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

Robert Clark
Queen's University

Decio Coviello
HEC Montreal

Adriano De Leverano
ZEW - Leibniz Centre for European Economic Research in Mannheim

Department of Economics
Queen's University
94 University Avenue
Kingston, Ontario, Canada
K7L 3N6

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

Robert Clark[a], Decio Coviello[b] & Adriano De Leverano[c]

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Abstract

A number of recent papers have proposed that a pattern of isolated winning bids may be associated with collusion. In contrast, others have suggested that bid clustering, especially of the two lowest bids, is indicative of collusion. In this paper, we present evidence from an actual procurement cartel uncovered during an anticollusion investigation that reconciles these two points of view and shows that both patterns arise naturally together as part of a cartel arrangement featuring complementary bidding. Using a difference-in-difference approach, we compare the extent of winning-bid isolation and clustering of bids in Montreal's asphalt industry before and after the investigation to patterns over the same time span in Quebec City, whose asphalt industry has not been the subject of collusion allegations. Our findings provide causal evidence that the collusive arrangement featured both clustering and isolation. We use information from testimony of alleged participants in the cartels to explain how these two seemingly contradictory patterns can be harmonized.

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 raising 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 an important share of investigated cartels arise in public procurement auctions and since public 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.

A number of recent papers have proposed that a pattern of *isolated winning bids* (missing bids) may also be consistent with collusion (see for instance Tóth et al., 2014, Imhof et al., 2018, and Chassang et al., 2020). These articles suggest that a gap between the winning bid and losing bids can be associated with collusion, since cartel members may wish to avoid scrutiny from authorities on the basis of identical (or extremely close) bids, or in order to help facilitate coordination on a designated winner. These predictions stand in contrast to those from many papers that have suggested that clustering of bids within auctions, especially of the two lowest bids, is indicative of collusion; see for instance Porter and Zona (1993), Marshall and Marx (2007), and Harrington (2008).[2]

In this paper, we present causal empirical evidence from an actual procurement cartel that illustrates that these two seemingly contradictory patterns coexist. That is, we demonstrate that, relative to the competitive situation, the collusive arrangement involves **both** more isolated winning bids and more clustering of bids, including the two lowest. We support these findings 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.

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*

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

[2] See also Feinstein et al. (1985), LaCasse (1995), and Ishii (2009).

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 both 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 confirm that both clustering and isolation were part of the collusive strategy we adopt a difference-in-difference approach in which we compare the extent of winning-bid isolation and clustering of bids in Montreal's asphalt industry before and after the police 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. More specifically we use distributional regression techniques (see Fortin et al., 2018, 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 both clustering and isolation. 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 two seemingly contradictory observations fit together. That is, they explain how isolated winning bids and clustered bidding could coexist as part of a collusive arrangement. 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.[4] According to the Enquête news program, complementary bids were submitted in order to mimic competition. Using coded language to avoid detection, the designated winner would provide guidance as to what should be the complementary bids.

[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.

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

The winner would then have incentive to bid just below the lowest bid it assigned, resulting in clustering. However, 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 (Théberge, 2013a). The result was a very small gap between the two lowest bids – isolated winning bids.

This testimonial evidence is consistent with the cartel behaviour described in Section 7 of Chassang et al. (2020) and in Ortner et al. (2020). As mentioned, 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 a cartel's primary preoccupation is to ensure the stage-game optimality of play. That is, firms instructed to provide complementary losing bids should be incentivized not to undercut the designated winner. 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.

We conclude by discussing ways in which antitrust authorities could make use of our findings when monitoring procurement auctions and to better understand the functioning of bidding rings. We present a simple linear probability regression that authorities could run to analyse the distribution of bid differences that might provide a red flag of suspicious behaviour in calls for tender. A bimodal, or twin-peaked, distribution of bid differences, centered around zero, can provide an indication of a collusive arrangement in which complementary bidding takes place with cartel members avoiding identical or nearly identical bids.

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), Kawai and Nakabayashi (2018), and Chassang and Ortner (2019). 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 linking isolated winning bids and clustered bidding as part of a collusive strategy.

This study also relates to the literature on explicit cartels and their functioning. 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).[5] The Quebec construction cartels were studied by Clark et al. (2018). Relative to these papers, here we provide new evidence on the role of 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 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 policy implications of our findings. 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.[6] 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.

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

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

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 cost 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.

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.[7] 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.[8] Contracts involving asphalt, sewers, aqueducts and sidewalks were all affected.[9]

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, including location and size, from officials.[10]

The police task force, Opération Marteau, was launched 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.

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[7] 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.

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

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

[10] 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 explain how isolated winning bids and clustered bidding could coexist as part of a collusive arrangement featuring complementary bidding. 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. As mentioned above, the authors explain that a cartel's main objective is to ensure the stage-game optimality of play. 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 then suggest two potential explanations as to why winning bids might be isolated when collusion is involved. First, in the context of the framework just described if the possibility of antitrust oversight is added and if nearly-identical bids attract antitrust scrutiny, then the 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.

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?[11]

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

[11] 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 (2013a).

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.[12]

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.[13]

To mimic a competitive environment and to avoid detection, the winner would 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.[14]

Sometimes, worried that their conversations might be overheard, the participants would employ a coded vocabulary when communicating. For instance, the specified winner would 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, 2013a; *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 tell 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, 2013a).[15]

[12] 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 (2013a).

[13] 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 (2013a).

[14] 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 (2013a).

[15] 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*

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

In Sections 5 and 6 we provide causal evidence in support of these arguments. That is, we show that both isolated winning bids and clustered bidding were part of the arrangement used by participants in the Montreal asphalt cartel.

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.[16] 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.

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 bid is \$68.73 per ton with a standard deviation of 10.32. Table 1 presents summary statistics for Montreal and Quebec City.[17] 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.

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 who 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

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.

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

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

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

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 change 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.

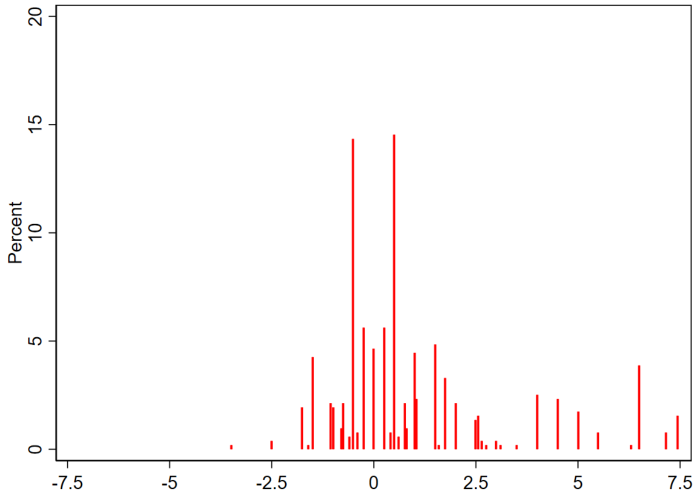
Given the design of this function, the difference between the winning bid and the most competitive bid (the second lowest bid) in the distribution appears to the left of 0, while the difference between a losing bid and the most competitive bid (the lowest bid) appears to the right of 0. Figure 1 from Chassang et al. (2020) plots the distribution of $\Delta_{i,a}^{CKNO}$ 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:

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

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.

Figure 1: Differences between own bid and most competitive bid (bid differences) – Montreal asphalt indudstry.



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

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.

6 Empirical analysis

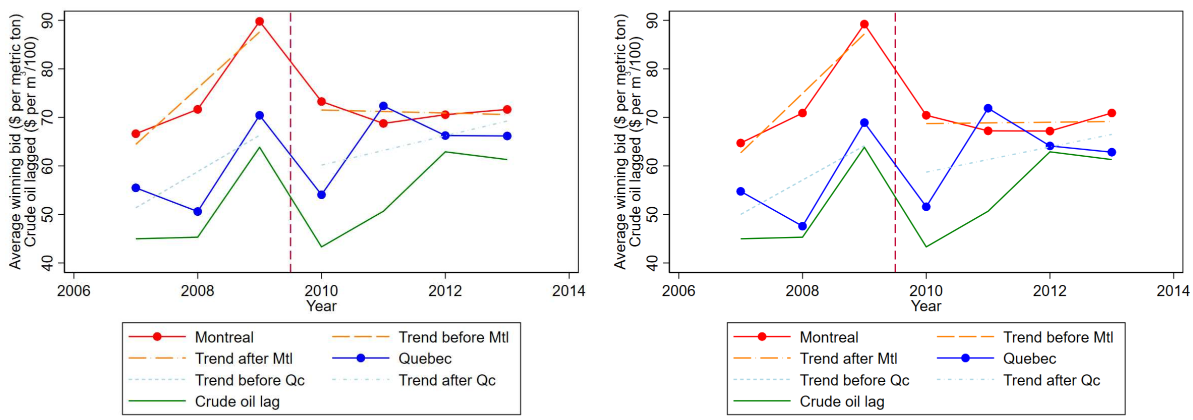
6.1 Empirical approach

In this section we provide causal evidence that both clustering and isolated winning bids are part of the collusive arrangement. We do so by comparing differences in isolation and clustering in Montreal before and after the investigation to the same differences in Quebec City. This sort of difference-in-difference approach has been used to study the impact of alleged price fixing in other markets (see for instance Clark and Houde, 2014; Miller and Weinberg, 2017; Clark et al., 2018, and Miller et al., 2020).

Our difference-in-difference approach relies on a number of assumptions. We must be able to properly establish periods during which the cartel functioned and when it ceased to be. Testimony during the Commission implied that the airing of the TV news show and the policy investigation in the fall of 2009 caused collusive activity to cease and bidding to return to more competitive levels. Because contracts in both Montreal and Quebec City are negotiated only once per year in the spring, it is natural to take 2010 as the end

Figure 2: Average raw bids

(a) All bids (b) Winning bids



point of the cartel and to assume that calls for tender were competitive from this time forward.

It is also necessary to adequately control for market-specific developments. As mentioned in Clark et al. (2018), Quebec City is a suitable control for the following reasons. First, the asphalt market in Quebec City was never cited during Operation Marteau or in documents from the Charbonneau Commission. Based on the *Enquête* broadcast, the allegations were focused mostly on the asphalt market in Montreal. Second, Quebec City is located further away from Montreal, at a distance of about 250 km. This is an important aspect since many municipalities surrounding Montreal were cited in investigative reports. In addition, the firms operating in Quebec City are different from the ones operating in Montreal. Finally, the auctions in the two cities are similar in terms of i) the period in which they are run, ii) the design of the auctions, i.e. per borough, and iii) the budget allocated to the procurement of asphalt.

Figure 2, reproduced from Clark et al. (2018), plots the evolution of raw bids over time in Montreal and Quebec City. Prices are higher in Montreal than in Quebec City prior to the investigation, but the trends in the two cities were common with bids roughly following the price of crude oil (with a lag) until the start of the investigation at which point prices in Montreal diverge. The existence of common trends is the main identifying assumption of the difference-in-difference estimation method. A violation of this assumption would imply that our estimates are non-causal. In Tables A.7, A.8, and A.9 of the Appendix we present difference-in-differences regression results and formal tests for the presence of common trends in prices between Montreal and Quebec City before the investigation. Panel A of Table A.8 shows that the hypothesis of linear trends is strongly rejected in our data, whereas Panel B shows that the coefficients of $MontrealXYear2008$ and $MontrealXYear2009$ are very similar and not statistically different (i.e., large p-values of the difference) for the majority of our specifications. This evidence is compatible with the non-linearities in prices depicted in Figure 2. To assess the robustness of our results to the possible violation of the common trend assumption, in Table A.9 we report estimates obtained with the same specification used in Table A.7, but adding heterogenous linear (Panel A) and non-linear trends (Panel B). We conclude that our estimates are robust to this possible threat to the identification strategy since, once we control for heterogeneous trends, our estimates are comparable in sign and magnitude to our baseline estimates.

