Collusion with asymmetric retailers: Evidence from a gasoline price-fixing case*

Robert Clark — HEC Montréal
Jean-François Houde — UW-Madison

August 22, 2011

Abstract

In this paper, we point out a fundamental difficulty of successfully colluding in retail markets with heterogeneous firms, and characterize the mechanism that recent gasoline cartels in Canada used to sustain collusion. Heterogeneity in cost and network size opens the door to explicit mechanisms 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 collusive arrangement has three features: (i) inter-temporal market-share transfers, (ii) extensive communications and stable hierarchical structure, and (iii) asymmetric pricing cycles.

*We have benefited from helpful comments from John Asker, Juan-Esteban Carranza, Allan Collard-Wexler, David Genesove, Amit Ghandi, Gautam Gowrisakaran, Joe Harrington, Ken Hendricks, Tom Holmes, Alan Sorensen, Bob Town, and seminar participants at Concordia University, UBC IO conference, CIRPEE Conference, IIOC, UCLA, University of Western Ontario, University of Waterloo, Yale, University of Minnesota, and University of Wisconsin. We also wish to thank people at the Canadian Competition Bureau and the *Régie de l'énergie du Québec* for their cooperation throughout the completion of this project. We received excellent assistance from Pierre-Olivier Lachance, Laurent Da-Silva, Jonathan Deslauriers, and Charles-David Sauvageau-Franche. Correspondence to Robert Clark: HEC Montréal, CIRANO and CIRPÉE, Montréal, Québec; Phone: (514) 340-7034; Email: robert.clark@hec.ca, and Jean-François Houde: University of Wisconsin-Madison, Madison, Wisconsin and CIRANO; Phone: (608) 262-3805; Email: houdejf@ssc.wisc.edu

Introduction

Collusion is prevalent in many retail markets, as evidenced by the large number of cases prosecuted each year by antitrust authorities.[1] This is even though collusion in most of these markets should actually be quite difficult since they feature a large number of asymmetric firms and very 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 are directly competing with independently owned stores selling primarily gasoline. Stores also differ in storage capacities and vertical arrangements, which directly lead to heterogenous costs due the presence of 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 gain extra market share by deviating, 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 (see Jacquemin and Slade (1989) for a review), 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. In the markets that we study, stations do not exhibit important spatial differentiation, nor do they face significant capacity constraints. As a result, when coordinating on a common price, market shares reflect mostly 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 get around the enforcement and agreement problems by implementing inter-temporal transfers based on a particular order of play through which "stronger" players were able to extract additional market shares 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 inter-temporal transfers are used, but in a different context, namely to solve an information friction.

The mechanism that we uncover implements transfers based on adjustment delays during

[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:
http://www.justice.gov/atr/cases, http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/02037.html, and http://ec.europa.eu/competition/cartels/cases/cases.html respectively.

price changes. Specifically, the cartel leaders systematically allowed 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, the same stations were 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, or 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.

A second contribution of our paper is to describe the amount of coordination involved in implementing collusion, something that is often overlooked in the theory literature. To organize and enforce this arrangement the cartels all shared a common organizational structure in which a leader, helped by a few independent chains, coordinated all price changes through repeated phone calls and active monitoring efforts. These efforts led to non-trivial coordination costs that were especially important during price increases, when the bulk of the transfer was implemented. In order to reduce the magnitude of coordination costs the cartel delegated the role of cutting prices to one of the stronger chains, and so communication was limited to instructing the followers to match the lowest price in the market.

We document these arrangements empirically by studying the reported phone conversations and pricing patterns of gasoline retailers accused of price-fixing by the Canadian Competition Bureau. Our analysis focuses on the four cities in Québec in which collusion was discovered to be taking place: Victoriaville, Thetford Mines, Sherbrooke, and Magog. To our knowledge, these are among the largest retail-market cartels in North American antitrust history in terms of the number of participants; with over seventy stations thought to be involved in one of the cartels and over twenty in each of the others.

