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Collusion with Asymmetric Retailers: Evidence from a Gasoline Price-Fixing Case†

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We point out a fundamental difficulty of successfully colluding in retail markets with heterogeneous firms, and characterize the mechanism recent gasoline cartels in Canada used to sustain collusion. Heterogeneity in cost and network size necessitates arrangements whereby participants split the market unequally to favor stronger players. We characterize empirically the strategy and transfer mechanism using court documents containing summaries and extracts of conversations between participants. The mechanism implements transfers based on adjustment delays during price changes. We estimate that these delays can translate into substantial transfers and provide examples in which they can substantially reduce deviation frequency. (*JEL* K21, L12, L71, L81)

Collusion is prevalent in many retail markets, with a large number of cases prosecuted each year by antitrust authorities.[1] In most of these markets, collusion should be difficult since they feature a large number of asymmetric firms and price-sensitive consumers. In this paper, we describe in detail the difficulties of successfully colluding in price-posting retail markets with heterogeneous firms, and characterize the strategies that recently discovered gasoline cartels used to resolve these difficulties and sustain a collusive agreement.

Even in markets like gasoline, where firms sell a homogeneous product, important asymmetries can exist. Networks of stations offering complementary goods and services compete with independently owned stores primarily selling gasoline. Stores also differ in storage capacities and vertical arrangements, which lead to heterogenous costs due to volume discounts and long-term contracts. When organizing a cartel, the presence of stronger players leads to enforcement and agreement problems: low-cost and/or single-station firms have greater incentive to deviate to

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[1] These cases are common in retail gasoline, banking, grocery, and other markets. For lists of recent cases in the United States, Canada, and Europe see: justice.gov, competitionbureau.gc.ca, and ec.uuropa.eu, respectively.

gain extra market share, and disagree with high-cost or multi-station firms as to what the equilibrium price under collusion should be. These conflicts open the door to explicit collusion mechanisms whereby cartel members agree to split the market in favor of certain players.

While the theory literature has long recognized the need for transfers to sustain collusion with heterogeneous firms (Jacquemin and Slade 1989), it has largely ignored the difficulty of implementing market-share transfers in price-setting (Bertrand) environments. Unlike upstream cartels that can restrict supply through production quotas or exclusive territories, cartels in price-posting retail markets do not directly control where consumers shop. As a result, when coordinating on a common price, market shares reflect the quality of each location, and not necessarily a firm's relative gains from collusion.

Our main contribution is to describe how actual gasoline cartels were able to overcome the enforcement and agreement problems by implementing intertemporal transfers based on a particular order of play through which "stronger" players were able to extract additional market share while colluding on a common price. To our knowledge, we are the first to document this type of mechanism empirically. In theoretical work, Athey and Bagwell (2001) construct an equilibrium in which intertemporal transfers are used in a different context, namely to solve an information friction.

The mechanism that we uncover implements transfers based on adjustment delays during price changes. Specifically, the cartel leaders systematically allow the most cost-effective firms to move last during price-increase episodes, thereby giving them a larger share of the market. In addition to this delay period, one of these firms is allowed to initiate price cuts, while the rest of the players moved subsequently to match the new price. This particular order of play is not simply the result of an imperfect ability to monitor price movements, nor an inability to communicate price adjustments in a timely fashion. Rather, it is clear that adjustment delays and first-mover identities are predictable, and firms understand the role of each player in the agreement.

We document these arrangements empirically by studying a recent price-fixing case involving 128 gasoline stations and 64 firms in four cities of Quebec: Victoriaville, Thetford Mines, Sherbrooke, and Magog. Our main source of information corresponds to extracts of reported phone conversations between station owners, recorded by the Canadian Competition Bureau in 2005 and 2006.[2] We use this information to characterize the internal functioning of the cartel, and the transfer mechanism. Specifically, we describe the communication patterns between the players and the set of stations making/receiving transfers.

[2] **Legal disclaimer:** The Canadian Competition Bureau's investigation into, and prosecution of, the alleged price fixing in retail gasoline markets in Quebec is ongoing. The allegations of the Competition Bureau have not been proven in a court of justice. This paper analyzes the alleged Quebec retail-gasoline cartel case strictly from an economic point of view. We base our understanding of the facts mostly on documents prepared by the Competition Bureau. We were given a copy of the 52-page affidavit of Mr. Pierre-Yves Guay of the Competition Bureau dated May 16, 2006 in file no 500-26-039962-067 of the Superior Court of Quebec, district of Montreal. The online Appendix provides a description of their content.

In order to quantify the value of transfers and their importance for the stability of the cartel, we supplement the primary source of information from the Competition Bureau with two additional datasets surveying prices and station characteristics. We use two empirical demand models to estimate the implicit market-share transfers associated with the price adjustment delays. Using the Victoriaville cartel as an example, we then use a simple dynamic pricing game to compute the change in the frequency of deviations, and in the minimum punishment levels that would be observed if the cartel did not implement transfers. Our results show that these adjustment delays can translate into substantial transfers even if they occur mostly during price increases: we estimate that stronger stations increase their sales volume by 4 percent in Victoriaville and 6 percent in the other markets. Moreover, we provide examples in which this form of transfer can substantially reduce the frequency of deviations.

Our paper is related to an empirical literature on explicit collusion (see, for instance, Porter 1983; Porter and Zona 1993; Scott-Morton 1997; Pesendorfer 2000; Röller and Steen 2006; and Asker 2010), and in particular to Genesove and Mullin (2001), who study internal documents from the sugar-refining cartel and contrast their findings with predictions from the economic theory on collusion. Most of this literature examines legal cartels, wholesale markets, or bidding rings. We provide one of the first studies of the internal functioning of a retail cartel. To our knowledge the only other paper to examine the internal organization of a retail-market cartel is Wang (2008), who also studies gasoline retail markets using information from the trial records of a price-fixing case in Australia. This cartel shares several features with ours: deterministic order of moves, heavy communication during price increases, and asymmetric price adjustments. The focus of our paper differs, however. We provide an interpretation of the cartel behavior in which delays are part of a collusive agreement with transfers, whereas Wang focuses on the role of communication in facilitating price increases (by avoiding a lengthy war of attrition) within the framework of Maskin and Tirole (1988). See also Wang (2009) for further evidence on the existence of a war of attrition during price increases.

The rest of the paper is structured as follows. In Section I, we describe the Competition Bureau documents and the investigation that led to the discovery of the cartels. In Section II, we characterize the organization and pricing strategy used by the cartels. In Section III, we describe the transfer mechanism and the timing of moves. In Section IV, we quantify the value of transfers. Finally, we conclude the paper by discussing the role of explicit communication and coordination costs in determining the agreement. The online Appendix contains additional information on the Competition Bureau documents, provides a theoretical example (published online), and a table of results.

I. Competition Bureau Investigation

A. *Discovery of the Cartel*

The cartels were discovered following the publication on June 6, 2004 of an article in a Victoriaville newspaper containing an interview with gas station owner

Christian Goulet, who claimed to be the victim of harassment by other station owners for not going along with their attempts at price fixing. This led the Canadian Competition Bureau to begin an investigation into suspected collusive behavior in violation of Section 45 of the Competition Act. On March 3, 2005 the bureau began recording private conversations of suspected cartel participants. Agents were also put in place in order to confirm the information gleaned from the recordings.

On May 29, 2006, the Competition Bureau began the execution of its search warrants. A first round of charges were publicly announced on June 12, 2008, with subsequent rounds in 2010 and 2012. In total fourteen companies and thirty-nine individuals were charged.[3]

The four cities targeted by the bureau's investigation are located in the south of the province. Thetford Mines and Victoriaville are sufficiently far apart (70 kms) to be considered different markets, while Magog and Sherbrooke are closer and share common market boundaries. The Sherbrooke metropolitan area (including Magog) has nearly 200,000 people, while the other two markets have populations of 25,000 and 40,000 respectively.[4]

B. *Competition Bureau Documents*

Our understanding of the functioning of the alleged cartels is primarily based on the documents submitted by the Competition Bureau to the court. The wiretaps took place from March to June 2005 in Victoriaville and Thetford Mines, and from March to June 2005 and December 2005 to April 2006 in Sherbrooke/Magog. The Competition Bureau documents provide a complete picture of almost all price increases and decreases that occurred in Victoriaville and Thetford Mines during this period, but are less complete for Sherbrooke and Magog in terms of the number of price decreases documented and the number of players whose conversations are described.[5]

The documents list the phone calls for each price adjustment. An extract or a summary of the conversation is given, along with information about who made the call, who received it, and the time of the call. For each price change, we coded the content of each reported conversation in order to measure the number and direction of phone calls, the duration of the price change, and the timing of moves for each player.