The evidence therefore qualifies Quebec City as a valid comparison group for Montreal such that we can interpret the difference-in-difference estimates of the impact of the investigation as causal. It should be noted that, despite the evidence that there was no collusion in Quebec City in the pre-investigation period, there might nonetheless be concern that collusion extended into this market. Given the similar trends experienced by the control, if there was in fact collusion, our findings still provide causal estimates of the effect of the investigation on prices, since the investigation focused on Montreal initially. In this case our results would underestimate the effect of collusion on prices.

6.2 Descriptive analysis

We start by plotting bid differences, $\Delta_{i,a}$, in Figure 3, 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.[18] 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 3, in Table 3 we provide statistics characterizing the changes in clustering and isolated winning bids observed from before to after the investigation in Montreal and Quebec City. Panel A presents the average bid difference in Montreal and Quebec City before and after the investigation. To

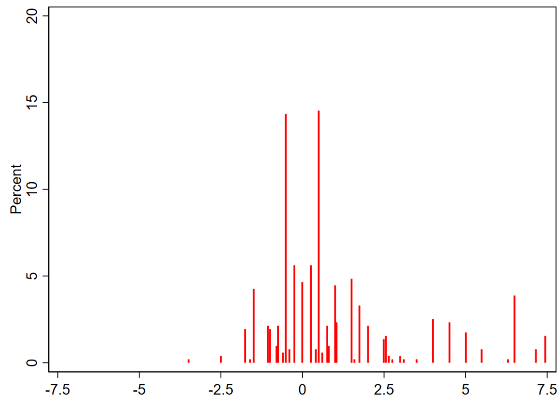
[18]We plot these on a range of +/- 10% of the average winning bid observed in Montreal before the start of the investigation. In the Appendix we plot this for alternative ranges to illustrate robustness.

quantify clustering, in Panel B we present information on the standard deviation of the bid differences. For isolation, in Panel C we calculate the probability of bid differences exactly equal to 0 relative to the probability that bid differences are in a small range near zero. For this range we use the median value of bid differences in Montreal in the pre-investigation period, which is 0.5 dollars per ton.

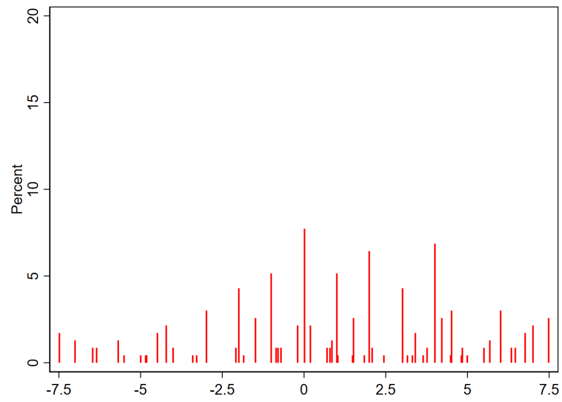
The standard deviation of bid differences is lower in Montreal than in Quebec City during the cartel period. The standard deviation increases substantially in Montreal after the start of the investigation, going from 2.62 to 5.79. The standard deviation in Quebec City also increases, but only by 0.74, going from 3.05 to 3.78. Together these results suggest that the collapse of the cartel caused the standard deviation of bid differences to increase by 2.43. In other words, clustering fell. Regarding the isolation measure, we see that in both Montreal and Quebec City winning bids are isolated – there is very little mass at zero compared to in a nearby neighborhood to zero. In both Montreal and Quebec City isolation decreases following the investigation, but the decrease is much larger in Montreal, going from 0.11 to 1.80, compare to 0.00 to 0.33 for Quebec City. These results imply that isolation was part of the collusive arrangement.

Figure 3: Bid differences for Montreal and Quebec City before and after the start of the police investigation.

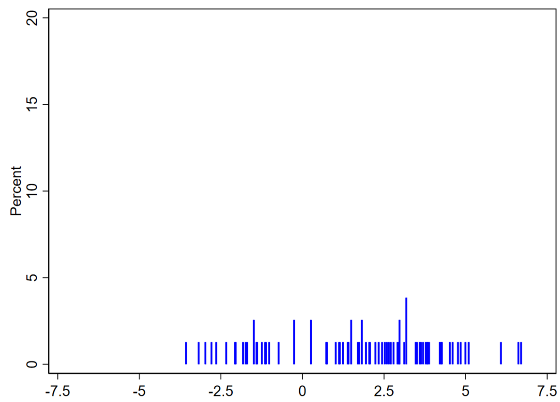
(a) Montreal Pre



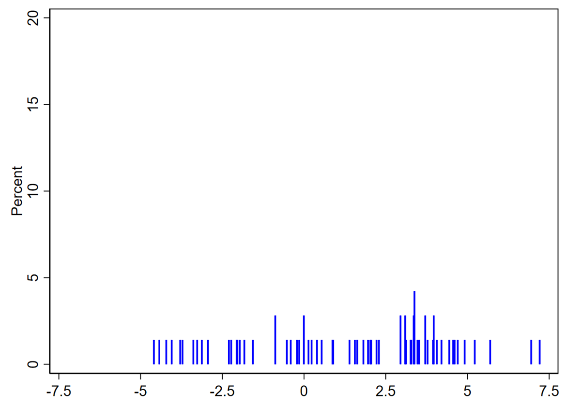
(b) Montreal Post



(c) Quebec City Pre



(d) Quebec City Post



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).

Table 3: Evidence of clustering and isolation from the bid differences

Panel A: Mean $\Delta_{i,a}$ (bid diff., \$ per ton)			
	Pre	Post	Post-Pre
Montreal	1.27	2.06	0.79
Quebec	1.95	2.09	0.14
Post-Pre	-0.68	-0.03	0.65
Panel B: Standard deviation of $\Delta_{i,a}$ (\$ per ton)			
	Pre	Post	Post-Pre
Montreal	2.62	5.79	3.17
Quebec	3.05	3.78	0.74
Post-Pre	-0.42	2.01	2.43
Panel C: $\frac{Pr(\Delta_{i,a}=0)}{PR(0<\Delta_{i,a}\leq\bar{\Delta}_{mtl,pre})}$			
	Pre	Post	Post-Pre
Montreal	0.11	1.80	1.69
Quebec	0.00	0.33	0.33
Post-Pre	0.11	1.47	1.36

6.3 Regression analysis

Figure 3 and Table 3 provide 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. (2018) use 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 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:

$$y_{i,a,q} = \beta_0 + \beta_1 Mtl_a \times Marteau_a + \beta_2 Mtl_a + \beta_3 Marteau_a + \gamma Z_a + \epsilon_{i,a,q}, \qquad (3)$$

where $y_{i,a,q}$ is an indicator equal to 1 if bidder i's bid difference in auction a ($\Delta_{i,a}$) 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. 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 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 coefficient β_1 in each regression. Studying these coefficients will inform as to how the collapse of the cartel shifted the distribution of bid differences.

Table 4: Distributional effect of the investigation on clustering & isolation

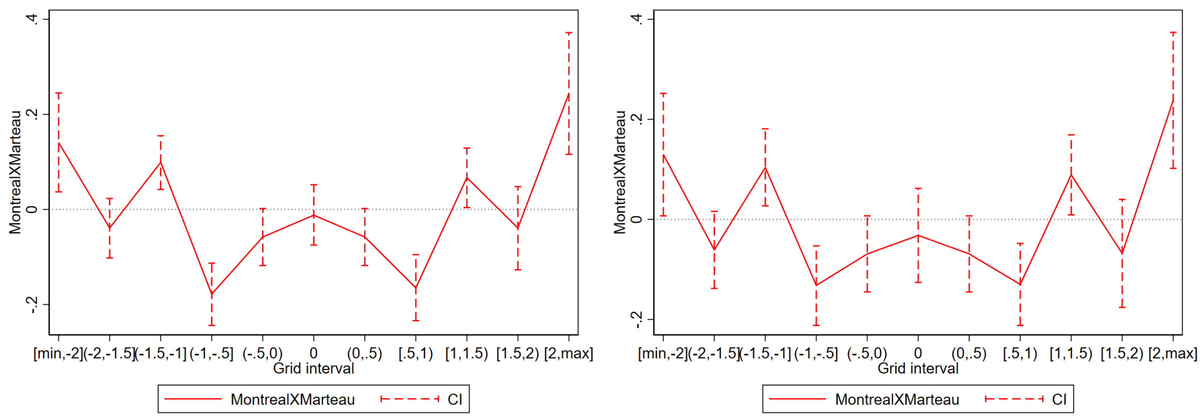
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dep.Var	Pr[min -2]	Pr(-2-1.5]	Pr(-1.5-1]	Pr(-1 -.5]	Pr(-.5 -0)	Pr[0]	Pr(0 .5)	Pr[.5 1)	Pr[1 1.5)	Pr[1.5 2)	Pr[2 max]
Panel A: Without controls											
Mtl×Marteau	0.1407***	-0.0394	0.0987***	-0.1784***	-0.0582*	-0.0115	-0.0582*	-0.1647***	0.0666**	-0.0394	0.2439***
	(0.053)	(0.032)	(0.029)	(0.033)	(0.031)	(0.032)	(0.031)	(0.035)	(0.032)	(0.044)	(0.065)
Mtl	-0.0914***	0.0241	-0.0599**	0.1599***	0.0364	0.0444***	0.0364	0.1494***	-0.0340	0.0179	-0.2833***
	(0.031)	(0.024)	(0.027)	(0.025)	(0.022)	(0.015)	(0.022)	(0.027)	(0.027)	(0.033)	(0.041)
Marteau	0.0784*	0.0009	-0.0988***	0.0256	0.0133	0.0253	0.0133	0.0133	-0.0861***	-0.0111	0.0258
	(0.046)	(0.029)	(0.026)	(0.024)	(0.026)	(0.025)	(0.026)	(0.026)	(0.029)	(0.042)	(0.053)
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	0.115	0.00691	0.0103	0.0621	0.0104	0.00587	0.0104	0.0585	0.00680	0.00889	0.0838
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
Mean Y Pre Montreal	-4.125	-1.58	-1.03	-.55	-.27	0	.27	.55	1.02	1.60	5.29
Panel B: With controls											
Mtl×Marteau	0.1296**	-0.0610	0.1038***	-0.1322***	-0.0689*	-0.0318	-0.0689*	-0.1301***	0.0886**	-0.0676	0.2383***
	(0.063)	(0.039)	(0.039)	(0.041)	(0.039)	(0.048)	(0.039)	(0.042)	(0.041)	(0.055)	(0.069)
Mtl	-0.1804**	0.0260	-0.0748*	0.1018	0.0515	0.0719	0.0515	0.1020	-0.1099	0.0644	-0.1040
	(0.083)	(0.043)	(0.043)	(0.091)	(0.046)	(0.048)	(0.046)	(0.089)	(0.081)	(0.063)	(0.137)
Marteau	0.8981*	-0.3513*	-0.1465	0.9584***	-0.3396*	-0.5496	-0.3396*	0.9631***	-0.1245	-0.2247	-0.7438
	(0.533)	(0.179)	(0.291)	(0.364)	(0.196)	(0.469)	(0.196)	(0.365)	(0.333)	(0.254)	(0.678)
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	0.182	0.0356	0.0324	0.134	0.104	0.0928	0.104	0.126	0.0226	0.0388	0.131
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
Mean Y Pre Montreal	-4.125	-1.58	-1.03	-.55	-.27	0	.27	.55	1.02	1.60	5.29

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. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Results are presented in Table 4 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 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

Figure 4: 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 4. Confidence intervals are computed with standard errors clustered at the borough and year levels.

removed from 0 consistent with a decrease in clustering following the investigation. We lump everything below -2 together and everything above 2 together, and we can see that there is a large increase in mass in this region. This pattern is confirmed in Figure A.11, which plots the difference-in-difference coefficient from the first row of Table 4.

In Table A.10 of the appendix we repeat the exercise but this time we assign bid differences of 0 to the -0.5 to 0 bin. 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 for even finer grids and the results are unchanged.

7 Implications for policy makers

What can antitrust authorities learn from our findings, and can the distributional regression approach proposed here be employed to provide some guidance for investigations? Our results 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.

