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Collusion in Public Procurement Auctions

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Abstract

We plan to analyze data from Montreal municipal tenders to analyze the effect of collusion on public procurement. Variation provided by the establishment and collapse of a cartel in Montreal's in the construction market following an anti-collusion investigation enables us to quantitatively test the effects of pricing coordination on the results of collusion. We plan to study the asphalt bid price change in three periods – before, during, and after – related to the cartel organization to analyze the markets. The collusion was reported to have been existing from 2000 to 2009 during which period significant price variation was observed. We analyzed descriptive statistics in terms of change in number of bidders, market share, winning price level and so on to know how the creation of cartel has impacted on the market.

Keywords: Collusion-proof auctions; asphalt; cartels; Marteau investigation

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Introduction

Charbonneau Commission was a public inquiry initiated by Quebec provincial government to investigate price coordination and corruption related to tenders in public construction market. The first allegations against public contracting schemes of collusion and corruption started in 2007. It is however not until on March 2009 when Radio-Canada's TV show *Enquête* which unveiled and alleged the stealth embezzlement that has aroused public attentions of a much larger scale cartel in the industry. The report of Auditor General of Quebec highlighted a situation of "low competition and worrying costs"[1]. In response, the Quebec government, in October 22, 2009, initiated the *Opération Marteau* to oversee the investigation regarding individuals and organizations involved in the allegation.

This study is inspired by the research of Clark, Coviello, Gauthier, and Shneyerov (2018) which studied the impact of an investigation against local cartel activities in public procurement auctions in Montreal. Clark et al. (2018) scrutinized the variation of economic behaviors of firms in the asphalt market before and after the investigation to study the organization of cartels during the tender process. More specifically, their research focused on public procurement auctions in terms of construction raw material called by the *Direction de l'approvisionnement* under *Service de l'approvisionnement*, City of Montreal, between 2007 and 2013. It calls for tender regarding production of 10 types of raw material of asphalt in Montreal. The Final report of the Charbonneau Commission (2015) disclosed the collusive behaviors had penetrated into more public procurement in downflow markets. Cartel activities are also found existing in municipal auctions call for construction projects, such as road paving and construction.

This article has the purpose to study the impact of collusive behaviors in construction procurement auctions called by *Service des infrastructure, transport et environnement* for a time period from 1998 to 2012, which captures the variation introduced by the investigation (2009), as well as the creation of the cartel (2000). This article contributes to study the entire evolution of cartel, including a complete process of creation and collapse of cartel (from 1998 to 2012), which is a supplement to the study by Clark et al. (2018). The construction work tenders are more important in market size as compared to public procurement tenders, as from 2011 to 2015 the value of contracts reached $11.9 billion for the public procurement market, while was $23

[1] See page 5 of the Final report of the Charbonneau Commission (Charbonneau and Lachance 2015)

billion in the construction market[2]. According to Final report of the Commission Charbonneau, the cartel in this market began in 2000 when six major bidding firms reached an agreement to bid with a price negotiated in advance among them.[3]

My study uses data of municipal tenders in the public construction sector from 1998 to 2012, as well as details provided by final report of Commission Charbonneau. However, different from the methodology applied by Clark et al. (2018), this study has no control group as a comparison, which could be a limit.

Review of Previous Literature

A large list of theoretical literature has contributed to our understanding of collusive behaviors. Graham and Marshall (1987) and Seres (2017) define cartel as a stable organization applying a "coordinated bidding strategy" while discouraging meaningful rivalries from non-cartel bidders. Giuseppe Lopomo, Robert Marshall, and Leslie Marx (2005) pointed out the loss in efficiency when entry is deterred by incumbents, and this conclusion is confirmed by the study of Asker (2010). Moreover, Fabra and Toro (2005) point out that uniform-priced auction and relatively inelastic demand in the short term, which is the case in Montreal public tender market, favor coordinated pricing practices among cartel bidders. Marshall and Marx (2006) also mentioned rent-seeking practices are observed where sellers are compensated by extra profits when cartel incumbents forcibly suppress competition.

Meanwhile, research efforts are also put on empirical studies. The study of Clark, Coviello, Gauthier, and Shneyerov (2018) has greatly inspired this paper. They adopt a difference-in-difference model measuring change in bid price of asphalt as the presence of a treatment (investigation of *Opération Marteau*) while comparing a treatment group (Montreal market) by a control group (Quebec market). In addition, time-series analysis is alternatively used by some others, for example, Von Blanckenburg and Geist (2009) and Fabra and Toro (2005). Green and Porter (1984) and Li and Zheng (2009) use game theory to unveil the mechanism of a cartel organization and identify the inner motivation for member firms.

[2] See page 72 of the Final report of the Charbonneau Commission (Charbonneau and Lachance 2015)
[3] Besides the 6 cartel firms, there are 11 more firms suspected to have been involved in cartel activities. But their degree of involvement and the year they entered the cartel are unknown. To avoid including irrelevant firms in the cartel group, I will focus solely on the 6 firms clearly identified by Commission Charbonneau.

In addition, incumbents' ability to deter potential rivalry is another focus of study, for example by Coviello and Mariniello (2014), Li and Zheng (2009), as well as Clark et al. (2018). Entry deterrence is the intention and behavior to prevent potential competitors from entering the market, such as bidding for the public auctions.

The data includes results of municipal tenders in the public construction sector for the period 1998 to 2012 through *Access to Information* requests at the Municipal Clerk's offices. The data provides information about price and quantity of raw material, as well as bidders, before and after the investigation.

The market

Public tender contracts are signed by the City with auction winners to implement projects for public service which are financed by public fonds. This requires the City to ensure the best price to be achieved. Also, to avoid rent-seeking activities, the City should ensure equal chance between bidders by avoiding favoring any certain organizations. The price is solicited in order to award the contract to the bidder with the lowest price. This norm is described as *du plus bas soumissionnaire conforme*, which means *the lowest bid wins*.[4]

Based on *Libéralisation des Marchés Publics du Québec et du Nouveau-Brunswick (AQNB 2008)*, the preferred method of solicitation is to call for public tenders. Contracts were awarded on a majority basis - 96.35% of the annual business volume - to local entrepreneurs in the Montréal metropolitan area. In the beginning, the City must prepare all the necessary documents and estimate the cost of the contracts to be awarded based on the specific project tasks. Bidders will announce their price through a first-price sealed bid auctions within the time frame set by the City. The bidder with the lowest quote wins the tender.

Once licenses and authorizations are issued from the *Autorité des marchés financiers*, a firm is qualified to bid for contracts from a public authority with the lowest price it can compete. The *Ministère des Transports du Québec* is the largest distributor, followed by the municipal and then the private sector clients[5].

[4] See Tome 1 and Partie 2 of the Final report of the Charbonneau Commission (Charbonneau and Lachance 2015)
[5] See *Mémoire Présenté à la Commission d'enquête sur l'octroi et la gestion des contrats publics dans l'industrie de la construction* by Association des constructeurs de routes et grands travaux du Québec p. 282

Public projects refer to projects initiated and financed by government. Each one project is made up by multiple items. An item is one specific task to complete part of the entire project. For instance, one complete project can include purchase of raw materials such as asphalt, sewer, or cement or tasks like construction, paving, transportation, and so on. Project are priced as sum of costs of all items. Bidder wins by asking the lowest price of whole project. Types of asphalt used varies depending on projects. Asphalts under different category are made for different use according to their distinct characteristics. Each type of asphalt is used in certain work conditions. For example, some are used to pave the base layer, while others are more suitable for road surface.