From the Superior Court of Québec, we have obtained access to the Competition Bureau documents containing summaries of, and extracts from, the conversations recorded by investigators in 2005 and 2006.[2] We supplement this primary source of data with two additional data-sets surveying prices and station characteristics. We use this information to characterize the internal functioning of the cartel, and the transfer mechanism. Specifically, we describe the communication

[2]The Canadian Competition Bureau's investigation into, and prosecution of, the alleged price fixing in retail gasoline markets in Quebec is ongoing. For the purpose of this paper, the authors base their understanding of the facts with respect to the alleged Quebec retail-gasoline cartel case mostly on documents prepared by the Competition Bureau. The authors 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. From the Court the authors received copies of the three annexes attached to the affidavit of Mr. Guay. Annex A is a 143-page document which contains mostly reported wiretap telephone conversations with respect to the region of Victoriaville; Annex B is a 45-page document which contains mostly reported wiretap telephone conversations with respect to the region of Thetford Mines; Annex C is a 121-page document which contains mostly reported wiretap telephone conversation with respect to the regions of Sherbrooke and Magog. We will refer to the affidavit of Mr. Guay and its three annexes as the "Competition Bureau documents." The authors also found information on the actions taken by the Competition Bureau on its website : http://www.competitionbureau.gc.ca. The allegations of the Competition Bureau have not been proven in a court of justice. This paper analyses the alleged Quebec retail-gasoline cartel case strictly from an economic point of view.

patterns between the players and the set of stations making/receiving transfers, and we calculate the value of the delay. 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 nearly 5% in Victoriaville and 3.2% in the other markets.

Our results also point to the fact that collusive prices exhibit a predictable cyclical pattern characterized by large and infrequent price increases, followed by frequent periods of sticky prices and small decreases. This is different from the conventional wisdom which suggests that collusive prices should exhibit a constant markup rule because aggregate gasoline demand is inelastic. Similar pricing patterns have been documented by researchers in several gasoline markets, some of which have previously been associated with collusion. For instance, Borenstein, Cameron, and Gilbert (1997) cite collusion as a possible explanation for asymmetric pass-through of oil shocks to gasoline prices, and the patterns we describe are similar to those uncovered by Slade's (1987, 1992) analysis of Vancouver price wars, although margins in our target markets are substantially larger. A recent literature documenting the existence of *Edgeworth Cycles* in gasoline markets typically explains the existence of asymmetric cycles through the non-cooperative model of Maskin and Tirole (1988) (see in particular Eckert (2002) and Noel (2007)). Our case study provides additional evidence suggesting that these cycles can be rationalized by a collusive agreement.

Our paper is related to an important empirical literature on explicit collusion (see for instance Porter (1983), Porter and Zona (1993), Scott-Morton (1997), Pesendorfer (2000), Roller and Steen (2006), and Asker (2010)), and in particular to Genesove and Mullin (2001), who study internal documents from the Sugar cartel and contrast their findings with predictions from the economic theory on collusion. While most of this literature is concentrated on legal cartels, wholesale markets, or on 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 adjustment delays during price increases. The focus of our paper differs, however, from his. While we provide an interpretation of the cartel behavior in which delays are part of a collusive agreement with transfers, Wang focuses on the role of communication in facilitating price increases (by avoiding a lengthy war of attrition) within the Maskin-Tirole framework (see also Wang (2009)).

The rest of the paper is structured as follows. In the next section we describe the Competition Bureau documents and the investigation that led to the discovery of the cartels. In Section 2 we describe the structure of the markets and the characteristics of the main players in order to highlight the important asymmetries that exist among them. In Section 3 we provide a detailed characterization of how the cartels were operating, including a description of the pricing strategy and the patterns of communication among players. In Section 4 we describe the transfer mechanism, namely the coordinated order of moves. In Section 5 we provide a back-of-the-envelope estimate of the size of transfers implied by the adjustment delays, using the observed sequence of price changes, and external data on stations' sales volume. Finally, we conclude the paper by discussing the role of coordination costs in explaining why the cartel leader chose to implement large and infrequent transfers mainly during price increase episodes, rather than maintaining a pricing policy that would exhibit constant margins. We also comment on the implications of our findings for cartel detection.

Additional results are located in the appendices. Appendix A contains further details on the court documents. In Appendix B we provide a theoretical example that illustrates the transfer mechanism that we observe in the data, and in Appendix C we describe two additional data sources that we use to estimate the short-run elasticity of demand at the station level.

1 Competition bureau investigation

1.1 Discovery of the cartel

The cartels were discovered following the publication on the 6th of June 2004 of an article in *La Nouvelle*, the local 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 article led Canadian Competition Bureau agents to question Goulet who confirmed the story but would not provide any further details. Starting in September of 2004 the Bureau began tracking prices and questioning other station owners and employees in Victoriaville. Finally, on the 18th of February 2005, the Bureau formally began an investigation into suspected collusive behavior in the retail gasoline markets in Victoriaville, Thetford Mines, Sherbrooke and Magog in violation of Section 45 of the Competition Act. On March 2nd 2005 the Bureau was granted permission by the Court of Québec to intercept private conversations of suspected cartel participants. The following day it began recording conversations. Agents were also put in place in order to confirm the information gleaned from the recordings.

