidding boroughs | Avg tons of asphalt | Nbr bidding firms | Nbr bids per contract | Avg winning bid ($/ton) |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Montreal** | | | |
| 2007 | 3.1 | 73 | . | 12 | 637 | 6 | 3 | 65 |
| 2008 | 2 | 61 | . | 11 | 443 | 4 | 2.5 | 71 |
| 2009 | 3 | 81 | . | 14 | 392 | 6 | 2.4 | 89 |
| 2010 | 3 | 174 | . | 19 | 244 | 8 | 3.6 | 68 |
| 2011 | 2 | 149 | . | 15 | 189 | 8 | 4.4 | 66 |
| 2012 | 2.6 | 43 | . | 16 | 879 | 8 | 3.7 | 65 |
| 2013 | 3.1 | 35 | . | 16 | 1287 | 7 | 2.9 | 69 |
| | Total | | | | | Average | | |
| 2007-2009 | 8.1 | 215 | . | 12 | 491 | 5.3 | 2.6 | 75 |
| 2010-2013 | 11 | 401 | . | 17 | 650 | 7.8 | 3.6 | 67 |
| | | | | | **Quebec City** | | | |
| 2007 | 1.6 | 7 | . | 7 | 3539 | 6 | 3.6 | 55 |
| 2008 | 1.4 | 7 | . | 7 | 3552 | 6 | 3.6 | 48 |
| 2009 | 2.9 | 8 | . | 8 | 4361 | 7 | 3.9 | 69 |
| 2010 | 2 | 6 | . | 6 | 5243 | 6 | 3.5 | 52 |
| 2011 | 2.9 | 6 | . | 6 | 5562 | 4 | 3.2 | 72 |
| 2012 | 2.6 | 6 | . | 6 | 5435 | 4 | 2.8 | 64 |
| 2013 | 2.6 | 6 | . | 6 | 5358 | 5 | 3.7 | 63 |
| | Total | | | | | Average | | |
| 2007-2009 | 5.9 | 22 | . | 7.3 | 3818 | 6.3 | 3.7 | 57 |
| 2010-2013 | 10 | 24 | . | 6 | 5399 | 4.8 | 3.3 | 63 |

Since we want to focus our analysis on the firms with allegations of collusion in the city of Montreal and given that part of the cartel scheme involved the deterrence of other players from entering the market (Clark et al., 2018), we exclude the firms that entered in the asphalt market in Montreal after the investigation was launched. In particular, to ensure that the entry of new firms does not contaminate the analysis, in our main

[21] Table 1 replicates exactly Table 1 in Clark et al. (2018).

specification we drop auctions in which new entrants participated. By doing so, we analyze only the differences in bids from the six firms suspected of having joined the cartel. There are 269 auctions dropped. Table 2 reports summary statistics for Montreal for the restricted sample (nothing changes in Quebec City). Dropping the auctions without entrants reduces the number of auctions in Montreal after the start of the investigation to 132. The average reduction in the winning bids is also slightly lower, falling from \$8 per ton to \$6 per ton. In the appendix we present results in which we do not drop the entrants and our results are largely unchanged. We also show that results are unchanged if we drop auctions from 2010, which features more contracts than in other years in the full sample with entrants, and

Table 2: Descriptive statistics for Montreal – restricted sample

| Year | \$ awarded (millions) | Nbr contracts | | Nbr bidding boroughs | Avg tons of asphalt | Nbr bidding firms | Nbr bids per contract | Avg winning bid (\$/ton) |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Montreal** | | | |
| 2007 | 3.1 | 73 | . | 12 | 637 | 6 | 3 | 65 |
| 2008 | 2 | 61 | . | 11 | 443 | 4 | 2.5 | 71 |
| 2009 | 3 | 81 | . | 14 | 392 | 6 | 2.4 | 89 |
| 2010 | .39 | 42 | . | 8 | 126 | 5 | 1.9 | 70 |
| 2011 | .48 | 40 | . | 6 | 166 | 5 | 2.6 | 67 |
| 2012 | 1.7 | 28 | . | 10 | 825 | 6 | 3.4 | 67 |
| 2013 | 1 | 22 | . | 10 | 641 | 5 | 2.4 | 71 |
| | Total | | | | | Average | | |
| 2007-2009 | 8.1 | 215 | . | 12 | 491 | 5.3 | 2.6 | 75 |
| 2010-2013 | 3.5 | 132 | . | 8.5 | 440 | 5.3 | 2.6 | 69 |

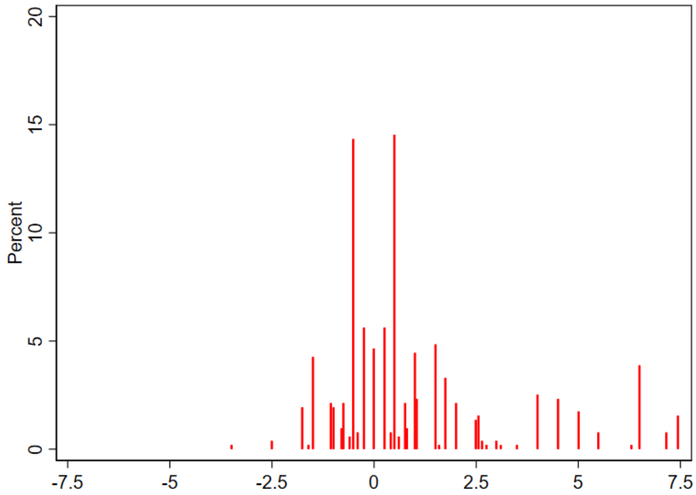
## 5 Motivating facts

Chassang et al. (2020) document *missing bids* around 0 in the distribution of bid differences for public works procurement auctions in Japan. The measure they focus on is the difference between a given bidder's own bid and the most competitive bid in the auction. In particular, they denote the bid for any firm $i$ bidding in auction $a$ is $b_{i,a}$, and by $\wedge \mathbf{b}_{-i,a}$ the minimum bid by $i$'s rivals. Consider, for example, an auction with three bidders. Suppose further that bids submitted by bidders 1, 2, and 3 are, respectively, \$60, \$75, and \$78 per ton. Then the difference between bidder 1's bid and the most competitive bid is -15 (since bidder 1 wins the auction, the most competitive bid is the second lowest bid), the difference between bidder 2's bid and the most competitive bid is +15, and the difference between bidder 3's bid and the most competitive bid is 18. In other words, bid differences capture bidders' margins of victory or defeat. Chassang et al. (2020) are interested in the distribution of

$$\Delta_{i,a}^{CKNO} = \frac{b_{i,a} - \wedge \mathbf{b}_{-i,a}}{r}, \tag{1}$$

where $r$ is the reserve price in auction $a$.

Figure 1: Differences between own bid and most competitive bid ($\Delta^1_{i,a}$) – Montreal asphalt industry.




This figure plots the differences between own bid and most competitive bid in auctions for asphalt procurement contracts in Montreal during the cartel period. Bid differences in $ per ton. Number of bins equal to 500.

Given the design of this function, the difference between the winning bid and the most competitive bid (the second lowest bid) in the distribution appears to the left of 0, while the difference between a losing bid and the most competitive bid (the lowest bid) appears to the right of 0. Figure 1 from Chassang et al. (2020) plots the distribution of $\Delta^{CKNO}_{i,a}$ on a range of plus or minus 10% of the reserve price. The distribution features a gap around 0 – the so-called *missing bids* – implying that winning bids are isolated. That is, only in very rare circumstances will there be tied winning bids. As mentioned above, this is consistent with the idea that cartel members are avoiding identical bids since these may attract scrutiny from antitrust authorities.

We construct the same measure of bid differences for our sample of auctions from the known cartel period in Montreal. Since auctions in Montreal do not have a reserve price and since the bids are already in dollars per ton, there is no need to normalize. We are interested in the following measure of bid differences:

$$\Delta^1_{i,a} = b_{i,a} - \wedge \mathbf{b}_{-i,a}. \tag{2}$$

In Figure 1 we plot the distribution of bid differences on a range plus or minus 10% of the average winning bid in this period. Like Chassang et al. (2020), we find that there is much less mass at 0 than in a small neighborhood around 0, suggesting that our winning bids are also isolated. The figure also provides our first evidence that there is clustering of bids, with most bid differences falling within about 3% of the average winning bid. Together, clustering and missing bids generate a bimodal, or twin-peaked, distribution of bid differences, centered around zero.

While this figure provides suggestive evidence of a pattern of clustered bids and isolated winning bids, it remains to show that this pattern is related to the collusive arrangement. This is what we turn to in the following section.[22]

# 6 Empirical analysis

## 6.1 Descriptive analysis

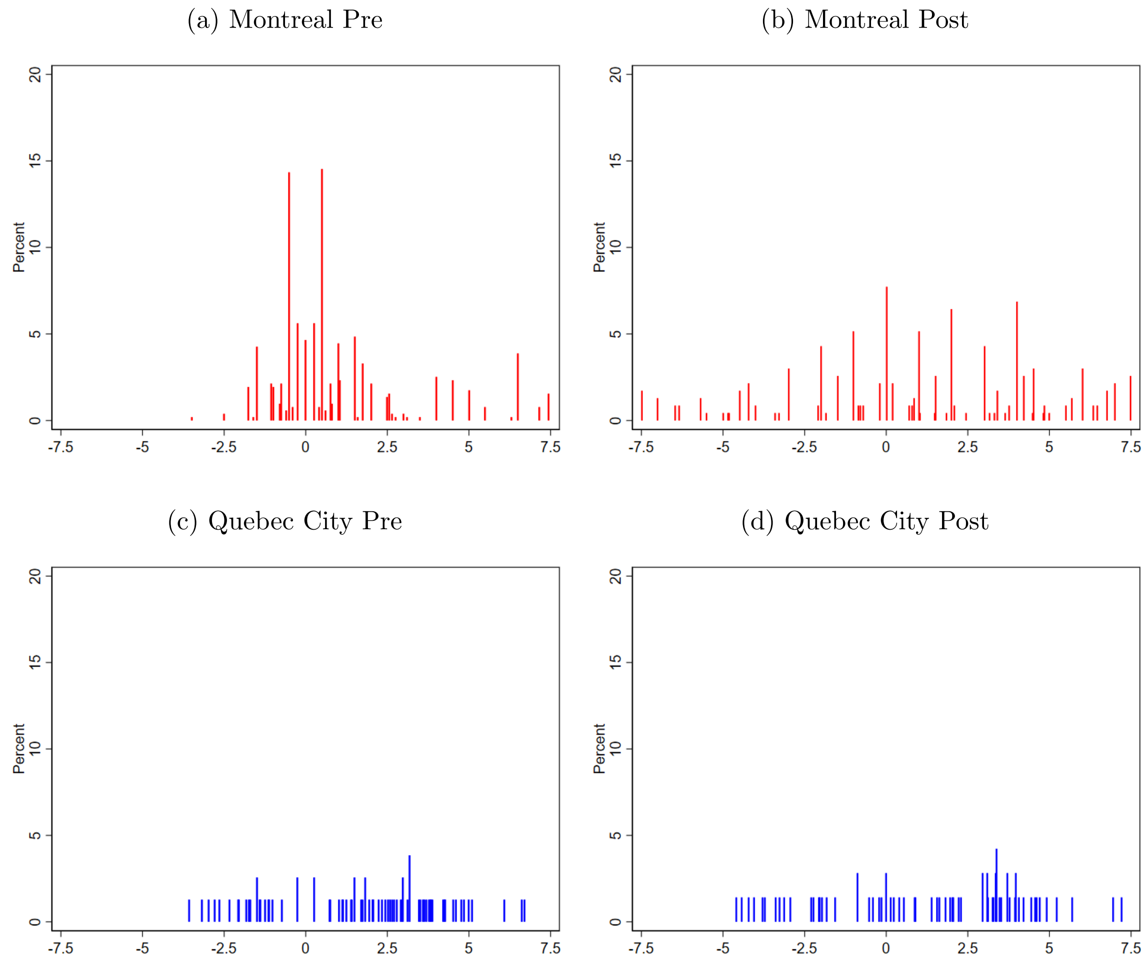
We start by plotting bid differences, $\Delta^1_{i,a}$, in Figure 2, this time not just for Montreal during the cartel period, but also for Montreal post-cartel and Quebec City both during the cartel period and afterwards.[23] As already seen, in Montreal before the investigation, there is evidence of isolated winning bids and clustering. There is much less mass directly at 0 than in a small neighborhood around 0, and bid differences are overall quite clustered around 0. Overall, there is a bimodal, or twin-peaked, distribution of bid differences centered at zero. Importantly, comparing this distribution to the one in Montreal after the investigation we see that it is much more dispersed and that there is more mass directly at 0 and less mass immediately nearby. The twin peaks are gone and the distribution is much more uniform. Together these results suggest that clustering and isolated winning bids were part of the collusive arrangement and that this behaviour ceased following its collapse. To confirm that other confounding factors were not behind this change we look at what happened in Quebec City. Here bid differences are much more spread out, although there is again less mass at 0 in the pre period and slightly more later on, but the increase is relatively much smaller than in Montreal, as is the decrease in mass in the region immediately next to 0.

To be more precise about the patterns observed in Figure 2, we provide statistics characterizing the changes in clustering and isolated winning bids observed from before to after the investigation in Montreal and Quebec City. Given the information on mean and standard deviation of the bid differences $\Delta^1_{i,a}$ for each city-period, we have run a t-test for the equality of means in Montreal Pre against Montreal Post, Quebec Pre against Quebec Post under the assumption of unequal variances. For the difference in means between Montreal Post and Montreal Pre, we find a difference in means of \$0.79 per ton with standard error of 0.35 (t-stat equal to 2.26). For the difference between Quebec Post and Pre, we find a difference in means of \$0.14 per ton with standard error of 0.54 (t-stat equal to 0.26).

[22] In Appendix A.2, we provide a check, plotting the bid differences $\Delta^1_{i,a}$ as fraction of the average winning bid in Montreal pre-investigation.

[23] We plot these on a range of +/- 10% of the average winning bid observed in Montreal before the start of the investigation. In the Appendix we plot this for alternative ranges to illustrate robustness (Figure A.3 and Figure A.4) and for alternative bin size (Figure A.5).

Figure 2: $\Delta^1_{i,a}$ for Montreal and Quebec City before and after the start of the police investigation.




Bid differences in $ per ton. The interval of bid differences is ±10% of the winning bid in Montreal before the start of the investigation ($7.5 per ton). The number of bins is equal to 500.

## 6.2 Regression analysis

Figure 2 provides suggestive evidence of the causal impact of collusion on clustering and the isolation of winning bids, pooling all bids from all auctions together. To confirm that these patterns are robust to changes in other variables we turn to regression analysis at the auction level.

To understand the causal effect of the investigation on the distribution of bid differences, we use a distributional regression approach. This approach was described by Chernozhukov et al. (2013), and more recently Fortin et al. (2021) used this method to understand the effect of the minimum wage at different points of the wage distribution using a difference-in-differences setup. Consistent with this literature, we estimate a linear probability model where the outcome variable is a binary variable equal to 1 if the bid difference in auction $a$ falls within a given interval of values. We estimate separate linear probability regressions, one for each interval. More specifically, the linear probability model that we estimate is the following:

$$y_{i,a,q} = \alpha_q + \beta_{1,q} Mtl_a \times Marteau_a + \beta_{2,q} Mtl_a + \beta_{3,q} Marteau_a + \gamma_q Z_a + \epsilon_{i,a,q}, \quad \text{for} \quad q = 1, 2, ..., Q \tag{3}$$

where $y_{i,a,q}$ is an indicator equal to 1 if bidder $i$'s bid difference in auction $a$ ($\Delta^1_{i,a}$) falls in interval $q$. We divide the bid-difference distribution into 10 intervals of width 0.5 ($ per ton), and one extra bin for values exactly equal to 0, for a total of eleven bins.[24] Allowing bid differences of 0 to get their own bin permits us to zoom in on bid isolation by studying the impact on identical bids. Since this might give the appearance of us arbitrarily choosing intervals, in the appendix we show that results are the same if we assign zero to a bin on the interval -0.5 to 0. $Mtl_a$ is a dummy equal to 1 if the auction is run for the procurement of asphalt in Montreal, $Marteau_a$ is a dummy equal to 1 if the contract is awarded after the start of the investigation in October 2009, and $Z_a$ represents auction characteristics such as the lagged (one period) average price of crude oil, the quantity of asphalt in the call for tender, and the Herfindahl index (city-specific). These are the same auction-level characteristics as in Clark et al. (2018). We include also borough and year fixed effects, and we cluster standard errors at the borough and year levels. We are interested in the coefficients $\beta_{1,q}$. Studying these coefficients will inform as to how the collapse of the cartel shifted the distribution of bid differences.

Results are presented in Table 3 and show that there is no impact of the collapse of the cartel on bid differences right at 0, and very little impact immediately on either side. In contrast, there is a big decrease in probability that bid differences fall in the range -1.0 to -0.5 and 0.5 to 1.0. Together these findings imply a decrease in isolation as a result of the investigation – during the collusive time period there was much less mass at 0 than

[24] For graphical purposes, we only show these 11 intervals. The results on additional intervals are available upon request.