Due to the wide variety of construction works demanded in Montreal, the sample data includes a long list of types of asphalt, while only certain types are reordered during my sample period. To better track the price variation across years and control type effects, only 10 types of asphalt will be studied. From 1998 to 2012, these 10 types of asphalt were used in common projects with continuous demand by the City every year. Also, most bidders joined in auctions to supply these 10 types of asphalt. Different from the categorization adopted by Clark et al. (2018), with which asphalts are classified under both the Standard 4201&4202[6] and grading systems[7] such as Superpave Performance Grading (PG) System, I only base my classification on Standard 4201&4202. The construction market involves a larger range of projects than the raw material procurement market studied by Clark et al. (2018). Using the Standard 4201&4202 and grading systems at the same time will divide asphalt into more than 40 different types, which consumes considerably the degrees of freedom of sample data. Standard 4201&4202 is sufficiently detailed to distinguish asphalts with physical performance and is widely used as a reference to indicate asphalt with different physical characteristics in the construction industry.

[6] A volumetric approach to normalise asphalt product with certain chemical composition and so required physical conditions, this is a normal way of classifying asphalt materials in Quebec.
[7] Another specific way to classify asphalt materials in terms of their physical characteristics, such as performance under certain temperature.

The cartel and the investigation

Witness testimony has confirmed the asphalt cartel in Montreal was formed around February or March 2000[8] by six member firms[9]. Collusive behaviors appeared before 2000, but the organization was not stable, because disagreement and competition still existed within the organization. For instance, in 1998 one member was dissatisfied with distribution of projects and caused the collusive attempt to have failed that year. In 2000, a meeting held by the six firms resulted in formal agreement among members and allowed the creation of a more stable cartel. This cartel gradually expanded to larger scale, which according to witness testimony "touched everyone". The testimony pointed out that more firms joined the cartel. However, neither the list of membership nor their year of participation is available. So, the study will focus on the six founding firms. Also, the six firms have expanded their influence also to other project categories, such as sewer and sidewalk pavement, while this research will focus on asphalt related projects.

Subsequent to Radio-Canada's disclosure of the stealth cartel, Charbonneau Commission[10] was formed on October 2011 to continue *Operation Marteau*'s efforts to investigate the allegation in a more extended scale. The objective of Charbonneau Commission was to uncover the mechanism behind the scheme activities. Its mandate has focus on corruption and collusion activities, which includes the financing of political parties. The Commission addresses such issues in the context of the contract awarding process in the construction industry. Its inquiry covers both public procurement and construction tenders. The Commission is also committed to dig into the organized crime featured by violent entry deterrence and other illegal behaviors, as well as to examine possible solutions and make recommendations with practical measures.

There is a division of territory among cartel members. Non-member firms were forced by violence to give only complement bids or excluded from the market. Government officials allegedly received bribes from bidding firms by which means cartel members were able to receive detailed auction information in advance[11]. Firms met before calls of tenders to make deals of which firm could get which contracts in terms of their respective location and

[8]Témoignage de Gilles Théberge, transcription du 23 mai 2013, p. 152

[9] While the final report of Charbonneau Commission only clearly mentioned five firms, based on the process of the creation of the cartel, a 6th firm has actively joined in. So, this firm is included in the cartel group too.

[10] A commonly known name for Commission of *Inquiry on the Awarding and Management of Public Contracts in the Construction Industry*

[11] Témoignage de Jean Théoret, transcription du 26 november 2012, p. 178 and p. 184

production capacity. Clark et al. (2018) has given a detailed description of how distribution of contracts was carried out using encrypted terms.

On the one hand, competition within the cartel was controlled by compensating those willing to "leave the way open to others"; on the other hand, outsiders were kept away from the market. The cartel forced new entrants to follow "rules" set by incumbents. Violent threats and harassments were usual approaches to intimidate and discourage competition. Even if some firms insisted to enter and submitted bid without letting cartel members know, incumbents would get informed by officials from the government. Once a non-member firm finally won a bid, it may encounter unexpected "incidents" and failed to finish the project in time. For instance, one firm's newly purchased equipment was damaged in fire because its president refused to yield[12].

Data and descriptive statistics

I use data from City of Montreal including all construction contracts auctioned during the years from 1998 to 2012, which covers pre-, peri-, and post-cartel periods. The data comes from the department of *Service des infrastructure, transport et environnement*, whose contracts are priced based on items (which are different tasks composing a complete project called for tender) of the same project. The database lists bids, items, bidders, quantity, and price sorted with year and type.

In order to get a clean and consistent data sample over time, I filter the data from varieties of item unrelated to asphalt. There are a large variety of items related to asphalt, but many of these are not called by the City regularly each year. So, these bids appear occasionally in the sample, and cause undesired shocks on the price. To reduce these unwanted sources of variation, I focus on two specific asphalt-related tasks: bituminous coating and supply and installation of coating, which are regularly called at tenders each year and include all the 10 types of asphalt need to be controlled. In addition, my data includes information about functions of asphalt raw material. The function of asphalt defines the way how the type of asphalt would be applied in construction work. Two functions are distinguished - surface layer and base layer. The City has the right to reject bids considered non-compliant, the dataset is clean of rejected bids.

[12] See *Rapport de la Commission d'enquête sur l'octroi et la gestion des contrats publics dans l'industrie de la construction* p. 423 and p. 893 (Charbonneau and Lachance 2015)

While it is reported at least 11 more firms joined the cartel following the creation of cartel in 2000, the list of cartel members is not clearly indicated in the final report from the Charbonneau Commission (2015). Neither their participation years nor their relations with the primary six members are clearly explained. Ignoring these firms will have limited impact on the outcomes of first-difference model because controlling winning firms from the others probably have these potential cartel firms controlled too. This is due to the belief that firms benefited from the coordination should have a larger chance of winning bids for tender.

In the construction market, the costs of operation for a firm to construct a road are mainly made up by three parts: labor cost (24%), raw material (18%), and fuel (13.5%). In addition, the price of an asphalt pavement is largely influenced by the costs of bitumen (43%), the evolution of unit price of which is directly associated with cost of bitumen itself, of granulates, and the transportation[13]. The transportation cost is not considered since they are registered separately in the contract, so the price data is clean of shipping cost. I will focus my study on measuring variation of raw price per ton to show how the creation and breakdown of the alleged conspiracy affected the construction market.

[13] See *Rapport de la Commission d'enquête sur l'octroi et la gestion des contrats publics dans l'industrie de la construction* p. 31 (Charbonneau and Lachance 2015)

Table 1. Descriptive statistics for Montreal City

Descriptive statistics - by year

	$ awarded (million)	Nbr contracts	Tons awarded (k tons)	Avg tons of asphalt	Nbr bidding firms	Nbr bids per contract	Avg winning bids ($/ton)
1998	1.338	39	21.335	547.057	18	1.103	62.698
1999	2.353	52	39.584	761.238	37	5.115	59.435
2000	6.674	48	77.581	1616.268	31	3.292	86.02
2001	5.836	44	54.38	1235.914	27	3.455	107.322
2002	6.467	72	57.389	797.065	31	4.639	112.694
2003	5.269	68	55.948	822.76	35	4.912	94.182
2004	18.693	122	194.436	1593.734	37	3.943	96.137
2005	12.368	54	108.323	2005.978	32	4.593	114.181
2006	17.462	70	134.544	1922.055	40	5.329	129.789
2007	18.978	100	160.269	1602.694	43	5.3	118.411
2008	30.125	140	244.542	1746.727	42	5.1	123.19
2009	29.524	121	219.857	1817.002	45	4.562	134.287
2010	3.158	30	32.716	1090.536	42	6.533	96.532
2011	7.352	66	80.934	1226.276	43	6.03	90.837
2012	8.686	52	95.155	1829.907	33	1.846	91.278