Figure 1 illustrates the patterns of clustering and isolated winning bids and could be used to identify this behaviour in procurement auctions. More formally, antitrust authorities could run a distributional regression of the following form estimated on the sample only from the market suspected of collusion during the time period of the suspected infraction:

$$y_{i,a,q} = \beta_0 + \epsilon_{i,a,q}, \tag{4}$$

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 in interval q. Again, we use the same grid with 0.5 distance for intervals and assign 0 to its own bin. We also again lump everything below -2 together and everything above 2 together. This is the same sort of regression run in the previous section, but, since it is run only on the target market during the infringement period, there are no indicators for the collapse of the cartel or for the infringement market. $y_{i,a,q}$ is simply regressed on a constant.

The idea is to investigate the bid-difference distribution during collusion. If bids are clustered and winning bids are isolated, then we would expect to observe high coefficients for the constant at low values of bid differences and lower coefficients at values within a small ϵ around 0. In contrast, in a competitive environment, the distribution of bid differences should be more uniform.

Table 5: Distributional regression of bid differences in Montreal before the investigation.

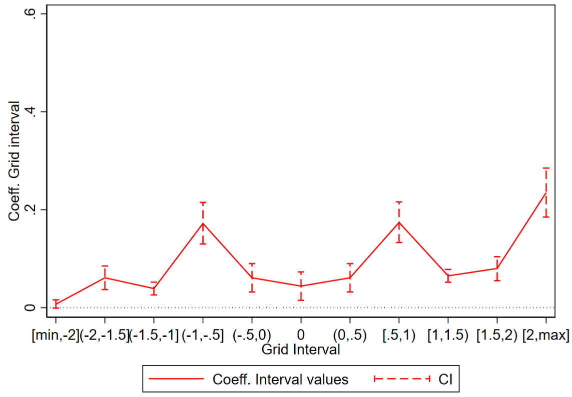
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dep.Var	Pr[min, -2]	Pr(-2,-1.5]	Pr(-1.5,-1]	Pr(-1, -.5]	Pr(-.5, -0)	Pr[0]	Pr(0,.5)	Pr[.5,1)	Pr[1,1-5)	Pr[1.5,-2)	Pr[2,max]
Constant	0.0074*	0.0611***	0.0389***	0.1722***	0.0611***	0.0444***	0.0611***	0.1741***	0.0648***	0.0796***	0.2352***
	(0.004)	(0.012)	(0.007)	(0.022)	(0.015)	(0.015)	(0.015)	(0.021)	(0.007)	(0.013)	(0.025)
Observations	540	540	540	540	540	540	540	540	540	540	540
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

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% (***).

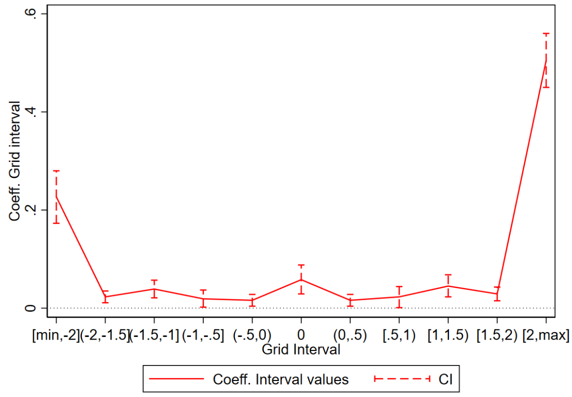
Results are presented in Table 5 and they show that the probability of being at 0 or within an interval of 0.5 from 0 is much lower than being in the interval -1.0 to -0.5 or 0.5 to 1.0. This is suggestive of isolation. We can also see that there is much lower probability of being at bigger (in absolute value) bid differences suggesting clustering. In particular, there is almost no mass at bigger negative differences. This reflects the fact that the difference between the lowest and second lowest bids are extremely close – although not identical – under the collusive arrangement. This is confirmed in Panel (a) of Figure 5,

Figure 5: Graphical representation of distributional regressions of bid differences

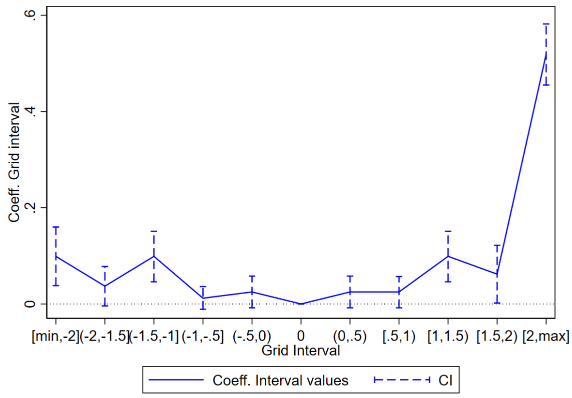
(a) Montreal Pre



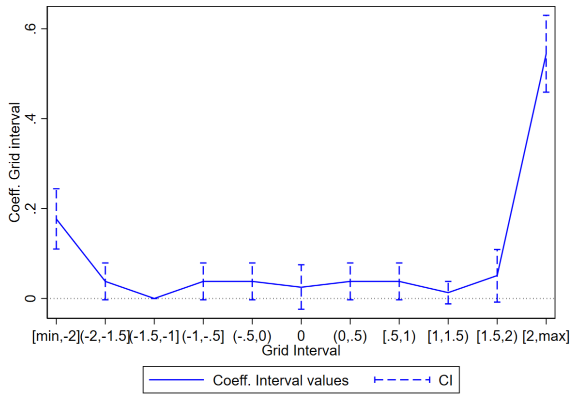
(b) Montreal Post



(c) Quebec City Pre



(d) Quebec City Post



This figure reports the estimated coefficient from equation (4), 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.

which reports the results graphically.[19] The figure again displays the twin peaks centered at 0 of the distribution of bid differences. (Because we lump everything below -2 together and everything above 2 together there is an additional peak that would be eliminated if we continued with smaller intervals.)

To get a sense of how useful this test might be, in Panels (b)-(d) of Figure 5 we plot the results from estimation of equation (4) for Montreal post-investigation and Quebec City pre- and post-investigation. In each case the distributions are much more uniform. This is especially true in the post period in both markets. In Quebec City during the cartel period we observe two smaller peaks further away from zero. As mentioned above, while there has been no uncovered evidence of a cartel operating in Quebec City's asphalt industry, it is possible that some degree of collusive activity extended into this market also.

[19]In the appendix we again present results showing that this is not driven by having put 0 into its own bin. See Table A.13.

Our findings suggest a simple procedure that antitrust authorities could use as a red flag for possible collusive behaviour in 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.

8 Conclusion

In this paper, we provided evidence from an actual procurement cartel that reconciles two seemingly contradictory features of collusive arrangements: that bids are clustered but winning bids are isolated. 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 two seemingly contradictory observations fit together. That is, they explain how isolated winning bids and clustered bidding could coexist as part of a collusive arrangement. 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.

Finally, based on our findings, we propose a simple test that antitrust authorities could implement as a quick first screen of collusion.

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A Appendix

A.1 Normalization with average winning bid in Montreal pre-investigation

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

$$\Delta_{i,a}^{CKNO} = \frac{b_{i,a} - \wedge \mathbf{b}_{-i,a}}{r}, \tag{5}$$

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:

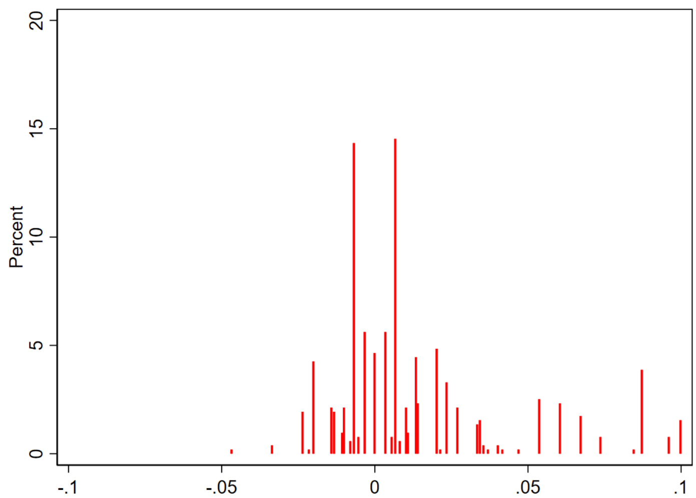
$$\Delta_{i,a} = b_{i,a} - \wedge \mathbf{b}_{-i,a}. \tag{6}$$

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:

$$\Delta_{i,a} = \frac{b_{i,a} - \wedge \mathbf{b}_{-i,a}}{\bar{b}_{mtl,pre}}. \tag{7}$$

Figures A.1 and A.2 replicate Figures 1 and 3 using this new definition of bid differences.

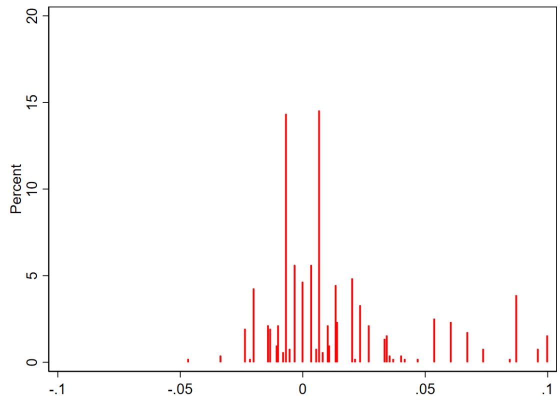
Figure A.1: Differences between own bid and most competitive bid (bid differences)



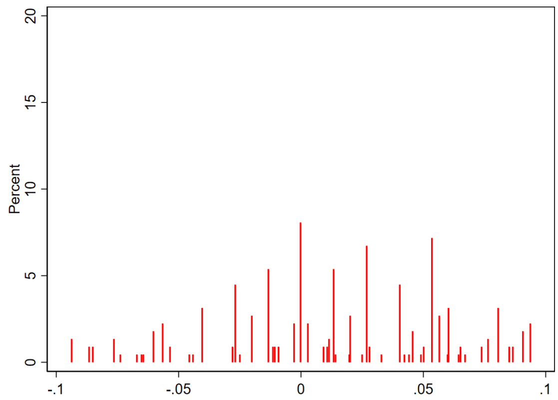
This figure plots the differences between own bid and the most competitive bid in auctions as a fraction of the average winning bid in the period before the investigation, for asphalt procurement contracts in Montreal during the cartel period. Bid differences in $ per ton.

Figure A.2: Bid differences for Montreal and Quebec City before and after the start of the police investigation.