## Table 3: Distributional effect of the investigation on clustering & isolation

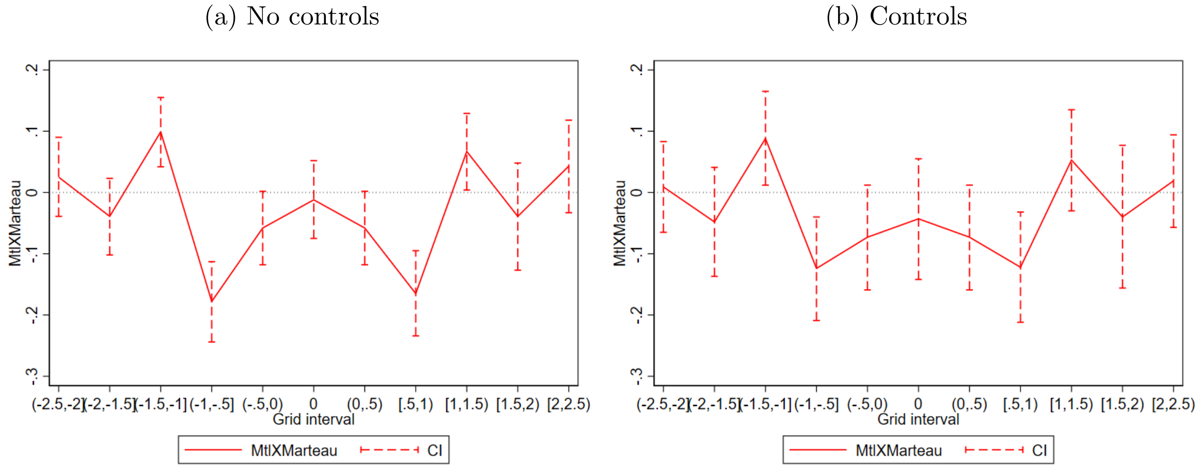
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-2.5 -2] | Pr(-2-1.5] | Pr(-1.5-1] | Pr(-1 -.5] | Pr(-.5 -0) | Pr[0] | Pr(0 .5) | Pr[.5 1) | Pr[1 1.5) | Pr[1.5 2) | Pr[2 2.5) |
| | | | | | | Panel A: Without controls | | | | | |
| Mtl×Marteau | 0.0252 | -0.0394 | 0.0987*** | -0.1784*** | -0.0582* | -0.0115 | -0.0582* | -0.1647*** | 0.0666** | -0.0394 | 0.0425 |
| | (0.033) | (0.032) | (0.029) | (0.033) | (0.031) | (0.032) | (0.031) | (0.035) | (0.032) | (0.044) | (0.039) |
| Mtl | -0.0370* | 0.0241 | -0.0599** | 0.1599*** | 0.0364 | 0.0444*** | 0.0364 | 0.1494*** | -0.0340 | 0.0179 | -0.0414 |
| | (0.021) | (0.024) | (0.027) | (0.025) | (0.022) | (0.015) | (0.022) | (0.027) | (0.027) | (0.033) | (0.027) |
| Marteau | 0.0136 | 0.0009 | -0.0988*** | 0.0256 | 0.0133 | 0.0253 | 0.0133 | 0.0133 | -0.0861*** | -0.0111 | -0.0111 |
| | (0.031) | (0.029) | (0.026) | (0.024) | (0.026) | (0.025) | (0.026) | (0.026) | (0.029) | (0.042) | (0.035) |
| Constant | 0.0370* | 0.0370* | 0.0988*** | 0.0123 | 0.0247 | 0.0000 | 0.0247 | 0.0247 | 0.0988*** | 0.0617** | 0.0617** |
| | (0.021) | (0.020) | (0.026) | (0.012) | (0.017) | (0.000) | (0.017) | (0.016) | (0.026) | (0.030) | (0.025) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0226 | 0.00691 | 0.0103 | 0.0621 | 0.0104 | 0.00587 | 0.0104 | 0.0585 | 0.00680 | 0.00889 | 0.00805 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 |
| | | | | | | Panel B: With controls | | | | | |
| Mtl×Marteau | 0.0093 | -0.0483 | 0.0884** | -0.1243*** | -0.0735* | -0.0434 | -0.0735* | -0.1217*** | 0.0526 | -0.0397 | 0.0186 |
| | (0.038) | (0.045) | (0.039) | (0.043) | (0.044) | (0.050) | (0.044) | (0.046) | (0.042) | (0.060) | (0.039) |
| Mtl | -0.0586 | -0.0124 | -0.0933** | 0.2440** | -0.0131 | 0.0115 | -0.0131 | 0.2336** | -0.1554* | 0.0105 | 0.0659 |
| | (0.093) | (0.046) | (0.044) | (0.094) | (0.053) | (0.039) | (0.053) | (0.092) | (0.086) | (0.064) | (0.097) |
| Marteau | -0.1261 | -0.4950** | -0.3219 | 1.1785*** | -0.2967 | -0.4930 | -0.2967 | 1.1000*** | -0.3464 | -0.3084 | -0.6414** |
| | (0.317) | (0.214) | (0.288) | (0.376) | (0.229) | (0.382) | (0.229) | (0.383) | (0.309) | (0.331) | (0.289) |
| Crude oil lag | 0.0010 | 0.0030** | 0.0013 | -0.0066*** | 0.0018 | 0.0027 | 0.0018 | -0.0062*** | 0.0016 | 0.0017 | 0.0040** |
| | (0.002) | (0.001) | (0.002) | (0.002) | (0.001) | (0.002) | (0.001) | (0.002) | (0.002) | (0.002) | (0.002) |
| Quantity | -0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.0473 | -0.1005 | -0.0075 | 0.2865*** | -0.4181*** | -0.0788 | -0.4181*** | 0.2453*** | 0.0355 | -0.1682 | -0.0254 |
| | (0.111) | (0.098) | (0.096) | (0.076) | (0.086) | (0.085) | (0.086) | (0.088) | (0.100) | (0.122) | (0.104) |
| Constant | -0.3432 | -1.3086** | -0.4759 | 2.9097*** | -0.6781 | -1.1910 | -0.6781 | 2.7580*** | -0.5555 | -0.7000 | -1.7353** |
| | (0.793) | (0.501) | (0.709) | (0.976) | (0.604) | (0.976) | (0.604) | (0.986) | (0.767) | (0.813) | (0.723) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0839 | 0.0981 | 0.102 | 0.176 | 0.168 | 0.148 | 0.168 | 0.169 | 0.0781 | 0.124 | 0.116 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 |

Dep. variable is the probability that bid differences fall in a given interval. *Marteau* is a dummy equal to 1 if the contract is awarded after the start of the investigations in October 2009. *Mtl* indicates that the contract was for Montreal. Panel A without controls. Panel B includes controls as well as borough, year and asphalt type effects. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

just outside of 0, but this changes after the collapse. The results also reveal that the mass that leaves the -1.0 to -0.5 and 0.5 to 1.0 ranges is relocated to intervals further removed from 0. This pattern is confirmed in Figure 3, which plots the difference-in-difference coefficient from the first row of Table 3. We replicate the analysis in this section for the sample including entrants in Montreal (Figure A.6, Table A.1, and Figure A.7). We also replicate the analysis for the sample excluding the year following the investigation (Figure A.8, Table A.2, and Figure A.9) and for the sample including entrants and excluding the year following the investigation (Figure A.10, Table A.3, and Figure A.11).

In the appendix (Table A.5 and Figure A.12) we also show the results of the difference-in-difference, showing also what happens to the left of -\$2.5 and to the right of \$2.5. We

Figure 3: Graphical representation of the distributional effect of the investigation on clustering & isolation




This figure reports the estimated coefficient for $Mtl \times Marteau$, along with confidence intervals, from Table 3. Confidence intervals are computed with standard errors clustered at the borough and year levels.

see that density losses in a neighborhood of 0 are relocated to the tails of the distribution of $\Delta^1_{i,a}$ in Montreal, as compared to Quebec City.

In Table A.6 of the appendix we repeat the exercise but this time we assign bid differences of 0 to the -0.5 to 0 bin (Table A.6 and Figure A.13). Results are unchanged. There is almost no effect of the collapse on bid differences right around 0, but there is a big decrease in the probability that bid differences fall in the range -1.0 to -0.5, confirming the decrease in isolation caused by the investigation. And we see the same patterns that confirm that clustering also fell after the collapse. In the appendix we also present results narrowing the grid intervals (Table A.7). Finally we also widen the grid intervals and the results are unchanged (Table A.8).

It is important to note that our difference-in-differences approach relies on the existence of common trends in the distribution of bid differences in Montreal and Quebec City. To confirm the existence of common trends, we perform a multivariate regression analysis in which we jointly test the significance in the period before the start of the investigation of a $Montreal \times Year$ interaction term. Our results, reported in Table A.4, suggest that, both in models with and without controls, the joint test does not reject the null hypothesis that the coefficients of $Montreal \times Year$ are jointly equal to 0.

# 7 Implications for antitrust enforcement: An easy-to-implement screen for collusion

What can antitrust authorities learn from our findings, and can the distributional regression approach proposed here be employed to provide some guidance for investigations? In this section we try to answer these questions and present an easy-to-implement screen for collusion.

The screen builds on our results, which suggest that the mutual occurrence of isolated winning bids and clustered bidding is indeed related to collusion. If antitrust authorities flag procurement auctions that feature tied, or nearly tied bids, cartel firms may benefit by adjusting their behaviour, leaving a gap between the winning and other bids. A gap is also optimal if it helps to guarantee that the designated winner comes away with the contract in cases where precise bids cannot be assigned to losers and/or if bids can be perturbed by small trembles. At the same time clustering is present, since the cartel will want to keep the second lowest bid relatively close to the first in order to lower the designated winner's temptation to increase its bid.

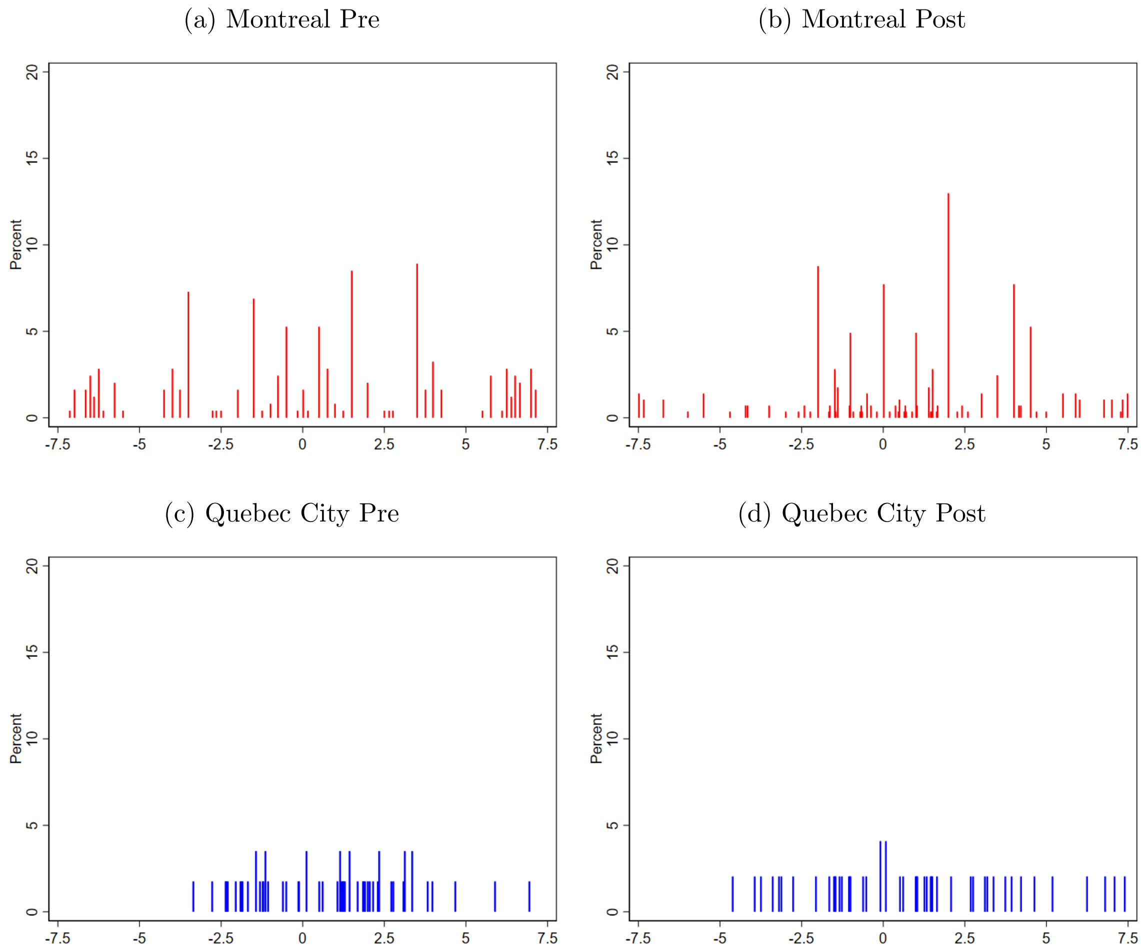
Our results so far though are based on a difference-in-differences setup that requires data from one or more control markets and being able to identify the beginning or end of collusive activity. Authorities interested in screening for collusion will not necessarily have access to such data. We therefore propose a screen that is based only on data from the suspect calls for tender.

The intuition for the screen is based on insights from Ortner et al. (2020) and LaCasse (1995) that the distribution of losing bids is not informative about the existence of a cartel once the winning bid is known.[25] If losing bids are drawn randomly from the distribution of bids of competitive bidders, then we can develop a screen for collusion based on the distribution of bid differences $\Delta^2_{i,a}$. These are defined similarly to the distribution of bid differences introduced in equation (2) (i.e. $\Delta^1_{i,a}$) but excluding winning bids.[26] In $\Delta^2_{i,a}$ the second-lowest bid takes the place of the winning bid in the construction of bid differences. Figure 4 plots $\Delta^2_{i,a}$ bid differences for Montreal and Quebec City before and after the start of the police investigation. Comparing this figure to Figure 2 (i.e. for $\Delta^1_{i,a}$) it is immediately apparent that the main differences can be found in their respective (a) panels (i.e. Montreal Pre investigation). The plot of $\Delta^2_{i,a}$ no longer displays the twin peaks around 0 that could be seen when plotting $\Delta^1_{i,a}$. There is also much more density in the tails, especially the negative tail.

[25]This is true for all-inclusive cartels, since in partial cartels predictions on losing bids might be different (Marshall and Marx (2007)).

[26]Chassang et al. (2020) construct $\Delta^2_{i,a}$ to rule out the possibility that isolation is instead the product of granular bids, comparing graphically the two distributions. Here we use predictions in Ortner et al. (2020) and LaCasse (1995) to directly test the significance of the collusive pattern found in the data.

Figure 4: $\Delta^2_{i,a}$ for Montreal and Quebec City before and after the start of the police investigation, excluding winning bids.




Bid differences in \$ per ton. The interval of bid differences is ±10% of the winning bid in Montreal before the start of the investigation (\$7.5 per ton). The number of bins is equal to 500.

In other words, according to the theoretical models of Ortner et al. (2020) and LaCasse (1995) and to the testimonial evidence presented in Section 3, under collusion the distributions of $\Delta^1_{i,a}$ and $\Delta^2_{i,a}$ should be similar, except in a small neighborhood, $H$, close to 0. In contrast, under competition the distributions should be everywhere similar, including inside $H$. Given the contrasting predictions under competition and collusion regarding the differences in bid distributions inside this interval our screen will focus exactly on this. Under competition we should have:

$$P(-H \leq \Delta^1_{i,a} \leq H) = P(-H \leq \Delta^2_{i,a} \leq H) \tag{4}$$

We choose $H$ based on the testimonial evidence presented in Section 3 and following Chassang et al. (2020), which describes the use during bidding of a buffer of 2 or 3 percent of the winning bid.

In order to implement our screen, we discretize the bid distributions using the same number of intervals, $Q$, we adopted in our difference-in-differences analysis (see Section 6). These intervals are of width \$0.5 per ton, and we consider 0 as an isolated bin. This gives a total of ten intervals with five intervals between \$0 and \$2.5, five intervals between -\$2.5 and \$0, and a separate bin for 0.

We then use a distributional regression approach in which we estimate a linear probability model for each of the ten intervals $q$ of bid differences, with width \$0.5 per ton, and for tied bid differences. We estimate this model using the sample of all bid differences, $\Delta_{i,a} = \{\Delta^1_{i,a}, \Delta^2_{i,a}\}$. These regressions allow us to test whether the distribution of $\Delta^1_{i,a}$ is statistically different from $\Delta^2_{i,a}$ in each interval $q$ of the distribution of bid differences. Specifically, the model we estimate is the following:

$$y_{i,a,q} = \alpha_q + \beta_q \mathbb{1}(f(\Delta^1_{i,a})) + \gamma_q Z_a + \epsilon_{i,a,q}, \quad \text{for} \quad q = 1, 2, ..., Q, \tag{5}$$

where, as above, $y_{i,a,q}$ is an indicator equal to 1 if bidder $i$'s bid difference in auction $a$, $\Delta_{i,a}$, falls within the interval $q$, $\mathbb{1}(f(\Delta^1_{i,a}))$ is an indicator variable equal to 1 if the observation is derived from the distribution of $\Delta^1_{i,a}$ and 0 if derived from the distribution of $\Delta^2_{i,a}$. Under no collusion, the null hypothesis that we test is the following:

$$H_0 : \beta_q = 0 \quad \forall q \in [-H, H]. \tag{6}$$

Panel A of Table 4 reports the results from our screen using data from Montreal pre-investigation. As mentioned above, for $H$ we focus on intervals that include bid differences within 2% of the average winning bid (however, we have also considered values of $H$ based on 1% or 3%). Since in Montreal during the infraction period the average winning bid was \$75 per ton, $H$ is calculated to be \$1.5 per ton. From the table we can see that in $H$ interval around 0 $\beta$ is positive and significant. This is in contrast to what is going on outside of $H$ and at 0 where we observe insignificant or negative coefficients, as we predicted, since there should be no difference between the distribution of $\Delta^1_{i,a}$ and $\Delta^2_{i,a}$. The not significant difference at 0 between the two distributions is consistent with the hypothesis that firms colluded knowing the existence of antitrust oversight that led firms to leave a gap (although small) between the winning and all other losing bids. In Appendix A.10, we also run the same test adding controls and borough, asphalt type and year effects, finding no significant differences with our main estimates (Table A.9 and Figure A.14).

A big advantage of our setting and data set is that we have multiple markets/periods where collusion was not suspected: (i) Montreal after the collapse of the cartel, (ii) Quebec during the collusive period and (ii) Quebec after the start of the investigation. This allows us to use our difference-in-difference set-up to evaluate the performance of our screen. We repeat the same exercise for each of the three other cases and report results in Panels B, C and D. Our main result is that in cases where there is no external evidence of collusion, our screen does not predict collusion, suggesting that our screen has some predictive power.

In Montreal post-collusion, our 2% value for $H$ implies intervals of values within 0 and \$1.34 per ton. We only observe negative and significant coefficients for Montreal post in intervals of bid differences containing values higher than \$2 per ton. In Quebec City before the investigation, we do not observe any significant difference in the two distributions and in Quebec post-investigation we only observe negative coefficients for intervals that are within 2 or 3% of the average winning bid (\$63 per ton). In any of the three markets, we do not observe significant changes at 0.[27]

Our findings suggest an easy-to-implement procedure that antitrust authorities could use as a red flag for possible collusive behaviour in procurement auctions. By running this simple distributional regression, authorities could check quickly whether at the same time bids are clustered and winning bids are isolated, and then use this to guide their investigation into possible bid rigging.[28] The invariance of the distribution of $\Delta^2_{i,a}$ between competition and collusion (see, for instance, Ortner et al., 2020 and LaCasse, 1995) provides us with a within auctions "control group/benchmark" to detect bid rigging.