Descriptive statistics - by period

	Total			Average			
1998-1999	1.845	91	60.92	669.446	27.5	3.396	60.577
2001-2009	15.14	839	1307.268	1558.126	36.3	4.62	115.811
2010-2012	6.399	148	208.805	1410.848	39.333	4.662	91.93

Descriptive statistics for contracts awarded by Montreal City during 1998 to 2012 are presented in Table 1. The first column shows amount awarded to bidders measured in dollar. The total amount only includes items that are asphalt related. The projects awarded vary considerably each year to another, which makes it a poor indicator for tracking price change but, along with number of contracts awarded, a barometer for construction activities. We observe a hike in number, 30.125 million and 140 contracts awarded, prior to the economic crisis in 2009 and which fell in 2010 to only 3.158 million and 30 contracts. Montreal's construction market is relatively open where we see large numbers of competitors and easy access. So, the number of bidders shows a slow and constant increasing trend from 21 in 1998 to 50 bidders in 2011, which does not show any evidence of entry deterrence by cartel firms. The average number of bids per contract is a better indicator of coordination's impact on price of calls for tender. We see the level of competition reacted immediately to the alleged conspiracy and the intervention of Committee Charbonneau. The bids per contract declined from 5.12 to 3.29 when the cartel was organized in 2000 and returned back from 4.56 to 6.53 once the investigation was launched in 2010. Meanwhile, the average winning bid price increased 44.72% from 1999 to 2000 and reduced

28.12% due to investigation. These outcomes imply material impact by cartel on raw bid price in the construction market in Montreal.

Table 2 includes three tables comparing the 6 cartel members with non-cartel bidders for each of the three periods. The period 1 is the pre-cartel period including year 1998 and 1999. Period 2 is from 2000 to 2009 covering the period of cartel activities, while period 3 includes 2010 to 2012 following the investigation. The average auctions won per firm by cartel bidders has increased significantly from 3.33 bids/firm to 45.83 bids/firm with price coordination and fell back to 11.67 bids/firm following government intervention. In terms of shares of market, before the cartel was created, the 6 cartel members gained 52.2% of total value of auctions awarded vis-à-vis 47.8% won by the rest 42 non-cartel bidders. Their average share increased to 80.3% due to collusion. This number slightly declined to 78.4% when the cartel broke down. The ratio of average value of auctions won by cartel to those by non-cartel firms increased from 3.12 to 5.73. The ratio then fell back to 3.42 at the end. The increase in ratio of bid value during the cartel period indicates cartel members managed to enhance their dominance in high value tenders. In general, it is observed that cartel firms' market position was enhanced with alleged conspiracy.

Table 2. Cartel vs. Non-cartel Firm statistics

Period 1

	Avg auctions won per firm	Market share	Avg value of auctions won (thousand$)
Non-cartel	2.139	.478	33.906
Cartel	3.333	.522	105.934

Period 2

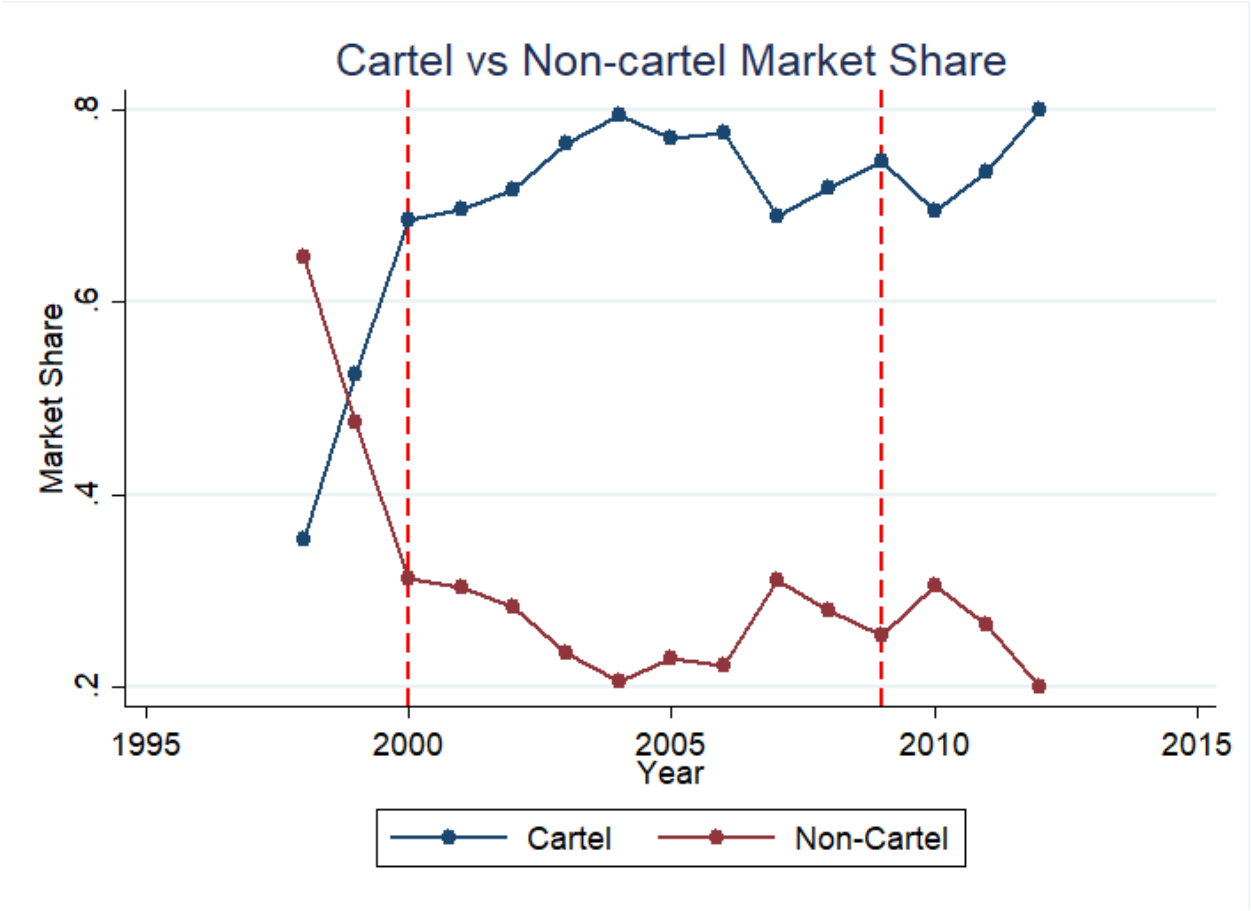
	Avg auctions won per firm	Market share	Avg value of auctions won (thousand$)
Non-cartel	8.758	.197	75.051
Cartel	45.833	.803	430.251

Period 3

	Avg auctions won per firm	Market share	Avg value of auctions won (thousand$)
Non-cartel	1.377	.216	65.721
Cartel	11.667	.784	225.045

If tracking the market share variation over the course of the sample years, shown in Figure 1, we can observe that the market share of cartel increased immediately once the cartel was formed. The high share remains unchanged even with the investigation.