It is important to note that the Competition Bureau documents only contain summaries of, and extracts from, the phone conversations and not the conversations themselves. Therefore, our analysis is subject to the caveat that the sections

[3] The allegations of the Competition Bureau have not been proven in a court of justice. As of September 2012, seven companies (including some of the larger players in the target markets) and 27 individuals had pleaded guilty to the charges with fines ranging from $90,000 to $1,850,000 for the companies, and from $3,000 to $50,000 for the individuals. All figures are in Canadian dollars unless otherwise noted. The Competition Bureau of Canada provides the details of the charges in this file (03079) on its website: competitionbureau.gc.ca. Other cases are still before the courts, and charges have been stayed against some companies, including Couche-Tard (see file 2012 QCCS 4721 at canlii.ca).

[4] In part owing to a lack of data on Magog's stations, we will sometimes refer to the Sherbrooke market as including Magog.

[5] The online Appendix provides more information on the nature of the Competition Bureau documents.

Table 1—Distribution of Stations Suspected of Price-Fixing in the Three Markets

Key players	Characteristics	Sherbrooke/ Magog	Thetford Mines	Victoriaville	Total
Bilodeau—Shell	Organizer	0	4	4	8
Bourassa—Olco	Organizer	9	0	0	9
Canadian Tire	Hardware store	3	0	1	4
Christian Goulet	Informant	0	0	1	1
Couche-Tard	Convenience store	13	2	3	18
Maxi	Grocery store	0	0	1	1
Petro-T	Wholesaler	5	2	1	8
Ultramar	Vertically integrated	18	3	2	23
Other	Independent	32	12	12	56
Total		80	23	25	128

of conversations are selected by bureau agents. For the purpose of our analysis, we operate under the assumption that all conversations related to price changes are included in the appendices of the Competition Bureau documents.

II. Organization of the Cartel

In this section, we first describe the players and the hierarchy of the cartels. We then describe the key features of the pricing strategy, namely the frequency and magnitude of price changes, and the dispersion of prices within periods.

A. *Players*

We define two stations as being part of the same company if they share the authority to set prices. In general, upstream suppliers are responsible for setting retail prices at company-owned stores and at stores with commission contracts, while owners with other vertical arrangements are free to choose prices within their network of stations.[6] Table 1 presents the number of stations and company names, broken down by city, during the period covered by the investigation. It shows important differences among stations in vertical arrangements and network sizes.

From the Competition Bureau documents, we identified two firms as the central organizers of the cartels (i.e., cartel leaders): Bourassa (Olco) in Sherbrooke, and Bilodeau (Shell) in Victoriaville and Thetford Mines. These two firms operate the largest networks of lessee stations, and sell a mix of branded and unbranded gasoline. Both firms are also distributors of gasoline in their respective markets, and therefore have business relationships with stations outside their network.

Ultramar is the largest chain of branded retailers. It is a vertically integrated company that operates the only refinery in the Eastern part of the province. Unlike other vertically integrated companies, the head office keeps full control over retail prices

[6] In this market, we observe four types of vertical contractual arrangements: company-owned stores, lessee stations, lessee stations under commission, and fully independent. Lessee stations are independently owned stores with long-term contracts with branded suppliers (e.g., Shell, Esso, Ultramar, Petro-Canada, and Irving), or unbranded suppliers (i.e., Olco, Crevier, Sonic, Petro-T, etc.). The largest category is lessee contracts, and the smallest is independent stations.

through a mix of company-owned stores and lessee retailers under commission. This unique feature allows Ultramar to promote a low-price guarantee (LPG) marketing policy (i.e., *Programme Valeur Plus*). According to the company, Ultramar stations must post the lowest prices within a neighborhood of each location. To implement the program, it uses a team of regional representatives who are responsible for setting and changing prices, and has invested in a centralized pricing center that monitors prices in all local markets of the province. The company also provides a free phone-line for consumers and competitors to report price differences.

In Victoriaville and Sherbrooke/Magog there are also two high-volume big-box retailers: Canadian Tire (a large hardware store chain) and Maxi (a large supermarket chain). These firms operate five of the largest stations in terms of number of pumps, and their stations serve as loss leaders for their affiliated stores.

The second biggest presence in the target markets, Couche-Tard, operates the largest chain of convenience stores in the province. It typically signs long-term lessee contracts with multiple vertically-integrated refiners, and controls its stations' prices through a common regional representative. This feature allows Couche-Tard employees to communicate directly with the representatives of other brands, which facilitates communication.

The remaining players consist mostly of independently owned stations, including Goulet, the informant in Victoriaville. This group represents between 30 percent and 50 percent of all sites in the target markets, and these stations are affiliated with a mix of branded and unbranded suppliers.

In Table 2, we present descriptive statistics on station sizes and amenities at the time of the recordings. The variables are measured using data from a quarterly survey of the market conducted by Kent Marketing. The first thing to notice from this table is the heterogeneity in size. The average station in Sherbrooke and Victoriaville sells almost 50,000 liters of gasoline per week, with a standard deviation close to 25,000 in both cities. Thetford Mines is a smaller market, with slightly smaller and more homogeneous stations. Heterogeneity is also reflected in the distribution of the number of pumps and service islands, and station amenities. The size of a station determines both its capacity to serve consumers, and potentially its wholesale price as a result of volume discounts.

Importantly, these differences translate into heterogeneity in marginal cost. Using parameter estimates reported in Houde (2012), we estimate a station-level marginal cost function that is additive in the minimum estimated price (MEP) published weekly by the Québec energy board (Régie de l'énergie du Québec) and below which stations are not allowed to set prices. This price floor is slightly higher than the tax-included spot price of refined gasoline (i.e., the rack price), which can be thought of as an upper bound on firms' marginal cost (ignoring long-term contracts which often include volume discounts).[7] Specifically, we estimate station j's marginal cost in period t to be

$$\mathrm{mc}_{j,t} = \mathrm{MEP}_t + c_j, \tag{1}$$

[7] The objective of the floor is to prevent below-cost pricing, and protect the average-sized station in the market. Carranza, Clark, and Houde (2012) analyze the content of the regulation and its impact on the market.

Table 2—Summary Statistics on the Characteristics of Stations in the Three Markets during Second Quarter of 2005

	Sherbrooke		Thetford Mines		Victoriaville	
Variables	Mean	SD	Mean	SD	Mean	SD
Volume	48.67	24.56	29.9	15.2	44.37	26.37
Share	0.01	0.01	0.03	0.02	0.03	0.02
Number of pumps	11.05	7.07	6.58	3.18	9.04	4.88
Number of islands	2.45	1.13	2	1.04	2.13	0.97
Conv. store	1.55	1.28	1.17	1.34	2.09	1.08
Full service	0.4	0.49	0.5	0.52	0.7	0.47
Carwash	0.22	0.42	0.08	0.29	0.17	0.39
24 hours	0.33	0.48	0.08	0.29	0.22	0.42
Major brand	0.77	0.43	0.83	0.39	0.43	0.51
Cost differentials	−0.82	0.52	−0.65	0.65	−0.51	0.45

Notes: Volume is measured in thousands of liters per week. *Conv. store* is an indicator variable equal to one if the station has a large convenience store. *Major brand* is an indicator variable equal to one if the station sells branded gasoline (i.e., Esso, Petro-Canada, Shell, Irving, or Ultramar).

where c_j is a time-invariant cost differential that depends on the characteristics of stations. The cost differentials range from -0.05 to -1.98 cents per liter (cpl) for Sherbrooke, -0.05 to -1.84 cpl for Thetford Mines, and -0.02 to -2.03 cpl for Victoriaville. We estimate that, everything else held constant, the Ultramar stations, which are the only vertically integrated stores in the market, are on average 1.6 cpl below the MEP.

B. *Patterns of Price Adjustment*

Although the Competition Bureau documents provide detailed information on prices during the wiretap period, the number of observations is too small to measure accurately the pricing patterns in the four markets. Since the pricing patterns in the three years before the wiretap are very similar to those of the wiretap period, we extend our analysis of pricing to cover the years between 2002 an 2005.[8] To study these patterns we rely on a station-level survey conducted by the province's energy board, which includes one station surveyed in Thetford Mines, two in Victoriaville, and three in Sherbooke/Magog, each observed for at least 100 consecutive weeks.

Figure 1 shows that, rather than colluding on a constant margin, the cartels coordinate on an asymmetric pricing cycle. Figure 1, panel A shows that the distribution of price increases is symmetric around 4 cpl (with an interquartile range of 2 cpl), while the density of price cuts is quickly increasing towards zero and clustered around 1 or 2 cpl (i.e., 70 percent are less than or equal to 2 cpl in absolute value). The distribution of cost changes, shown in panel B of Figure 1, is more symmetric, confirming that prices adjust faster upwards than downwards. Indeed, the ratio of price increases over decreases, adjusted for the ratio of cost changes, shows that price increases are more than twice the size of price decreases.