To summarize, the steps required for implementation of the screen are:

1. Construct $\Delta^1_{i,a}$, using the entire sample of contracts and bids.
2. Construct $\Delta^2_{i,a}$, using the same approach as for $\Delta^1_{i,a}$ but excluding winning bids.
3. Append the two sets of bid differences constructed in steps 1 and 2. This will be the sample of $\Delta_{i,a}$ that we will use for the screen.
4. Generate an indicator variable $\mathbb{1}(f(\Delta^1_{i,a}))$ equal to 1 when bid differences $\Delta_{i,a}$ are from the distribution of $\Delta^1_{i,a}$, and equal to 0 when they come from the distribution of $\Delta^2_{i,a}$.
5. Generate an indicator variable $y_{i,a,q}$ equal to 1 if a bid difference $\Delta_{i,a}$ is within a given interval $q$, and to 0 otherwise.
6. Run Q linear probability models, represented by equation (5), in the market suspected of collusion.
7. Check the statistical significance of coefficients $\beta_q$, which indicate a statistical significant difference between the distributions of $\Delta^1_{i,a}$ and $\Delta^2_{i,a}$ in the interval $q$. Under the null of competitive behavior the two distributions should not be statistically different for intervals $q$ within $-H$ and $H$.

[27]For Quebec Pre, we do not have any tied bids and so that is why the coefficient $\beta_1$ has not been estimated.

[28]Figure A.15 and Figure A.16 report the plot of the coefficients for the test run on the total bids. Results are consistent with the main findings.

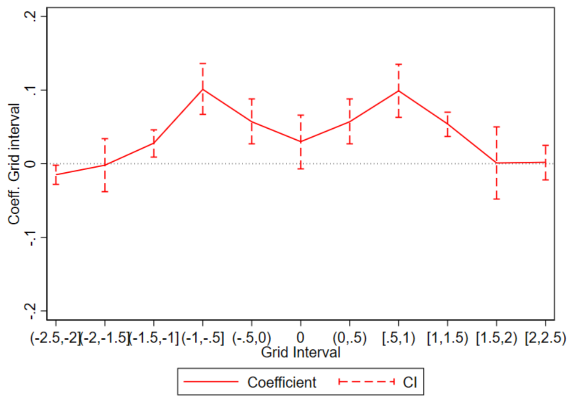
Table 4: Distributional regression of bid differences $\Delta^1_{i,a}$ with respect to $\Delta^2_{i,a}$ in Montreal and Quebec City before and after the investigation.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-2.5 -2] | Pr(-2-1.5] | Pr(-1.5-1] | Pr(-1 -.5] | Pr(-.5 -0) | Pr[0] | Pr(0 .5) | Pr[.5 1) | Pr[1 1.5) | Pr[1.5 2) | Pr[2 2.5) |
| | | | | | | Panel A: Montreal Pre | | | | | |
| $\mathbb{1}(\Delta^1_{i,a})$ | -0.0149** | -0.0023 | 0.0277*** | 0.1013*** | 0.0574*** | 0.0295 | 0.0574*** | 0.0994*** | 0.0536*** | 0.0013 | 0.0017 |
| | (0.007) | (0.018) | (0.009) | (0.018) | (0.015) | (0.019) | (0.015) | (0.018) | (0.008) | (0.025) | (0.012) |
| Constant | 0.0149** | 0.0634*** | 0.0112* | 0.0709*** | 0.0037 | 0.0149 | 0.0037 | 0.0746*** | 0.0112* | 0.0784*** | 0.0187*** |
| | (0.007) | (0.015) | (0.006) | (0.013) | (0.004) | (0.010) | (0.004) | (0.014) | (0.006) | (0.021) | (0.007) |
| Observations | 808 | 808 | 808 | 808 | 808 | 808 | 808 | 808 | 808 | 808 | 808 |
| R-squared | 0.0100 | 2.06e-05 | 0.00590 | 0.0191 | 0.0181 | 0.00577 | 0.0181 | 0.0181 | 0.0142 | 4.91e-06 | 3.35e-05 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No |
| | | | | | | Panel B: Montreal Post | | | | | |
| $\mathbb{1}(\Delta^1_{i,a})$ | -0.0381** | -0.0076 | -0.0216 | -0.0026 | 0.0052 | -0.0022 | 0.0052 | 0.0007 | -0.0179 | -0.0038 | -0.0554*** |
| | (0.016) | (0.011) | (0.016) | (0.011) | (0.009) | (0.025) | (0.009) | (0.013) | (0.019) | (0.012) | (0.019) |
| Constant | 0.0769*** | 0.0302*** | 0.0604*** | 0.0220*** | 0.0110** | 0.0604*** | 0.0110** | 0.0220*** | 0.0632*** | 0.0330*** | 0.1071*** |
| | (0.015) | (0.008) | (0.010) | (0.007) | (0.005) | (0.016) | (0.005) | (0.007) | (0.011) | (0.009) | (0.021) |
| Observations | 673 | 673 | 673 | 673 | 673 | 673 | 673 | 673 | 673 | 673 | 673 |
| R-squared | 0.00644 | 0.000546 | 0.00242 | 7.99e-05 | 0.000507 | 2.12e-05 | 0.000507 | 5.20e-06 | 0.00153 | 0.000121 | 0.0101 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No |
| | | | | | | Panel C: Quebec Pre | | | | | |
| $\mathbb{1}(\Delta^1_{i,a})$ | -0.0308 | -0.0308 | -0.0368 | -0.0216 | -0.0092 | | -0.0092 | -0.0092 | -0.0538 | -0.0230 | -0.0230 |
| | (0.040) | (0.040) | (0.055) | (0.028) | (0.030) | | (0.030) | (0.022) | (0.057) | (0.051) | (0.047) |
| Constant | 0.0678** | 0.0678** | 0.1356*** | 0.0339 | 0.0339 | | 0.0339 | 0.0339 | 0.1525*** | 0.0847** | 0.0847** |
| | (0.032) | (0.031) | (0.043) | (0.024) | (0.023) | | (0.023) | (0.024) | (0.044) | (0.033) | (0.034) |
| Observations | 140 | 140 | 140 | 140 | 140 | | 140 | 140 | 140 | 140 | 140 |
| R-squared | 0.00486 | 0.00486 | 0.00327 | 0.00540 | 0.000745 | | 0.000745 | 0.000745 | 0.00661 | 0.00195 | 0.00195 |
| Borough FE | No | No | No | No | No | | No | No | No | No | No |
| Year FE | No | No | No | No | No | | No | No | No | No | No |
| Type FE | No | No | No | No | No | | No | No | No | No | No |
| | | | | | | Panel D: Quebec Post | | | | | |
| $\mathbb{1}(\Delta^1_{i,a})$ | 0.0314 | 0.0187 | -0.1346*** | -0.0197 | -0.0005 | 0.0253 | -0.0005 | -0.0005 | -0.1220** | 0.0122 | 0.0314 |
| | (0.032) | (0.030) | (0.042) | (0.034) | (0.036) | (0.025) | (0.036) | (0.028) | (0.047) | (0.036) | (0.032) |
| Constant | 0.0192 | 0.0192 | 0.1346*** | 0.0577* | 0.0385 | 0.0000 | 0.0385 | 0.0385 | 0.1346*** | 0.0385 | 0.0192 |
| | (0.019) | (0.019) | (0.042) | (0.033) | (0.027) | (0.000) | (0.027) | (0.027) | (0.044) | (0.027) | (0.019) |
| Observations | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 |
| R-squared | 0.00643 | 0.00284 | 0.0858 | 0.00213 | 1.55e-06 | 0.0102 | 1.55e-06 | 1.55e-06 | 0.0621 | 0.000811 | 0.00643 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No |

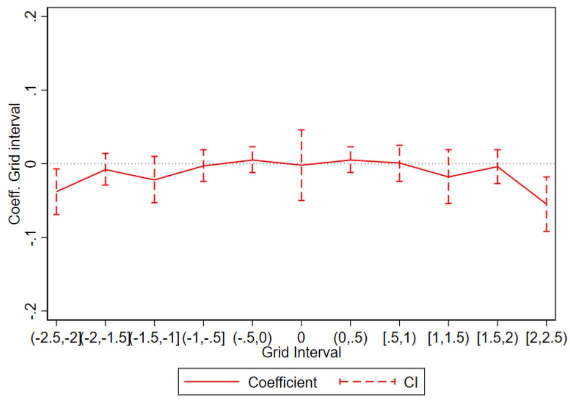
The outcome is the probability that bid differences fall in a given interval of values. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure 5: Graphical representation of coefficients for equation 5. Adding controls.

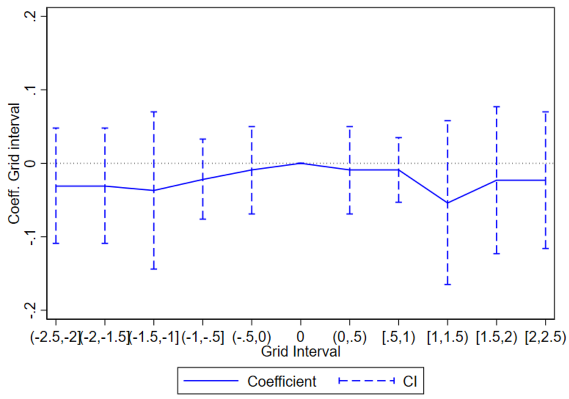
(a) Montreal Pre



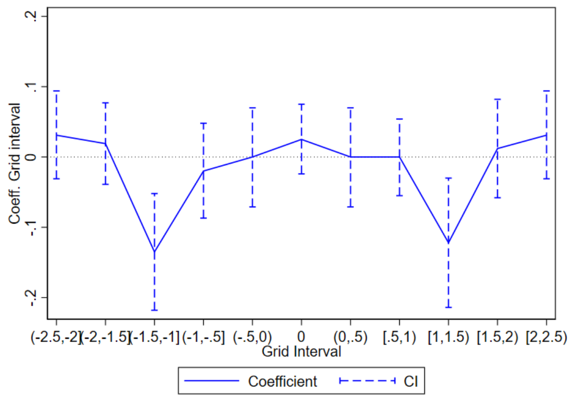

(b) Montreal Post




(c) Quebec City Pre




(d) Quebec City Post




This figure reports the estimated coefficient from equation (5), along with confidence intervals, obtained separately for each city/time period. Confidence intervals are computed with standard errors clustered at the borough and year levels.

# 8 Conclusion

In this paper, we provided evidence from an actual procurement cartel that clustered bidding and isolated winning bids are associated of collusive arrangements that feature complementary bidding. Using a difference-in-differences approach, we compared the extent of winning-bid isolation and clustering of bids in Montreal's asphalt industry before and after the investigation to isolation and clustering patterns over the same time span in Quebec City, whose asphalt industry has not been the subject of collusion allegations. We used distributional regression techniques to compare the distribution of bid differences (differences between own and most competitive bids) in Montreal and Quebec City before and after the investigation. Our findings provide causal evidence that the collusive arrangement featured both clustered bids and isolated winning bids.

Interviews from the news program and testimony from the Commission help us to understand how these observations fit together. The cartel arrangement involved market segmentation and complementary bidding. Representatives from each of the cartel firms would get together to decide which of them would be assigned a given contract as a function on the firms' production capacities and their plant locations. The designated winner would then organize the bidding for the contract by contacting the other cartel members and giving instructions on complementary bidding. Complementary bids were submitted in order to mimic competition. The designated winner would provide guidance as to what should be the complementary bids. The winner would then have incentive to bid just below the lowest bid it assigned, resulting in clustering. Despite this incentive to bid as close to the next lowest bid as possible, the designated winner would, according to testimony, allow a small margin between the assigned lowest losing bid and its bid. It would do so to guard against any mistake in the bidding, such as a secretary making a typing mistake. The result was a very small gap between the two lowest bids, or isolated winning bids.

Based on our findings we propose an easy-to-implement screen based on the distributional regression approach. Since a competitive control market may not be available for comparison, our screen leverages the fact that the distribution of losing bids is uninformative about collusion. We evaluate the performance of our screen and show that it successfully diagnoses collusion in a market where it took place and does not in markets where there is no evidence of collusion.

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# A Appendix

## A.1 Transport charges and final bids

We concentrate our main analysis on raw bids, but contract allocation is based on final bids. In Montreal, firms are asked to submit a raw bid for each asphalt type. Firms must also take into account the transport cost they face and submit transport charges for each type in each borough. The sum of the raw bid on transport charges is the final bid. In Québec City however, we do not have enough information to build a perfect measure of transport charges and thus, of final bids. We know only raw bids per asphalt type per borough and the aggregated final bid of each firm per borough. Since the contracts are won at the borough level, not the asphalt type level as in Montreal, firms submit an aggregated transport charge for a borough. Since prices per type are usually different, it is impossible for us to map an accurate transport charge per asphalt type. More precisely, for each aggregated auction we have:

$$\sum_{k=1}^{K} (\mathbf{P}_k + t_k) * \mathbf{Quantity}_k = \mathbf{Aggregated\ final\ bid}$$

where $k$ is the asphalt type, $t$ is the unknown transport charge and $P$ is the raw bid (what we know is is in bold text). We can rewrite the equation above as:

$$\sum_{k=1}^{K} (\mathbf{P}_k * \mathbf{Quantity}_k + t_k * \mathbf{Quantity}_k) = \mathbf{Aggregated\ final\ bid}$$

$$\sum_{k=1}^{K} (t_k * \mathbf{Quantity}_k) = \mathbf{Aggregated\ final\ bid} - \sum_{k=1}^{K} (\mathbf{P}_k * \mathbf{Quantity}_k)$$

$$\sum_{k=1}^{K} (t_k * \mathbf{Quantity}_k) = \mathbf{Aggregated\ transport\ charge}$$

since $t_k$ is unknown for all k, the best we can do is compute the average transport charge:

$$\overline{T} = \frac{\mathbf{Aggregated\ transport\ charge}}{\sum_{k=1}^{K} (\mathbf{Quantity}_k)}$$

Similarly, we cannot compute final bids per type for Québec City.[29] This measure is imperfect, but we believe it is relevant to estimate DiD for transport charges and final bids.

[29]Note that since there is one winner per borough, we know that the firm that bids the lowest aggregated final bid, which we observe, is the actual winner.

## A.2 Normalization with average winning bid in Montreal pre-investigation

Chassang et al. (2020) are interested in the distribution of

$$\Delta_{i,a}^{CKNO} = \frac{b_{i,a} - \wedge \mathbf{b}_{-i,a}}{r}, \tag{7}$$

where $b_{i,a}$ is bidder $i$'s bid in auction $a$, $\wedge \mathbf{b}_{-i,a}$ is the minimum bid by $i$'s rivals, and $r$ is the reserve price in auction $a$. Since our auctions are for a homogeneous good, bid are in dollars per ton, and there is no reserve price, there is no need to normalize by the reserve price they way Chassang et al. (2020) do. This is why in the text, we focus on the following measure of bid differences:

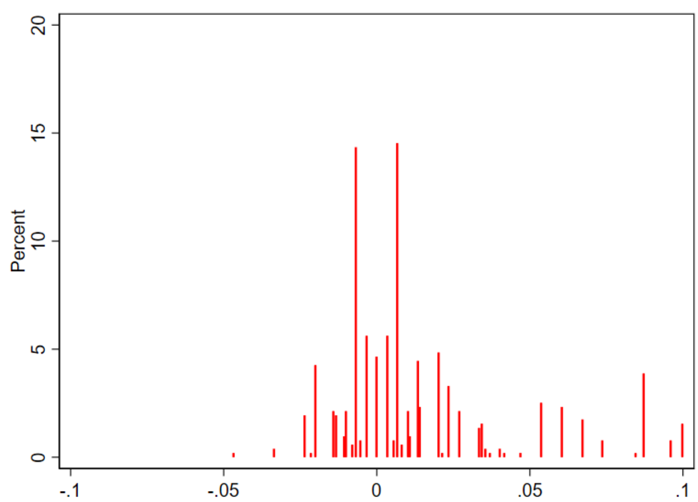
$$\Delta_{i,a}^{1} = b_{i,a} - \wedge \mathbf{b}_{-i,a}. \tag{8}$$

As a check on this specification, here we present results in which we normalize by the average winning bid observed in Montreal in the period before the start of the investigation ($\bar{b}_{mtl,pre}$). The measure of bid differences is then:

$$\Delta_{i,a}^{1,norm} = \frac{b_{i,a} - \wedge \mathbf{b}_{-i,a}}{\bar{b}_{mtl,pre}}. \tag{9}$$

Figures A.1 and A.2 replicate Figures 1 and 2 using this new definition of bid differences.

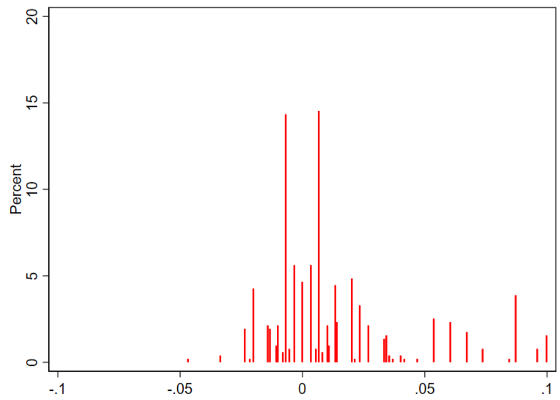
Figure A.1: Differences between own bid and most competitive bid (bid differences)



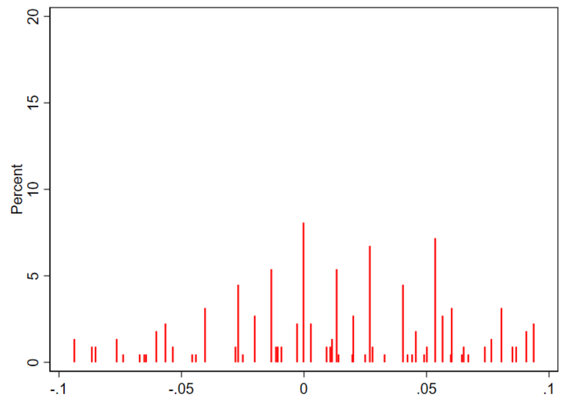

This figure plots the differences between own bid and the most competitive bid in auctions as a fraction of the average winning bid in the period before the investigation, for asphalt procurement contracts in Montreal during the cartel period. Bid differences in $ per ton.

Figure A.2: Bid differences $\Delta_{i,a}^{1,norm}$ for Montreal and Quebec City before and after the start of the police investigation.