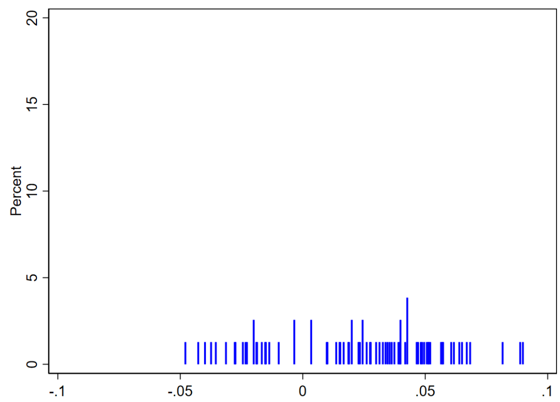
(a) Montreal Pre



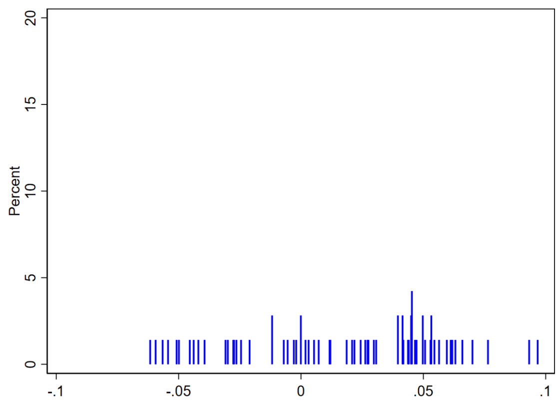
(b) Montreal Post



(c) Quebec City Pre



(d) Quebec City Post

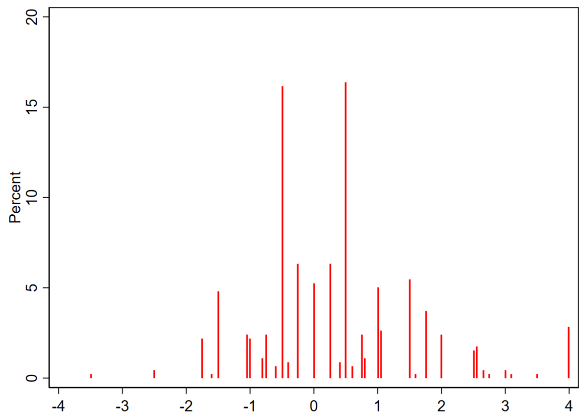


Differences between own bid and the most competitive bid in auctions as a fraction of the average winning bid in the period before the investigation, for asphalt procurement contracts in Montreal during the cartel period. Bid differences in \$ per ton. The interval of bid differences is ±10% of the winning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

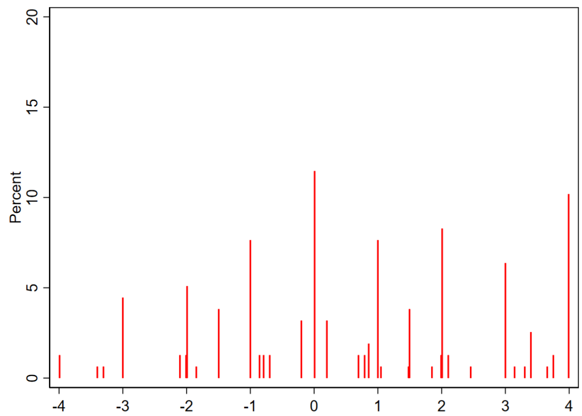
A.2 Different intervals for bid differences

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

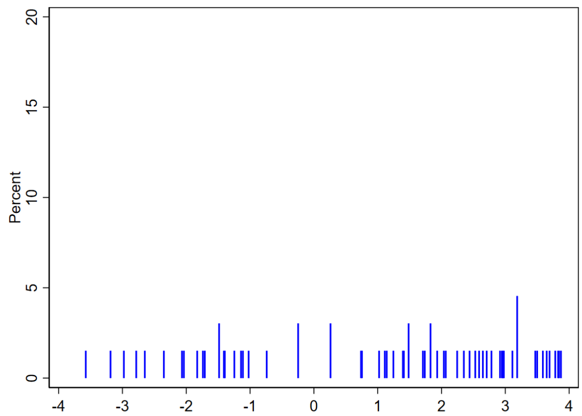
(a) Montreal Pre



(b) Montreal Post



(c) Quebec City Pre



(d) Quebec City Post

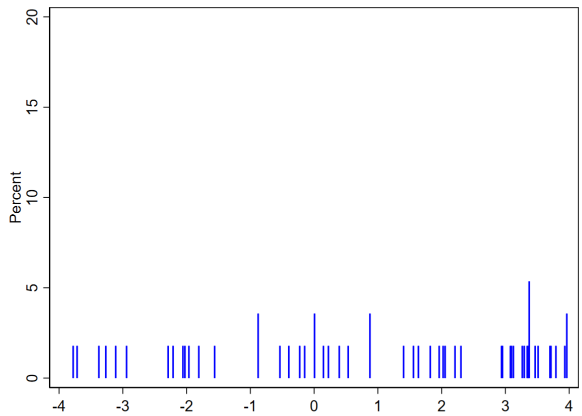
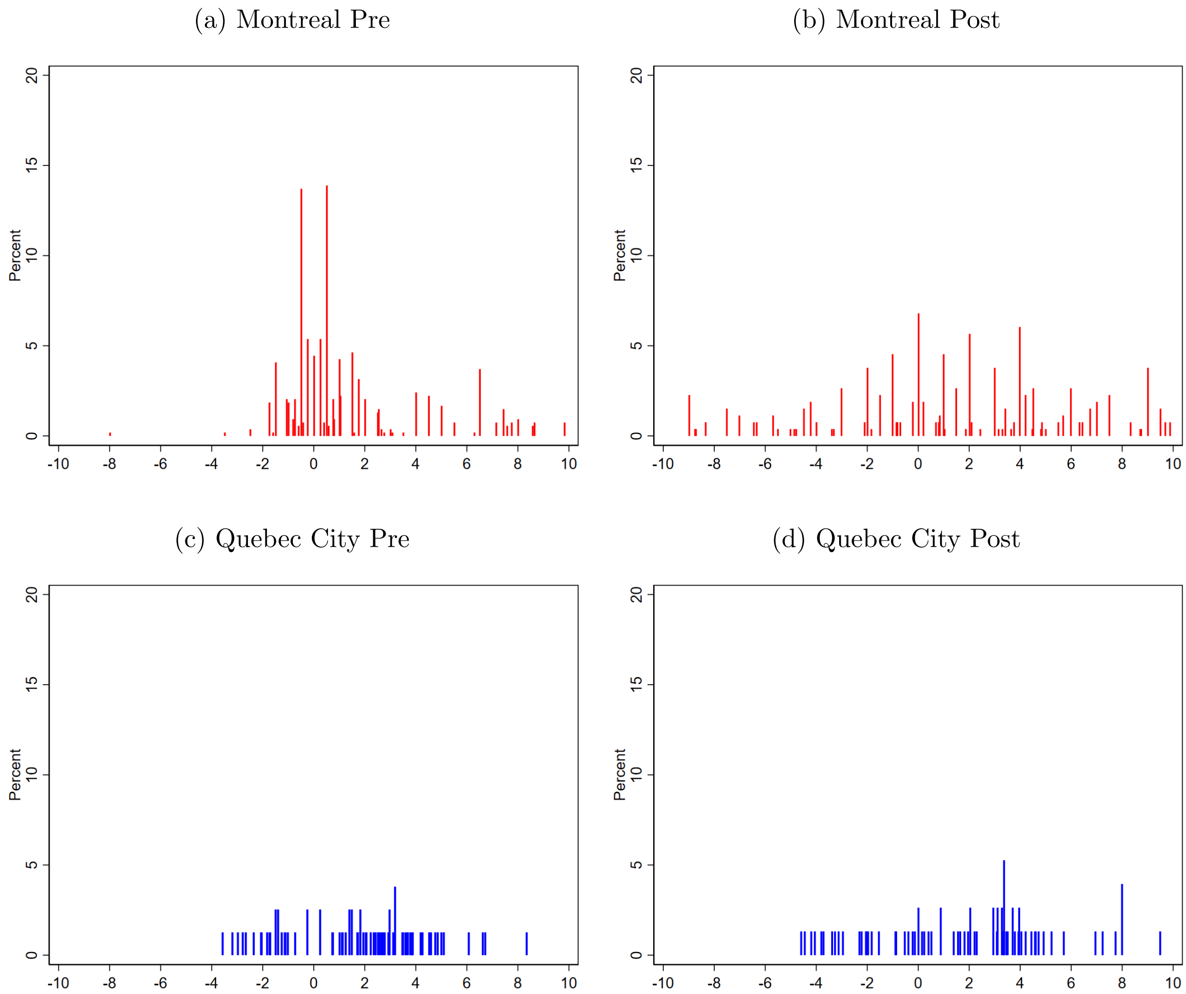


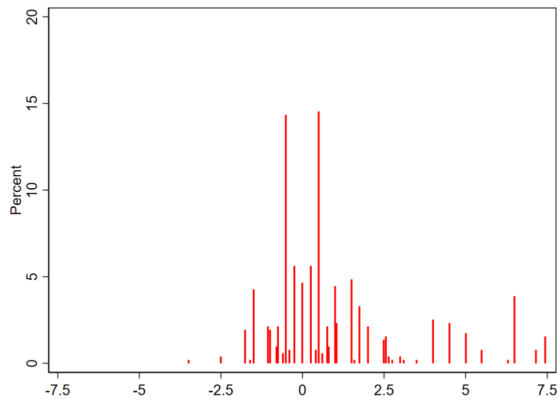
Figure A.4: Differences between own bid and most competitive bid. Difference in $ per ton. Interval of $10 per ton.



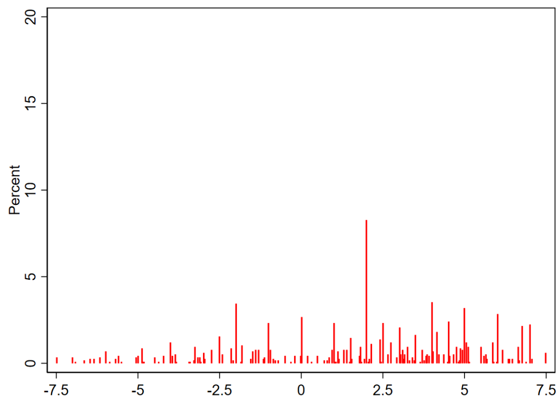
A.3 Sample of auctions: Original sample plus auctions with entrants

Figure A.5: Bid differences for Montreal and Quebec City before and after the start of the police investigation. Original sample plus auctions with entrants.

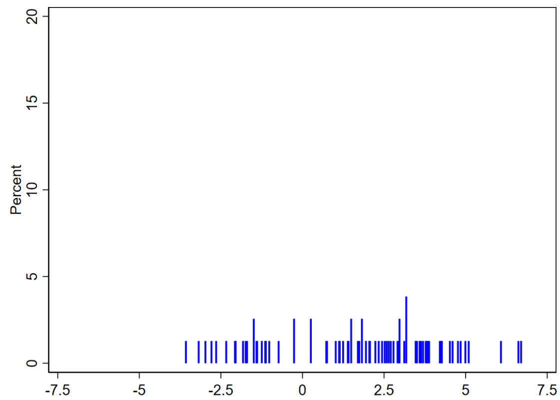
(a) Montreal Pre



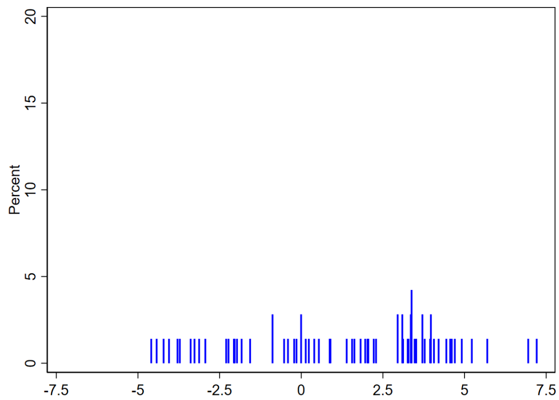
(b) Montreal Post



(c) Quebec City Pre



(d) Quebec City Post



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: Evidence of clustering and isolation from the bid differences. Original sample plus auctions with entrants.