[8] A comparative table is available upon request.

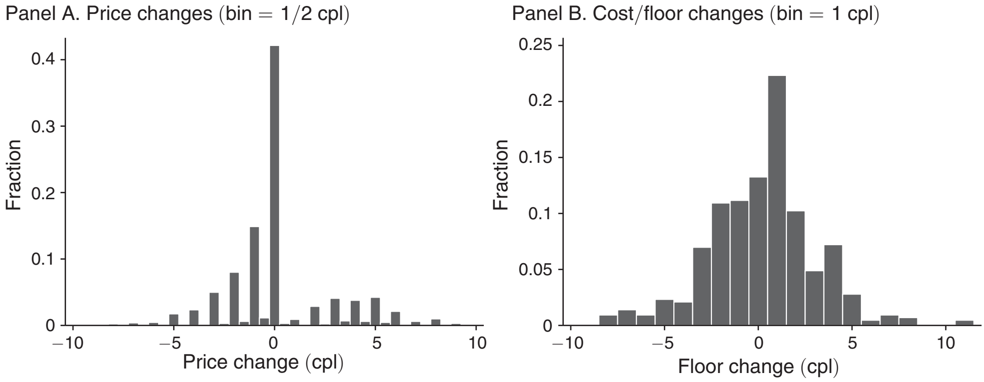

Figure 1. Distribution of Weekly Price and Cost Changes in the Collusive Cities from 2002 to 2005

It follows from this asymmetry, that prices exhibit frequent periods of stickiness. The majority of price changes are zero over the period. In Victoriaville and Thetford Mines, prices are constant two weeks in a row 48 percent and 57 percent of the time, respectively. Sherbrooke tends to exhibit more volatility; the proportion of stable weeks is 36 percent. In comparison, the price floor remains constant only 1.2 percent of the time.

Finally, another feature of the pricing strategy is the coarseness of the price grid. Figure 1, panel A shows that the vast majority of price changes are done in one cent increments. Between 2002 and 2005, 95 percent of price changes in Victoriaville and Thetford Mines held fixed the ending digit, and this fraction was slightly smaller for Sherbrooke.[9]

C. *Distribution of Prices*

From the Competition Bureau documents, we observe that the distribution of prices is remarkably stable over time, and concentrated around one or a small number of prices. In Victoriaville, the cartel organizers allow two stations located in the fringe of the city to post prices that are at most 2 cpl below the suggested price. Violations of this rule are subject to retaliation. The Thetford Mines cartel is also very explicit: self-service stations are allowed to post a price 1/2 cpl below full-service stations. In contrast, in Sherbrooke the majority of stations coordinate on the same minimum price, while the remaining post a price that is 1 or 2 cpl above the suggested price.

To measure the distribution of prices between 2002 and 2005, we use the quarterly survey of gasoline stations conducted by Kent Marketing.[10] Figure 2 shows the distribution of price differences from the minimum price in each market/day.

[9] The use of focal digit is also common in other gasoline markets. Lewis (2011), for instance, shows that stations systematically posting "odd-digits" in US markets also tend to post higher prices, and exhibit more price stickiness.

[10] Sites are visited on the same day at the end of each quarter, which allows us to characterize the full cross-sectional distribution of prices. The city of Magog was not surveyed by Kent Marketing until the end of 2005, and is excluded from our pricing analysis. Kent Marketing surveys all stations located in the main local neighborhoods of each city: 70 in Sherbrooke, 29 in Victoriaville, and 14 in Thetford Mines.

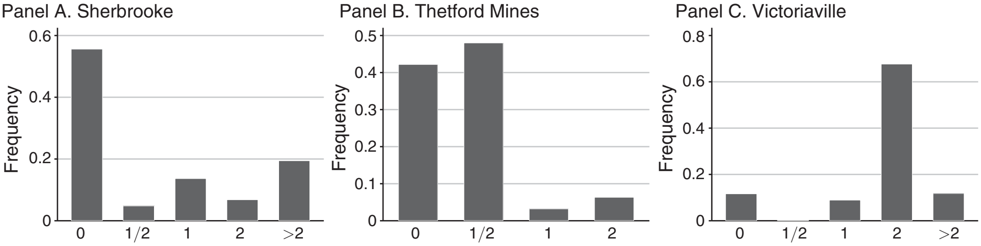

Figure 2. Distribution of Differences (*in cpl*) from the Minimum Price in Each Market (*2002 to 2005*)

The histograms clearly show that the distribution of prices before 2005 is consistent with what we observe in the Competition Bureau documents. In Victoriaville and Sherbrooke the distribution is highly concentrated around one price (Victoriaville's suggested price is 2 cpl above the minimum), while Thetford Mines' stations are almost evenly split between the self and full service prices (i.e., 0 or 1/2 cpl).

III. Transfer Mechanism: Coordinated Order of Play

Gasoline markets can, for the most part, be characterized as oligopolies with price-setting firms, selling homogeneous products, with no capacity or information constraints. These features should make collusion easier to sustain.

However, as we discussed in Section II, the market is characterized by important differences in marginal costs and amenities, and in ownership structure, which lead to heterogeneous network sizes. These differences can limit the ability of firms to sustain and implement a tacit collusive agreement. A firm's cost level or market share can affect its gain from deviation and, therefore, its incentives to participate in the collusive agreement.

This can be seen from the following dynamic model. Consider a market with inelastic demand and two homogeneous good retailers, H and L, with heterogeneous marginal cost levels $c_H = c \geq c_L = 0$. Firms repeatedly play a simultaneous Bertrand game with complete information. Collusive market shares for the two firms are s_H and s_L, representing, for instance, unequal networks.[11] Since products are homogeneous, the profit of firm H in the punishment phase will be zero, and firm L will serve the whole market at a price c. This setup yields the following incentive constraints when punishments are infinite:

$$\mathrm{IC}^H : \frac{s_H(\overline{p} - c)}{(1-\delta)} \geq p_H^d - c,$$

$$\mathrm{IC}^L : \frac{s_L \overline{p}}{(1-\delta)} \geq p_L^d + \delta \frac{c}{1-\delta},$$

[11] According to this interpretation, if there are no other sources of asymmetry, then $s_j = n_j/(n_H + n_L)$, where n_j is the number of retail outlets controlled by firm $j = \{H, L\}$.

where $\overline{p}$ is the agreed-upon cartel price, p_j^d is the deviation price for firm $j = \{H, L\}$, and δ is the discount factor.

It is clear from these constraints that, for symmetric collusive market shares, the low-cost retailer has greater incentive to deviate than its high-cost counterpart, which increases the minimum discount factor that can sustain collusion. Similarly, holding fixed marginal cost, varying market share can loosen or tighten these constraints. Specifically, the smaller a firm's market share, the greater its incentive to deviate from the agreement in order to increase its share of volume.

In our case, the main cartel organizers operate large networks of stations in their respective markets, and therefore benefit the most from collusion.[12] At the other extreme, the two big-box retailers operate large-scale independent stations and benefit from loss-leader incentives. They have the greatest incentive to deviate (since they are both small network and low cost). Ultramar is the other important low-cost player. It operates large networks of stations in each market, but faces a lower marginal cost than other competitors owing to its vertically integrated structure. Most of the other players operate small networks and face relatively high costs, and tend simply to follow the decisions of the leaders. However, there is also a group that consists of independent firms who operate relatively large capacity stations (and so are relatively low cost), and have high incentive to deviate. In what follows, we label these stations "dissidents."

When asymmetries are large, collusion can fail without transfers. This leads to an *enforcement problem*. A related issue is the difficulty in agreeing on a price level when firms receive heterogeneous marginal gains from deviation. This leads to a *coordination problem* that is present even when collusion is sustainable. Once again, transfers can allow firms with little bargaining power (for instance, the high-cost firm) to coordinate a higher price equilibrium by implementing transfers towards firms with more bargaining power (for instance, the low-cost firm).

The theory literature on collusion with asymmetric firms often assumes that enforcement and coordination problems are resolved through implicit or explicit side payments (see Jacquemin and Slade 1989). In some cases, this can take the form of explicit negotiation over the allocation of market shares. For instance, Harrington (1991) shows that an allocation that gives a higher share to the low-cost firm can relax its participation constraint, and allow firms to collude on a higher price. The empirical literature provides many examples of similar mechanisms used in actual cartels.[13]

Transfer schemes based on uneven within-period market splitting are not implementable in our context, since firms do not directly control where consumers shop. This is a fundamental barrier to collusion in price-posting markets. When colluding on a common price, market shares are a function of locations and store amenities, and do not necessarily reflect the incentive constraints of the firms.

[12] From Table 1, Bilodeau (Shell) and Bourassa (Olco) are the two main cartel leaders. Couche-Tard also initiates and receives a large number of calls in every market.