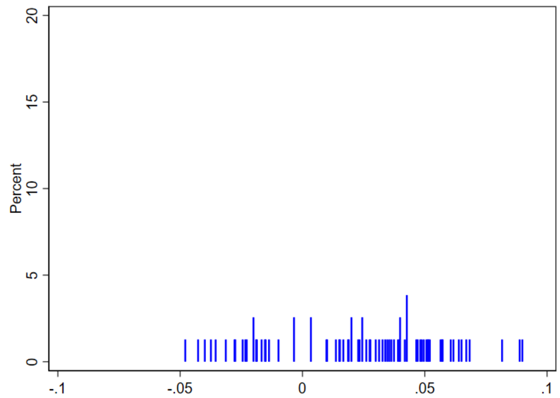
(a) Montreal Pre



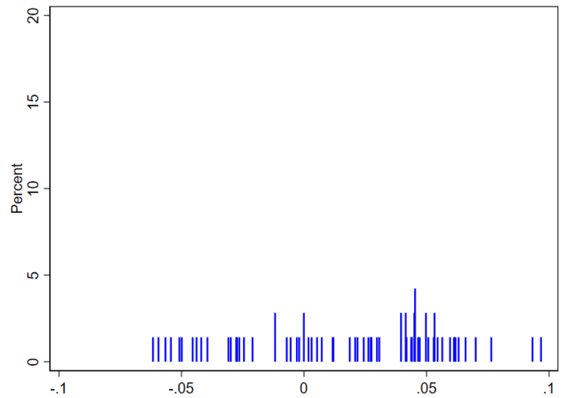

(b) Montreal Post




(c) Quebec City Pre




(d) Quebec City Post

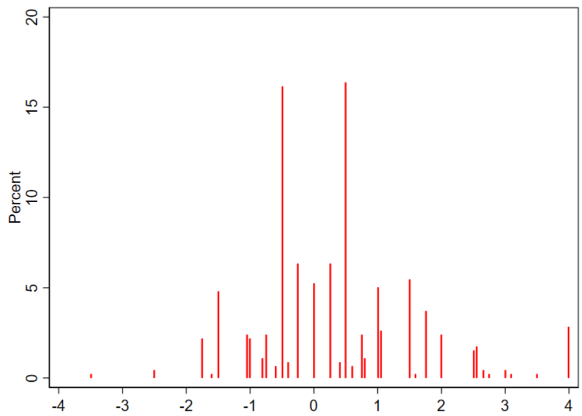



Differences between own bid and the most competitive bid in auctions as a fraction of the average winning bid in the period before the investigation, for asphalt procurement contracts in Montreal during the cartel period. Bid differences in \$ per ton. The interval of bid differences is $\pm 10\%$ of the winning bid in Montreal before the start of the investigation (\$7.5 per ton).

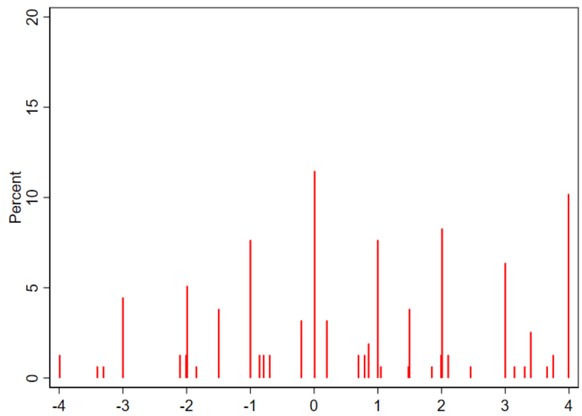
## A.3 Different intervals for bid differences

Figure A.3: Differences between own bid and most competitive bid. Difference in $ per ton. Interval of $4 per ton.

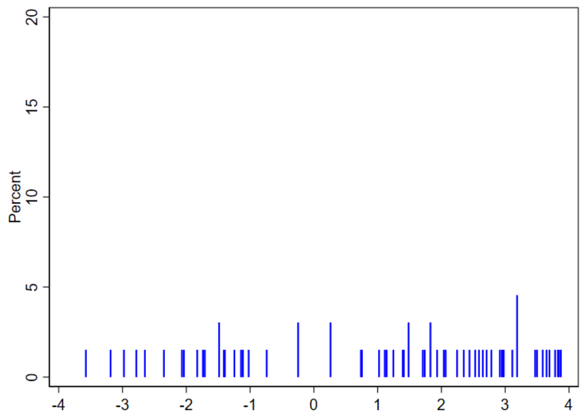
(a) Montreal Pre




(b) Montreal Post




(c) Quebec City Pre




(d) Quebec City Post

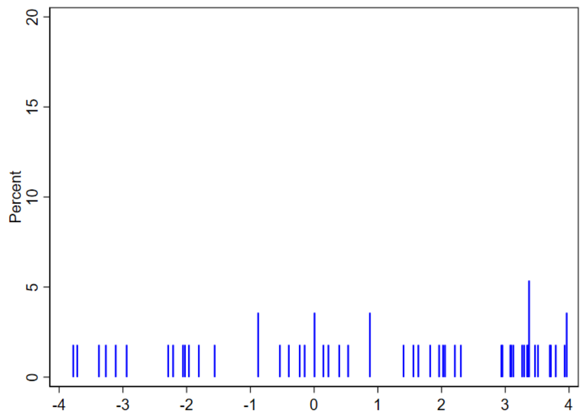
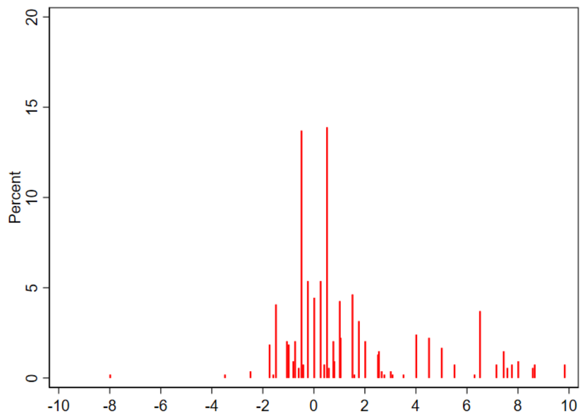
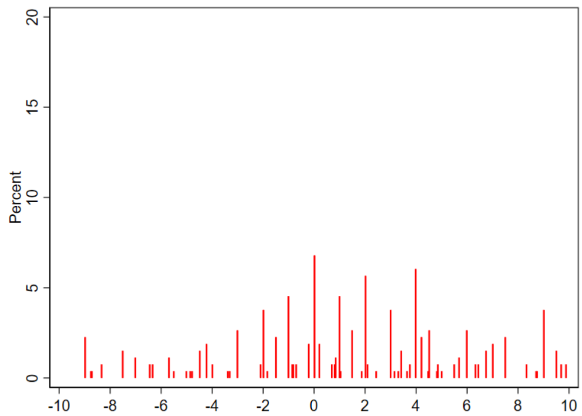


Figure A.4: Differences between own bid and most competitive bid. Difference in $ per ton. Interval of $10 per ton.

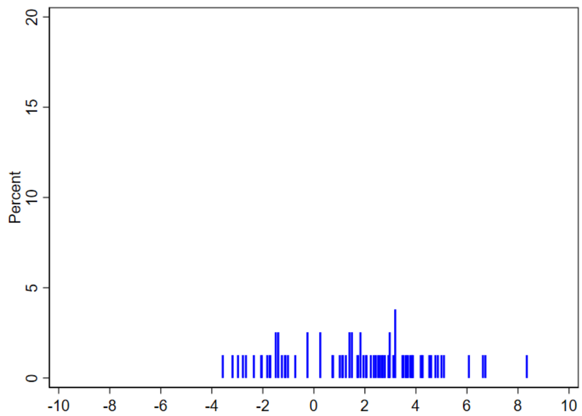
(a) Montreal Pre



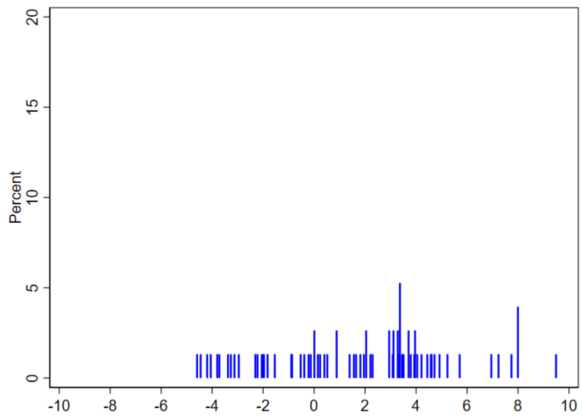

(b) Montreal Post




(c) Quebec City Pre

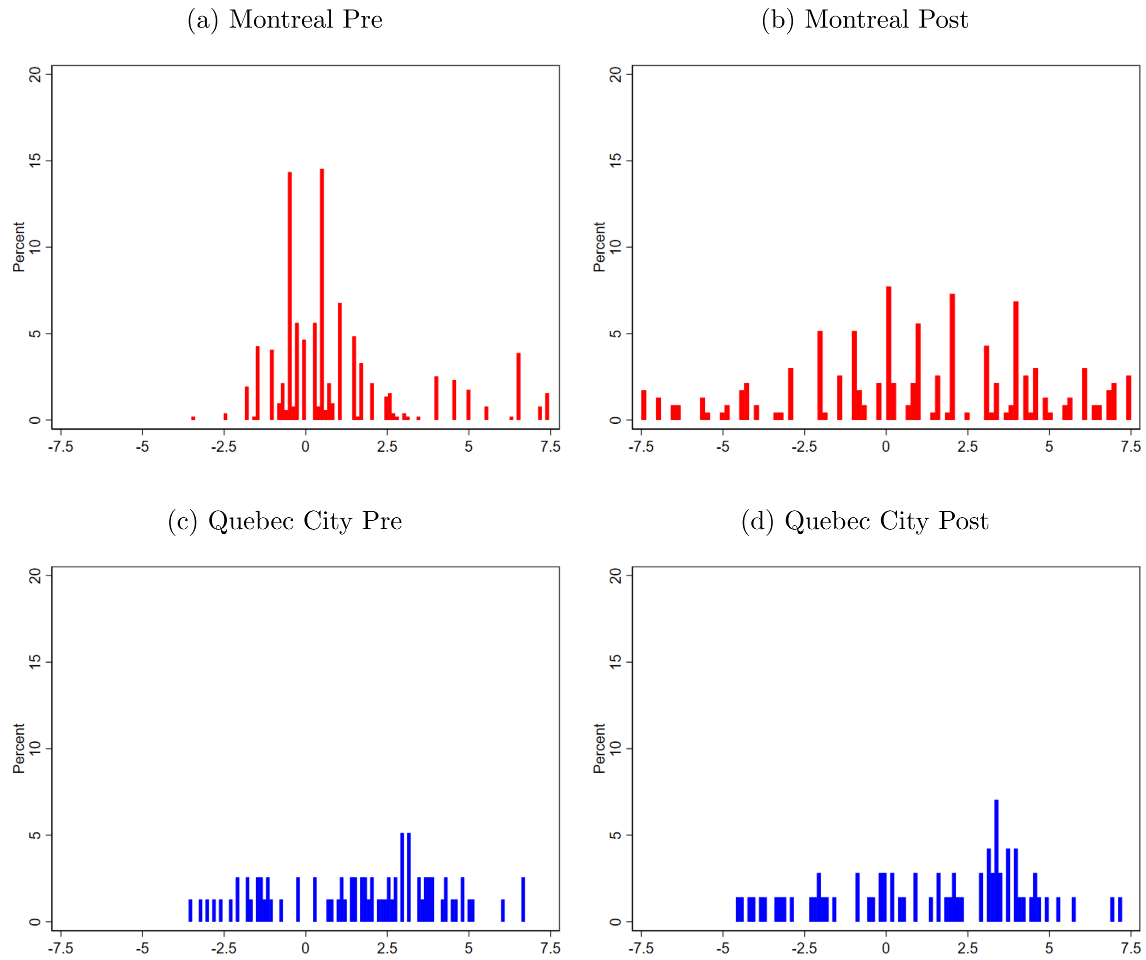



(d) Quebec City Post



## A.4 Different bin size

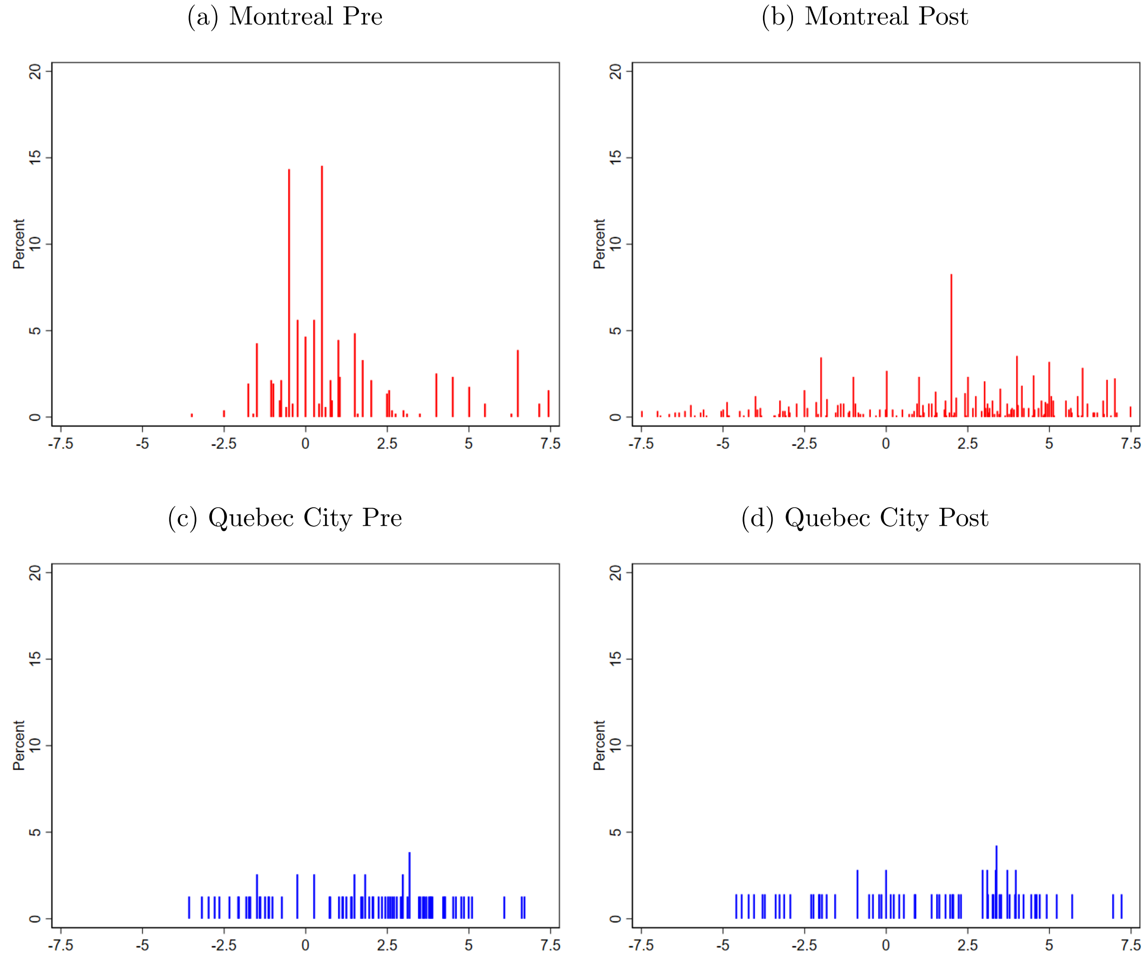
Figure A.5: Bid differences for Montreal and Quebec City before and after the start of the police investigation. The number of bins is equal to 100.




Bid differences in \$ per ton. The interval of bid differences is ±10% of the winning bid in Montreal before the start of the investigation (\$7.5 per ton). The number of bins is equal to 100.

## A.5 Sample of auctions: Original sample plus auctions with entrants

Figure A.6: Bid differences for Montreal and Quebec City before and after the start of the police investigation. Original sample plus auctions with entrants.




Bid difference in bids in \$ per ton. The interval of bid differences is ±10% of the winning bid in Montreal before the start of the investigation (\$7.5 per ton).