Figure 1. Cartel vs Non-Cartel Market Shares

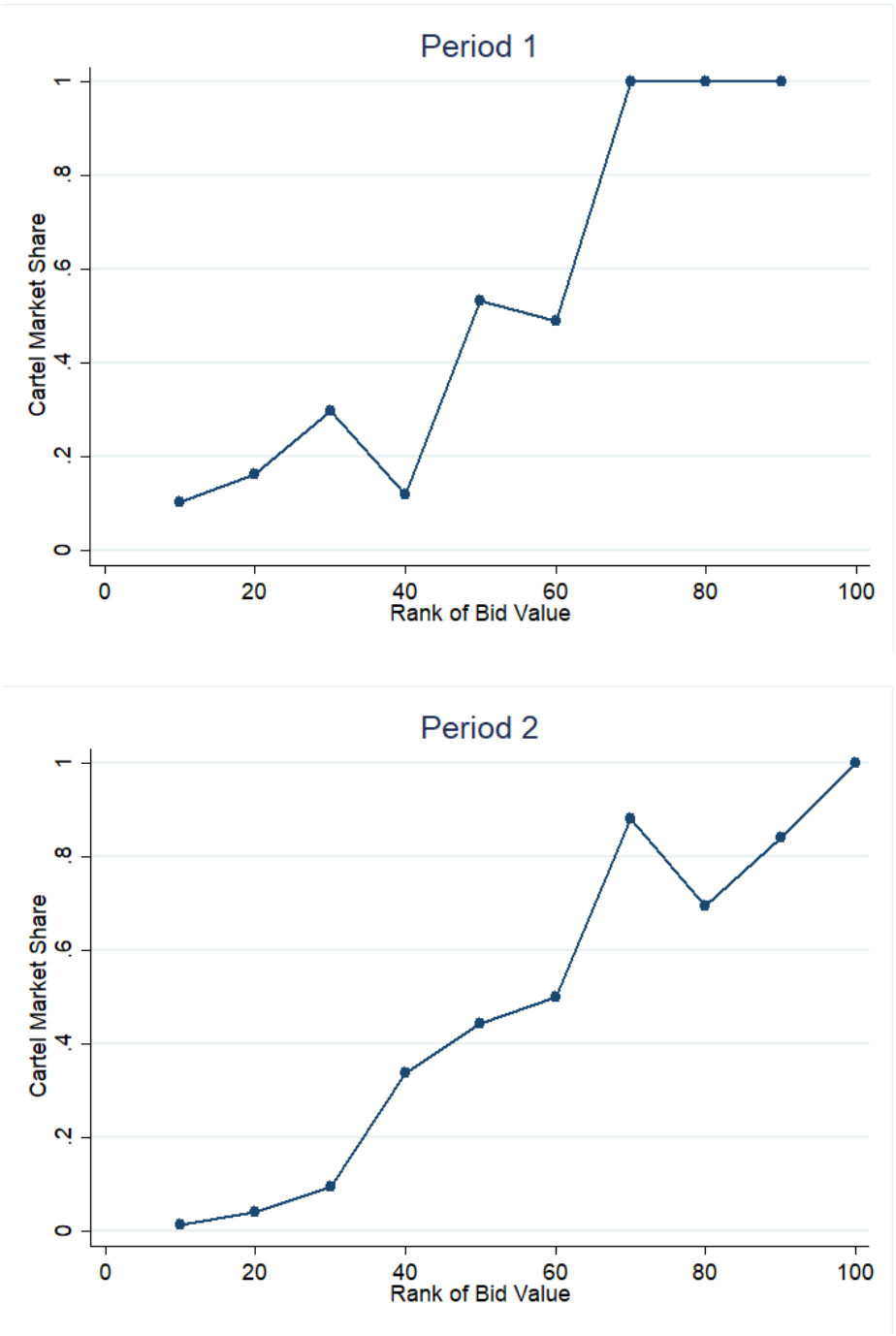


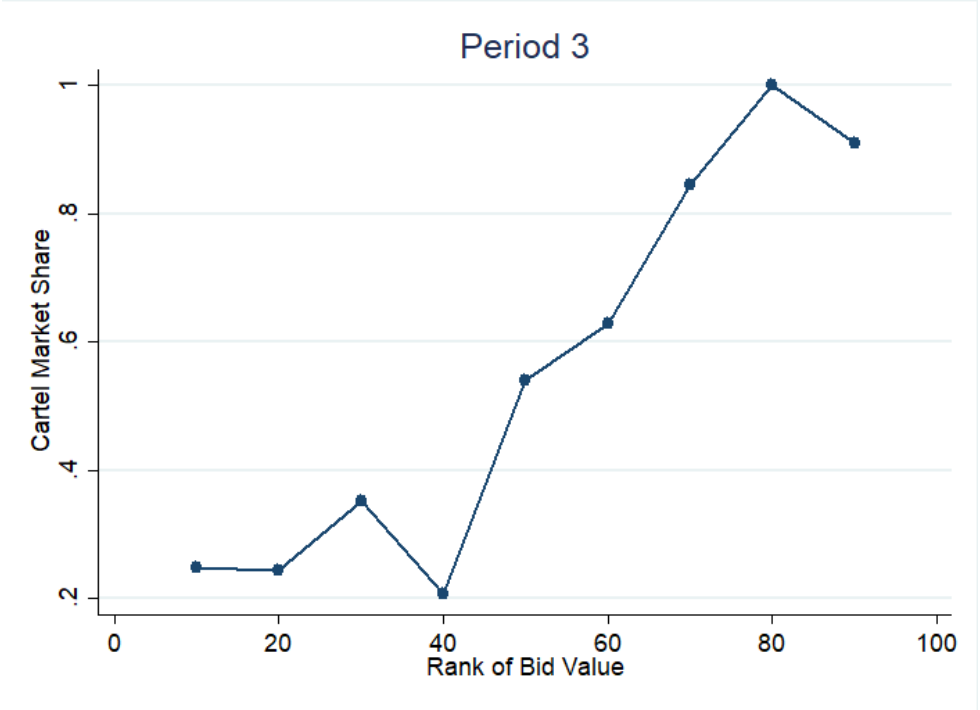
However, if classifying bids into four different groups based on value size, the impact of price coordination on market share of cartel becomes less clear. In figure 2, I separate bids into four groups with different values. For example, the first group includes bids with the 25% cheapest bids, while the fourth group is made up by the 25% most high value bids. If only looking at each group, the market shares of cartel and non-cartel firms do not show any clear tendency across years. Market shares tend to stay in the same level for each group of bids.

Figure 2. Cartel vs Non-Cartel Market Share with Different Bid Value Sizes

However, if compare market share levels across groups, we can see as value of bids rises, market share of cartel increases, which means cartel firms tend to have higher market importance in higher value segments. In Figure 3, this positive relationship is more visible. I sort bids in terms of bid value size and created a variable representing the rank of bid value. This variable includes the array of values 10, 20, 30 and so on till 100, where 10 represents bids with the 10% lowest value and 100 the highest 10% bids in value. Positive relationship between market share of cartel and bid value is observed in all 3 periods. The existence of cartel or not shows little impact on this tendency. In other words, cartel members' dominance in large bid segment is not related to their ability to collude bids for tender.