[13] In the Lysine cartel firms were assigned output levels, and a sales quota scheme was implemented in the citric acid cartel (see Harrington and Skrzypacz 2011; Connor 2001; and Levenstein and Suslow 2006 for studies of these cartels). Similarly, Asker (2010) documents the role of knockout auctions introduced in the theory literature by Graham and Marshall (1987) to determine participation in auctions and allocate side payments among cartel members. Marshall and Marx (2008) review 20 cartel decisions of the European Commission and find that almost all of them feature either customer, geographic, and/or market-share allocation.

Since firms cannot allocate market shares through quotas or exclusive territories, and if we assume away the possibility of explicit side payments, a collusive arrangement in a homogeneous good market must involve recurrent periods of temporary price differences during which firms with more incentive to deviate are allowed to price below the collusive price. In theory, there are many ways a cartel can implement such intertemporal transfers. In the online Appendix we analyze a theoretical example in which one firm is allowed to price below the market price for T periods. Within the same framework, we also discuss the role of the price floor and competition in constraining the collusive arrangement.

In retail gasoline markets, conditions fluctuate tremendously as a result of the volatility of wholesale prices. Observable cost measures, like the posted rack price, provide an obvious focal point for identifying the timing of transfers. Importantly, this leads the cartel to coordinate the timing and magnitude of *price changes*, rather than on the level of prices or markups. In the next two subsections, we describe the particular order of play on which firms coordinate in order to implement price increases and decreases, and the communication patterns involved.

A. *Price Increase Delays*

The communication process on price increases is analogous to a negotiation, and typically involves two steps. According the Competition Bureau documents, the leader first communicates with Couche-Tard and a group of active cartel members (i.e., followers). Together they determine a new target price for the market (or two prices in the case of Thetford Mines), and a time t_0 at which the leader and most followers first raise their prices. Once an agreement is reached, the leader communicates with Ultramar and the big-box retailers to propose a time t_1 ($\geq t_0$) at which they are supposed to increase their price. Sometimes these firms will renegotiate the price down. The leader also directly or indirectly announces the upcoming price increase to a group of dissident stations. These are independently owned stations, and either have large capacities or are located outside the cities' centers.[14]

Table 3 describes this communication process in Victoriaville.[15] We present the distribution of contacts initiated over the course of a typical price increase, classified by type of station receiving the phone call(s). The second and third columns report the average number of contacts initiated or received by each player type. On average, price increases involve 65 phone calls, a large number of which are between the leader and Couche-Tard. As a group, followers initiate and receive the largest number of contacts, but since the group includes many stations, each receives or sends on average about one phone call per episode. Note also that dissidents and the low-cost group tend to receive significantly more phone calls than they send.

In terms of timing, Ultramar and the big-box retailers are usually contacted after the first price change. The pattern differs for the Couche-Tard price-setting agent

[14] For instance, in Victoriaville the informant (Goulet), a low-cost station operator owing to the type of contract he has with his supplier, only randomly goes along with the cartel. In Victoriaville there is also a single firm that does not explicitly participate in the cartel, and is allowed to price 2 cpl below the cartel price.

[15] Similar summary statistics are available for Thetford Mines, but have been omitted to save on space. The Sherbrooke and Magog recorded phone conversations are not sufficiently detailed to produce similar tables.

Table 3—Distribution of Communications during Price Increases in Victoriaville

Player types	Number of contacts rcv./send	Share of contacts received in time grid (min.)						
		≤ -120	-60	0	60	120	180	≥ 240
Follower	20/25	0.09	0.10	0.51	0.01	0.07	0.04	0.17
Leader	19/28	0.03	0.16	0.19	0.16	0.14	0.03	0.29
Couche-Tard	9/7	0.25	0.19	0.38	0.00	0.06	0.00	0.13
Dissident	6/2	0.00	0.27	0.09	0.36	0.00	0.09	0.18
Ultramar/big-box	11/3	0.00	0.08	0.04	0.29	0.25	0.08	0.25

Notes: A contact is defined as a sequence of phone calls between two individuals. The contact time corresponds to the time of the first phone calls, and is expressed relative to the time of the first recorded price change. Each entry is calculated by averaging over all successful price increases in Victoriaville.

who is contacted early in the negotiation process. Notice that communication is often initiated more than three hours before the first price change, since firms share information about prices in neighboring cities.

The delay accorded to stronger stations before they must raise their prices is explicitly discussed in the Competition Bureau documents, and stations raising their prices early expect Ultramar and the big-box retailers to raise their prices at or around t_1. For instance, the cartel leader Bilodeau says: "I know that, I'm not worried, it's always the same thing," when responding to the owner of the EMCO station who was informing him that he would increase only when the neighboring Ultramar station raised its price.[16]

Although the length of delays and the identity of late movers differ slightly across markets, the order of play during price increase episodes is a common feature. The following quotation from an Ultramar employee working at the national pricing center office suggests that the order of play is common across all markets in the province: "We built the system seven years ago, the competitors know that the program belongs to us and we want to be sure that we are the last one to move [up]."[17] The program most likely refers to Ultramar's LPG established in the summer of 1996, which commits each of its stations to sell at the lowest price in its neighborhood. This commitment also implies that, when coordinating the timing of moves, Ultramar's stations will systematically try to increase their prices last.

Using the reported conversations for Thetford Mines and Victoriaville, we can accurately measure the length of price adjustment delays accorded to each station. We measure delays as the difference between the time at which a station is reported to have increased its price, and the earliest time at which a station in the market increased its price.

Figure 3, panels A and B illustrate the distribution of median delays observed across all successful price increases in Victoriaville and Thetford Mines. In both cities, the vast majority of stations adjust their prices early, and a group of stations

[16] April 6, 2005 in Thetford Mines. Translated from: "Ah je l'sais, ca, j'pas inquiet, c'est toujours de meme ca c'est."

[17] Conversation between an Ultramar manager and the regional representative responsible for the South-Eastern region of Quebec on April 8, 2005.

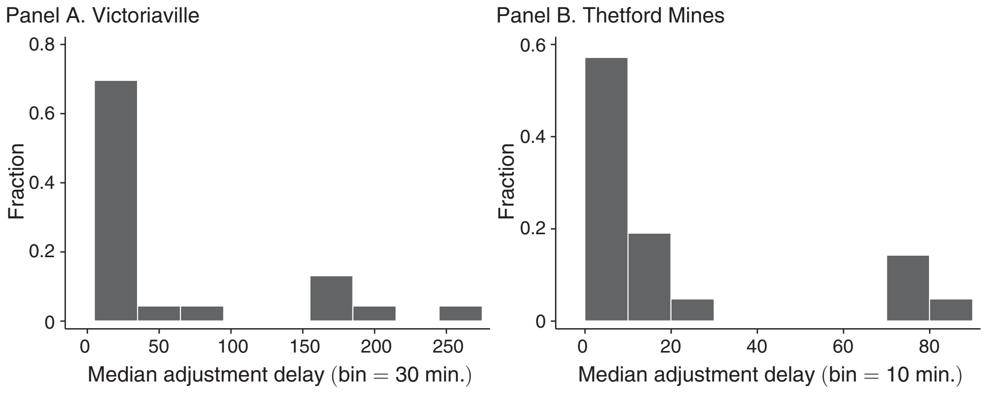

Figure 3. Distribution of Median Price Adjustment Delays During Successful Price Increase Episodes

delay their actions up to four hours in Victoriaville and 80 minutes in Thetford Mines. The larger delays in Victoriaville are consistent with the fact that, in addition to Ultramar stations, the market features the presence of two big-box retailers. As we noted above (and as we show in the model presented in the Appendix), the presence of multiple firms that are "receiving" transfers increases the length of delays necessary to reach an agreement. Finally, notice that in both cities, there exists a group of stations that systematically delay their actions, moving after t_0, but before the Ultramar and big-box stations.

Table 4 analyzes further the relationship between delays, store characteristics, and prices. Using the panel of adjustment times, we regress the observed delay for each station/date on dummies for store categories (i.e., Ultramar/big-box, dissidents, Couche-Tard), distance measures, and characteristics of suggested price increases. Notice that the dependent variable is truncated for the group of dissidents because we observe their actions only if they cooperated with other players.[18] In both regressions, the reference groups are the stations controlled by the leader (i.e., Shell stations). These stations, together with the group of Couche-Tard stations, are the first to move. On average, the remaining followers delay their actions by just 30 minutes in Victoriaville and 13 minutes in Thetford Mines. In contrast, the group of Ultramar and big-box stations increase their prices on average 145 and 66 minutes after the leader in the two cities. Notice that the dissidents in Victoriaville, who are observed to eventually raise their prices, do so at about the same time as the Ultramar and big-box stations.

The two distance measures explain part of the behavior of the group of followers in Thetford Mines, but not in Victoriaville.[19] In Thetford Mines, stations located close to Ultramar tend to delay their actions. Similarly, stations that are less spatially differentiated from their competitors tend to move late, although this relationship is statistically significant only in Thetford Mines.