On May 29th 2006, the Competition Bureau began the execution of its search warrants. A first round of charges were publicly announced on June 12th 2008, with a subsequent round on July 15th 2010.[3] In total fourteen companies and thirty-eight individuals were charged. As of March of 2010 four companies and ten individuals, including some of the larger players in the target markets, had pleaded guilty to the charges with fines for the companies ranging from $90,000 to $1,850,000 (all figures are in Canadian dollars unless otherwise noted), and for the individuals from $5,000 to $50,000. Some of the individuals were also sentenced to up to a year in jail.

[3] See http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/02694.html and http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/03262.html.

Proceedings were stayed against two companies and one individual.[4] The other parties, notably Couche-Tard, are contesting the charges against them. On December 20, 1010, Couche-Tard filed a motion for a stay of proceedings.[5] The allegations of the Competition Bureau have not yet been proven in a court of justice.

1.2 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 wire taps 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 the wire-tap period, but are less complete for Sherbrooke and Magog both in terms of the number of price decreases documented and the number of players whose conversations are described.[6]

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 of conversations are selected by Bureau agents. We operate under the assumption that the Competition Bureau included all conversations related to price changes in the Annexes of the Competition Bureau documents.

2 Markets, players, and heterogeneity

In this section we describe the markets in which collusion was discovered to be taking place and we characterize the set of players operating in them. Our objective is to highlight the important asymmetries that exist between payers in these markets. We focus on describing the type of contractual relationships that exists between stations, as well as their observed attributes (e.g. size and amenities).

[4]See http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/03079.html.

[5]See http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/02037.html
and http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/vwapj/
Litigation-Status-Report-2010-12-02.pdf/$FILE/Litigation-Status-Report-2010-12-02.pdf

[6]Appendix A provides more information on the nature of the information in 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 - Global	Organizer	9	0	0	9
Canadian Tire	Hardware store	3	0	1	4
Christian Goulet	Informant	0	0	1	1
Couche-Tard	Convience store	13	2	3	18
Maxi	Grocery store	0	0	1	1
Petro-T	Wholesaler	5	2	1	8
Ultramar	Vert.-integrated	18	3	2	23
Other	Independent	32	12	12	56
Total		80	23	25	128

The four cities targeted by the Bureau's investigation are medium-sized cities 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 a population size of nearly 200,000 people, while the other two markets have population sizes of 25,000 and 40,000 respectively. Table 1 presents the number of stations and company names, broken down by city during the period covered by the investigation.

Throughout the paper, 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 the 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.[7] Table 1 shows important differences between stations in terms of 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 (Petroles Global/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 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

[7] 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.

Table 2: Summary statistics on the characteristics of stations in the three markets during second quarter of 2005

VARIABLES	Sherbrooke			Thetford-Mines			Victoriaville		
	Mean	S.D.	Max	Mean	S.D.	Max	Mean	S.D.	Max
Volume	6.50	3.18	14.81	4.15	1.99	7.61	7.14	5.41	20.37
Share	0.02	0.01	0.05	0.09	0.04	0.17	0.06	0.04	0.16
Nb. Pumps	11.05	7.07	32	6.58	3.18	12	8.55	4.36	18
Nb. Islands	2.45	1.13	5	2.00	1.04	5	2.05	0.90	4
Large conv.-store	0.53	0.50	1	0.42	0.51	1	0.73	0.46	1
Self service	0.55	0.50	1	0.50	0.52	1	0.27	0.46	1
Carwash	0.22	0.42	1	0.08	0.29	1	0.18	0.39	1
24 Hours	0.33	0.48	1	0.08	0.29	1	0.23	0.43	1
Major brand	0.77	0.43	1	0.83	0.39	1	0.45	0.51	1

Volume is measured in thousands of liter per day. Conv. Store is an indicator variable equal to one is 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).

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). The gas stations serve as loss-leaders for their affiliated stores, and operate five of the largest stations in terms of number of pumps.

The second largest 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 representative of other brands, which facilitates communication.