Panel A: Mean $\Delta_{i,a}$ (bid diff.)			
	Pre	Post	Post-Pre
Montreal	1.27	3.86	2.59
Quebec	1.95	2.09	0.14
Post-Pre	-0.68	1.77	2.45
Panel B: Standard deviation of $\Delta_{i,a}$			
	Pre	Post	Post-Pre
Montreal	2.62	6.51	3.89
Quebec	3.05	3.78	0.74
Post-Pre	-0.42	2.73	3.15
Panel C: $Pr(\frac{\Delta_{i,a}=0}{0<\Delta_{i,a}\leq\Delta_{mtl,pre}})$			
	Pre	Post	Post-Pre
Montreal	0.11	0.96	0.85
Quebec	0.00	0.33	0.33
Post-Pre	0.11	0.63	0.52

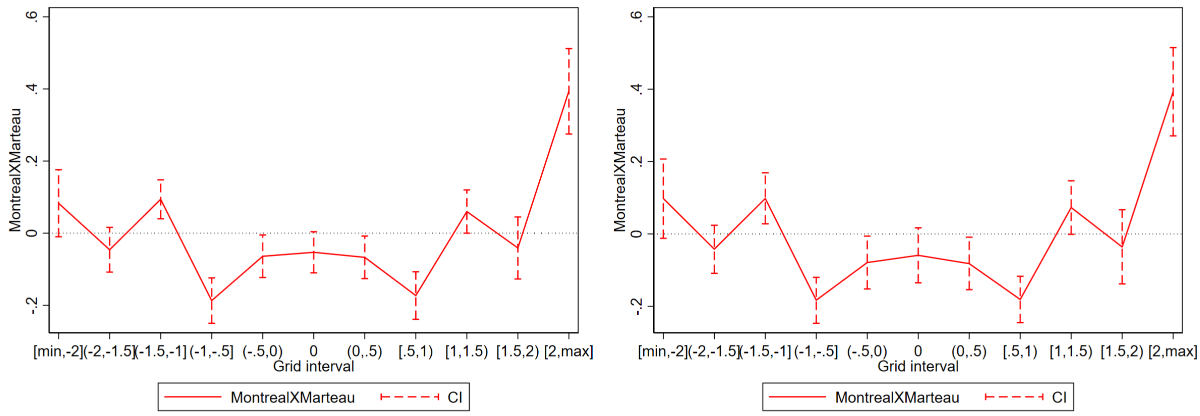
Table A.2: Distributional effect of the investigation on clustering & isolation. Original sample plus auctions with entrants.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dep.Var	Pr[min -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 max]
					Panel A: Without controls						
Mtl×Marteau	0.0832*	-0.0463	0.0941***	-0.1873***	-0.0639**	-0.0527*	-0.0672**	-0.1729***	0.0601*	-0.0409	0.3936***
	(0.047)	(0.032)	(0.028)	(0.032)	(0.030)	(0.029)	(0.030)	(0.034)	(0.031)	(0.044)	(0.060)
Mtl	-0.0914***	0.0241	-0.0599**	0.1599***	0.0364	0.0444***	0.0364	0.1494***	-0.0340	0.0179	-0.2833***
	(0.031)	(0.024)	(0.027)	(0.025)	(0.022)	(0.015)	(0.022)	(0.027)	(0.027)	(0.032)	(0.041)
Marteau	0.0784*	0.0009	-0.0988***	0.0256	0.0133	0.0253	0.0133	0.0133	-0.0861***	-0.0111	0.0258
	(0.045)	(0.029)	(0.026)	(0.024)	(0.026)	(0.025)	(0.026)	(0.026)	(0.029)	(0.042)	(0.053)
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	0.0432	0.0136	0.00551	0.0985	0.0196	0.00677	0.0246	0.0896	0.00593	0.0124	0.127
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
Mean Y Pre Montreal	-4.12	-1.58	-1.03	-.55	-.27	0	.27	.55	1.02	1.6	5.29
					Panel B: With controls						
Mtl×Marteau	0.0976*	-0.0423	0.0982***	-0.1833***	-0.0788**	-0.0589	-0.0818**	-0.1809***	0.0729*	-0.0357	0.3930***
	(0.056)	(0.034)	(0.036)	(0.032)	(0.037)	(0.039)	(0.037)	(0.033)	(0.038)	(0.052)	(0.062)
Mtl	-0.1872**	0.0300	-0.0596	0.1303	0.0373	0.0756*	0.0386	0.1286	-0.1018	0.0553	-0.1471
	(0.090)	(0.041)	(0.044)	(0.096)	(0.044)	(0.045)	(0.043)	(0.096)	(0.084)	(0.058)	(0.172)
Marteau	0.5634	-0.1499	-0.0494	0.6289***	-0.2556*	-0.4760	-0.2451*	0.6109**	-0.0293	0.1461	-0.7438
	(0.394)	(0.146)	(0.266)	(0.240)	(0.137)	(0.297)	(0.134)	(0.239)	(0.291)	(0.216)	(0.479)
Crude oil lag	-0.0027	0.0008	-0.0004	-0.0032**	0.0016**	0.0028*	0.0016**	-0.0031**	-0.0004	-0.0011	0.0040
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)
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	0.2700***	-0.0867	-0.1143	0.2860***	-0.3468***	-0.0229	-0.3488***	0.2829***	-0.0508	-0.1715	0.3030**
	(0.096)	(0.090)	(0.085)	(0.076)	(0.071)	(0.053)	(0.071)	(0.082)	(0.090)	(0.115)	(0.143)
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	0.0850	0.0285	0.0310	0.147	0.0915	0.0541	0.102	0.133	0.0278	0.0245	0.154
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
Mean Y Pre Montreal	-4.12	-1.58	-1.03	-.55	-.27	0	.27	.55	1.02	1.6	5.29

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. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.6: Graphical representation of the distributional effect of the investigation on clustering & isolation. Original sample plus auctions with entrants.

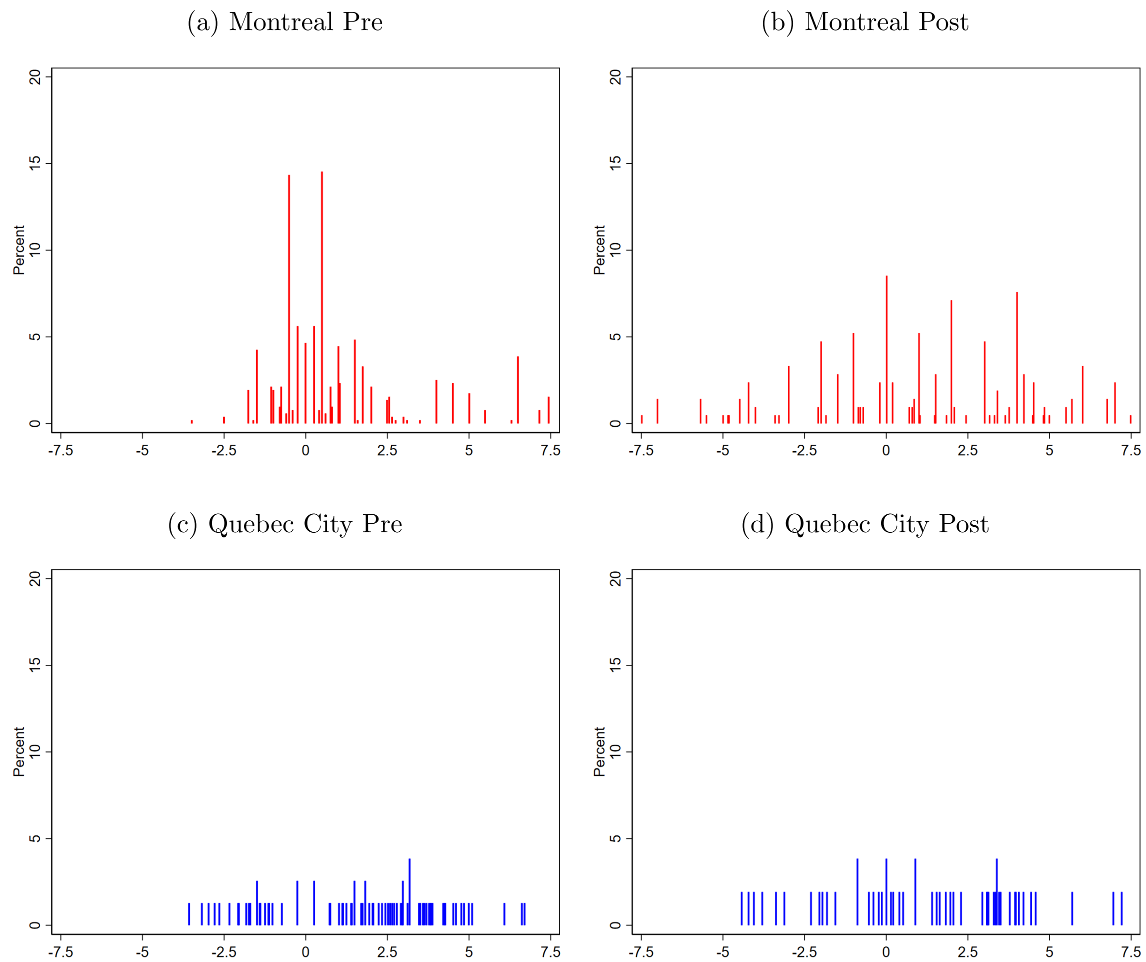
(a) No controls (b) Controls



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

A.4 Sample of auctions: Original sample minus year 2010

Figure A.7: 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.3: Evidence of clustering and isolation from the bid differences. Original sample minus year 2010

Panel A: Mean $\Delta_{i,a}$ (bid diff.)			
	Pre	Post	Post-Pre
Montreal	1.27	2.11	0.84
Quebec	1.95	2.00	0.04
Post-Pre	-0.68	0.12	0.80
Panel B: Standard deviation of $\Delta_{i,a}$			
	Pre	Post	Post-Pre
Montreal	2.62	4.66	2.04
Quebec	3.05	3.68	0.64
Post-Pre	-0.42	0.98	1.40
Panel C: $Pr(\frac{\Delta_{i,a}=0}{0<\Delta_{i,a}\leq\Delta_{mtl,pre}})$			
	Pre	Post	Post-Pre
Montreal	0.11	1.80	1.69
Quebec	0.00	0.33	0.33
Post-Pre	0.11	1.47	1.36

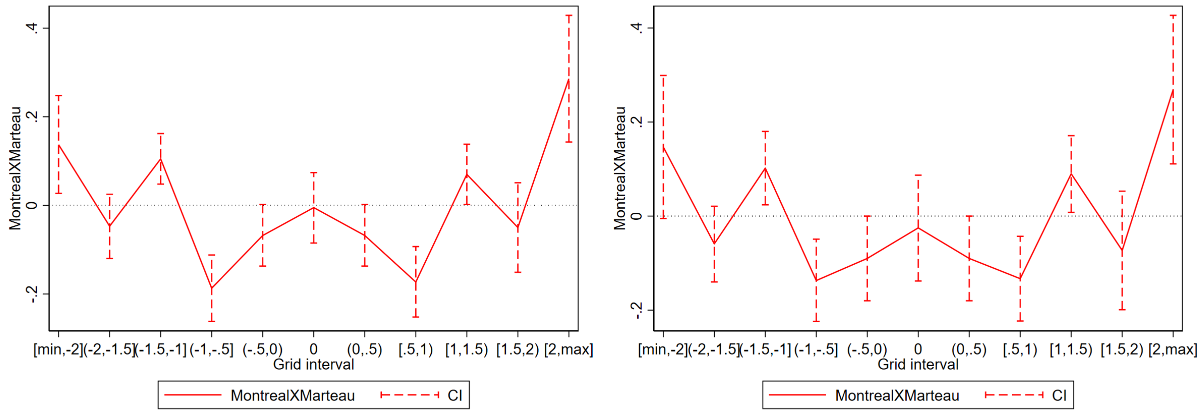
Table A.4: Distributional effect of the investigation on clustering & isolation. Original sample minus year 2010.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dep.Var	Pr[min -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 max]
	Panel A: Without controls										
Mtl×Marteau	0.1371**	-0.0472	0.1048***	-0.1871***	-0.0677*	-0.0055	-0.0677*	-0.1725***	0.0698**	-0.0501	0.2863***
	(0.056)	(0.037)	(0.029)	(0.038)	(0.036)	(0.041)	(0.036)	(0.041)	(0.035)	(0.052)	(0.073)
Mtl	-0.0914***	0.0241	-0.0599**	0.1599***	0.0364	0.0444***	0.0364	0.1494***	-0.0340	0.0179	-0.2833***
	(0.031)	(0.024)	(0.027)	(0.025)	(0.022)	(0.015)	(0.022)	(0.027)	(0.027)	(0.033)	(0.041)
Marteau	0.0392	0.0147	-0.0988***	0.0394	0.0270	0.0345	0.0270	0.0270	-0.0815**	0.0072	-0.0358
	(0.051)	(0.034)	(0.026)	(0.030)	(0.032)	(0.033)	(0.032)	(0.032)	(0.031)	(0.050)	(0.060)
Observations	924	924	924	924	924	924	924	924	924	924	924
R-squared	0.0929	0.00441	0.00964	0.0530	0.00786	0.00866	0.00786	0.0491	0.00466	0.00548	0.0716
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
Mean Y Pre Montreal	-4.12	-1.58	-1.03	-.55	-.27	0	.27	.55	1.02	1.6	5.29
	Panel B: With controls										
Mtl×Marteau	0.1469*	-0.0590	0.1019**	-0.1368***	-0.0901*	-0.0254	-0.0901*	-0.1328***	0.0896**	-0.0732	0.2690***
	(0.078)	(0.041)	(0.040)	(0.045)	(0.046)	(0.058)	(0.046)	(0.046)	(0.042)	(0.064)	(0.081)
Mtl	-0.2042*	0.0339	-0.0713	0.0810	0.0716	0.0847	0.0716	0.0815	-0.1408	0.0826	-0.0906
	(0.106)	(0.047)	(0.044)	(0.114)	(0.054)	(0.059)	(0.054)	(0.111)	(0.098)	(0.072)	(0.166)
Marteau	1.0261*	-0.3563*	-0.1454	0.8618**	-0.3463*	-0.5242	-0.3463*	0.8704**	-0.1320	-0.3200	-0.5878
	(0.523)	(0.191)	(0.301)	(0.381)	(0.193)	(0.475)	(0.193)	(0.381)	(0.340)	(0.263)	(0.654)
Crude oil lag	-0.0055*	0.0021**	0.0001	-0.0047**	0.0022*	0.0030	0.0022*	-0.0047**	0.0002	0.0017	0.0033
	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)	(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
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
HHI	0.2426**	-0.0800	-0.0975	0.2806***	-0.3561***	0.0025	-0.3561***	0.2790***	-0.0275	-0.1704	0.2829**
	(0.096)	(0.092)	(0.088)	(0.074)	(0.070)	(0.053)	(0.070)	(0.083)	(0.091)	(0.118)	(0.139)
Observations	924	924	924	924	924	924	924	924	924	924	924
R-squared	0.142	0.0335	0.0316	0.128	0.102	0.0943	0.102	0.119	0.0196	0.0371	0.124
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
Mean Y Pre Montreal	-4.12	-1.58	-1.03	-.55	-.27	0	.27	.55	1.02	1.6	5.29