[18] The actions of the two Thetford Mines dissidents are never observed.
[19] Distances are calculated using the Euclidian distance between the latitude/longitude coordinates of stations.

Table 4—Distribution of Communications during Price Decreases in Victoriaville

Variables	Victoriaville (1)	Thetford Mines (2)
Dissidents stations	157.6***	
	(37.88)	
Low-cost chains	149.4***	64.70***
	(21.33)	(9.206)
Followers stations	37.41**	13.71*
	(15.75)	(7.019)
Couche-Tard stations	23.68	−13.74***
	(23.50)	(4.879)
Distance to low-cost chains	8.676	−2.074***
	(10.18)	(0.773)
Distance to closest competitor	−14.51	−6.920***
	(15.09)	(2.439)
Proposed increase	−35.06***	−11.35*
	(4.794)	(6.135)
Current margin	−40.50***	−6.582**
	(2.977)	(2.563)
Last increase ≥ 20 days	76.21***	19.60
	(17.59)	(19.53)
Constant	215.3	161.1***
	(136.4)	(48.17)
Observations	122	83
R^2	0.657	0.535

Notes: Robust standard errors in parentheses. Dependent variable: price adjustment delay in minutes. Stations in the reference group are part of the leader's network.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

The coefficients on proposed price increases suggest a trade-off between price differences and delays. In both cities, large proposed increases are associated with shorter average delays. This is consistent with our interpretation of delays as transfers: large price increases are more costly for the group of early movers (and transfer larger sales to late movers), and thus lead to tighter expiration times. Similarly, the longer it has been since the previous price increase, the longer the delays, since transfers are being made less frequently.

Lastly, the coefficients associated with current margins suggest that delays are shorter when initial profit margins are high. This correlation is likely caused by observations from the early parts of the wiretap period that were associated with low margins and a high level of disagreement among stations. Between January and March 2005, the Victoriaville price stayed near the floor for several consecutive weeks, consistent with a price war related to the behavior of a dissident that led to the newspaper article and the subsequent investigators' visits.[20]

[20] The precision of the last two coefficients is misleading (i.e., standard errors are biased downwards), since we observe only a small number of price increases common to all stations.

We are unable to determine the actual delay period for each store in Sherbrooke and Magog since the Competition Bureau documents are much less detailed for these markets. Our reading suggests, however, that delays are even longer in Sherbrooke. It is not uncommon to observe delays of five or six hours for Ultramar's stations. In Magog, price increases were more complicated during the period covered by the Competition Bureau document. This is reflected in the timing chosen to initiate price increases. Price increases for Magog were arranged such that all stations, except Ultramar, adjusted overnight and then the next morning Ultramar surveyed prices and increased once it had verified that all of the stations had adjusted. According to a reported conversation, the timing had always been the same in Magog as in Sherbrooke, but the Ultramar stations were taking too long to increase their prices: their period of delay had extended until late in the afternoon following early morning price increases. The leader and the active followers tried to convince the laggers to increase their prices earlier, but, when this failed, they decided to facilitate coordination by having all of the stations except Ultramar increase at closing time.

B. *Price Decrease Delays*

Price decreases are much less coordinated than increases, and involve less communication. Participants explicitly delegate the leadership role of initiating price cuts to Ultramar (i.e., LPG chain). Moreover, price cuts are quickly matched, and do not involve any retaliation.

Nine of the ten documented price decreases in Victoriaville are initiated by Ultramar, while three of the four documented decreases in Thetford Mines are.[21] Although price cuts are not announced by the company, it is explicit that only Ultramar stations are allowed to cut prices without warning.[22] As a result, the chain becomes a price leader during price decrease periods. The role of the cartel leader during price decreases is limited to calling the group of followers to warn them of a recent price cut.

The communication patterns during price decrease periods are summarized in Table 5. Relative to increases, we observe fewer conversations: on average, 26 decreases relative to 65 increases. Most of the conversations are between Couche-Tard and the cartel leader, and the leader initiates the vast majority of phone calls. Notice also that not all followers receive calls during price decreases, unlike during price increases.

With respect to timing, conversations are concentrated around the first recorded price change. Stations associated with the cartel leader and Couche-Tard tend to be called early, while other followers are usually warned later. Notice that a significant fraction of communications are initiated more than two hours before the first price change. These conversations usually concern upcoming price cuts since stations often anticipate the behavior of the Ultramar stations based on price cuts in nearby cities.

[21] One decrease in Victoriaville was initiated by one of the big-box retailers, and one in Thetford Mines was initiated by Couche-Tard. In the latter case, Couche-Tard called the cartel leader to justify her action, arguing that Ultramar was "late" and that prices in nearby regions were too low.

[22] When a station in Sherbrooke cut its price because it was replacing a reservoir tank, it was immediately warned that this would result in a price war.

Table 5—Regressions of the Probability of Being Called during Price Decreases on Store Characteristics

		Share of contacts received in time grid (min.)						
Player labels	Number of contacts receive/send	≤ −120	−60	0	60	120	180	≥ 240
Follower	10/9	0.10	0.00	0.49	0.27	0.05	0.04	0.05
Leader	7/12	0.06	0.00	0.70	0.13	0.04	0.00	0.08
Couche-Tard	4/3	0.14	0.07	0.54	0.07	0.04	0.04	0.11
Dissidents	3/0	0.14	0.00	0.57	0.29	0.00	0.00	0.00
Ultramar/big-box	2/2	0.00	0.00	0.75	0.19	0.00	0.00	0.06

Note: See footnote of Table 3 for details.

Table 6—Estimated Change in Volume Associated with the Observed Transfer Scheme

Variables	Victoriaville (1)	Thetford Mines (2)	Pooled sample (3)
Low-cost chains	−0.698***	−0.640***	−0.670***
	(0.104)	(0.144)	(0.0854)
Followers stations	−0.193***	−0.533***	−0.235***
	(0.0727)	(0.0954)	(0.0605)
Couche-Tard stations	−0.0898	−0.372*	0.215*
	(0.0851)	(0.194)	(0.123)
Distance to low-cost chains	−0.00474	0.0274	0.0416
	(0.0341)	(0.0225)	(0.0342)
Distance to closest competitor	−0.0452	0.0626	−0.135**
	(0.0656)	(0.0567)	(0.0645)
Number of pumps			0.0150**
			(0.00591)
Full service			−0.138***
			(0.0446)
24 hours			−0.473***
			(0.106)
Observations	210	84	250
R^2	0.212	0.283	0.351

Notes: Robust standard errors in parentheses. Dependent variable: dummy variable equal to one if station receives a warning. Low-cost chains refer to Ultramar and big-box stations.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

While we do not observe significant delays during price decrease periods, the speed at which the leader diffuses the information about Ultramar's price reduction is important in order to guarantee the participation of all followers. On several occasions, we observe the leader reminding the followers not to cut their prices before receiving a call. In exchange, the leader promises a fast diffusion of information in the event of a price cut, so that cooperating stations remain competitive.

In Table 6, we analyze the relationship between the characteristics of stores and the probability of receiving a phone call warning of a recent price cut. Each specification estimates a linear probability model by OLS on three samples: Victoriaville, Thetford Mines, and the pooled sample. The samples are larger than before because we observe a larger number of price declines, especially in Victoriaville.

All specifications confirm that calls warning of a price cut rarely involve the group of stronger stations, since they most often initiate the cuts. Not all followers are warned of a price decline however; in the pooled sample, followers are 25 percent less likely to receive a phone call than stations associated with the leader. Stations located in denser areas are also less likely to be called, suggesting that some of the communications do not involve phone conversations. In the last specification, we also control for characteristics of the stations.[23] It is interesting to note that stations associated with the group of more efficient stations (i.e., larger capacity, self-service) are more likely to be warned of a price cut. Since these stations have less to gain from collusion, it is not surprising that the leader tries to diffuse the information to them more quickly.

IV. The Value of Delay

The particular order of play described above clearly favors firms that are able to lower prices first, and increase prices last. Delays on the way up are particularly valuable for late movers since most stations move early, and price increases are large in magnitude.

Our goal in this section is to measure the magnitude of the market-share transfers associated with the observed recurrent temporary price differences, and their importance for the stability of the cartels. To do so, we use two empirical demand models: one with and one without differentiation. This allows us, in a first step, to quantify the counterfactual distribution of volumes had firms instead been changing prices simultaneously. We then use the models to show that the transfer mechanism lowers the probability of deviation, and we quantify the net surplus it yields.