Figure 3. Cartel Market Share Related to Bid Value





Model

$$B_{i,a} = \alpha + \delta_1 Non\_Cartel_{i,a} + \delta_2 Marteau_{i,a} + \beta X_{i,a} + \varepsilon_{i,a} \qquad (1)$$

where $B_{i,a}$ refers to the bid price per ton offered by bidder *i* for item *a* related to asphalt of type *j*. $Non\_Cartel_{i,a}$ is a dummy equal to 1 if in the pre-cartel period, otherwise equal to 0, while $Marteau_{i,a}$ is a dummy for the *Opération Marteau* equal to 1 if in the post-announcement period, otherwise equal to 0. By setting *Non_Cartel* and *Marteau* as dummy variables featuring period 1 and 3, the constant α by default represent the average raw price for cartel period. $X_{i,a}$ controls year and type fixed effects, and as well as (1) the average price of crude oil[14], (2) average and median level of annual labor cost[15], (3) firm's potential capacity[16], (4) the value of asphalt in the tender offer, (5) firm *i*'s proportion of contracts obtained in the previous year, and (6) the HHI. I'm modeling to test the significance of *Non_Cartel* and *Marteau*. I expect outputs

[14] I use current oil price rather than the price of year before, since the Rapport Final of Charbonneau Commission indicates each year, the City will ask for provision of materials for road repair and require bid to be submitted on February, with exception that cartel members may request to set price after the OPEC meeting later than February of the year.
[15] Data of average and median annual income for employees in the construction industry from Statistics Canada.
[16] Defined as the largest quantity proposed during the period of dataset.

for both dummies to be negative. In other words, it means pre- and post-cartel average raw prices are significantly lower than that when there is price collusion.

Figure 4. All Bids Price

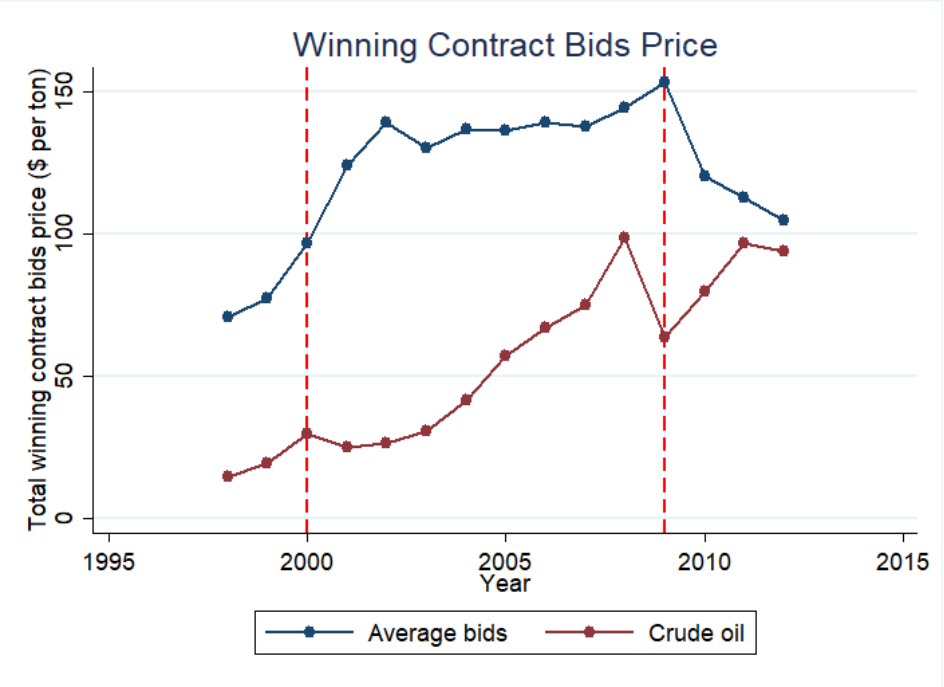
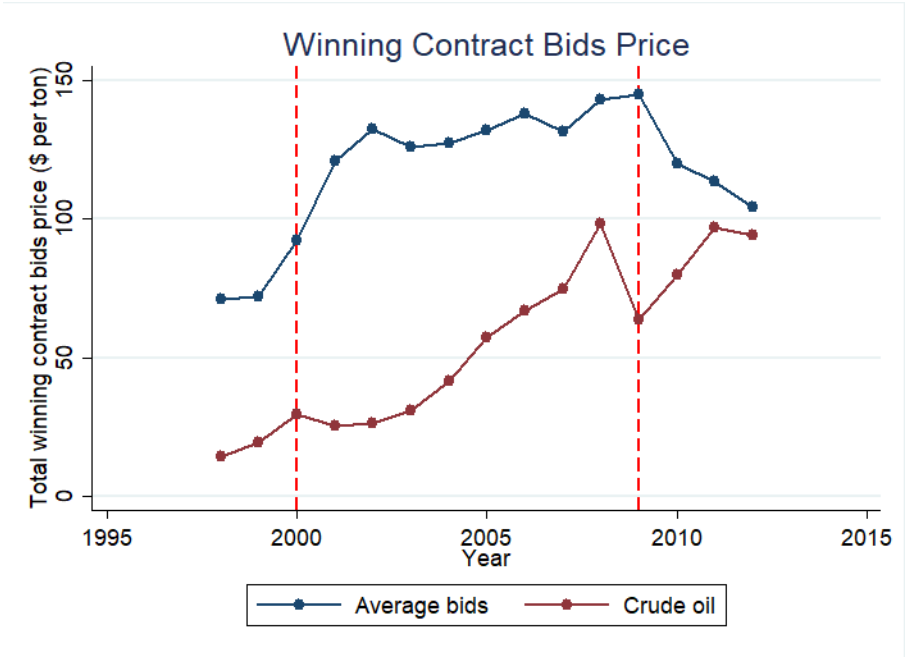


Figure 4 shows evolution of raw price per ton over time compared to crude oil price. The competition was higher in 1998 due to the failure of colluding a common price among the cartel members, since at that time there existed "libre concurrence", meaning free competition. Then, in 1999, the six initial member firms tried to reduce internal competition and formally reached an agreement to coordinate bidding price in 2000. We can see the price already began to increase since 1999 and jumped quickly to nearly $100 in 2000.

Considered a main contributor to inflation of asphalt price, we see crude oil price rose over years before 2009. After reaching a peak price in 2000, it took another two three years to regain its upward tendency in 2002 or 2003. Also, the oil price fell in 2008 due to the economic crisis, while raw price maintained the upward trend till 2009 the year when the investigation was launched. In Figure 5, where the raw price curve only includes winning bids price change, the movement of the curve is highly similar to that in Figure 4 where all bids are involved.

Figure 5. Winning Bids Price



In Figure 6 and 7, I reclassify winning bids into different groups according to tasks and functions. We see little difference in price trends between bids from different groups.