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. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.8: Graphical representation of the distributional effect of the investigation on clustering & isolation. Original sample minus year 2010.

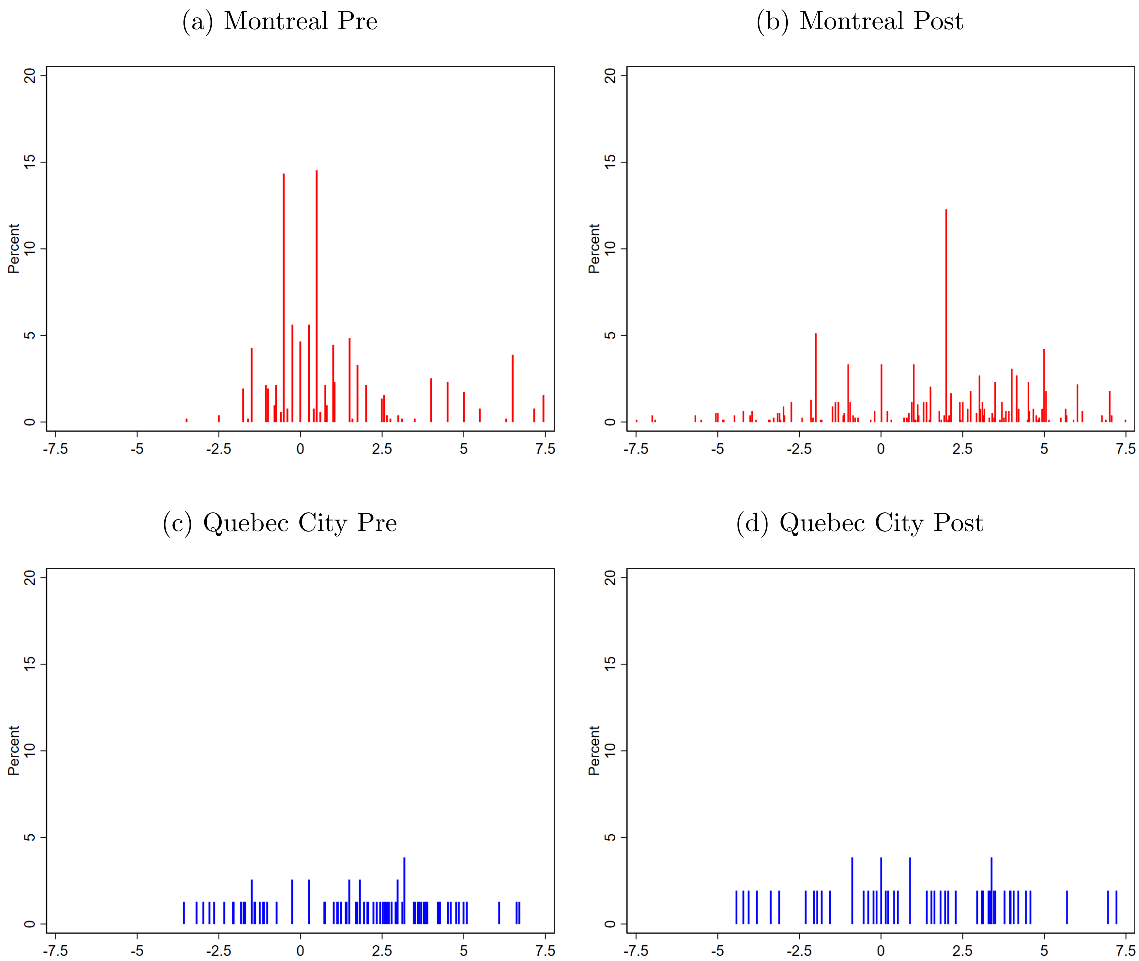
(a) No controls (b) Controls



This figure reports the estimated coefficient for $Mtl \times Marteau$, along with confidence intervals, from Table A.4. Confidence intervals are computed with standard errors clustered at the borough and year levels.

A.5 Sample of auctions: Original sample plus auctions with entrants, minus year 2010

Figure A.9: 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.5: Evidence of clustering and isolation from the bid differences. Original sample plus auctions with entrants, minus year 2010.

Panel A: Mean $\Delta_{i,a}$ (bid diff.)			
	Pre	Post	Post-Pre
Montreal	1.27	3.05	1.78
Quebec	1.95	2.00	0.04
Post-Pre	-0.68	1.05	1.73

Panel B: Standard deviation of $\Delta_{i,a}$			
	Pre	Post	Post-Pre
Montreal	2.62	4.63	2.01
Quebec	3.05	3.68	0.64
Post-Pre	-0.42	0.94	1.37

Panel C: $Pr(\frac{\Delta_{i,a}=0}{0<\Delta_{i,a}\leq\Delta_{mtl,pre}})$			
	Pre	Post	Post-Pre
Montreal	0.11	2.17	2.06
Quebec	0.00	0.33	0.33
Post-Pre	0.11	1.83	1.72

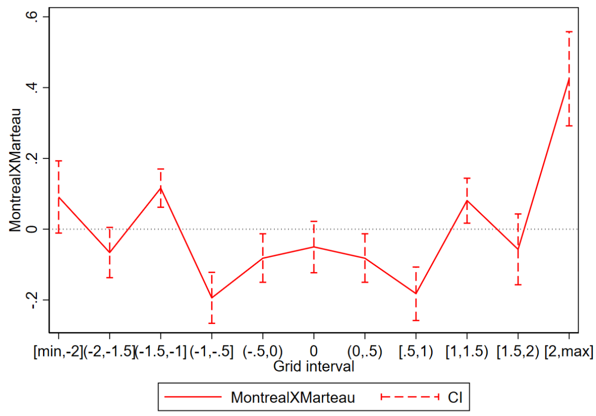
Table A.6: Distributional effect of the investigation on clustering & isolation. Original sample plus auctions with entrants, minus year 2010

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dep.Var	Pr[min -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 max]
					Panel A: Without controls						
Mtl×Marteau	0.0911*	-0.0659*	0.1160***	-0.1940***	-0.0815**	-0.0503	-0.0815**	-0.1824***	0.0806**	-0.0571	0.4250***
	(0.052)	(0.036)	(0.028)	(0.037)	(0.035)	(0.037)	(0.035)	(0.038)	(0.033)	(0.051)	(0.068)
Mtl	-0.0914***	0.0241	-0.0599**	0.1599***	0.0364	0.0444***	0.0364	0.1494***	-0.0340	0.0179	-0.2833***
	(0.031)	(0.024)	(0.027)	(0.025)	(0.022)	(0.015)	(0.022)	(0.027)	(0.027)	(0.032)	(0.041)
Marteau	0.0392	0.0147	-0.0988***	0.0394	0.0270	0.0345	0.0270	0.0270	-0.0815**	0.0072	-0.0358
	(0.051)	(0.034)	(0.026)	(0.030)	(0.032)	(0.033)	(0.032)	(0.032)	(0.031)	(0.049)	(0.060)
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	0.0447	0.0198	0.00577	0.0802	0.0243	0.00350	0.0243	0.0782	0.00236	0.0117	0.130
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
Mean Y Pre Montreal	-4.12	-1.58	-1.03	-.55	-.27	0	.27	.55	1.02	1.6	5.29
					Panel B: With controls						
Mtl×Marteau	0.1469**	-0.0591	0.1101***	-0.1869***	-0.1115**	-0.0689	-0.1115**	-0.1873***	0.0873**	-0.0567	0.4376***
	(0.069)	(0.038)	(0.036)	(0.038)	(0.044)	(0.050)	(0.044)	(0.038)	(0.038)	(0.065)	(0.072)
Mtl	-0.2121*	0.0325	-0.0519	0.1024	0.0614	0.0881	0.0614	0.1017	-0.1259	0.0736	-0.1311
	(0.113)	(0.044)	(0.044)	(0.123)	(0.049)	(0.056)	(0.049)	(0.123)	(0.105)	(0.067)	(0.216)
Marteau	0.6969*	-0.2005	-0.0437	0.5731**	-0.2806**	-0.5005	-0.2806**	0.5665**	-0.0256	0.0514	-0.5564
	(0.386)	(0.148)	(0.265)	(0.255)	(0.128)	(0.304)	(0.128)	(0.255)	(0.291)	(0.220)	(0.476)
Crude oil lag	-0.0037*	0.0012	-0.0005	-0.0029**	0.0019***	0.0030*	0.0019***	-0.0028**	-0.0004	-0.0004	0.0027
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)
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	0.2809***	-0.0966	-0.1098	0.2816***	-0.3631***	-0.0218	-0.3631***	0.2769***	-0.0476	-0.1824	0.3449**
	(0.095)	(0.092)	(0.086)	(0.075)	(0.070)	(0.052)	(0.070)	(0.083)	(0.090)	(0.119)	(0.146)
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	0.0795	0.0464	0.0204	0.132	0.115	0.0528	0.115	0.126	0.0125	0.0318	0.160
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
Mean Y Pre Montreal	-4.12	-1.58	-1.03	-.55	-.27	0	.27	.55	1.02	1.6	5.29

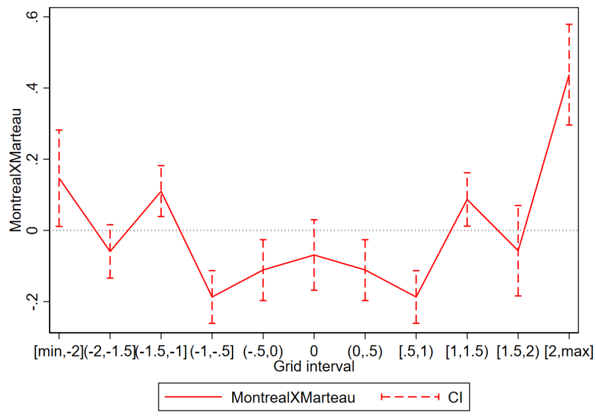
Dep. variable is the probability that bid differences fall in a given interval. *Marteau* is a dummy equal to 1 if the contract is awarded after the start of the investigations in October 2009. *Mtl* indicates that the contract was for Montreal. Panel A without controls. Panel B with controls. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Figure A.10: 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



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.