A. *Volume Transfer*

The value of delay is a function of consumers' responsiveness to prices. There are a number of statements in the Competition Bureau documents suggesting that delays create important market-share transfers from the leaders and followers to late movers. Referring to an Ultramar station in Sherbrooke whose price was below the just increased price of all of the other stations in the city, one of the managers who was becoming impatient at how long Ultramar was taking to adjust said: "There are people lined up into the streets, the lot is full."[24] Similarly, in Thetford Mines the Competition Bureau summarizes a discussion between Bilodeau and the manager of the EMCO station: "Alain asks whether all of the Ultramars are like this.

[23] Controlling for station characteristics reduces the number of observations, since 2 stores in Victoriaville and 12 in Thetford Mines are located outside of the territory surveyed by Kent Marketing.

[24] May 28, 2005 in Sherbrooke. Translated from: "il y a du monde jusqu'a dans la rue chez Ultramar, la cour est pleine."

Mr. Bilodeau responds that it's similar everywhere and adds that when they offer a lower price than the others, the pumps are full and they profit from it."[25]

In order to model the transfer mechanism, we assume that firms raising their prices late (or decreasing early) receive a fraction α_t of the weekly demand associated with the initial price vector. Since time is discrete, deviation or participation decisions are made at the beginning of the week (i.e., before the transfers occur). Three firms are allowed to delay during price increases (Ultramar, Maxi, and Canadian Tire), and only one (Ultramar) is allowed to initiate price cuts during price decrease periods.

Our estimate of α_t is arrived at in the following way. We first consider information in the Competition Bureau documents, which suggests that delays on increases last approximately half a day, that delays on decreases last roughly thirty minutes, and that delays never occur more than once a week. If demand is uniformly distributed over the week for every station, this would imply that delays correspond to $1/14$th of weekly sales during price increase, and $1/168$th during price decreases (assuming stations are open 12 hours per day). However, demand is most likely not uniformly distributed, especially during price increases. This is because price increases are predictable, and they induce a significant amount of price dispersion (three times the range of prices typically observed). Together these factors increase the short-run price elasticity of demand by creating a stockpiling effect observed in other retail markets (see, for instance, Erdem, Imai, and Keane 2003 and Hendel and Nevo 2006).[26] This effect can operate both by delaying purchases before prices hit the lowest point in the cycle (demand accumulation), or by increasing the quantity purchased in order to save on future consumption (filling up the tank). Moreover, because gasoline is storable, consumers can substitute their purchasing decision across days of the week by filling up when prices are low. Taking these factors into account, we therefore set the delay length to $1/7$th of a week for increases, and $1/140$th of a week for decreases (i.e., 100 percent and 5 percent of a day respectively).

In order to quantify the size of volume transfers associated with delays, we consider two demand specifications. The first is the extreme case in which stations are homogenous, and consumers choose the cheapest option. When prices are equal, market shares are uniform (i.e., $1/N$), and, during delay periods, stations posting low prices serve the full market. We assume that the market size is equal to the population of Victoriaville times three liters of gasoline per day.

The second allows for differentiation, using a discrete choice logit model with heterogeneous quality. The quality of store j, $\delta_{jt} = \beta' \mathbf{X}_{jt} + \xi_{qt}$, is a function of observed size and amenities $\mathbf{X}_{jt}$, and a quarter fixed effect ξ_q, controlling for changes in aggregate demand. More specifically, demand at store j is given by

$$D_j(\mathbf{p}_t) = M \frac{\exp(\delta_{jt} - \gamma p_{j,t})}{\exp(-\gamma p_{0,t}) + \sum_k \exp(\delta_{kt} - \gamma p_{k,t})}, \qquad (2)$$

[25] April 26, 2005 in Thetford Mines. Translated from: "Alain demande si tous les Ultramars sont comme ca. M. Bilodeau répond que c'est semblable partout et ajoute que quand ils sont moins chers que les autres, les pompes sont pleines et ils en profitent."

[26] See Levin, Lewis, and Wolak (2009) for an analysis of consumers' short-run reaction to price changes.

where $p_{j,t}$ is the price posted at station j in week t, $p_{0,t}$ is the average price in neighboring markets, and M is the market size. Unlike in the model with homogenous products, high-price stores will still earn positive profits during transfer periods.

To model the demand function with delays, we use $\tilde{\mathbf{p}}_t$ to the denote the vector of prices at the beginning of the period, before the late movers change their prices.[27] The demand function can then be written as

$$(3) \qquad D_{j,t}(\mathbf{p}_t, \alpha_t) = \begin{cases} \alpha_t D_j(p_{j,t-1}, \tilde{\mathbf{p}}_{-j,t}) + (1-\alpha_t) D_j(\mathbf{p}_t) & \text{if} \quad j \in \mathcal{T}_t \\ \alpha_t D_j(p_{j,t}, \tilde{\mathbf{p}}_{-j,t}) + (1-\alpha_t) D_j(\mathbf{p}_t) & \text{if} \quad j \notin \mathcal{T}_t \end{cases},$$

where $\mathcal{T}_t$ denotes the set of firms receiving an implicit transfer during period t.

We estimate parameters in equation (2) by combining quarterly volume data between 2001 and 2007 from Kent Marketing, and weekly price data from the Régie. Although both datasets cover all three markets, we focus on Victoriaville to estimate the price sensitivity parameter. We do this because we have more information for Victoriaville from the Competition Bureau documents on the exact price distribution and timing of moves during the collusive period. To compute our weekly panel of prices, we use the Régie survey as the "market" price, and we use the end-of-quarter price survey by Kent to generate the distribution.

Victoriaville also exhibited important price variation that allows us to identify the price elasticity. Between 2002 and 2005, we observe two distinct prices among the stations in this market: all but two stations setting the market price, with the two dissident stations pricing 2 cpl below. After the collapse of the agreement, and during two price wars in 2005, the weekly Régie survey clearly shows that the market price dropped near to the price floor for most of the weeks (the median margin over the floor is 1 cpl after May 2006), and cross-sectional dispersion nearly disappeared. Also, a small number of stations maintained prices higher than the floor during the post-collapse period, suggesting that these stations faced marginal costs higher than MEP_t. The data also exhibit intertemporal price variation, owing to the fact that average weekly prices in nearby cities became higher than the Victoriaville price in the post-collapse period. Before the collapse, the difference between $p_{j,t}$ and $p_{0,t}$ was between 1 and 2 cpl on average.

Let $\hat{Q}_{jq}$ denote the observed sales volume of station j in quarter q. To estimate the model parameters, we minimize the following nonlinear least square problem for the Victoriaville sample with nonmissing volume information:

$$(4) \qquad \min_{\theta} \sum_j \sum_q \left(\log \hat{Q}_{j,q} - \log Q_{j,q}(\theta) \right)^2,$$

where $Q_{jq}(\theta) = \sum_{t \in q} D_{j,t}(\mathbf{p}_t, \alpha_t | \theta)$ is the quarterly predicted volume, $\hat{Q}_{jq}$ is the observed volume from Kent Marketing, and $\theta = (\gamma, \beta, \xi)$. Notice that we condition

[27] The initial price vector is defined as follows. During price increase periods, the first movers raise their prices to p_t at the beginning of the period, and the late movers initially post a price equal to p_{t-1}. The ordering is reversed during price decreases.

on α_t in the evaluation of the weekly demand function, since we incorporate the delays in the estimation of the parameters. Then, holding fixed the estimated price coefficient $\hat{\gamma}$, we estimate the quality parameters (β, ξ) for the other two markets.

In Table 4 in the online Appendix, we report the key parameter estimates. The price coefficient is estimated to be -0.409, which yields a very high store-level price elasticity of around -30.[28] Recall that this elasticity is in large part identified by the elimination of cross-sectional price dispersion during price wars, which favored stations allowed to set their price below the market price. The quarterly volume data show, for instance, that one of these stations experienced a 50 percent drop in market share after the collapse of the agreement (i.e., in the second quarter of 2006). Note also that prices are treated as exogenous with respect to the residual (the difference between observed and predicted demand), conditional on quarter fixed effects and observed station characteristics. As just mentioned, the price coefficient is identified primarily off the price variation provided by the two dissident stations. Since these stations are not randomly assigned to charge low prices, there may be an endogeneity problem and the price coefficient may be biased.

In Table 7, we calculate the implied transfer of sales volume that results from the asymmetric timing of price adjustments. The first two columns show the fraction of weeks in which there are price increases and decreases. As we discussed above, price increases are relatively infrequent but large in magnitude, which leads to important transfers in the model with differentiation. To measure the change in sales volume over the collusive period, we simulate both demand models with and without the delay scheme. Columns 3 and 5 present the percentage change in total sales volume, and columns 4 and 6 present the same change in thousands of liters. The results from both demand models are similar. We estimate that the price adjustment delays increase the sales of the low-cost retailers by about 4 percent in Victoriaville, and about 6 percent in Sherbrooke and Thetford Mines. The homogenous product model predicts a much larger gain in Victoriaville, mostly because it ignores the unequal distribution of observed market shares due to location and amenities.