The table also lists Goulet, the informant in Victoriaville. The remaining players consist mostly of independently owned stations. This group represents between 30% and 50% 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 large size heterogeneity. The average station in Sherbrooke and Victoriaville sells about $7,000$ liters of gasoline per day, with a standard-deviation close to $4,000$ 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. For instance, the cost estimates for Québec city in Houde (2010) suggest a difference of roughly $1/2$ cents per liter (cpl) between the marginal cost of the largest and smallest stations in our data. This corresponds to nearly 10% of average margins over the rack price (i.e. spot wholesale price). Similarly, upstream marginal costs differ across brands, with unbranded retailers facing significantly higher wholesale costs than most brands, and Ultramar being the most efficient brand with an average cost difference of nearly 1 cpl relative to unbranded suppliers. Also, the share of total revenue streaming from other lines of business, such as grocery products or car-wash facilities, is an important determinant of the opportunity cost of selling gasoline, since demand for these products/services is typically positively correlated with gasoline. The cost differences induced by convenience stores or car-wash facilities are estimated to be roughly 0.2 cpl in Houde (2010).

Another important characteristics of the Québec retail gasoline market is the presence of a price-floor policy, also known as a below-cost regulation. The floor is slightly higher than the tax-included spot price of refined gasoline (i.e. rack), which can be thought of as an upper bound on firms' marginal cost (i.e. ignoring long-term contracts which often include volume discounts).[8] Throughout the rest of the paper we refer to margins as the difference between the posted price and the floor.

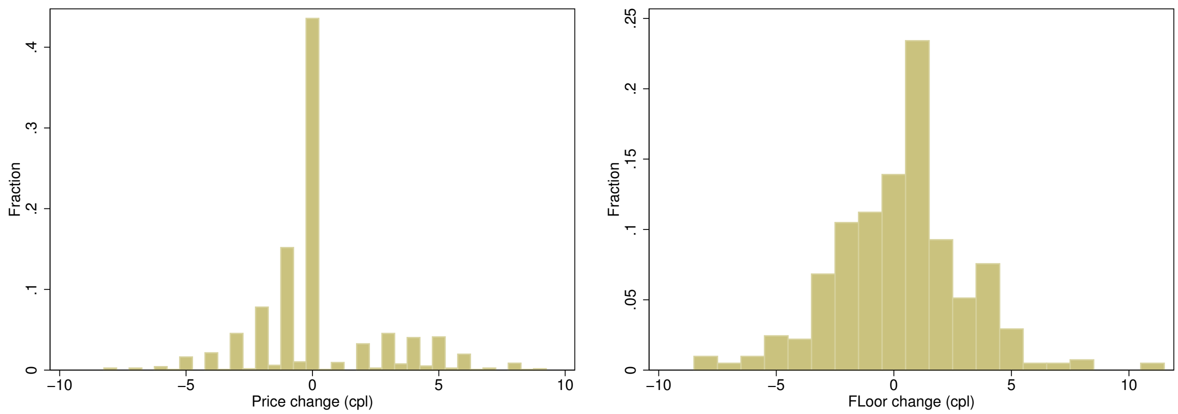
3 How do the cartels operate?

The strategy followed by the cartels is centered around the coordination of price changes, and most of the firms agree on posting a common price within each market. Because the spot wholesale price is adjusted nearly every week, the cartel repeatedly faces the same decisions about increasing or decreasing prices. In the following subsections we describe in greater details the pricing patterns, both adjustments and dispersion, and the communication involved in implementing price changes.

3.1 Patterns of price adjustment

Although the Competition Bureau documents provide detailed information on prices during the wire-tap period, the number of observations is too small to accurately measure the pricing patterns in the four markets. Since the pricing patterns in the three years before the wire tap are very similar to those of the wire-tap period, we extend our analysis of pricing to cover the years between 2002

[8]The objective of the floor is to prevent below-cost pricing, and protect the average-sized station in the market. Carranza et al. (2009) analyze the content of the regulation and its impact on the market.