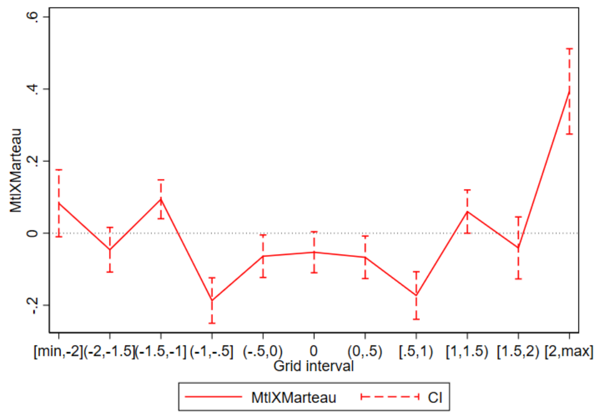
Table A.1: Distributional effect of the investigation on clustering & isolation. Original sample plus auctions with entrants.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-2.5 -2] | Pr(-2-1.5] | Pr(-1.5-1] | Pr(-1 -.5] | Pr(-.5 -0) | Pr[0] | Pr(0 .5) | Pr[.5 1) | Pr[1 1.5) | Pr[1.5 2) | Pr[2 2.5) |
| | Panel A: Without controls | | | | | | | | | | |
| MtlXMarteau | 0.0246 | -0.0463 | 0.0941*** | -0.1873*** | -0.0639** | -0.0527* | -0.0672** | -0.1729*** | 0.0601* | -0.0409 | 0.0749* |
| | (0.032) | (0.032) | (0.028) | (0.032) | (0.030) | (0.029) | (0.030) | (0.034) | (0.031) | (0.044) | (0.039) |
| Mtl | -0.0370* | 0.0241 | -0.0599** | 0.1599*** | 0.0364 | 0.0444*** | 0.0364 | 0.1494*** | -0.0340 | 0.0179 | -0.0414 |
| | (0.021) | (0.024) | (0.027) | (0.025) | (0.022) | (0.015) | (0.022) | (0.027) | (0.027) | (0.032) | (0.027) |
| Marteau | 0.0136 | 0.0009 | -0.0988*** | 0.0256 | 0.0133 | 0.0253 | 0.0133 | 0.0133 | -0.0861*** | -0.0111 | -0.0111 |
| | (0.031) | (0.029) | (0.026) | (0.024) | (0.026) | (0.025) | (0.026) | (0.026) | (0.029) | (0.042) | (0.035) |
| Constant | 0.0370* | 0.0370* | 0.0988*** | 0.0123 | 0.0247 | 0.0000 | 0.0247 | 0.0247 | 0.0988*** | 0.0617** | 0.0617** |
| | (0.021) | (0.020) | (0.026) | (0.012) | (0.017) | (0.000) | (0.017) | (0.016) | (0.026) | (0.030) | (0.025) |
| Observations | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 |
| R-squared | 0.00988 | 0.0136 | 0.00551 | 0.0985 | 0.0196 | 0.00677 | 0.0246 | 0.0896 | 0.00593 | 0.0124 | 0.0119 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 |
| | Panel B: With controls | | | | | | | | | | |
| MtlXMarteau | 0.0227 | -0.0439 | 0.0817** | -0.1844*** | -0.0778** | -0.0518* | -0.0815** | -0.1793*** | 0.0563 | -0.0342 | 0.0302 |
| | (0.038) | (0.035) | (0.035) | (0.032) | (0.038) | (0.030) | (0.037) | (0.034) | (0.036) | (0.054) | (0.042) |
| Mtl | -0.0582 | 0.0018 | -0.0630 | 0.1922* | 0.0222 | 0.0332 | 0.0263 | 0.1783* | -0.1190 | 0.0237 | 0.0047 |
| | (0.099) | (0.043) | (0.044) | (0.098) | (0.049) | (0.029) | (0.049) | (0.098) | (0.086) | (0.059) | (0.115) |
| Marteau | -0.8632*** | -0.2478 | 0.0338 | 0.6380** | -0.2784* | -0.4642** | -0.2870** | 0.5930** | 0.0566 | 0.0514 | -1.4523*** |
| | (0.278) | (0.165) | (0.281) | (0.247) | (0.146) | (0.222) | (0.142) | (0.256) | (0.303) | (0.248) | (0.280) |
| Crude oil lag | 0.0053*** | 0.0014* | -0.0008 | -0.0032** | 0.0017** | 0.0026** | 0.0018** | -0.0031** | -0.0008 | -0.0005 | 0.0087*** |
| | (0.002) | (0.001) | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.001) | (0.002) |
| Quantity | -0.0000 | 0.0000 | 0.0000 | -0.0000*** | 0.0000 | 0.0000 | 0.0000 | -0.0000* | 0.0000 | 0.0000** | -0.0000** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.0599 | -0.1277 | -0.0475 | 0.2939*** | -0.3914*** | -0.0795 | -0.3925*** | 0.2531*** | 0.0045 | -0.2128* | -0.0394 |
| | (0.109) | (0.095) | (0.093) | (0.076) | (0.085) | (0.071) | (0.085) | (0.085) | (0.096) | (0.122) | (0.106) |
| Constant | -2.2761*** | -0.5781* | 0.4913 | 1.3732** | -0.6590* | -1.1411** | -0.6883** | 1.3117** | 0.5219 | 0.3361 | -3.8430*** |
| | (0.694) | (0.348) | (0.693) | (0.602) | (0.334) | (0.557) | (0.320) | (0.619) | (0.756) | (0.572) | (0.703) |
| Observations | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 | 2,220 |
| R-squared | 0.0550 | 0.0605 | 0.0708 | 0.167 | 0.115 | 0.0847 | 0.122 | 0.151 | 0.0597 | 0.0764 | 0.0968 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 |

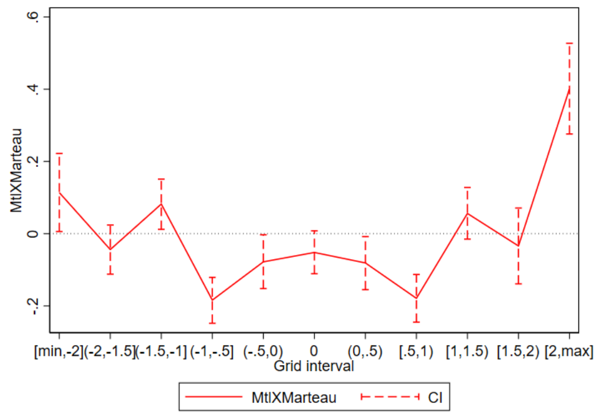
Dep. variable is the probability that bid differences fall in a given interval. *Marteau* is a dummy equal to 1 if the contract is awarded after the start of the investigations in October 2009. *Mtl* indicates that the contract was for Montreal. Panel A without controls. Panel B with controls. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.7: Graphical representation of the distributional effect of the investigation on clustering & isolation. Original sample plus auctions with entrants.

(a) No controls



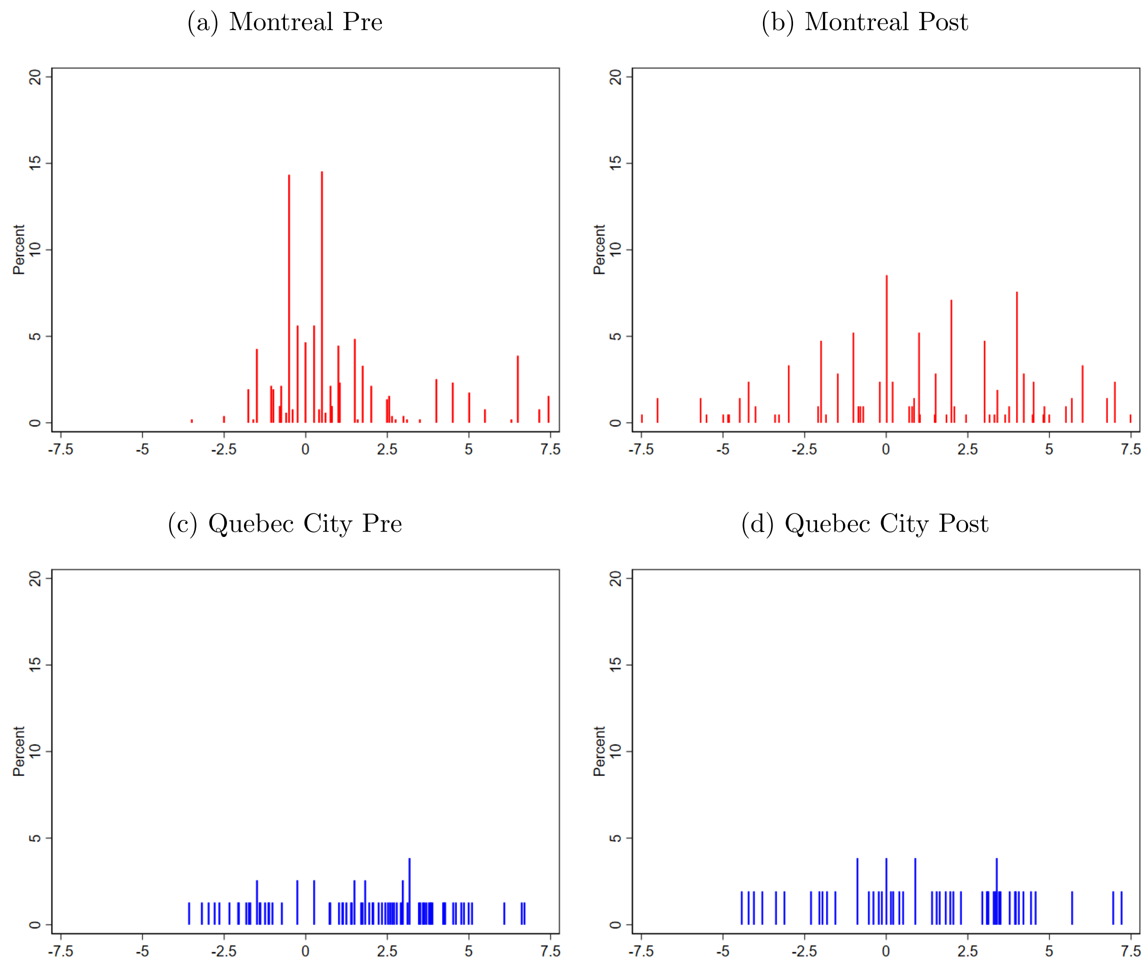

(b) Controls




This figure reports the estimated coefficient for $Mtl \times Marteau$, along with confidence intervals, from Table A.1. Confidence intervals are computed with standard errors clustered at the borough and year levels.

## A.6 Sample of auctions: Original sample minus year 2010

Figure A.8: Bid differences for Montreal and Quebec City before and after the start of the police investigation. Original sample minus year 2010




Bid difference in bids in \$ per ton. The interval of bid differences is ±10% of the winning bid in Montreal before the start of the investigation (\$7.5 per ton).

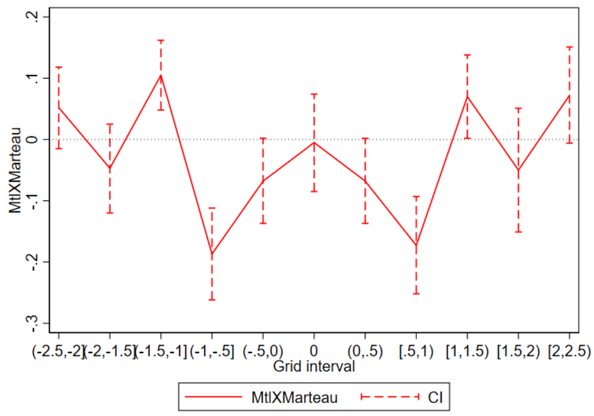
Table A.2: Distributional effect of the investigation on clustering & isolation. Original sample minus year 2010.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-2.5 -2] | Pr(-2-1.5] | Pr(-1.5-1] | Pr(-1 -.5] | Pr(-.5 -0) | Pr[0] | Pr(0 .5) | Pr[.5 1) | Pr[1 1.5) | Pr[1.5 2) | Pr[2 2.5) |
| | Panel A: Without controls | | | | | | | | | | |
| MtlXMarteau | 0.0515 | -0.0472 | 0.1048*** | -0.1871*** | -0.0677* | -0.0055 | -0.0677* | -0.1725*** | 0.0698** | -0.0501 | 0.0722* |
| | (0.034) | (0.037) | (0.029) | (0.038) | (0.036) | (0.041) | (0.036) | (0.041) | (0.035) | (0.052) | (0.040) |
| Mtl | -0.0370* | 0.0241 | -0.0599** | 0.1599*** | 0.0364 | 0.0444*** | 0.0364 | 0.1494*** | -0.0340 | 0.0179 | -0.0414 |
| | (0.021) | (0.024) | (0.027) | (0.025) | (0.022) | (0.015) | (0.022) | (0.027) | (0.027) | (0.033) | (0.027) |
| Marteau | -0.0026 | 0.0147 | -0.0988*** | 0.0394 | 0.0270 | 0.0345 | 0.0270 | 0.0270 | -0.0815** | 0.0072 | -0.0272 |
| | (0.031) | (0.034) | (0.026) | (0.030) | (0.032) | (0.033) | (0.032) | (0.032) | (0.031) | (0.050) | (0.035) |
| Constant | 0.0370* | 0.0370* | 0.0988*** | 0.0123 | 0.0247 | -0.0000 | 0.0247 | 0.0247 | 0.0988*** | 0.0617** | 0.0617** |
| | (0.021) | (0.020) | (0.026) | (0.012) | (0.017) | (.) | (0.017) | (0.016) | (0.026) | (0.030) | (0.026) |
| Observations | 924 | 924 | 924 | 924 | 924 | 924 | 924 | 924 | 924 | 924 | 924 |
| R-squared | 0.0273 | 0.00441 | 0.00964 | 0.0530 | 0.00786 | 0.00866 | 0.00786 | 0.0491 | 0.00466 | 0.00548 | 0.0121 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 |
| | Panel B: With controls | | | | | | | | | | |
| MtlXMarteau | 0.0232 | -0.0366 | 0.0843** | -0.1372*** | -0.0851 | -0.0400 | -0.0851 | -0.1307** | 0.0529 | -0.0380 | 0.0376 |
| | (0.038) | (0.046) | (0.040) | (0.047) | (0.052) | (0.053) | (0.052) | (0.050) | (0.043) | (0.068) | (0.038) |
| Mtl | 0.0211 | -0.0104 | -0.0871* | 0.2245** | 0.0032 | 0.0257 | 0.0032 | 0.2109* | -0.1846* | 0.0215 | 0.1442** |
| | (0.044) | (0.049) | (0.045) | (0.113) | (0.064) | (0.045) | (0.064) | (0.109) | (0.107) | (0.073) | (0.056) |
| Marteau | -0.2105 | -0.5137** | -0.3399 | 1.0876*** | -0.2740 | -0.4420 | -0.2740 | 1.0054** | -0.3853 | -0.4337 | -0.6007** |
| | (0.315) | (0.226) | (0.305) | (0.392) | (0.230) | (0.394) | (0.230) | (0.399) | (0.323) | (0.344) | (0.279) |
| Crude oil lag | 0.0014 | 0.0030** | 0.0014 | -0.0061*** | 0.0018 | 0.0025 | 0.0018 | -0.0057** | 0.0018 | 0.0025 | 0.0037** |
| | (0.002) | (0.001) | (0.002) | (0.002) | (0.001) | (0.002) | (0.001) | (0.002) | (0.002) | (0.002) | (0.002) |
| Quantity | -0.0000 | 0.0000 | 0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.0278 | -0.1083 | -0.0039 | 0.2853*** | -0.4218*** | -0.0709 | -0.4218*** | 0.2437*** | 0.0358 | -0.1740 | -0.0073 |
| | (0.112) | (0.101) | (0.096) | (0.075) | (0.088) | (0.084) | (0.088) | (0.088) | (0.100) | (0.127) | (0.105) |
| Constant | -0.6158 | -1.3367** | -0.5369 | 2.6778** | -0.6646 | -1.0771 | -0.6646 | 2.5285** | -0.6203 | -1.0308 | -1.6727** |
| | (0.788) | (0.535) | (0.755) | (1.025) | (0.624) | (0.992) | (0.624) | (1.034) | (0.804) | (0.853) | (0.698) |
| Observations | 924 | 924 | 924 | 924 | 924 | 924 | 924 | 924 | 924 | 924 | 924 |
| R-squared | 0.100 | 0.105 | 0.107 | 0.171 | 0.170 | 0.151 | 0.170 | 0.163 | 0.0783 | 0.130 | 0.125 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 |

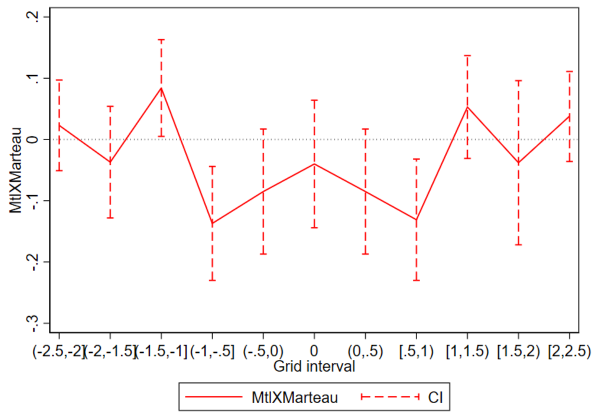
Dep. variable is the probability that bid differences fall in a given interval. *Marteau* is a dummy equal to 1 if the contract is awarded after the start of the investigations in October 2009. *Mtl* indicates that the contract was for Montreal. Panel A without controls. Panel B with controls. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.9: Graphical representation of the distributional effect of the investigation on clustering & isolation. Original sample minus year 2010.

(a) No controls



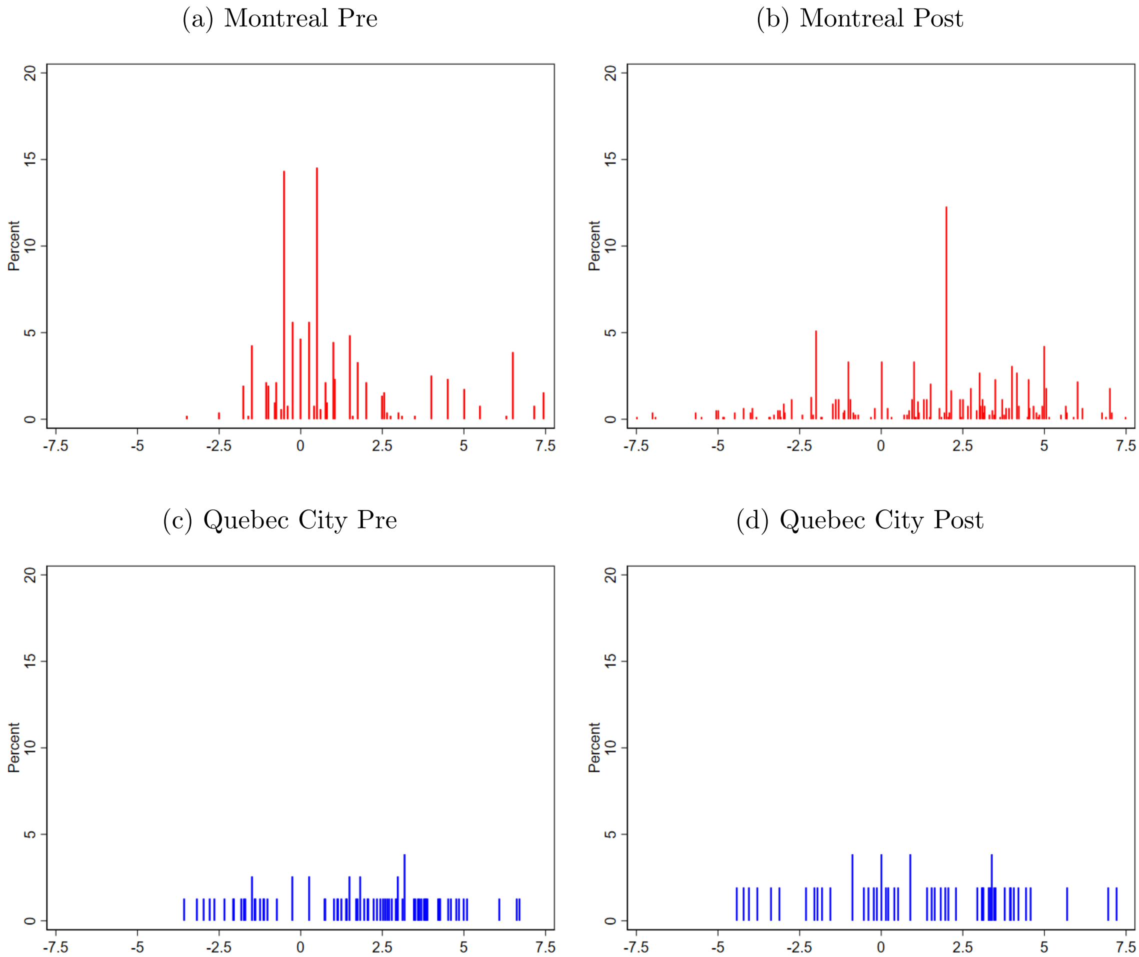

(b) Controls




This figure reports the estimated coefficient for $Mtl \times Marteau$, along with confidence intervals, from Table A.2. Confidence intervals are computed with standard errors clustered at the borough and year levels.