B. *The Transfer Mechanism and Cartel Stability*

To study the question of stability, we consider a simple dynamic pricing game, in which collusion is enforced via a "carrot-and-stick" strategy. We assume that information is perfect and symmetric, and therefore price wars occur only off the equilibrium path. To determine the collusive price on the equilibrium path, we assume that the observed price sequence fully describes the cooperation strategy, and satisfies the incentive constraints of all players. We define the collusive period as a three-year window, between January 2002 and October 2004, during which collusion appears to be stable, and prices exhibit the patterns that we associate with the cartel strategy. We also assume that firms collude on one price, denoted by p_t.

Punishments are a latent feature of the data, and conversations reported in the court documents do not precisely determine the markup level and length of price

[28] Using bimonthly data from Quebec, Houde (2012) also estimates very high store-level elasticities for certain stations, although overall his estimates yield a lower average (-15) than the one reported here.

Table 7—Estimated Change in Volume Associated with the Observed Transfer Scheme

Markets	Players	Percent increase (1)	Percent decrease (2)	Δ Vol. − logit Percent (3)	Δ Vol. − logit × 1,000 l. (4)	Δ Vol. − Homo. Percent (5)	Δ Vol. − Homo. × 1,000 l. (6)
Sherbrooke	Ultramar	0.225	0.373	0.061	6,759.584	0.055	733.012
	Big-box	0.224	0.372	0.059	773.265	0.047	651.790
	Other	0.223	0.370	−0.014	−275.124	−0.035	−442.205
Thetford Mines	Ultramar	0.169	0.350	0.064	895.420	0.056	763.006
	Other	0.168	0.349	−0.009	−52.570	−0.027	−337.746
Victoriaville	Ultramar	0.164	0.284	0.040	522.315	0.079	752.152
	Big-box	0.164	0.284	0.038	366.553	0.054	515.890
	Other	0.161	0.288	−0.010	−79.329	−0.025	−215.419

wars.[29] We define a period as a week, and we model the punishment mechanism by assuming that firms set a price equal to the price floor for T consecutive weeks. The price floor regulation has two levels: the *minimum estimated price* (or MEP) measured as the rack price posted at the nearest wholesale terminal, and a "long-run" price floor equal to the MEP plus a 3 cpl margin. In the simulations, we therefore consider two possible punishment schemes: (i) prices at the MEP for T weeks, or (ii) prices at the MEP plus 3 cpl for T weeks.

We use the estimated marginal cost function described in Section IIA. To capture the loss-leader incentive of the two big-box retailer chains (absent in the estimates), we add an extra 2 cpl cost advantage to the Maxi and Canadian Tire stations. This makes them the most cost-efficient firms (i.e., cost differential around −3 cpl), followed by Ultramar (i.e., $c_j = -2.03$).

Given the demand function described in equation (3), the profit function can be written as follows:

$$\Pi_{f,t} = \begin{cases} \sum_{j\in J_f} \alpha_t \pi_j(p_{j,t-1}, \tilde{\mathbf{p}}_{-j,t}) + (1-\alpha_t)\pi_j(\mathbf{p}_t) & \text{if} \quad f \in \mathcal{T}_t \\ \sum_{j\in J_f} \alpha_t \pi_j(p_{j,t}, \tilde{\mathbf{p}}_{-j,t}) + (1-\alpha_t)\pi_j(\mathbf{p}_t) & \text{if} \quad f \notin \mathcal{T}_t \end{cases},$$

where

$$\pi_j(\mathbf{p}_t) = D_j(\mathbf{p}_t)(p_{j,t} - \mathrm{mc}_{j,t}),$$

and where J_f is the set of stations owned by firm f.

A collusive agreement is characterized by an infinite sequence of prices, timing of moves, and punishment length: $\mathcal{A} = \{p_t, \alpha_t, \mathcal{T}_t, T\}_{t=0}^{\infty}$. We assume that firms have perfect foresight, and therefore the equilibrium is deterministic. Collusion is enforceable if it satisfies the incentive constraint of each firm:

$$V_{f,t}^c(\mathcal{A}) - V_{f,t}^d(\mathcal{A}) = \sum_{\tau=0}^{T} \delta^\tau \Pi_{f,t+\tau} - \left[\Pi_{f,t}^d + \sum_{\tau=1}^{T} \delta^\tau \Pi_{f,t+\tau}^p\right] \geq 0,$$

[29] This is not to say that price wars did not occur during the period covered by the Régie survey. For instance, over five consecutive weeks between January 2005 and March 2005, prices in Victoriaville were within 1 cpl of the floor set by the government. The early phone conversations recorded by the bureau mention this price war episode, and identify it as a punishment towards a dissident in the summer of 2004.

where

$$\Pi^d_{f,t} = \max_{u \in \mathbb{N}^+} \begin{cases} \sum_{j \in J_f} \alpha_t \pi_j\big(p_{j,t-1} - u, \tilde{\mathbf{p}}^d_{-j,t}\big) & \text{if} \quad f \in \mathcal{T}_t \\ \qquad + (1 - \alpha_t)\,\pi_j\big(p_t - u, \mathbf{p}^d_{-j,t}\big) & \\ \sum_{j \in J_f} \alpha_t \pi_j\big(p_{j,t} - u, \tilde{\mathbf{p}}^d_{-j,t}\big) & \text{if} \quad f \notin \mathcal{T}_t \\ \qquad + (1 - \alpha_t)\,\pi_j\big(p_t - u, \mathbf{p}^d_{-j,t}\big) & \end{cases},$$

$$\Pi^p_{f,t} = \sum_{j \in J_f} \pi_j\big(\mathbf{p}^f_t\big).$$

Notice that we use a simple deviation strategy: firms choose the optimal undercutting amount, u, in 1 cpl increments. This strategy simplifies the derivation of value functions, and captures the fact that firms nearly always change prices by 1 cpl increments. We use a discount factor equal to 0.99 in all of our simulations.

The participation constraints assume that deviations occur at the beginning of the week, and that other firms react only at the beginning of the following period. This is clearly an approximation of the way in which deviations are punished in practice. For instance, during the investigation period we document two episodes of deviation. In both cases, the more efficient firms eventually started a price war by refusing to increase prices, and posting a price equal to the floor. However, retaliation started several weeks after the deviation occurred. The cartel leaders initially tried to "negotiate" directly with the dissident firms using verbal threats and intimidations. These two deviations were initiated by small firms, and it is not clear whether a similar approach would have been used if deviations had instead been initiated by one of the larger stations.

We measure empirically the difference between the value of cooperating and deviating, by calculating the stream profits from cooperation and deviation for every week between January 2002 and November 2004. For all simulations we fix the model parameters, and vary the length of punishment, demand specification, price floor level, and delay period (i.e., zero or α_t). With respect to the punishment length, we measure the probability of deviation as the fraction of week/firm observations for which the incentive constraint is not satisfied. We are particularly interested in the probability of deviation from one of the three "low-cost" firms. We also define the minimum punishment level T^* as the shortest price war length, such that no deviation occurs during our sample period.

Table 8 summarizes the results related to the deviation frequencies and minimum punishments. The rows report the results for the four model specifications: high/low price floor, and differentiated/homogenous products. In columns 1 to 4, we vary the punishment length and report the implied frequency of deviations with transfers. The numbers in parentheses correspond to the percentage change in frequency when we remove the implicit transfers. Columns 5 and 6 report the minimum punishment lengths.

The transfer mechanism employed by the cartel reduces the frequency of deviations, sometimes substantially. When the length of price wars is either too small or too large, the frequency of deviations is either one or zero with or without transfers.

Table 8—Deviation Frequencies and Minimum Punishment Lengths in the Victoriaville Market

Specifications		Deviation frequencies				Punishment (T^*)	
Floor	Demand	$T = 4$ (1)	$T = 8$ (2)	$T = 32$ (3)	$T = 52$ (4)	Delays (5)	No delays (6)
$MEP_t + 3$	logit	0.868 (0.017)	0.516 (0.085)	0.009	0.000	35	41
MEP_t	logit	0.460 (0.073)	0.078 (0.004)	0.000	0.000	15	15
$MEP_t + 3$	Homo.	1.000 (0.000)	0.981 (0.016)	0.636 (0.104)	0.394 (0.406)	144	171
MEP_t	Homo.	1.000 (0.000)	0.956 (0.022)	0.340 (0.435)	0.071 (0.286)	67	76

Notes: Homo and logit represent the two demand specifications. Homo is the extreme case in which stations are homogenous. Logit allows for differentiation, using a discrete choice logit model with heterogeneous quality.