A.6 Test of common trends

In this Appendix we provide evidence of common trends in bidding behaviour in Montreal and Quebec City prior to the investigation. Figure 2 plots the evolution of raw bids over time in Montreal and Quebec City. Prices are higher in Montreal than in Quebec City prior to the investigation, but the trends in the two cities were common with bids roughly following the price of crude oil (with a lag) until the start of the investigation at which point prices in Montreal diverge. The existence of common trends is the main identifying assumption of the difference-in-difference estimation method.

The main econometric specification is:

$$B_{i,a} = \alpha + \delta_1 Mtl_{i,a} * Marteau_{i,a} + \delta_2 Marteau_{i,a} + \delta_3 Mtl_{i,a} + \beta X_{i,a} + \epsilon_{i,a}, \qquad (8)$$

where $B_{i,a}$ is the raw bid of bidder i in auction a taking place in borough r, and where $X_{i,a}$ includes year, borough and asphalt-type fixed effects, and variables that capture (i) the proportion of contracts in borough r won by firm i in the previous year (Con), (ii) the lagged average price of crude oil, (iii) the distance between the production site and the delivery site (Distance), (iv) the HHI, (v) the quantity of asphalt in the call for tender and (vi) the firm's potential capacity defined as the maximum quantity ever bid on by the firms under competition (Capacity).[20] $Marteau$ indicates the start of Opération Marteau in 2010 and Mtl is a dummy for Montreal. The parameter of interest is δ_1, which can be interpreted as the difference between the change in the price in Montreal relative to the change in price in Quebec from before to after the investigation started. Standard errors are clustered at the borough-year level, but our results are robust to different forms of clustering (for instance city, and city-year).[21] Results from Clark et al. (2018) are reproduced in Tale A.7

[20]For Quebec City we use the HHI that would have prevailed had there been no change in legislation regarding the maximum number of contracts.

[21]Note that we omit two time dummies: one for the constant and one for the (lagged) crude oil variable. This is because lagged crude oil shows a very high correlation with prices (See Figure 2). Furthermore, we omit one borough from the specification.

Table A.7: Difference-in-difference for the submitted raw bids

Dependent Variable	Raw bids					
Sample	All bids	All bids	All bids	Winning bid	Winning bid	Winning bid
	(1)	(2)	(3)	(4)	(5)	(6)
Mtl×Marteau	-9.908***	-6.942**	-7.311**	-11.834***	-8.130**	-8.680**
	(3.338)	(3.205)	(3.036)	(3.510)	(3.774)	(3.378)
Mtl	16.264***	8.583**	7.302*	18.078***	10.951***	9.443
	(2.957)	(3.668)	(3.883)	(3.112)	(2.527)	(5.753)
Marteau	4.760*	-5.604*	-6.152*	4.982*	-4.967	-5.985
	(2.679)	(3.062)	(3.392)	(2.869)	(3.687)	(3.883)
Crude oil lag		0.126***	0.131***		0.134***	0.132***
		(0.003)	(0.004)		(0.003)	(0.006)
Capacity			-0.033			0.115**
			(0.031)			(0.045)
Quantity			-0.205			-0.438
			(0.444)			(0.442)
Distance			-0.039			-0.032
			(0.034)			(0.071)
CON			-1.853***			1.147
			(0.510)			(1.066)
HHI			-4.060			-8.027
			(4.098)			(4.914)
Year FE	No	Yes	Yes	No	Yes	Yes
Type FE	No	Yes	Yes	No	Yes	Yes
Borough FE	No	Yes	Yes	No	Yes	Yes
Observations	1,051	1,051	1,051	393	393	393
R-squared	0.200	0.843	0.848	0.216	0.905	0.912
Average outcome	72.22	72.22	72.22	71.59	71.59	71.59

Notes. Coefficient (standard error in parenthesis) of the effect of the announcement of the Marteau investigation on raw bids: all bids (columns 1 to 3), winning bids (columns 4 to 6). *Marteau* is a dummy variable = 0 if the observations are previous to the investigation announcement (2007 to 2009 included). *Mtl* is also a dummy variable = 1 if the observations are those of Montreal. *Crude oil lag* is the price of the crude oil lagged. *Capacity* is the firm's potential capacity, defined as the maximum quantity ever bid on by the firm in our sample for Quebec, while in Montreal it is defined in all post-cartel years. *Quantity* is the number of tons in the call. $Distance_{i,x}$ is the distance from a firm to the delivery point of the borough where the job is located. *CON* is percentage of all contracts won in a borough by a firm in the previous year. For Quebec City we use the one that would prevail without the change in legislation in 2009. SEs are clustered at the borough and year levels. Significance at the 10% (*), at the 5% (**), and at the 1% (***).

Table A.8: Test of the Common trend assumption

Dependent Variable	Raw bids					
Sample	All bids	All bids	All bids	Winning bid	Winning bid	Winning bid
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Linear Trend					
Mtl×Year	3.595***	5.998***	7.874***	4.957*	6.692**	8.285***
	(1.214)	(2.201)	(2.404)	(2.607)	(2.798)	(2.666)
Year FE	No	No	No	No	No	No
Type FE	No	Yes	Yes	No	Yes	Yes
Borough FE	No	Yes	Yes	No	Yes	Yes
R-squared	0.715	0.948	0.953	0.754	0.971	0.978
	Panel B: Non-linear Trend					
Mtl×Year2008	9.898***	11.406***	12.067***	13.355***	14.971***	13.758***
	(2.310)	(3.564)	(3.551)	(4.661)	(4.594)	(3.953)
Mtl×Year2009	8.208***	11.962***	12.605***	10.341**	13.818**	12.468**
	(2.248)	(4.247)	(4.198)	(4.675)	(5.335)	(4.693)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Type FE	No	Yes	Yes	No	Yes	Yes
Borough FE	No	Yes	Yes	No	Yes	Yes
Observations	640	640	640	237	237	237
R-squared	0.786	0.951	0.953	0.817	0.977	0.978
Avr outcome	73.91	73.91	73.91	74.03	74.03	74.03
pval	0.0774	0.804	0.808	2.80e-05	0.669	0.629

Notes. Coefficient (standard error in parenthesis) of the interaction term between Mtl and a linear trend ($Year$) on raw bids: all bids (columns 1 to 3), winning bids (columns 4 to 6) for all the observations before the $Marteau$ investigation announcement (2007 to 2009 included). Mtl is also a dummy variable = 1 if the observations are those of Montreal. In Panel B, the trend is specified with two dummy variables for the years 2008 and 2009. *p-value* is the p-value for the F-test $Mtl \times Year2008 = Mtl \times Year2009$. The columns include the same variables included in Table A.7. SEs are clustered at the borough and year levels. Significance at the 10% (*), at the 5% (**), and at the 1% (***).

Table A.9: Heterogeneous trends

Dependent Variable	Raw bids					
Sample	All bids	All bids	All bids	Winning bid	Winning bid	Winning bid
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Linear heterogenous trend					
Mtl×Marteau	-8.552*	-5.700	-6.589	-11.817**	-10.209*	-10.442*
	(4.351)	(4.784)	(4.989)	(5.167)	(5.672)	(5.688)
Year FE	No	Yes	Yes	No	Yes	Yes
Type FE	No	Yes	Yes	No	Yes	Yes
Borough FE	No	Yes	Yes	No	Yes	Yes
Observations	1,051	1,051	1,051	393	393	393
R-squared	0.689	0.843	0.847	0.740	0.905	0.911
	Panel B: Non-linear heterogenous trend					
Mtl×Marteau	-13.895***	-20.978***	-21.633***	-17.233***	-14.850***	-14.388***
	(1.167)	(1.348)	(1.395)	(1.663)	(2.417)	(2.326)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Type FE	No	Yes	Yes	No	Yes	Yes
Borough FE	No	Yes	Yes	No	Yes	Yes
Observations	1,051	1,051	1,051	393	393	393
R-squared	0.732	0.886	0.891	0.783	0.945	0.949
Avr outcome	72.22	72.22	72.22	71.59	71.59	71.59

Notes. Coefficient (standard error in parenthesis) of the effect of the announce of the Marteau investigation on raw bids: all bids (columns 1 to 3), winning bids (columns 4 to 6). $Marteau$ is a dummy variable = 0 if the observations are previous to the investigation announcement (2007 to 2009 included). Mtl is also a dummy variable = 1 if the observations are those of Montreal. The model includes heterogenous trends: In Panel A, an interaction term between Mtl and a linear trend ($Year$); In Panel B interactions terms between Mtl and a year indicators (2007-20013). The columns include the same variables included in Table A.7. SEs are clustered at the borough and year levels. Significance at the 10% (*), at the 5% (**), and at the 1% (***).

A.7 Main results – robustness

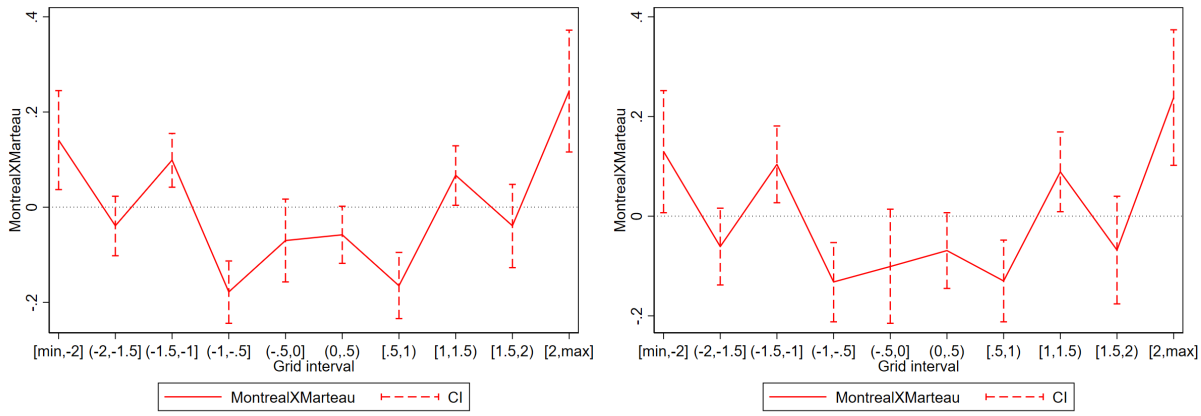
Table A.10: Distributional effect of the investigation on clustering & isolation – no separate bin for 0.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dep.Var	Pr[min -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 max]
					Panel A: Without controls					
Mtl×Marteau	0.1407***	-0.0394	0.0987***	-0.1784***	-0.0697	-0.0582*	-0.1647***	0.0666**	-0.0394	0.2439***
	(0.053)	(0.032)	(0.029)	(0.033)	(0.044)	(0.031)	(0.035)	(0.032)	(0.044)	(0.065)
Mtl	-0.0914***	0.0241	-0.0599**	0.1599***	0.0809***	0.0364	0.1494***	-0.0340	0.0179	-0.2833***
	(0.031)	(0.024)	(0.027)	(0.025)	(0.026)	(0.022)	(0.027)	(0.027)	(0.033)	(0.041)
Marteau	0.0784*	0.0009	-0.0988***	0.0256	0.0386	0.0133	0.0133	-0.0861***	-0.0111	0.0258
	(0.046)	(0.029)	(0.026)	(0.024)	(0.035)	(0.026)	(0.026)	(0.029)	(0.042)	(0.053)
Observations	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009
R-squared	0.115	0.00691	0.0103	0.0621	0.00746	0.0104	0.0585	0.00680	0.00889	0.0838
Borough FE	No	No	No	No	No	No	No	No	No	No
Year FE	No	No	No	No	No	No	No	No	No	No
Mean Y Pre Montreal	-4.125	-1.58	-1.03	-.55	-.16	.27	.55	1.02	1.60	5.29
					Panel B: With controls					
Mtl×Marteau	0.1296**	-0.0610	0.1038***	-0.1322***	-0.1006*	-0.0689*	-0.1301***	0.0886**	-0.0676	0.2383***
	(0.063)	(0.039)	(0.039)	(0.041)	(0.058)	(0.039)	(0.042)	(0.041)	(0.055)	(0.069)
Mtl	-0.1804**	0.0260	-0.0748*	0.1018	0.1234*	0.0515	0.1020	-0.1099	0.0644	-0.1040
	(0.083)	(0.043)	(0.043)	(0.091)	(0.068)	(0.046)	(0.089)	(0.081)	(0.063)	(0.137)
Marteau	0.8981*	-0.3513*	-0.1465	0.9584***	-0.8892*	-0.3396*	0.9631***	-0.1245	-0.2247	-0.7438
	(0.533)	(0.179)	(0.291)	(0.364)	(0.489)	(0.196)	(0.365)	(0.333)	(0.254)	(0.678)
Crude oil lag	-0.0048	0.0021**	0.0001	-0.0052**	0.0053*	0.0021*	-0.0053**	0.0001	0.0012	0.0044
	(0.003)	(0.001)	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)	(0.004)
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	0.2495***	-0.0744	-0.0982	0.2785***	-0.3511***	-0.3462***	0.2758***	-0.0278	-0.1668	0.2606*
	(0.094)	(0.090)	(0.088)	(0.074)	(0.079)	(0.071)	(0.082)	(0.091)	(0.114)	(0.138)
Observations	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009
R-squared	0.182	0.0356	0.0324	0.134	0.107	0.104	0.126	0.0226	0.0388	0.131
Borough FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean Y Pre Montreal	-4.125	-1.58	-1.03	-.55	-.16	.27	.55	1.02	1.60	5.29