Figure 6. Winning Bids Price by Functions

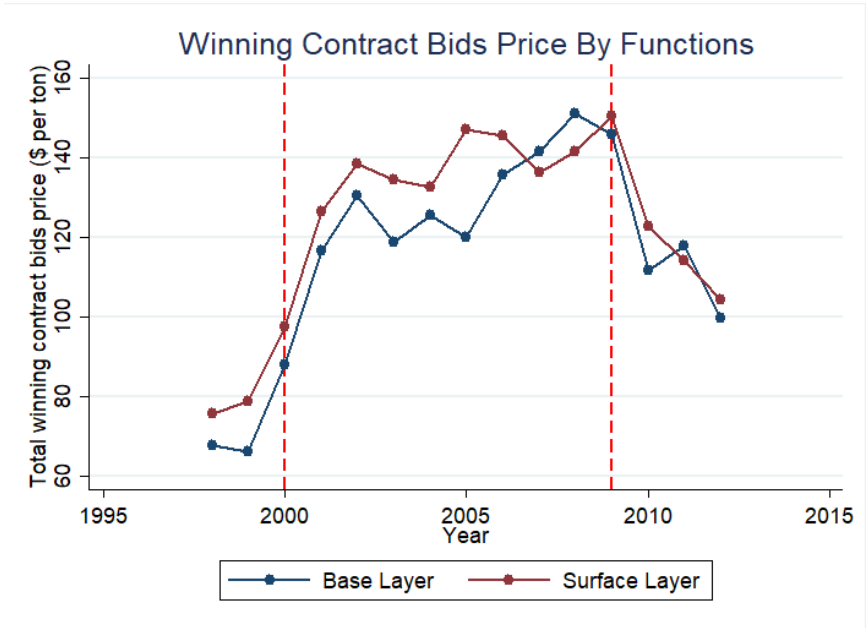


Figure 7. Winning Bids Price by Tasks

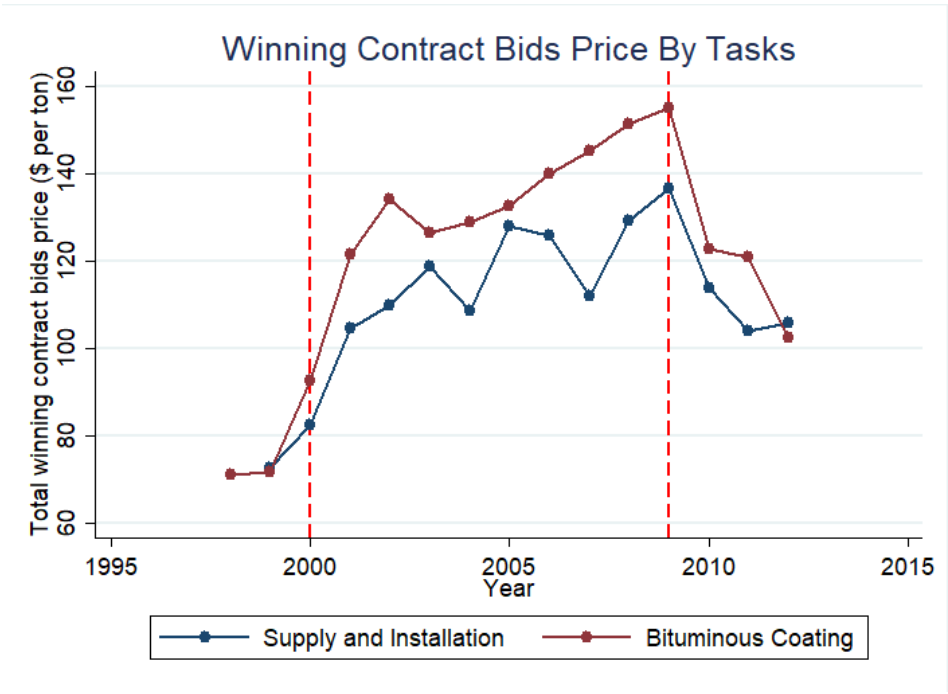


Table 3. First-difference test for asphalt-related items

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-61.54***	-55.67***	-64.74***	-57.12***	-51.11***	-51.86**
	(6.960)	(12.27)	(13.60)	(7.525)	(12.90)	(10.86)
Marteau	-17.14**	-27.34***	-37.46***	-17.87**	-29.89***	-37.70**
	(5.796)	(6.368)	(6.558)	(6.267)	(6.685)	(9.051)
Oil		0.298*	0.465***		0.352**	0.446*
		(0.121)	(0.117)		(0.127)	(0.142)
Average Labor Cost		-0.00652	-0.00667*		-0.00764*	-0.00642
		(0.00354)	(0.00326)		(0.00372)	(0.00428)
Median Labor Cost		0.00438	0.00378		0.00476	0.00305
		(0.00331)	(0.00321)		(0.00350)	(0.00366)
Capacity			-0.00110			0.00263
			(0.00381)			(0.00292)
Value			-0.000168*			-0.000121
			(0.0000661)			(0.0000671)
CON			190.3			-28.75
			(139.2)			(103.8)
HHI			34.81			40.82
			(18.54)			(36.26)
_cons	136.2***	249.9*	272.4*	128.8***	273.0*	267.4
	(2.471)	(120.6)	(114.2)	(2.693)	(126.8)	(125.6)
N	85	85	76	84	84	73
R^2	0.524	0.625	0.625	0.456	0.596	0.601

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Outputs of equation *(1)* are presented in Table 3. Table 3 describes model outputs for all bids and winning bids. While including all bids demonstrate the overall trend, winning bid price alone can directly tell us how auctions awarded were affected by cartel activity due to that cartel firms were usually winners of calls for tender. For all columns, the dummy variables *Non_Cartel* and *Marteau* are significant and negative, which means without presence of cartel raw prices are significantly lower. From column (5) to (6), we can see controlling more variables only slightly reduces the price difference between period 2 and those of period 1 and 3. The focus of analysis

lies in column (6), where winning bid price on average per year increased $51.86/ton. So, during the entire period 2, it cost the Montreal government $67.79 million more due to cartel. Following the investigation, raw bid price reduced on average $37.7/ton.

Table 4. DID controlling for the number of auctions

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-63.09***	-51.53***	-61.95***	-57.52***	-49.40***	-51.14***
	(7.007)	(12.19)	(14.30)	(7.670)	(13.14)	(14.05)
Marteau	-19.86**	-32.45***	-39.23***	-18.57**	-31.98***	-38.46***
	(6.088)	(6.745)	(7.114)	(6.663)	(7.251)	(7.960)
Number of auctions	-0.169	-0.229*	-0.0855	-0.0435	-0.0936	-0.0333
	(0.122)	(0.115)	(0.130)	(0.134)	(0.124)	(0.138)
Oil		0.347**	0.476***		0.372**	0.454***
		(0.121)	(0.119)		(0.130)	(0.126)
Average Labor Cost		-0.00601	-0.00647		-0.00743	-0.00629
		(0.00347)	(0.00329)		(0.00374)	(0.00358)
Median Labor Cost		0.00570	0.00421		0.00531	0.00322
		(0.00331)	(0.00329)		(0.00359)	(0.00351)
Capacity			-0.000256			0.00282
			(0.00403)			(0.00358)
Value			-0.000173*			-0.000124
			(0.0000669)			(0.0000757)
CON			159.4			-34.25
			(147.5)			(100.8)
HHI			30.99			37.39
			(19.51)			(33.39)
_cons	140.9***	194.5	252.6*	130.0***	250.2	257.8
	(4.171)	(121.4)	(118.6)	(4.612)	(130.7)	(130.6)
N	85	85	76	84	84	73
R^2	0.536	0.645	0.628	0.457	0.600	0.602

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Table 4, by controlling number of bids, the period dummies are always robust, except that the values of both dummies have slightly decreased.

Discussion

The outcomes of my study show significant relationship between price change and the coordination of price in calls for tender over the course of my sample years. Raw prices are observed to have increased significantly since the start of alleged conspiracy and fell back once the police investigation was launched. The outcomes of test imply cartel members to have made collusive agreements to influence bidding prices and to increase profits. Entry deterrence cannot be tested due to two main reasons. First, names of potential cartel members joining the cartel lately are unknown, nor are their years of participation. Second, the large numbers of bidding firms in the construction market reduces the possibility of any effective entry deterrence. However, the large number of bidders in the market did not guarantee a competitive market condition as shown by study outcomes.

Studying the coordination activities in public market allows the authority to have better knowledge of mechanism of cartel, to assess impact on cost at municipal tenders, and thus to produce effective solutions to solve collusion. Cartel bidders influence calls for tender by coordinating price among them, so to reduce competition within the market. The study points out that cartel firms usually have a considerable high market share and their total market share increases, especially for high value calls for tender, following the creation of the cartel. Despite of the presence of many non-cartel bidders in the market, the high market concentration has reduced the necessary competition in the market. This implies that policymakers need to allocate more resources to permit small and medium firms to have equivalent chance in participation and keep an eye on calls for tender with higher values. In conclusion, more efforts are recommended to put to provide qualified medium and small appropriate opportunities to bid for tenders, while to enhance supervision to reduce large bidders' ability to manipulate bid price by coordination and corruption.