However, for intermediate levels of punishments, incorporating delays into the model can increase the stability of the cartel significantly. Doing so also translates into shorter minimum punishments. This issue is particularly obvious in the specifications without differentiation, where a cartel can be sustained with delay transfers with 27 fewer weeks of price war for a high price floor, and 9 fewer for a low floor. With differentiation, the transfers reduce the length of price wars by six weeks with the high price floor, and do not affect T^* with the low price floor.

In general, transfers are necessary to sustain collusion when cartels are more susceptible to deviations. In our simulations, since we are holding fixed the level of asymmetries among firms, the cartel is more unstable when we increase the level of the price floor (i.e., weaken the punishments), and when we eliminate differentiation (i.e., reduce undercutting benefits). Therefore, in our setting, differentiation and a lower price floor are two important facilitating factors. This is not to say that eliminating the floor would automatically make the cartels more stable, since removing the floor could increase the likelihood of deviations from low-cost firms that could more easily steal market shares by undercutting their rivals below the current MEP.[30]

Neither demand specification perfectly depicts the functioning of the market. The homogenous product assumption implies a very large demand elasticity, which increases the value of transfers substantially, and at the same time makes the cartel look more unstable. The logit model, on the other hand, softens price competition by assuming that large market-share stores, such as the three low-cost stations, have high-quality products (i.e., δ_j). This feature of the model weakens their incentive to deviate, unless we assume a high price elasticity. For smaller values of the price coefficient, the deviation frequency of large-scale stations would be significantly lower, which would eliminate completely the need for a transfer. The reality lies somewhere between these two extremes.

[30] In the online Appendix, we present a numerical example that illustrates this.

Table 9—Distribution of Gains and Losses from the Delay Transfers in the Victoriaville Market

Model specifications		Transfer net value, \$ × 1,000 (percent)			
Floor	Demand	Canadian Tire (1)	Maxi (2)	Ultramar (3)	Others (4)
$\text{MEP}_t + 3$	logit	14.956 (0.129)	17.000 (0.127)	7.373 (0.075)	−1.685 (−0.025)
MEP_t	logit	15.424 (0.049)	17.471 (0.048)	7.478 (0.032)	−1.577 (−0.011)
$\text{MEP}_t + 3$	Homo.	41.892 (0.523)	42.195 (0.531)	46.386 (0.273)	−4.528 (−0.051)
MEP_t	Homo.	44.420 (0.290)	44.736 (0.294)	47.985 (0.168)	−5.695 (−0.032)

Notes: Homo and logit represent the two demand specifications. Homo is the extreme case in which stations are homogenous. Logit allows for differentiation, using a discrete choice logit model with heterogeneous quality.

In Table 9 we calculate the impact of the transfers on the change in the net value of cooperation, defined as $V^c_{f,t}(\mathcal{A}) - V^d_{f,t}(\mathcal{A})$, evaluated at the minimum punishment T^* defined in column 6 of Table 8. This statistic represents the value to the firms over and above what they earn from deviating. We report an average for the four groups of firms: the three low-cost firms, and the rest of the players.

Not surprisingly, the delays increase the net value of colluding for firms receiving the transfers. With differentiation, the transfer increases valuations between 3 percent and 13 percent (for the low and high price floors). Assuming homogenous products, the increase is substantially higher: up to 17 percent with a low price floor, and 53 percent with a high price floor. The large difference between the two demand models is explained by the responsiveness of consumers to price differences (infinite with homogenous products), and the fact that, without delays, low-cost stations earn the same market share as other stores (i.e., $1/n$), while shares are already asymmetric with the logit demand model as a result of quality differentiation.

Notice also that Ultramar is benefiting the least from the transfer despite the fact that it also receives transfers during decrease periods. This is because Ultramar operates a network of two stations in the market, and therefore benefits relatively less from deviations than the other two low-cost stations. Indeed, our simulation results suggest that the number of stations within the same network is the major source of asymmetry in the value of colluding. This is partly due to the presence of a price floor regulation, which tends to reduce the impact of cost differences on the stability of the cartel.

The last column of Table 9 reports the average cost of the transfer for other firms. Stations moving early during price increases lose value (between 1 percent and 10 percent), but we estimate that this loss is relatively small compared to the gain for late movers. This is because the fraction of firms moving early is much larger (i.e., 88 percent of firms). The asymmetric timing of moves, therefore, generates a significant transfer towards low-cost stations, without costing too much individually to the rest of the cartel participants. This also implies that the transfers only marginally increase the probability of observing a deviation from a "high-cost" station.

This exercise illustrates that the delays can solve the enforcement problem of the cartel. However, it is important to note that our analysis focused only on the enforcement role of transfers, and not on their impact on the choice of equilibrium. In reality, firms are bargaining over the length of adjustment delays and the magnitude of price changes, and there typically exists a large number of enforceable agreements. In this context, firms with better outside options (higher V^d) have more bargaining power and can negotiate a more favorable collusive price and delay period. For instance, Harrington (1991) provides a Nash bargaining model in which market-share transfers can emerge in equilibrium even in the absence of an enforcement problem. Implementing those considerations in our context is beyond the scope of the paper, given the large number of players.

V. Conclusion

Our analysis of the functioning of four retail-market cartels reveals that the main impediment to collusion is the asymmetry that exists, which necessitates transfers to encourage the participation of all players. This leads us to conclude that traditional allocation schemes are not practical for most price posting retail markets, and that temporary price differences can be used to sustain collusion. In the price-fixing case that we describe, this takes the form of regular and predictable delays during price changes. These delays are more pronounced during price increases, which are both larger and less frequent than price decreases. This asymmetry produces a cycle in margins which lasts about a month on average.

Importantly, these patterns do not match well with the standard features used by antitrust authorities to identify collusive behavior: (i) parallel price changes, and (ii) stable profit margins. Therefore a conclusion of our paper is that sequential ordering during price changes, and pricing cycles that overall are asymmetric can be part of a collusive agreement. In a companion paper, Clark and Houde (forthcoming), we provide empirical evidence that the asymmetric adjustments documented here can be linked with collusion. We show that the degree of price asymmetry decreased substantially in the four cartel cities after the collapse of the cartels, triggered by the execution of the search warrants. Furthermore, we show that this decrease in asymmetry stems largely from the fact that price cuts increased in magnitude following the collapse, which is consistent with the idea that the cartel was no longer able to prevent firms from undercutting their rivals during this phase.

Our analysis does not focus on the optimality of the mechanism, including the timing and magnitude of price changes. Other mechanisms might be possible. For instance, the cartels could instead coordinate on a vector of prices with permanent differences that yields the appropriate market shares (to encourage everyone's participation). However, our analysis suggests that this would be difficult to implement because of the lack of differentiation among the stations: even small price differences induce sizeable market-share transfers. Alternatively, the cartel leader could choose to implement transfers more frequently. For example, the cartel could use a constant markup rule based on the floor, and implement transfers both during price increases and decreases. This is not what we observe. Price decreases involve short periods of delay, and benefit only one chain (Ultramar).

The Competition Bureau documents suggest that the presence of large coordination costs limits the attractiveness of a symmetric pricing strategy. During increase periods, the cartel leader must ensure that all followers move early during the day. Since he cannot perfectly observe the timing of price changes, many stations are tempted to delay their actions. This creates a prisoner's dilemma which puts the coordination attempt at risk, especially if the detection probability is low.[31] To implement transfers through delays, the cartel must therefore invest in significant monitoring and communication efforts to increase the probability of detecting laggers. The large number of phone calls initiated by the leader reflects the leader's continuous effort to convince Ultramar, the big-box retailers, and dissident stations to increase their prices.

All of this communication is costly, both in terms of time, and because explicit communication increases the risk of being caught by antitrust authorities. Ultramar's LPG policy, which encourages it to move first on price decreases is helpful in this respect. On average, there are many fewer conversations during price decreases than price increases. This role for the LPG is consistent with the theory literature initiated by Salop (1986) that associates price-matching policies with facilitating practices. While this literature focuses on the commitment power of these practices, we view Ultramar's LPG as a coordination device that reduces the cost of organizing price decreases. As such, the cartel leader only bears the cost of coordinating transfers during price increase periods.

From this perspective, the choice of collusive arrangement can be viewed as an effort to balance the benefit of sustaining collusion on a higher price with the cost of coordinating the actions of all players (which enters the incentive constraints of the organizers). The cartel's problem then is analogous to a menu-cost model of price adjustment (see, for instance, Chapter 8 of Blanchard and Fischer 1989). A pricing strategy based on large price increases, followed by a sequence of small decreases or constant prices, resembles an (s, S) rule that helps reduce coordination costs and implements infrequent but important transfers. In comparison, a constant markup rule would necessitate frequent small price adjustments (as a result of the volatility of costs), which would translate into more frequent delays, and possibly higher coordination costs.

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[31] We observe several examples of imperfect monitoring in the phone conversations. For instance, independent station operators pretend not to have received the correct instruction from the leader, or simply do not answer the phone.

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