(a) Price changes (bin=1/2 cpl)

(b) Cost/floor changes (bin=1 cpl)

Figure 1: Distribution of weekly price and cost changes in the collusive cities from 2002 to 2005

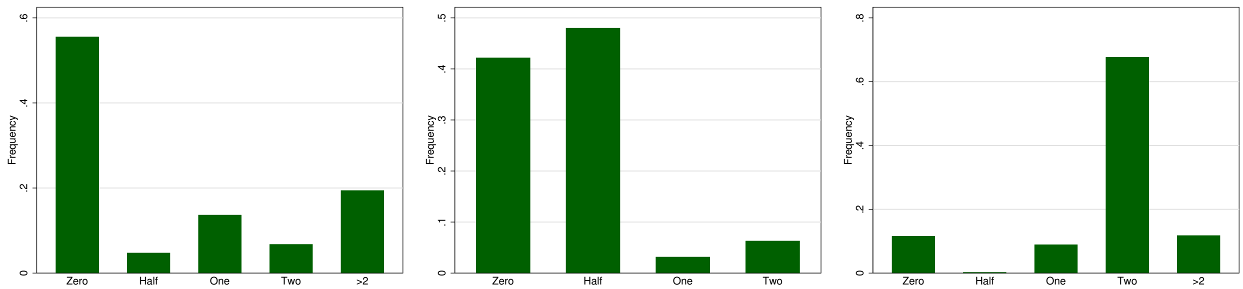
an 2005.[9] To study these patterns we rely on a station-level survey conducted by the province's energy market regulatory board (i.e. Régie de l'énergie du Québec), which includes one station surveyed in Thetford Mines, two in Victoriaville, and three in Sherbooke/Magog, each observed for at least 100 consecutive weeks.

The pricing strategy adopted by the cartels is first characterized by large margins, measured relative to the price floor. Between 2002 and 2005, average margins were equal to 6.96 cents in the four cities, compared to 5.2 the whole province. Margins were not constant, with an average inter-temporal standard-deviation (i.e. within stations) equal to 1.9, but were slightly more stable than in the rest of the province (i.e. average s.d.=2.5).

Rather than colluding on a constant margin, Figure 1 shows that the cartels coordinate on an asymmetric pricing cycle. Figure 1a shows that the distribution of price increases is symmetric around four cpl (with an inter-quartile range of two cents), while the density of price cuts is quickly increasing towards zero and clustered around one or two cents (i.e. 70% are less than or equal to two in absolute value). The distribution of cost changes, shown in Figure 1b, 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.

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% and 57% of the time respectively. Sherbrooke tends to exhibit more volatility; the proportion of stable weeks is 36%. In comparison, the price floor remains constant only 1.2% of the time.

[9] A comparative table is available upon request.



(a) Sherbrooke (b) Thetford Mines (c) Victoriaville

Figure 2: Distribution of differences from the minimum price in each market (from 2002 to 2005)

Finally, another feature of the pricing strategy is the coarseness of the price grid. Figure 1a clearly shows that the vast majority of price changes are done in one cent increments, which corresponds to nearly 15% of the average profit margins over this period. Between 2002 and 2005, 95% of price changes in Victoriaville and Thetford Mines held fixed the ending digit, and this fraction was slightly smaller for Sherbrooke. This feature is a reflection of the fact that in the three markets, nearly all observed prices end in either 4 or 9.[10]

3.2 Distribution of prices

From the recorded conversations, we observe that the distribution of prices is remarkably stable over time, and concentrated around one or a small number of prices. For instance, in Victoriaville the cartel organizers allow two stations located in the fringe of the city to post prices that are at most 2 cents 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 one or two 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.[11] Figures 2 shows the distribution of price differences from the minimum price in each market/day. The histograms clearly show that the distribution of prices before 2005 is consistent with what we observe in the wire tap documents. In Victoriaville and Sherbrooke the distribution is highly concentrated around one price (Victo-

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

[11]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.

riaville's suggested price is two cents above the minimum), while Thetford Mines' stations are almost evenly split between the self and full service prices (i.e. 0 or 1/2).

3.3 Communication patterns

Our objective in this section is to document the amount of coordination involved in implementing price changes. For this we construct a station-level panel which measures the number of phone calls made on a given day between every pair of stations. We aggregate this information across price changes to measure the intensity of communications between each type of players, and describe the hierarchy of the cartel. We also aggregate phone calls across blocks of time within each day to describe the timing of communications. Both features are useful for understanding the transfer mechanism that we analyze in the next section.

Phone conversations about price increases

The communication process is analogous to a negotiation, and typically involves two steps. First, the leader 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.[12]

Table 3 describes more formally this communication process in Victoriaville.[13] In Table 3a, 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). Ultramar and the big-box retailers are usually contacted after the first price change. The pattern differs for the Couche Tard price-setting agent 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.