## A.7 Sample of auctions: Original sample plus auctions with entrants, minus year 2010

Figure A.10: Bid differences for Montreal and Quebec City before and after the start of the police investigation. Original sample plus auctions with entrants, minus year 2010.




Bid difference in bids in $ per ton. The interval of bid differences is ±10% of the winning bid in Montreal before the start of the investigation ($7.5 per ton).

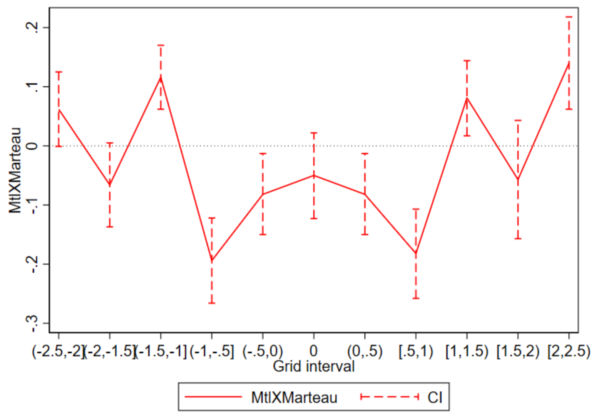
Table A.3: Distributional effect of the investigation on clustering & isolation. Original sample plus auctions with entrants, minus year 2010

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-2.5 -2] | Pr(-2-1.5] | Pr(-1.5-1] | Pr(-1 -.5] | Pr(-.5 -0) | Pr[0] | Pr(0 .5) | Pr[.5 1) | Pr[1 1.5) | Pr[1.5 2) | Pr[2 2.5) |
| | Panel A: Without controls | | | | | | | | | | |
| MtlXMarteau | 0.0620* | -0.0659* | 0.1160*** | -0.1940*** | -0.0815** | -0.0503 | -0.0815** | -0.1824*** | 0.0806** | -0.0571 | 0.1401*** |
| | (0.032) | (0.036) | (0.028) | (0.037) | (0.035) | (0.037) | (0.035) | (0.038) | (0.033) | (0.051) | (0.040) |
| Mtl | -0.0370* | 0.0241 | -0.0599** | 0.1599*** | 0.0364 | 0.0444*** | 0.0364 | 0.1494*** | -0.0340 | 0.0179 | -0.0414 |
| | (0.021) | (0.024) | (0.027) | (0.025) | (0.022) | (0.015) | (0.022) | (0.027) | (0.027) | (0.032) | (0.027) |
| Marteau | -0.0026 | 0.0147 | -0.0988*** | 0.0394 | 0.0270 | 0.0345 | 0.0270 | 0.0270 | -0.0815** | 0.0072 | -0.0272 |
| | (0.031) | (0.034) | (0.026) | (0.030) | (0.032) | (0.033) | (0.032) | (0.032) | (0.031) | (0.049) | (0.035) |
| Constant | 0.0370* | 0.0370* | 0.0988*** | 0.0123 | 0.0247 | -0.0000 | 0.0247 | 0.0247 | 0.0988*** | 0.0617** | 0.0617** |
| | (0.021) | (0.020) | (0.026) | (0.012) | (0.017) | (.) | (0.017) | (0.016) | (0.026) | (0.030) | (0.025) |
| Observations | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 |
| R-squared | 0.0211 | 0.0198 | 0.00577 | 0.0802 | 0.0243 | 0.00350 | 0.0243 | 0.0782 | 0.00236 | 0.0117 | 0.0359 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 |
| | Panel B: With controls | | | | | | | | | | |
| MtlXMarteau | 0.0460 | -0.0532 | 0.0883** | -0.1943*** | -0.1066** | -0.0593 | -0.1066** | -0.1907*** | 0.0661* | -0.0468 | 0.0653* |
| | (0.036) | (0.040) | (0.036) | (0.037) | (0.046) | (0.040) | (0.046) | (0.039) | (0.037) | (0.068) | (0.037) |
| Mtl | 0.0358 | -0.0016 | -0.0618 | 0.1851 | 0.0190 | 0.0374 | 0.0190 | 0.1714 | -0.1547 | 0.0346 | 0.1132* |
| | (0.045) | (0.047) | (0.044) | (0.125) | (0.058) | (0.038) | (0.058) | (0.124) | (0.109) | (0.070) | (0.064) |
| Marteau | -0.8777*** | -0.2941* | 0.0142 | 0.5765** | -0.3064** | -0.4429* | -0.3064** | 0.5190* | 0.0310 | -0.0299 | -1.4228*** |
| | (0.287) | (0.164) | (0.288) | (0.267) | (0.138) | (0.227) | (0.138) | (0.272) | (0.309) | (0.247) | (0.299) |
| Crude oil lag | 0.0052*** | 0.0017** | -0.0007 | -0.0029* | 0.0020*** | 0.0026** | 0.0020*** | -0.0026* | -0.0007 | 0.0001 | 0.0083*** |
| | (0.002) | (0.001) | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) | (0.001) | (0.002) |
| Quantity | -0.0000 | 0.0000 | 0.0000* | -0.0000*** | 0.0000 | 0.0000 | 0.0000 | -0.0000*** | 0.0000 | 0.0000** | -0.0000*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.0461 | -0.1355 | -0.0402 | 0.2849*** | -0.4072*** | -0.0681 | -0.4072*** | 0.2422*** | 0.0073 | -0.2125* | -0.0361 |
| | (0.111) | (0.098) | (0.094) | (0.075) | (0.085) | (0.071) | (0.085) | (0.085) | (0.097) | (0.127) | (0.107) |
| Constant | -2.3304*** | -0.7234** | 0.4480 | 1.2384* | -0.7972** | -1.1253** | -0.7972** | 1.1473* | 0.5110 | 0.0630 | -3.7269*** |
| | (0.720) | (0.348) | (0.713) | (0.667) | (0.324) | (0.562) | (0.324) | (0.667) | (0.774) | (0.578) | (0.754) |
| Observations | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 | 1,587 |
| R-squared | 0.0697 | 0.0792 | 0.0786 | 0.161 | 0.150 | 0.0954 | 0.150 | 0.155 | 0.0593 | 0.106 | 0.111 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 |

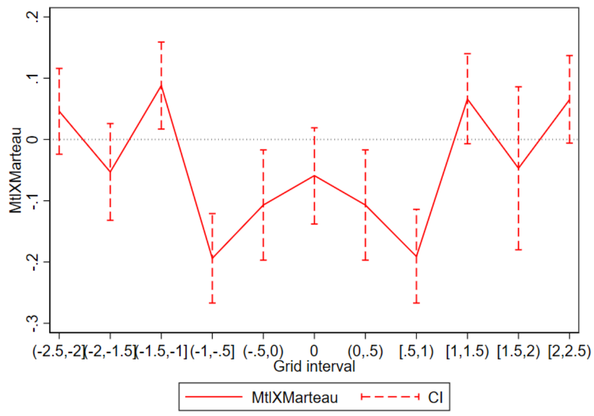
Dep. variable is the probability that bid differences fall in a given interval. *Marteau* is a dummy equal to 1 if the contract is awarded after the start of the investigations in October 2009. *Mtl* indicates that the contract was for Montreal. Panel A without controls. Panel B with controls. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.11: Graphical representation of the distributional effect of the investigation on clustering & isolation. Original sample plus auctions with entrants, minus year 2010

(a) No controls




(b) Controls

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This figure reports the estimated coefficient for $Mtl \times Marteau$, along with confidence intervals, from Table A.3. Confidence intervals are computed with standard errors clustered at the borough and year levels.

## A.8 Test of common trends

Table A.4: Test common trend using Multivariate Regression Analysis (mvreg command in STATA)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-2.5 -2] | Pr(-2-1.5] | Pr(-1.5-1] | Pr(-1 -.5] | Pr(-.5 -0) | Pr[0] | Pr(0 .5) | Pr[.5 1) | Pr[1 1.5) | Pr[1.5 2) | Pr[2 2.5) |
| | Panel A: Without controls | | | | | | | | | | |
| MtlXYear | 0.0040 | -0.0010 | -0.0198 | 0.0500 | -0.0025 | -0.0429 | -0.0025 | 0.0695 | 0.0084 | -0.0149 | 0.0318 |
| | (0.010) | (0.034) | (0.030) | (0.050) | (0.033) | (0.027) | (0.033) | (0.051) | (0.037) | (0.038) | (0.023) |
| Mtl | -8.0693 | 1.9719 | 39.6307 | -100.3275 | 5.0259 | 86.2765 | 5.0259 | -139.4795 | -16.9622 | 29.9331 | -63.8755 |
| | (19.717) | (67.449) | (60.321) | (101.307) | (66.572) | (54.695) | (66.572) | (102.380) | (73.317) | (77.183) | (45.266) |
| Year | -0.0040 | 0.0140 | -0.0107 | 0.0167 | -0.0027 | -0.0000 | -0.0027 | -0.0027 | -0.0107 | 0.0113 | -0.0067 |
| | (0.009) | (0.031) | (0.028) | (0.047) | (0.031) | (0.025) | (0.031) | (0.048) | (0.034) | (0.036) | (0.021) |
| Observations | 621 | 621 | 621 | 621 | 621 | 621 | 621 | 621 | 621 | 621 | 621 |
| R-squared | 0.033 | 0.004 | 0.022 | 0.044 | 0.003 | 0.037 | 0.003 | 0.041 | 0.002 | 0.001 | 0.024 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No |
| Mtl×Year Joint Test | | | | | | .575 | | | | | |
| | Panel B: With controls | | | | | | | | | | |
| MtlXYear | 0.0316** | 0.0006 | -0.0224 | 0.0189 | 0.0234 | -0.0487 | 0.0234 | 0.0337 | -0.0074 | 0.0236 | 0.0309 |
| | (0.013) | (0.046) | (0.041) | (0.067) | (0.043) | (0.034) | (0.043) | (0.068) | (0.050) | (0.051) | (0.031) |
| Mtl | -63.5204** | -1.3405 | 44.9516 | -37.6433 | -47.1467 | 97.7742 | -47.1467 | -67.4195 | 14.8651 | -47.6565 | -61.8860 |
| | (26.738) | (91.595) | (81.360) | (135.314) | (85.428) | (68.306) | (85.428) | (137.155) | (99.917) | (102.481) | (61.299) |
| Year | -0.0328** | 0.0470 | -0.0026 | -0.1606** | 0.2593*** | 0.0023 | 0.2593*** | -0.1536** | -0.0204 | 0.0003 | -0.0400 |
| | (0.014) | (0.048) | (0.043) | (0.071) | (0.045) | (0.036) | (0.045) | (0.072) | (0.052) | (0.054) | (0.032) |
| Crude oil lag | 0.0000 | -0.0001 | 0.0000 | 0.0018*** | -0.0028*** | -0.0000 | -0.0028*** | 0.0016*** | 0.0002 | 0.0001 | 0.0004* |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Quantity | -0.0000 | 0.0000 | 0.0000 | -0.0000 | -0.0000 | 0.0000*** | -0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | 0.0052 | -0.1174 | 0.0370 | 0.2647 | -0.5736*** | -0.0017 | -0.5736*** | 0.1720 | 0.0708 | -0.1788 | 0.0014 |
| | (0.041) | (0.140) | (0.124) | (0.207) | (0.131) | (0.104) | (0.131) | (0.210) | (0.153) | (0.157) | (0.094) |
| Observations | 621 | 621 | 621 | 621 | 621 | 621 | 621 | 621 | 621 | 621 | 621 |
| R-squared | 0.132 | 0.103 | 0.132 | 0.168 | 0.199 | 0.267 | 0.199 | 0.160 | 0.096 | 0.141 | 0.126 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mtl×Year Joint Test | | | | | | .385 | | | | | |

The outcome is the probability that bid differences fall in a given interval of values. *Mtl× Year Joint Test* shows the p-value of the joint test of the coefficient of *Mtl× Year* equal to 0. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Significance at 10% (*), 5% (**), and 1% (***).

## A.9 Main results – robustness

Table A.5: Distributional effect of the investigation on clustering & isolation – entire distribution

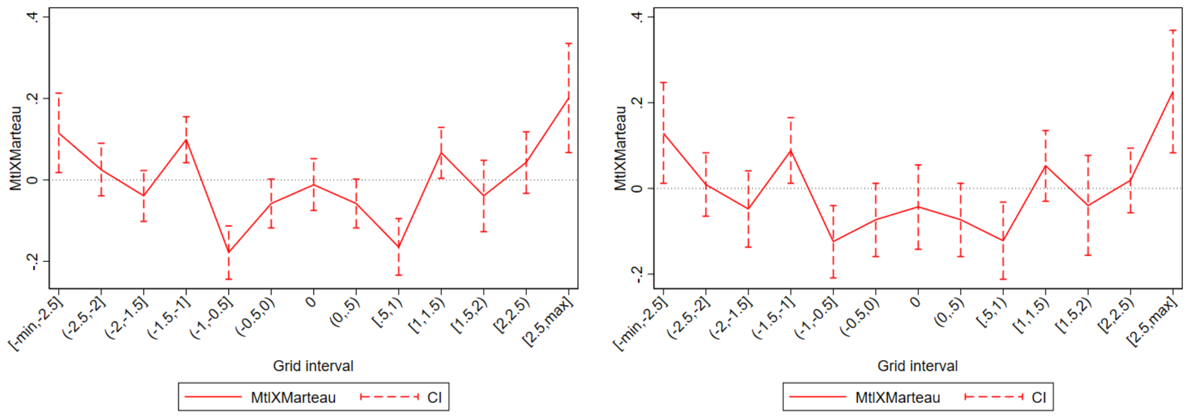
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var. | Pr[min -2.5] | Pr(-2.5 -2) | Pr(-2 -1.5) | Pr(-1.5 -1) | Pr(-1 -.5) | Pr(-.5 0) | Pr[0] | Pr(0 .5) | Pr(.5 1) | Pr(1 1.5) | Pr(1.5 2) | Pr(2 2.5) | Pr[2.5 max] |
| | Panel A: Without controls | | | | | | | | | | | | |
| MtlXMarteau | 0.1154** | 0.0252 | -0.0394 | 0.0987*** | -0.1784*** | -0.0582* | -0.0115 | -0.0582* | -0.1647*** | 0.0666** | -0.0394 | 0.0425 | 0.2014*** |
| | (0.050) | (0.033) | (0.032) | (0.029) | (0.033) | (0.031) | (0.032) | (0.031) | (0.035) | (0.032) | (0.044) | (0.039) | (0.068) |
| Mtl | -0.0543** | -0.0370* | 0.0241 | -0.0599** | 0.1599*** | 0.0364 | 0.0444*** | 0.0364 | 0.1494*** | -0.0340 | 0.0179 | -0.0414 | -0.2420*** |
| | (0.026) | (0.021) | (0.024) | (0.027) | (0.025) | (0.022) | (0.015) | (0.022) | (0.027) | (0.027) | (0.033) | (0.027) | (0.049) |
| Marteau | 0.0649 | 0.0136 | 0.0009 | -0.0988*** | 0.0256 | 0.0133 | 0.0253 | 0.0133 | 0.0133 | -0.0861*** | -0.0111 | -0.0111 | 0.0369 |
| | (0.041) | (0.031) | (0.029) | (0.026) | (0.024) | (0.026) | (0.025) | (0.026) | (0.026) | (0.029) | (0.042) | (0.035) | (0.060) |
| Constant | 0.0617** | 0.0370* | 0.0370* | 0.0988*** | 0.0123 | 0.0247 | 0.0000 | 0.0247 | 0.0247 | 0.0988*** | 0.0617** | 0.0617** | 0.4568*** |
| | (0.025) | (0.021) | (0.020) | (0.026) | (0.012) | (0.017) | (0.000) | (0.017) | (0.016) | (0.026) | (0.030) | (0.025) | (0.042) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0930 | 0.0226 | 0.00691 | 0.0103 | 0.0621 | 0.0104 | 0.00587 | 0.0104 | 0.0585 | 0.00680 | 0.00889 | 0.00805 | 0.0685 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No | No | No |
| Mean Y Pre Montreal | -4.12 | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 | 5.6 |
| | Panel B: With controls | | | | | | | | | | | | |
| MtlXMarteau | 0.1293** | 0.0093 | -0.0483 | 0.0884** | -0.1243*** | -0.0735* | -0.0434 | -0.0735* | -0.1217*** | 0.0526 | -0.0397 | 0.0186 | 0.2260*** |
| | (0.060) | (0.038) | (0.045) | (0.039) | (0.043) | (0.044) | (0.050) | (0.044) | (0.046) | (0.042) | (0.060) | (0.039) | (0.073) |
| Mtl | -0.1218 | -0.0586 | -0.0124 | -0.0933** | 0.2440** | -0.0131 | 0.0115 | -0.0131 | 0.2336** | -0.1554* | 0.0105 | 0.0659 | -0.0976 |
| | (0.126) | (0.093) | (0.046) | (0.044) | (0.094) | (0.053) | (0.039) | (0.053) | (0.092) | (0.086) | (0.064) | (0.097) | (0.134) |
| Marteau | 1.0368** | -0.1261 | -0.4950** | -0.3219 | 1.1785*** | -0.2967 | -0.4930 | -0.2967 | 1.1000*** | -0.3464 | -0.3084 | -0.6414** | 0.0103 |
| | (0.488) | (0.317) | (0.214) | (0.288) | (0.376) | (0.229) | (0.382) | (0.229) | (0.383) | (0.309) | (0.331) | (0.289) | (0.617) |
| Crude oil lag | -0.0058** | 0.0010 | 0.0030** | 0.0013 | -0.0066*** | 0.0018 | 0.0027 | 0.0018 | -0.0062*** | 0.0016 | 0.0017 | 0.0040** | -0.0003 |
| | (0.003) | (0.002) | (0.001) | (0.002) | (0.002) | (0.001) | (0.002) | (0.001) | (0.002) | (0.002) | (0.002) | (0.002) | (0.004) |
| Quantity | 0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 | 0.0000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | 0.3318*** | -0.0473 | -0.1005 | -0.0075 | 0.2865*** | -0.4181*** | -0.0788 | -0.4181*** | 0.2453*** | 0.0355 | -0.1682 | -0.0254 | 0.3650** |
| | (0.102) | (0.111) | (0.098) | (0.096) | (0.076) | (0.086) | (0.085) | (0.086) | (0.088) | (0.100) | (0.122) | (0.104) | (0.154) |
| Constant | 2.6080** | -0.3432 | -1.3086** | -0.4759 | 2.9097*** | -0.6781 | -1.1910 | -0.6781 | 2.7580*** | -0.5555 | -0.7000 | -1.7353** | 0.3897 |
| | (1.250) | (0.793) | (0.501) | (0.709) | (0.976) | (0.604) | (0.976) | (0.604) | (0.986) | (0.767) | (0.813) | (0.723) | (1.637) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.182 | 0.0839 | 0.0981 | 0.102 | 0.176 | 0.168 | 0.148 | 0.168 | 0.169 | 0.0781 | 0.124 | 0.116 | 0.130 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean Y Pre Montreal | -4.12 | . | -1.58 | -1.03 | -.55 | -.27 | 0 | .27 | .55 | 1.02 | 1.6 | 2 | 5.6 |

Dep. variable is the probability that bid differences fall in a given interval. *Marteau* is a dummy equal to 1 if the contract is awarded after the start of the investigations in October 2009. *Mtl* indicates that the contract was for Montreal. Panel A without controls. Panel B with controls. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.12: Graphical representation of the distributional effect of the investigation on clustering & isolation. Entire distribution.