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. 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.

(a) No controls (b) Controls



This figure reports the estimated coefficient for $Mtl \times Marteau$, along with confidence intervals, from Table A.10. Confidence intervals are computed with standard errors clustered at the borough and year levels.

Table A.11: 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[min -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 max]
	Panel A: Without controls																		
Mtl×Marteau	0.1407***	-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	0.2439***
	(0.053)	(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)	(0.065)
Mtl	-0.0914***	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	-0.2833***
	(0.031)	(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)	(0.041)
Marteau	0.0784*	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	0.0258
	(0.046)	(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)	(0.053)
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	0.115	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	0.0838
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
Mean Y Pre Montreal	-4.12	-1.75	-1.5	.	-1.03	-.77	-.5	-.27	.	0	.	.27	.5	.77	1.02	.	1.5	1.75	5.29
	Panel B: With controls																		
Mtl×Marteau	0.1296**	-0.0154**	-0.0455	0.0453	0.0585*	-0.0275	-0.1047***	-0.0398	-0.0291	-0.0318	-0.0291	-0.0398	-0.1080***	-0.0221	0.0406	0.0480	-0.0709	0.0033	0.2383***
	(0.063)	(0.007)	(0.040)	(0.030)	(0.032)	(0.023)	(0.035)	(0.026)	(0.026)	(0.048)	(0.026)	(0.026)	(0.035)	(0.025)	(0.033)	(0.030)	(0.052)	(0.020)	(0.069)
Mtl	-0.1804**	-0.0036	0.0295	-0.0405	-0.0343	-0.0506	0.1524***	0.0074	0.0441	0.0719	0.0441	0.0074	0.1512***	-0.0491	0.0245	-0.1344	0.0785	-0.0141	-0.1040
	(0.083)	(0.009)	(0.042)	(0.037)	(0.029)	(0.079)	(0.034)	(0.033)	(0.028)	(0.048)	(0.028)	(0.033)	(0.034)	(0.077)	(0.030)	(0.086)	(0.053)	(0.030)	(0.137)
Marteau	0.8981*	-0.3599***	0.0087	-0.0152	-0.1313	0.0882	0.8702***	-0.4157***	0.0761	-0.5496	0.0761	-0.4157***	0.8558***	0.1072	0.0276	-0.1521	-0.0116	-0.2130	-0.7438
	(0.533)	(0.115)	(0.145)	(0.095)	(0.283)	(0.215)	(0.313)	(0.100)	(0.155)	(0.469)	(0.155)	(0.100)	(0.308)	(0.219)	(0.288)	(0.131)	(0.159)	(0.202)	(0.678)
Crude oil lag	-0.0048	0.0021***	-0.0001	-0.0002	0.0003	-0.0007	-0.0045**	0.0023***	-0.0002	0.0032	-0.0002	0.0023***	-0.0045**	-0.0008	-0.0005	0.0006	0.0001	0.0010	0.0044
	(0.003)	(0.001)	(0.001)	(0.000)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(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	-0.0000	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	0.2495***	-0.1402***	0.0658	0.0271	-0.1253	-0.0041	0.2826***	-0.3857***	0.0395*	-0.0049	0.0395*	-0.3857***	0.2723***	0.0035	-0.0391	0.0113	0.0478	-0.2145***	0.2606*
	(0.094)	(0.025)	(0.084)	(0.073)	(0.082)	(0.030)	(0.073)	(0.064)	(0.023)	(0.054)	(0.023)	(0.064)	(0.075)	(0.036)	(0.084)	(0.075)	(0.089)	(0.057)	(0.138)
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	0.182	0.0706	0.0473	0.0919	0.0241	0.0540	0.161	0.132	0.0416	0.0928	0.0416	0.132	0.158	0.0579	0.0192	0.0763	0.0501	0.0501	0.131
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
Mean Y Pre Montreal	-4.12	-1.75	-1.5	.	-1.03	-.77	-.5	-.27	.	0	.	.27	.5	.77	1.02	.	1.5	1.75	5.29

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. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Table A.12: Distributional effect of the investigation on clustering & isolation. No separate bin for 0. Finer grid – 0.25

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Dep.Var	Pr[min -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 .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 max]
	Panel A: Without controls																	
Mtl×Marteau	0.1407***	-0.0283	-0.0111	0.0494**	0.0493**	-0.0420**	-0.1364***	-0.0491*	-0.0206	-0.0091	-0.0491*	-0.1383***	-0.0264	0.0266	0.0400	-0.0294	-0.0101	0.2439***
	(0.053)	(0.022)	(0.025)	(0.022)	(0.024)	(0.020)	(0.030)	(0.025)	(0.037)	(0.018)	(0.025)	(0.030)	(0.025)	(0.024)	(0.026)	(0.033)	(0.027)	(0.065)
Mtl	-0.0914***	0.0062	0.0179	-0.0494**	-0.0105	0.0296***	0.1302***	0.0364	0.0444***	-0.0000	0.0364	0.1321***	0.0173	0.0154	-0.0494**	0.0235	-0.0056	-0.2833***
	(0.031)	(0.013)	(0.021)	(0.022)	(0.022)	(0.007)	(0.027)	(0.022)	(0.015)	(0.000)	(0.022)	(0.026)	(0.014)	(0.022)	(0.022)	(0.021)	(0.021)	(0.041)
Marteau	0.0784*	0.0130	-0.0120	-0.0494**	-0.0494**	0.0253	0.0003	-0.0120	0.0506*	0.0253	-0.0120	0.0003	0.0130	-0.0494**	-0.0367	0.0006	-0.0117	0.0258
	(0.046)	(0.021)	(0.021)	(0.022)	(0.021)	(0.017)	(0.017)	(0.021)	(0.029)	(0.017)	(0.021)	(0.017)	(0.021)	(0.021)	(0.026)	(0.030)	(0.026)	(0.053)
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
R-squared	0.115	0.00414	0.00463	0.0456	0.00346	0.00450	0.0606	0.0229	0.00833	0.0119	0.0229	0.0616	0.00201	0.00675	0.0298	0.00530	0.00437	0.0838
Borough FE	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
Mean Y Pre Montreal	-4.12	-1.75	-1.5	.	-1.03	-.77	-.5	-.27	0	.	.27	.5	.77	1.02	.	1.5	1.75	5.29
	Panel B: With controls																	
Mtl×Marteau	0.1296**	-0.0154**	-0.0455	0.0453	0.0585*	-0.0275	-0.1047***	-0.0398	-0.0608	-0.0291	-0.0398	-0.1080***	-0.0221	0.0406	0.0480	-0.0709	0.0033	0.2383***
	(0.063)	(0.007)	(0.040)	(0.030)	(0.032)	(0.023)	(0.035)	(0.026)	(0.052)	(0.026)	(0.026)	(0.035)	(0.025)	(0.033)	(0.030)	(0.052)	(0.020)	(0.069)
Mtl	-0.1804**	-0.0036	0.0295	-0.0405	-0.0343	-0.0506	0.1524***	0.0074	0.1160**	0.0441	0.0074	0.1512***	-0.0491	0.0245	-0.1344	0.0785	-0.0141	-0.1040
	(0.083)	(0.009)	(0.042)	(0.037)	(0.029)	(0.079)	(0.034)	(0.033)	(0.054)	(0.028)	(0.033)	(0.034)	(0.077)	(0.030)	(0.086)	(0.053)	(0.030)	(0.137)
Marteau	0.8981*	-0.3599***	0.0087	-0.0152	-0.1313	0.0882	0.8702***	-0.4157***	-0.4736	0.0761	-0.4157***	0.8558***	0.1072	0.0276	-0.1521	-0.0116	-0.2130	-0.7438
	(0.533)	(0.115)	(0.145)	(0.095)	(0.283)	(0.215)	(0.313)	(0.100)	(0.479)	(0.155)	(0.100)	(0.308)	(0.219)	(0.288)	(0.131)	(0.159)	(0.202)	(0.678)
Crude oil lag	-0.0048	0.0021***	-0.0001	-0.0002	0.0003	-0.0007	-0.0045**	0.0023***	0.0030	-0.0002	0.0023***	-0.0045**	-0.0008	-0.0005	0.0006	0.0001	0.0010	0.0044
	(0.003)	(0.001)	(0.001)	(0.000)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(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	0.0000	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)
HHI	0.2495***	-0.1402***	0.0658	0.0271	-0.1253	-0.0041	0.2826***	-0.3857***	0.0346	0.0395*	-0.3857***	0.2723***	0.0035	-0.0391	0.0113	0.0478	-0.2145***	0.2606*
	(0.094)	(0.025)	(0.084)	(0.073)	(0.082)	(0.030)	(0.073)	(0.064)	(0.060)	(0.023)	(0.064)	(0.075)	(0.036)	(0.084)	(0.075)	(0.089)	(0.057)	(0.138)
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
R-squared	0.182	0.0706	0.0473	0.0919	0.0241	0.0540	0.161	0.132	0.0997	0.0416	0.132	0.158	0.0579	0.0192	0.0763	0.0501	0.0501	0.131
Borough FE	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
Mean Y Pre Montreal	-4.12	-1.75	-1.5	.	-1.03	-.77	-.5	-.27	0	.	.27	.5	.77	1.02	.	1.5	1.75	5.29

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. Standard errors are clustered at the borough and year levels. Significance at 10% (*), 5% (**), and 1% (***).

Table A.13: Distributional regression of bid differences in Montreal before the investigation. Sample includes only auctions in Montreal before the investigation. No separate bin for 0.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dep.Var	Pr[min,-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,max]
Constant	0.0074*	0.0611***	0.0389***	0.1722***	0.1056***	0.0611***	0.1741***	0.0648***	0.0796***	0.2352***
	(0.004)	(0.012)	(0.007)	(0.022)	(0.020)	(0.015)	(0.021)	(0.007)	(0.013)	(0.025)
Observations	540	540	540	540	540	540	540	540	540	540
Borough FE	No	No	No	No	No	No	No	No	No	No
Year FE	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% (***).