Table 3b organizes phone calls by callers and receivers. On average we observe 65 recorded phone conversations per price increase period. The distribution is asymmetric for the leader on the one hand and Ultramar, the big-box retailers, and the dissidents on the other: the former initiates more communication than he receives, and vice-versa for latter. This reflects the continuous effort

[12]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 two cents below the cartel price.

[13]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

(a) Distribution of contacts over time by receiver types for price increases

Receiver labels	Average nb. Contacts	Share of contacts initiated in time grid (min.)						
		≤ -120	-60	0	60	120	180	≥ 240
Follower	19	0.09	0.10	0.51	0.01	0.07	0.04	0.17
Leader	17	0.03	0.16	0.19	0.16	0.14	0.03	0.29
Couche-Tard	12	0.25	0.19	0.38	0.00	0.06	0.00	0.13
Ultramar/Big-box	10	0.00	0.08	0.04	0.29	0.25	0.08	0.25
Dissident	6	0.00	0.27	0.09	0.36	0.00	0.09	0.18

(b) Average number of phone calls between firm types for price increases

		Receiver labels					*Total*
		Leader	Couche-Tard	Follower	Dissident	Ultramar /Big-box	
Caller labels	Leader	4	7	10	1	7	28
	Couche-Tard	3	2	1	1	0	7
	Follower	9	1	7	3	5	25
	Dissident	0	0	1	1	0	2
	Ultramar /Big-box	2	0	1	0	0	3
Total		19	9	20	6	11	65

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.

of the leader to convince Ultramar, the big-box retailers, and dissident stations to increase their prices. Moreover, nearly 80% of recorded phone calls are made across stations of different types, confirming that most price communications are between competitors rather than between firms of the same network.[14]

Phone conversations about price decreases

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.[15] Although price cuts are not announced by the company, it is explicit that only Ultramar stations are allowed to cut prices

[14] This statistic is calculated by taking the ratio of the number of calls along the diagonal over the total.

[15] One decrease in Victoriaville was initiated by one of the Big-box retailers, and one in Thetford Mines was initiated jointly by Couche Tard and Irving. 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.

Table 4: Distribution of communications during price decreases in Victoriaville

(a) Distribution of contacts over time by receiver types for price decreases

Receiver labels	Average nb. Contacts	Share of contacts initiated in time grid (min.)						
		≤ -120	-60	0	60	120	180	≥ 240
Follower	15	0.10	0.00	0.49	0.27	0.05	0.04	0.05
Couche-Tard	14	0.14	0.07	0.54	0.07	0.04	0.04	0.11
Leader	11	0.06	0.00	0.70	0.13	0.04	0.00	0.08
Ultramar/Big-box	4	0.00	0.00	0.75	0.19	0.00	0.00	0.06
Dissident	3	0.14	0.00	0.57	0.29	0.00	0.00	0.00

(b) Average number of phone calls between firm types for price decreases

		Receiver labels					*Total*
		Leader	Couche-Tard	Follower	Dissident	Ultramar /Big-box	
Caller labels	Leader	3	2	6	0	1	13
	Couche-Tard	1	2	0	0	0	3
	Follower	2	0	4	2	1	9
	Dissident	0	0	0	0	0	0
	Ultramar /Big-box	1	0	0	1	0	2
Total		7	4	10	3	2	27

See footnote of Table 3 for details.

without warning.[16] 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 4. Relative to increases, phone conversations associated with price cuts are more concentrated in time around the first recorded price changes. We also observe fewer conversations: 27 relative to 65 on average. Table 4a shows that stations associated with the cartel leader and Couche Tard tend to be called early, since communications are initiated before or within 30 minutes of the first price change. Other followers tend to be warned later, since 27% of contacts are initiated an hour after the recorded price decline. 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.

[16]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.

4 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. What limits collusion in these markets is the presence of heterogeneity amongst firms, and the associated necessity of implementing transfers.

As we discussed in Section 2, the market is characterized by important differences in the observed characteristics determining marginal costs, and in ownership structure which leads to heterogeneous network sizes. On the one hand we have firms like Ultramar and the big-box retailers, whose vertical structure and low-price guarantee policy, and complementary sales and single station status respectively imply that they are more efficient than their competitors. On the other, we have the leaders, Couche Tard, and some of the more active followers that are part of horizontal chains.