(a) No controls

(b) Controls




This figure reports the estimated coefficient for $Mtl \times Marteau$, along with confidence intervals, from Table A.5. Confidence intervals are computed with standard errors clustered at the borough and year levels.

Table A.6: Distributional effect of the investigation on clustering & isolation – no separate bin for 0.

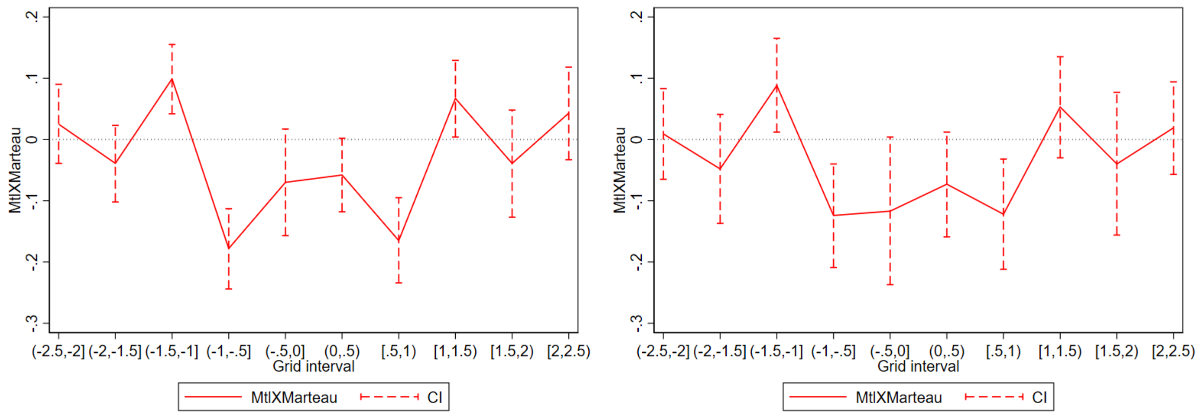
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-2.5 -2] | Pr(-2-1.5] | Pr(-1.5-1] | Pr(-1 -.5] | Pr(-.5 -0] | Pr(0 .5) | Pr[.5 1) | Pr[1 1.5) | Pr[1.5 2) | Pr[2 2.5) |
| | | | | | Panel A: Without controls | | | | | |
| MtlXMarteau | 0.0252 | -0.0394 | 0.0987*** | -0.1784*** | -0.0697 | -0.0582* | -0.1647*** | 0.0666** | -0.0394 | 0.0425 |
| | (0.033) | (0.032) | (0.029) | (0.033) | (0.044) | (0.031) | (0.035) | (0.032) | (0.044) | (0.039) |
| Mtl | -0.0370* | 0.0241 | -0.0599** | 0.1599*** | 0.0809*** | 0.0364 | 0.1494*** | -0.0340 | 0.0179 | -0.0414 |
| | (0.021) | (0.024) | (0.027) | (0.025) | (0.026) | (0.022) | (0.027) | (0.027) | (0.033) | (0.027) |
| Marteau | 0.0136 | 0.0009 | -0.0988*** | 0.0256 | 0.0386 | 0.0133 | 0.0133 | -0.0861*** | -0.0111 | -0.0111 |
| | (0.031) | (0.029) | (0.026) | (0.024) | (0.035) | (0.026) | (0.026) | (0.029) | (0.042) | (0.035) |
| Constant | 0.0370* | 0.0370* | 0.0988*** | 0.0123 | 0.0247 | 0.0247 | 0.0247 | 0.0988*** | 0.0617** | 0.0617** |
| | (0.021) | (0.020) | (0.026) | (0.012) | (0.017) | (0.017) | (0.016) | (0.026) | (0.030) | (0.025) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0226 | 0.00691 | 0.0103 | 0.0621 | 0.00746 | 0.0104 | 0.0585 | 0.00680 | 0.00889 | 0.00805 |
| Borough FE | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.16 | .27 | .55 | 1.02 | 1.6 | 2 |
| | | | | | Panel B: With controls | | | | | |
| MtlXMarteau | 0.0093 | -0.0483 | 0.0884** | -0.1243*** | -0.1169* | -0.0735* | -0.1217*** | 0.0526 | -0.0397 | 0.0186 |
| | (0.038) | (0.045) | (0.039) | (0.043) | (0.062) | (0.044) | (0.046) | (0.042) | (0.060) | (0.039) |
| Mtl | -0.0586 | -0.0124 | -0.0933** | 0.2440** | -0.0016 | -0.0131 | 0.2336** | -0.1554* | 0.0105 | 0.0659 |
| | (0.093) | (0.046) | (0.044) | (0.094) | (0.068) | (0.053) | (0.092) | (0.086) | (0.064) | (0.097) |
| Marteau | -0.1261 | -0.4950** | -0.3219 | 1.1785*** | -0.7897* | -0.2967 | 1.1000*** | -0.3464 | -0.3084 | -0.6414** |
| | (0.317) | (0.214) | (0.288) | (0.376) | (0.410) | (0.229) | (0.383) | (0.309) | (0.331) | (0.289) |
| Crude oil lag | 0.0010 | 0.0030** | 0.0013 | -0.0066*** | 0.0046* | 0.0018 | -0.0062*** | 0.0016 | 0.0017 | 0.0040** |
| | (0.002) | (0.001) | (0.002) | (0.002) | (0.002) | (0.001) | (0.002) | (0.002) | (0.002) | (0.002) |
| Quantity | -0.0000 | 0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.0473 | -0.1005 | -0.0075 | 0.2865*** | -0.4970*** | -0.4181*** | 0.2453*** | 0.0355 | -0.1682 | -0.0254 |
| | (0.111) | (0.098) | (0.096) | (0.076) | (0.098) | (0.086) | (0.088) | (0.100) | (0.122) | (0.104) |
| Constant | -0.3432 | -1.3086** | -0.4759 | 2.9097*** | -1.8690* | -0.6781 | 2.7580*** | -0.5555 | -0.7000 | -1.7353** |
| | (0.793) | (0.501) | (0.709) | (0.976) | (1.049) | (0.604) | (0.986) | (0.767) | (0.813) | (0.723) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0839 | 0.0981 | 0.102 | 0.176 | 0.176 | 0.168 | 0.169 | 0.0781 | 0.124 | 0.116 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean Y Pre Montreal | . | -1.58 | -1.03 | -.55 | -.16 | .27 | .55 | 1.02 | 1.6 | 2 |

Dep. variable is the probability that bid differences fall in a given interval. *Marteau* is a dummy equal to 1 if the contract is awarded after the start of the investigations in October 2009. *Mtl* indicates that the contract was for Montreal. Panel A without controls. Panel B with controls. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.13: Graphical representation of the distributional effect of the investigation on clustering & isolation.

(a) No controls

(b) Controls




This figure reports the estimated coefficient for $Mtl \times Marteau$, along with confidence intervals, from Table A.6. Confidence intervals are computed with standard errors clustered at the borough and year levels.

Table A.7: Distributional effect of the investigation on clustering & isolation. Finer grid – 0.25

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var. | Pr(-2.25 -2] | Pr(-2 -1.75] | Pr(-1.75 -1.5] | Pr(-1.5 -1.25] | Pr(-1.25 -1] | Pr(-1 -.75] | Pr(-.75 -.5] | Pr(-.5 -.25] | Pr(-.25 0) | Pr[0] | Pr(0 .25) | Pr[.25 .5) | Pr[.5 .75) | Pr[.75 1) | Pr[1 1.25) | Pr[1.25 1.5) | Pr[1.5 1.75) | Pr[1.75 2) | Pr[2 2.25) |
| | | | | | | | | | Panel A: Without controls | | | | | | | | | | |
| MtlXMarteau | 0.0256 | -0.0283 | -0.0111 | 0.0494** | 0.0493** | -0.0420** | -0.1364*** | -0.0491* | -0.0091 | -0.0115 | -0.0091 | -0.0491* | -0.1383*** | -0.0264 | 0.0266 | 0.0400 | -0.0294 | -0.0101 | 0.0272 |
| | (0.029) | (0.022) | (0.025) | (0.022) | (0.024) | (0.020) | (0.030) | (0.025) | (0.018) | (0.032) | (0.018) | (0.025) | (0.030) | (0.025) | (0.024) | (0.026) | (0.033) | (0.027) | (0.034) |
| Mtl | -0.0247 | 0.0062 | 0.0179 | -0.0494** | -0.0105 | 0.0296*** | 0.1302*** | 0.0364 | -0.0000 | 0.0444*** | -0.0000 | 0.0364 | 0.1321*** | 0.0173 | 0.0154 | -0.0494** | 0.0235 | -0.0056 | -0.0167 |
| | (0.017) | (0.013) | (0.021) | (0.022) | (0.022) | (0.007) | (0.027) | (0.022) | (0.000) | (0.015) | (0.000) | (0.022) | (0.026) | (0.014) | (0.022) | (0.022) | (0.021) | (0.021) | (0.022) |
| Marteau | 0.0133 | 0.0130 | -0.0120 | -0.0494** | -0.0494** | 0.0253 | 0.0003 | -0.0120 | 0.0253 | 0.0253 | 0.0253 | -0.0120 | 0.0003 | 0.0130 | -0.0494** | -0.0367 | 0.0006 | -0.0117 | 0.0009 |
| | (0.027) | (0.021) | (0.021) | (0.022) | (0.021) | (0.017) | (0.017) | (0.021) | (0.017) | (0.025) | (0.017) | (0.021) | (0.017) | (0.021) | (0.021) | (0.026) | (0.030) | (0.026) | (0.029) |
| Constant | 0.0247 | 0.0123 | 0.0247 | 0.0494** | 0.0494** | -0.0000 | 0.0123 | 0.0247 | 0.0000 | 0.0000 | 0.0000 | 0.0247 | 0.0123 | 0.0123 | 0.0494** | 0.0494** | 0.0247 | 0.0370* | 0.0370* |
| | (0.017) | (0.012) | (0.017) | (0.022) | (0.021) | (.) | (0.012) | (0.017) | (0.000) | (0.000) | (0.000) | (0.017) | (0.012) | (0.012) | (0.021) | (0.022) | (0.017) | (0.020) | (0.020) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0205 | 0.00414 | 0.00463 | 0.0456 | 0.00346 | 0.00450 | 0.0606 | 0.0229 | 0.0119 | 0.00587 | 0.0119 | 0.0229 | 0.0616 | 0.00201 | 0.00675 | 0.0298 | 0.00530 | 0.00437 | 0.00524 |
| Borough FE | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No |
| Mean Y Pre Montreal | -1.75 | -1.75 | -1.5 | . | -1.03 | -.77 | -.5 | -.27 | . | -1.75 | . | .27 | .5 | .77 | 1.02 | . | 1.5 | 1.75 | 2 |
| | | | | | | | | | Panel B: With controls | | | | | | | | | | |
| MtlXMarteau | 0.0302 | -0.0003 | -0.0480 | 0.0474 | 0.0410 | -0.0255 | -0.0988*** | -0.0423 | -0.0312 | -0.0434 | -0.0312 | -0.0423 | -0.1057*** | -0.0159 | -0.0002 | 0.0529* | -0.0748 | 0.0352* | 0.0355 |
| | (0.034) | (0.010) | (0.046) | (0.031) | (0.028) | (0.026) | (0.035) | (0.028) | (0.027) | (0.050) | (0.027) | (0.028) | (0.036) | (0.029) | (0.030) | (0.031) | (0.057) | (0.021) | (0.035) |
| Mtl | -0.0937 | -0.0149 | 0.0024 | -0.0431 | -0.0502** | 0.0349 | 0.2091*** | -0.0561 | 0.0430 | 0.0115 | 0.0430 | -0.0561 | 0.2059*** | 0.0277 | -0.0161 | -0.1393 | 0.0479 | -0.0374 | 0.0365 |
| | (0.089) | (0.012) | (0.045) | (0.038) | (0.023) | (0.081) | (0.046) | (0.036) | (0.030) | (0.039) | (0.030) | (0.036) | (0.046) | (0.079) | (0.024) | (0.087) | (0.056) | (0.029) | (0.093) |
| Marteau | -0.2087 | -0.3737*** | -0.1213 | -0.0310 | -0.2909 | 0.1231 | 1.0554*** | -0.3717** | 0.0750 | -0.4930 | 0.0750 | -0.3717** | 1.0125*** | 0.0875 | -0.1869 | -0.1594 | -0.1736 | -0.1349 | -0.7075*** |
| | (0.283) | (0.134) | (0.165) | (0.103) | (0.276) | (0.218) | (0.327) | (0.148) | (0.156) | (0.382) | (0.156) | (0.148) | (0.319) | (0.220) | (0.274) | (0.131) | (0.186) | (0.248) | (0.269) |
| Crude oil lag | 0.0013 | 0.0023*** | 0.0007 | -0.0001 | 0.0014 | -0.0009 | -0.0057*** | 0.0020** | -0.0002 | 0.0027 | -0.0002 | 0.0020** | -0.0055*** | -0.0008 | 0.0010 | 0.0006 | 0.0011 | 0.0006 | 0.0043*** |
| | (0.002) | (0.001) | (0.001) | (0.000) | (0.002) | (0.001) | (0.002) | (0.001) | (0.001) | (0.002) | (0.001) | (0.001) | (0.002) | (0.001) | (0.002) | (0.001) | (0.001) | (0.001) | (0.002) |
| Quantity | -0.0000 | 0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | 0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | 0.0000 | 0.0000 | -0.0000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.1328** | -0.1108*** | 0.0103 | 0.0181 | -0.0256 | 0.0120 | 0.2745*** | -0.4741*** | 0.0560 | -0.0788 | 0.0560 | -0.4741*** | 0.2592*** | -0.0139 | 0.0344 | 0.0011 | -0.0121 | -0.1561*** | -0.0823 |
| | (0.062) | (0.030) | (0.091) | (0.074) | (0.081) | (0.032) | (0.076) | (0.068) | (0.037) | (0.085) | (0.037) | (0.068) | (0.078) | (0.041) | (0.084) | (0.075) | (0.097) | (0.059) | (0.063) |
| Constant | -0.4223 | -1.0037*** | -0.3049 | 0.0843 | -0.5601 | 0.5357 | 2.3740*** | -0.6926* | 0.0146 | -1.1910 | 0.0146 | -0.6926* | 2.2658*** | 0.4922 | -0.4093 | -0.1462 | -0.5027 | -0.1973 | -1.7951*** |
| | (0.723) | (0.345) | (0.350) | (0.163) | (0.711) | (0.599) | (0.807) | (0.365) | (0.420) | (0.976) | (0.420) | (0.365) | (0.785) | (0.606) | (0.703) | (0.262) | (0.428) | (0.625) | (0.684) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0975 | 0.180 | 0.102 | 0.0937 | 0.103 | 0.112 | 0.183 | 0.193 | 0.0772 | 0.148 | 0.0772 | 0.193 | 0.180 | 0.115 | 0.0843 | 0.0802 | 0.102 | 0.222 | 0.125 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean Y Pre Montreal | . | -1.75 | -1.5 | . | -1.03 | -.77 | -.5 | -.27 | . | -1.75 | . | .27 | .5 | .77 | 1.02 | . | 1.5 | 1.75 | 2 |

Dep. variable is the probability that bid differences fall in a given interval. *Marteau* is a dummy equal to 1 if the contract is awarded after the start of the investigations in October 2009. *Mtl* indicates that the contract was for Montreal. Panel A without controls. Panel B with controls. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Table A.8: Distributional regression doubling intervals around 0.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-4 -3] | Pr(-3 -2] | Pr(-2 -1] | Pr(-1 0) | Pr[0] | Pr(0 1) | Pr[1, 2) | Pr[2 3) | Pr[3 4) |
| | Panel A: Without controls | | | | | | | | |
| MtlXMarteau | -0.0113 | 0.0459 | 0.0593 | -0.2366*** | -0.0115 | -0.2229*** | 0.0272 | 0.0950* | -0.0133 |
| | (0.031) | (0.039) | (0.040) | (0.039) | (0.032) | (0.044) | (0.048) | (0.048) | (0.045) |
| Mtl | -0.0228 | -0.0704** | -0.0358 | 0.1963*** | 0.0444*** | 0.1858*** | -0.0160 | -0.1191*** | -0.1531*** |
| | (0.017) | (0.028) | (0.031) | (0.027) | (0.015) | (0.034) | (0.033) | (0.037) | (0.035) |
| Marteau | 0.0386 | -0.0108 | -0.0978*** | 0.0389 | 0.0253 | 0.0266 | -0.0972** | -0.0969** | 0.0674 |
| | (0.030) | (0.038) | (0.035) | (0.033) | (0.025) | (0.039) | (0.044) | (0.045) | (0.044) |
| Constant | 0.0247 | 0.0741*** | 0.1358*** | 0.0370* | 0.0000 | 0.0494* | 0.1605*** | 0.1728*** | 0.1605*** |
| | (0.017) | (0.028) | (0.028) | (0.019) | (0.000) | (0.028) | (0.031) | (0.036) | (0.034) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0205 | 0.0252 | 0.00849 | 0.0739 | 0.00587 | 0.0707 | 0.0128 | 0.0177 | 0.0880 |
| Borough FE | No | No | No | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No | No | No | No |
| Type FE | No | No | No | No | No | No | No | No | No |
| Mean Y Pre Montreal | -3.5 | -2.5 | -1.36 | -.48 | 0 | .48 | 1.34 | 2.34 | 3.15 |
| | Panel B: With controls | | | | | | | | |
| MtlXMarteau | 0.0117 | 0.0535 | 0.0401 | -0.1977*** | -0.0434 | -0.1951*** | 0.0130 | 0.0620 | 0.0369 |
| | (0.034) | (0.046) | (0.059) | (0.058) | (0.050) | (0.060) | (0.066) | (0.057) | (0.046) |
| Mtl | -0.0528 | -0.0837 | -0.1058* | 0.2308*** | 0.0115 | 0.2204** | -0.1449 | -0.0438 | -0.1118 |
| | (0.084) | (0.094) | (0.062) | (0.088) | (0.039) | (0.087) | (0.092) | (0.108) | (0.106) |
| Marteau | 0.3556 | -0.0493 | -0.8169** | 0.8818** | -0.4930 | 0.8033* | -0.6548 | -1.2352*** | 0.0411 |
| | (0.272) | (0.344) | (0.353) | (0.413) | (0.382) | (0.421) | (0.419) | (0.379) | (0.316) |
| Crude oil lag | -0.0019 | 0.0003 | 0.0043** | -0.0048** | 0.0027 | -0.0044* | 0.0033 | 0.0068*** | -0.0001 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Quantity | -0.0000 | 0.0000 | 0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0000 | -0.0000 | -0.0000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | 0.1608** | 0.0901 | -0.1080 | -0.1317 | -0.0788 | -0.1729 | -0.1327 | -0.1393 | 0.1667* |
| | (0.073) | (0.105) | (0.121) | (0.112) | (0.085) | (0.126) | (0.125) | (0.154) | (0.093) |
| Constant | 0.8725 | -0.0578 | -1.7845** | 2.2316** | -1.1910 | 2.0800* | -1.2554 | -2.7975*** | 0.1231 |
| | (0.709) | (0.872) | (0.870) | (1.087) | (0.976) | (1.102) | (1.055) | (0.922) | (0.796) |
| Observations | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 | 1,009 |
| R-squared | 0.0850 | 0.0939 | 0.115 | 0.152 | 0.148 | 0.149 | 0.137 | 0.0867 | 0.144 |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean Y Pre Montreal | -3.5 | -2.5 | -1.36 | -.48 | 0 | .48 | 1.34 | 2.34 | 3.15 |

The outcome is the probability that bid differences fall in a given interval of values. *Quantity* represents the number of tons in the call. *Crude oil lag* represents the lagged price of crude oil. *HHI* is the Herfindahl index of each city at the year level. Significance at 10% (*), 5% (**), and 1% (***).