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Appendix A

Categorization of asphalts under Formulation LC (Standard 4202) and Formulation Marshall (Standard 4201):

Formulation Marshall (Standard 4201) [17]

Hot Mix Asphalt (*Enrobés bitumineux*): EB-20, EB-14, EB-10S, EB-10C, EB-5

Formulation LC (Standard 4202)

Gritted asphalt (*Enrobés grenus (EG)*):	EG-10, EGA-10, GB-20
Semi-gritted asphalt (*Enrobés semi-grenus (ESG)*) :	ESG-10, ESG-14, ESG-5
Correction asphalt (*Enrobé de correction)*:	EC-10
Stone matrix asphalt (*Enrobés à matrice de pierre*):	SMA-10
Asphalt for palliative (*Enrobé pour palliatif*):	EGM-10

[17] The English terms are translated based on their French name; their original French name is in the brackets.

Appendix B

Robustness

Different explanatory variables: to verify the possibility if project price is associated with the square of potential capacity or value of auctions, I include each variable in X_a (see Table B2 and B3). By adding square of capacity which controls any non-linear relation between capacity or value and bid price, in column (6) the significance of *Cartel* and *Marteau* dummies declined but still robust. Controlling the square of value does not undermine the robustness of the estimation.

I modify control variables to test the robustness under different possible conditions. In Table B1, I stop controlling type and year fixed effects and the results remain robust. In Table B4, eliminating *Con* and *HHI* variables does not affect the significance of outcomes.

Using contemporary crude oil price: In the study Clark et al. (2018), they used lagged crude oil price because they believe contemporaneous asphalt price should more likely reflect oil price of previous year. So, I replace contemporaneous crude oil by lagged crude oil price by which means the outcomes remain robust. The rationale behind using a lagged oil price variable lies in the assumption that firms base their price decision on crude oil price quoted in the previous year. However, according to the final investigation rapport (2015), cartel members set price after the OPEC meeting early (around February) in the year. So, contemporary crude oil price is more appropriate for the construction market. The result is shown in Table B5.

When including both contemporary and lagged oil price variable in the model in Table B6, the results become less significant in general but stay significant. Moreover, in column (5) and (6), both *Oil* and *Lagged Oil* variables are insignificant because each of the two variables shares the explanatory power of the other one.

Different time window: In Table B7 and B8, I also tested the robustness of results by assuming a different start or end year of the cartel. I found the results are more sensitive in response to start year change than to that of end year. In Table B7, assuming the start year of cartel to be one year later slightly change test results. We can see the absolute values of variable *Non-Cartel* and *Marteau* decrease because the average bid price in 2000 rose 144.72%. So, setting 2001 as the first year of cartel ignores the price surge in 2000. In Table B8, the variable *Non-Cartel* is no longer significant in column since I extend the last year of cartel to 2010 because the decline in

raw price in 2010 causes the average price level for the cartel period to decrease considerably, so its difference from pre-cartel price level becomes insignificant. This means the we can say with confidence the coordination of price stopped in 2009, the same year the *Marteau* investigation was launched.

Table B1. Not controlling fixed effect of asphalt type

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-60.60***	-55.29***	-55.05***	-59.60***	-53.11***	-51.77***
	(1.224)	(2.079)	(2.397)	(2.201)	(4.322)	(4.878)
Marteau	-22.91***	-31.58***	-36.19***	-18.61***	-28.08***	-31.59***
	(1.051)	(1.222)	(1.246)	(2.172)	(2.607)	(2.690)
Oil		0.177***	0.311***		0.227***	0.366***
		(0.0200)	(0.0208)		(0.0429)	(0.0443)
Average Labor Cost		-0.00968***	-0.0104***		-0.00895***	-0.00745***
		(0.000622)	(0.000621)		(0.00129)	(0.00129)
Median Labor Cost		0.00928***	0.00915***		0.00770***	0.00742***
		(0.000636)	(0.000649)		(0.00124)	(0.00131)
Capacity			-0.00454***			-0.00312***
			(0.000161)			(0.000324)
Value			-0.0000158***			-0.0000259**
			(0.00000414)			(0.00000837)
CON			-71.02***			-3.020
			(16.63)			(29.06)
HHI			-27.12			3.378
			(24.45)			(40.41)
_cons	137.5***	239.4***	280.7***	131.2***	248.3***	200.6***
	(0.372)	(20.27)	(20.31)	(0.800)	(42.31)	(43.12)
N	16575	16575	14973	3370	3370	2982
R^2	0.141	0.172	0.203	0.184	0.224	0.200

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B2. Controlling for square of the capacity

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-65.23***	-63.72***	-59.01***	-56.87***	-51.08***	-46.98***
	(6.914)	(10.89)	(12.34)	(7.901)	(12.93)	(12.57)
Marteau	-16.70**	-28.20***	-34.84***	-17.39**	-28.84***	-34.65***
	(5.560)	(5.579)	(5.949)	(6.417)	(6.775)	(6.720)
Capacity	0.0217	0.0274*	0.0416***	0.00546	0.0124	0
	(0.0123)	(0.0104)	(0.0117)	(0.0117)	(0.0104)	(.)
Capacity2	-2.833*	-3.729***	-4.896***	-0.586	-1.340	-3.563**
	(1.240)	(1.058)	(1.279)	(1.183)	(1.052)	(1.043)
Oil		0.339**	0.379***		0.350**	0.450***
		(0.107)	(0.108)		(0.128)	(0.110)
Average Labor Cost		-0.00874**	-0.00856**		-0.00847*	-0.00798*
		(0.00314)	(0.00298)		(0.00381)	(0.00325)
Median Labor Cost		0.00494	0.00385		0.00537	0.00372
		(0.00291)	(0.00290)		(0.00354)	(0.00314)
Value			-0.0000763			-0.000128
			(0.0000641)			(0.0000680)
CON			-2.480			-124.9
			(135.2)			(93.65)
HHI			54.18**			36.78
			(17.46)			(27.50)
_cons	209.6***	418.7***	462.9***	141.5***	317.5*	387.6**
	(27.27)	(115.4)	(114.3)	(26.58)	(132.7)	(118.6)
N	85	85	76	84	84	73
R^2	0.576	0.721	0.701	0.458	0.606	0.670

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B3. Controlling for square of the value

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-64.09***	-60.23***	-63.37***	-57.53***	-55.92***	-55.55***
	(7.776)	(11.60)	(14.05)	(8.588)	(13.68)	(14.49)
Marteau	-18.57**	-35.45***	-37.11***	-17.97**	-33.70***	-38.01***
	(5.882)	(6.184)	(6.654)	(6.765)	(7.319)	(7.296)
Value	-0.000194	-0.000208	-0.000237	0.0000263	0.0000231	0.00000334
	(0.000194)	(0.000162)	(0.000174)	(0.000196)	(0.000174)	(0.000179)
Value2	0.0608	0.0139	0.0419	-0.0161	-0.0553	-0.0767
	(0.110)	(0.0921)	(0.0967)	(0.109)	(0.0977)	(0.101)
Oil		0.435***	0.462***		0.384**	0.451***
		(0.115)	(0.118)		(0.130)	(0.121)
Average Labor Cost		-0.00688*	-0.00666*		-0.00766*	-0.00640
		(0.00321)	(0.00328)		(0.00372)	(0.00352)
Median Labor Cost		0.00417	0.00395		0.00425	0.00250
		(0.00302)	(0.00326)		(0.00357)	(0.00350)
Capacity			-0.00117			0.00279
			(0.00384)			(0.00348)
CON			190.5			-19.33
			(140.1)			(98.48)
HHI			35.11			36.19
			(18.68)			(30.66)
_cons	136.2***	273.2*	263.5*	130.3***	296.4*	289.3*
	(10.91)	(111.1)	(116.8)	(11.04)	(130.6)	(127.2)
N	85	85	76	84	84	73
R^2	0.547	0.699	0.626	0.456	0.607	0.605

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B4. Omitting Con and HHI

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-61.54***	-55.67***	-60.43***	-57.12***	-51.11***	-54.82***
	(6.960)	(12.27)	(11.20)	(7.525)	(12.90)	(13.16)
Marteau	-17.14**	-27.34***	-34.81***	-17.87**	-29.89***	-34.61***
	(5.796)	(6.368)	(6.291)	(6.267)	(6.685)	(7.460)
Oil		0.298*	0.434***		0.352**	0.384**
		(0.121)	(0.114)		(0.127)	(0.129)
Average Labor Cost		-0.00652	-0.00690*		-0.00764*	-0.00799*
		(0.00354)	(0.00321)		(0.00372)	(0.00375)
Median Labor Cost		0.00438	0.00434		0.00476	0.00447
		(0.00331)	(0.00303)		(0.00350)	(0.00351)
Capacity			-0.00185			0.00255
			(0.00357)			(0.00345)
Value			-0.000162*			-0.000101
			(0.0000625)			(0.0000709)
_cons	136.2***	249.9*	273.5*	128.8***	273.0*	293.4*
	(2.471)	(120.6)	(109.7)	(2.693)	(126.8)	(128.3)
N	85	85	85	84	84	84
R^2	0.524	0.625	0.700	0.456	0.596	0.608

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B5. Controlling for the lagged price of crude oil

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-61.54***	-51.26***	-60.37***	-57.12***	-52.19***	-48.93***
	(6.960)	(12.25)	(13.43)	(7.525)	(13.19)	(13.88)
Marteau	-17.14**	-27.40***	-33.01***	-17.87**	-27.92***	-31.81***
	(5.796)	(5.852)	(5.653)	(6.267)	(6.295)	(6.464)
Lagged Oil		0.366**	0.461***		0.342**	0.419***
		(0.113)	(0.103)		(0.122)	(0.111)
Average Labor Cost		-0.00518	-0.00591		-0.00741	-0.00592
		(0.00350)	(0.00319)		(0.00377)	(0.00354)
Median Labor Cost		0.00455	0.00375		0.00503	0.00268
		(0.00341)	(0.00313)		(0.00370)	(0.00340)
Capacity			-0.00295			0.000953
			(0.00370)			(0.00345)
Value			-0.000120			-0.0000651
			(0.0000620)			(0.0000720)
CON			159.1			-51.61
			(133.8)			(96.55)
HHI			32.56			36.89
			(18.01)			(29.92)
_cons	136.2***	190.1	248.0*	128.8***	258.6	263.2*
	(2.471)	(121.8)	(111.0)	(2.693)	(131.3)	(123.0)
N	85	81	76	84	80	73
R^2	0.524	0.568	0.646	0.456	0.531	0.604

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B6. Controlling for the contemporaneous and lagged price of crude oil

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-61.54***	-49.48***	-57.81***	-57.12***	-47.49***	-45.48**
	(6.960)	(12.85)	(13.37)	(7.525)	(13.71)	(13.83)
Marteau	-17.14**	-28.57***	-37.59***	-17.87**	-31.01***	-37.12***
	(5.796)	(6.356)	(6.300)	(6.267)	(6.775)	(7.131)
Oil		0.0789	0.232		0.208	0.260
		(0.161)	(0.148)		(0.172)	(0.157)
Lagged Oil		0.317*	0.326*		0.212	0.260
		(0.152)	(0.134)		(0.162)	(0.146)
Average Labor Cost		-0.00483	-0.00492		-0.00648	-0.00490
		(0.00360)	(0.00321)		(0.00384)	(0.00355)
Median Labor Cost		0.00456	0.00371		0.00507	0.00283
		(0.00343)	(0.00309)		(0.00369)	(0.00335)
Capacity			-0.00218			0.00174
			(0.00368)			(0.00344)
Value			-0.000149*			-0.0000987
			(0.0000639)			(0.0000737)
CON			190.3			-35.73
			(133.7)			(95.61)
HHI			33.84			36.60
			(17.81)			(29.48)
_cons	136.2***	173.7	202.9	128.8***	215.2	211.6
	(2.471)	(127.0)	(113.4)	(2.693)	(135.7)	(125.1)
N	85	81	76	84	80	73
R^2	0.524	0.570	0.660	0.456	0.541	0.623

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B7. DID with cartel period from 2001 to 2009

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-56.92***	-43.00***	-45.93***	-53.25***	-38.32***	-38.42***
	(5.663)	(8.522)	(7.422)	(6.189)	(9.086)	(8.111)
Marteau	-19.42***	-29.42***	-35.60***	-20.05**	-31.98***	-36.25***
	(5.432)	(6.063)	(6.030)	(5.937)	(6.453)	(6.907)
Oil		0.330**	0.385***		0.390**	0.404***
		(0.110)	(0.110)		(0.117)	(0.114)
Average Labor Cost		-0.00165	-0.00317		-0.00310	-0.00208
		(0.00308)	(0.00281)		(0.00329)	(0.00298)
Median Labor Cost		0.00281	0.000741		0.00346	-0.000307
		(0.00330)	(0.00304)		(0.00354)	(0.00338)
Capacity			-0.00445			-0.000860
			(0.00347)			(0.00321)
Value			-0.000146*			-0.0000852
			(0.0000600)			(0.0000683)
CON			-77.54			-148.6
			(111.9)			(87.28)
HHI			32.55			39.56
			(17.00)			(28.42)
_cons	138.8***	102.9	241.4*	131.3***	130.1	207.8*
	(2.387)	(90.65)	(97.33)	(2.630)	(96.59)	(103.5)
N	85	85	76	84	84	73
R^2	0.586	0.644	0.685	0.517	0.606	0.641

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B8. DID with cartel period from 2000 to 2010

	All bids	All bids	All bids	Winning bids	Winning bids	Winning bids
	(1)	(2)	(3)	(4)	(5)	(6)
Non-Cartel	-60.88***	-35.40*	-38.61*	-56.02***	-39.14*	-29.58
	(6.943)	(15.16)	(16.45)	(7.652)	(16.80)	(17.76)
Marteau	-19.62**	-35.88***	-43.84***	-16.37*	-29.03**	-34.20**
	(6.703)	(9.303)	(10.03)	(7.388)	(10.29)	(11.36)
Oil		0.423**	0.569***		0.370*	0.471**
		(0.148)	(0.155)		(0.164)	(0.167)
Average Labor Cost		-0.000825	0.000287		-0.00399	-0.00108
		(0.00423)	(0.00427)		(0.00467)	(0.00478)
Median Labor Cost		0.00486	0.00517		0.00514	0.00379
		(0.00338)	(0.00350)		(0.00377)	(0.00389)
Capacity			-0.00299			-0.000345
			(0.00408)			(0.00382)
Value			-0.0000930			-0.00000754
			(0.0000678)			(0.0000769)
CON			171.5			-68.71
			(151.1)			(109.2)
HHI			35.78			32.42
			(20.32)			(33.92)
_cons	135.4***	1.521	-52.02	127.4***	113.9	31.56
	(2.369)	(156.5)	(166.9)	(2.630)	(173.4)	(189.8)
N	85	85	76	84	84	73
R^2	0.523	0.610	0.560	0.434	0.534	0.493

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$