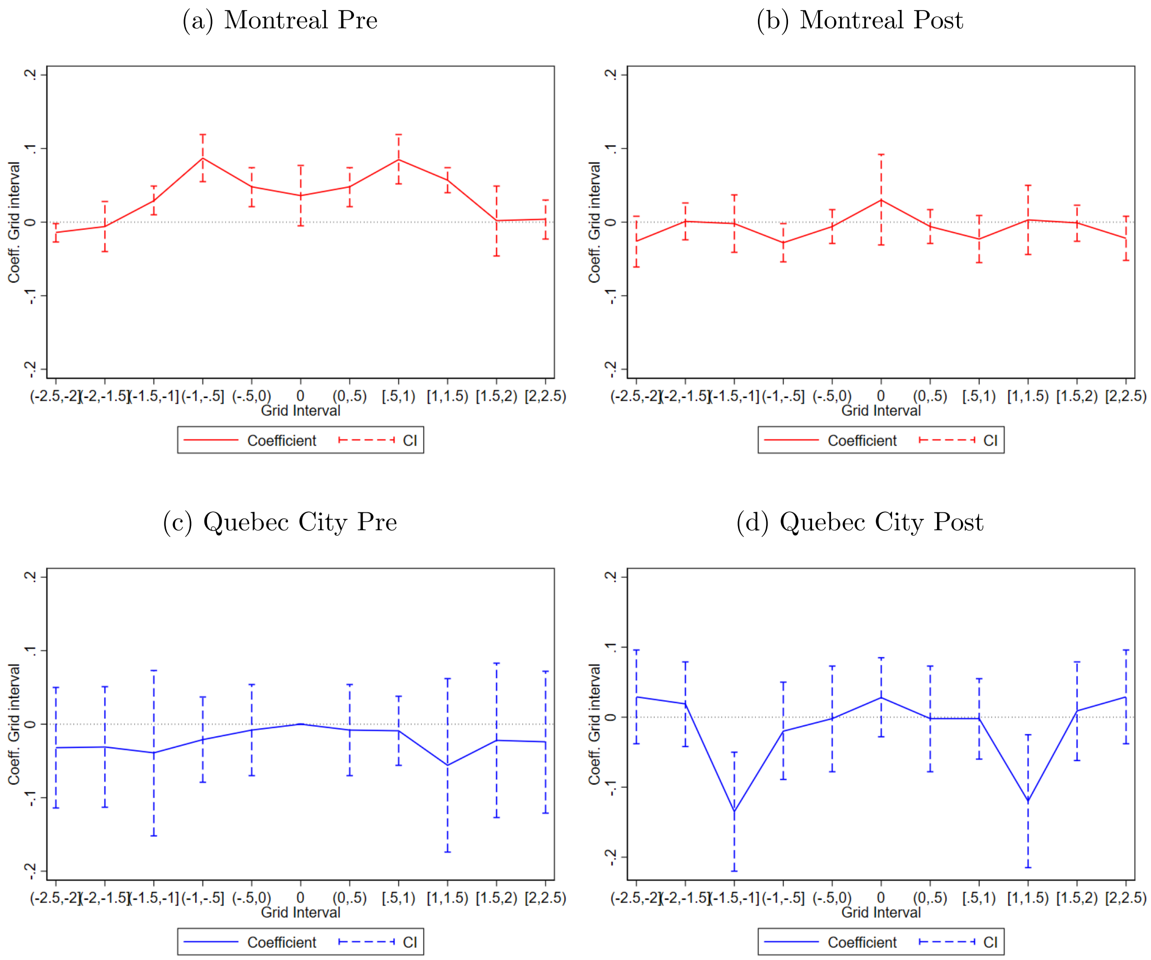
## A.10 Test adding controls

Table A.9: Distributional regression of bid differences $\Delta^1_{i,a}$ with respect to $\Delta^2_{i,a}$ in Montreal and Quebec City before and after the investigation. Adding controls.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep.Var | Pr(-2.5 -2] | Pr(-2-1.5] | Pr(-1.5-1] | Pr(-1 -.5] | Pr(-.5 -0) | Pr[0] | Pr(0 .5) | Pr[.5 1) | Pr[1 1.5) | Pr[1.5 2) | Pr[2 2.5) |
| | | | | | | Panel A: Montreal Pre | | | | | |
| $\mathbb{1}(\Delta^1_{i,a})$ | -0.0144** | -0.0060 | 0.0295*** | 0.0870*** | 0.0477*** | 0.0360* | 0.0477*** | 0.0852*** | 0.0570*** | 0.0016 | 0.0035 |
| | (0.006) | (0.017) | (0.010) | (0.016) | (0.014) | (0.021) | (0.014) | (0.017) | (0.009) | (0.024) | (0.014) |
| Constant | 0.0411*** | -0.1645* | 0.0710*** | -0.0255 | 0.0708** | 0.1806*** | 0.0708** | -0.0050 | -0.0038 | -0.1052 | 0.0618** |
| | (0.013) | (0.092) | (0.018) | (0.090) | (0.032) | (0.038) | (0.032) | (0.095) | (0.041) | (0.093) | (0.024) |
| Observations | 808 | 808 | 808 | 808 | 808 | 808 | 808 | 808 | 808 | 808 | 808 |
| R-squared | 0.0562 | 0.0655 | 0.0937 | 0.121 | 0.156 | 0.150 | 0.156 | 0.117 | 0.0813 | 0.0759 | 0.0599 |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | | | | | | Panel B: Montreal Post | | | | | |
| $\mathbb{1}(\Delta^1_{i,a})$ | -0.0265 | 0.0006 | -0.0018 | -0.0281** | -0.0062 | 0.0304 | -0.0062 | -0.0232 | 0.0031 | -0.0014 | -0.0220 |
| | (0.018) | (0.013) | (0.020) | (0.013) | (0.012) | (0.032) | (0.012) | (0.016) | (0.024) | (0.013) | (0.015) |
| Constant | -0.4693* | 0.2374* | -0.0318 | 0.4793*** | 0.0200 | -0.5772*** | 0.0200 | 0.4755*** | -0.0969 | 0.5730*** | -1.4407*** |
| | (0.254) | (0.125) | (0.153) | (0.135) | (0.043) | (0.181) | (0.043) | (0.138) | (0.158) | (0.156) | (0.310) |
| Observations | 673 | 673 | 673 | 673 | 673 | 673 | 673 | 673 | 673 | 673 | 673 |
| R-squared | 0.108 | 0.0912 | 0.0789 | 0.0622 | 0.0902 | 0.137 | 0.0902 | 0.0572 | 0.0829 | 0.0893 | 0.152 |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | | | | | | Panel C: Quebec Pre | | | | | |
| $\mathbb{1}(\Delta^1_{i,a})$ | -0.0317 | -0.0309 | -0.0395 | -0.0214 | -0.0079 | | -0.0079 | -0.0089 | -0.0560 | -0.0219 | -0.0242 |
| | (0.042) | (0.042) | (0.057) | (0.030) | (0.032) | | (0.032) | (0.024) | (0.060) | (0.054) | (0.049) |
| Constant | 0.0225 | -0.0267 | 0.5467*** | -0.0242 | -0.0033 | | -0.0033 | -0.0052 | 0.6677*** | 0.1399 | 0.0809 |
| | (0.125) | (0.149) | (0.178) | (0.077) | (0.114) | | (0.114) | (0.101) | (0.142) | (0.198) | (0.115) |
| Observations | 140 | 140 | 140 | 140 | 140 | | 140 | 140 | 140 | 140 | 140 |
| R-squared | 0.0695 | 0.0814 | 0.0678 | 0.0670 | 0.0785 | | 0.0785 | 0.0960 | 0.0686 | 0.0609 | 0.0632 |
| Controls | Yes | Yes | Yes | Yes | Yes | | Yes | Yes | Yes | Yes | Yes |
| Borough FE | Yes | Yes | Yes | Yes | Yes | | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | | Yes | Yes | Yes | Yes | Yes |
| | | | | | | Panel D: Quebec Post | | | | | |
| $\mathbb{1}(\Delta^1_{i,a})$ | 0.0289 | 0.0187 | -0.1350*** | -0.0197 | -0.0023 | 0.0285 | -0.0023 | -0.0023 | -0.1202** | 0.0086 | 0.0289 |
| | (0.034) | (0.031) | (0.044) | (0.036) | (0.039) | (0.029) | (0.039) | (0.029) | (0.049) | (0.036) | (0.034) |
| Constant | -0.5365** | -0.3011 | -0.4335** | -0.0917 | 0.2047 | 0.3931* | 0.2047 | 0.0984 | -0.3770** | -0.5844 | -0.5365** |
| | (0.221) | (0.196) | (0.204) | (0.323) | (0.202) | (0.191) | (0.202) | (0.297) | (0.161) | (0.352) | (0.221) |
| Observations | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 |
| R-squared | 0.0829 | 0.101 | 0.151 | 0.0873 | 0.0660 | 0.225 | 0.0660 | 0.0990 | 0.157 | 0.140 | 0.0829 |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Borough FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

The outcome is the probability that bid differences fall in a given interval of values. Controls include *Quantity* which represents the number of tons in the call, *Crude oil lag* which represents the lagged price of crude oil and *HHI* which represents the Herfindahl index of each city at the year level.Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.14: Graphical representation of coefficients for equation 5. Adding controls

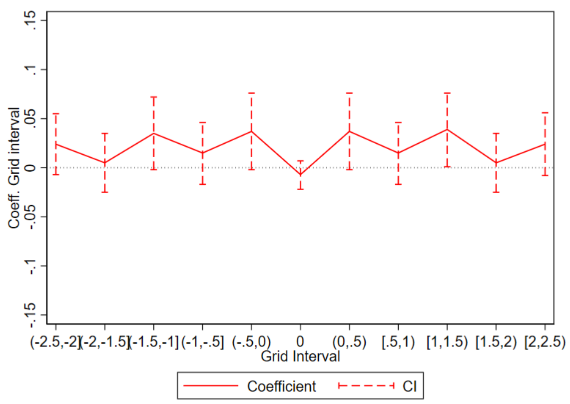



This figure reports the estimated coefficient from equation (5), along with confidence intervals, obtained separately for each city/time period. Confidence intervals are computed with standard errors clustered at the borough and year levels.

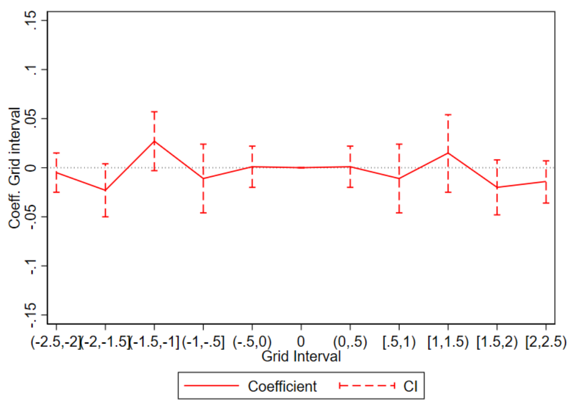
## A.11 Test for total bids

Figure A.15: Total bids

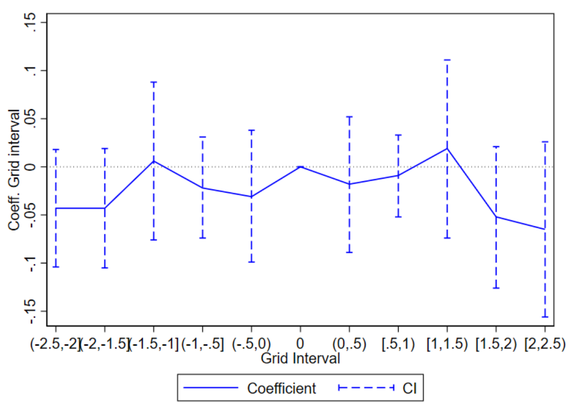
(a) Montreal Pre



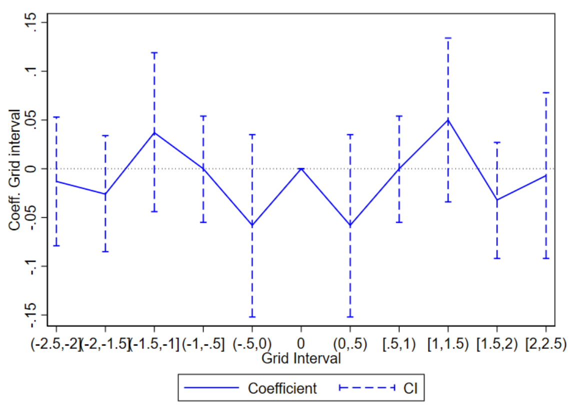

(b) Montreal Post




(c) Quebec City Pre



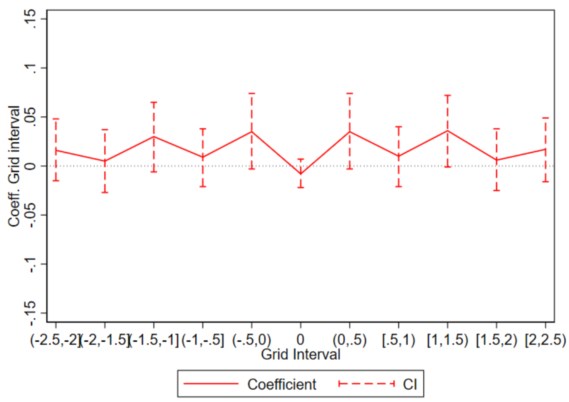

(d) Quebec City Post



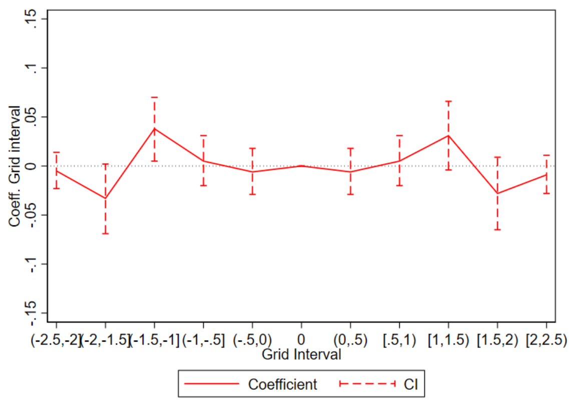

This figure reports the estimated coefficient from equation (5), along with confidence intervals, obtained separately for each city/time period. Confidence intervals are computed with standard errors clustered at the borough and year levels.

Figure A.16: Total bids adding controls

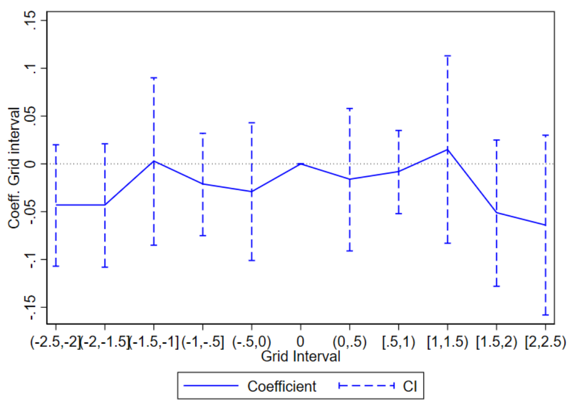
(a) Montreal Pre



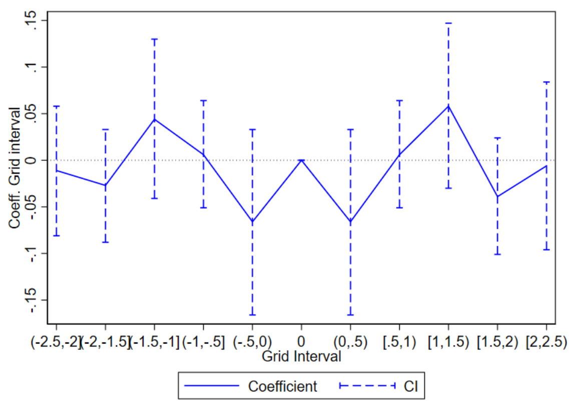

(b) Montreal Post




(c) Quebec City Pre




(d) Quebec City Post




This figure reports the estimated coefficient from equation (5), along with confidence intervals, obtained separately for each city/time period. Confidence intervals are computed with standard errors clustered at the borough and year levels.

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