These differences in costs and network size can limit the ability of firms to sustain and implement a tacit collusive agreement. When firms have asymmetric cost levels, the most efficient firms gain relatively more from deviating, which raises the minimum discount factor that can sustain collusion. Similarly, network size affects firms' incentives to participate in a collusive agreement because of the lack of differentiation among locations. If firms operate networks of different sizes, when colluding on a common price, market shares are roughly proportional to the number of retail outlets. Everything else being equal, the firm holding the smallest network has the largest incentive to deviate from the agreement and increase its volume. See Appendix B for a theoretical example.

When these asymmetries are large and/or demand is very elastic, 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.

The theory literature on collusion with asymmetric firms often assumes that firms resolve the enforcement and coordination problems 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.[17]

[17] 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 (2010), 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 twenty cartel decisions of the European Commission and find that almost all of them feature either customer, geographic, and/or market share allocation.

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. In other words, players who benefit the most from collusion (e.g. high-costs) cannot use within-period market-share transfers to encourage those with better bargaining positions (e.g. low-costs) to participate.

Since firms cannot allocate market shares through quotas or exclusive territories, and assuming away the possibility of side-payments, a collusive arrangement in a homogeneous-good market must involve recurrent periods of temporary price differences during which low-cost firms are allowed to price below the collusive price. In theory, there are many ways a cartel can implement such inter-temporal transfers. For instance, low-cost firms could be allowed to hold recurrent sales. Alternatively, if market conditions change frequently à la Rotemberg and Saloner (1986), transfers could be based on a particular order of play at the moment of a price change. In retail-gasoline markets conditions fluctuate tremendously due to the volatility of wholesale prices. Observable cost measures, like the posted-rack price, provide an obvious focal point to identify the timing of transfers.[18]

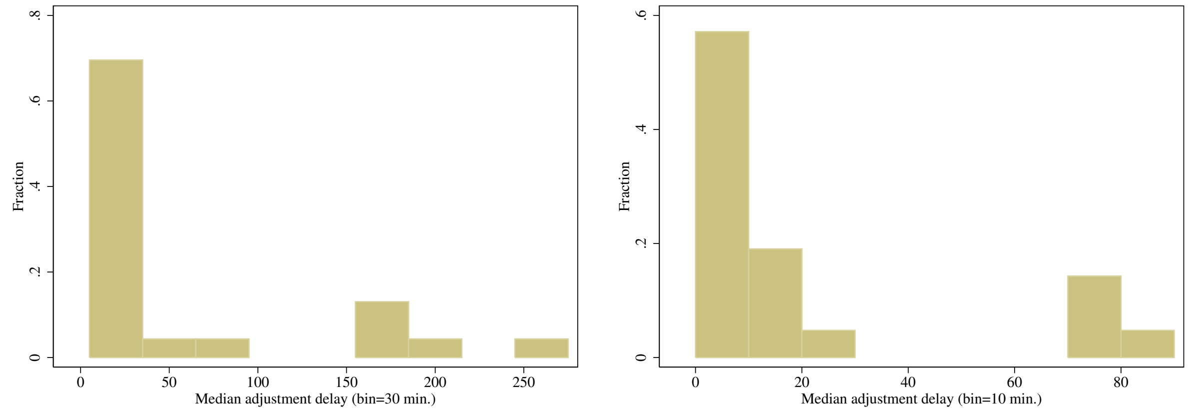
In the next two subsections we describe the particular order of play on which firms coordinate in order to implement price increases and decreases. This is the central feature of the collusive arrangement. Consistent with the theory, we show that price changes are coordinated in such a way as to provide inter-temporal transfers to stronger stations by permitting these stations to delay on price increases, and lead on price decreases. We show that the delay allowed on price increases is much longer than the lead on decreases. Since from Section 3 we know that price increases are much larger than price decreases, the transfers generated on the way up are much larger than those on on the way down.

4.1 Price increase delays

The timing schedule proposed by the leader implies a period of delay before the stronger stations raise their prices. This delay 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, responding to the owner of the EMCO station located near an Ultramar station in Thetford Mines who was informing him that he would increase only when Ultramar raised its price, the cartel leader Bilodeau says: "I know that, I'm not worried, it's always the same thing with them."[19]

[18] In Appendix B we analyze the problem of implementing market share transfers in an homogenous good market through a simple textbook tacit collusion example. Within the same framework, we also discuss the role of the price floor and competition in constraining the collusive arrangement.

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



(a) Victoriaville

(b) Thetford Mines

Figure 3: Distribution of median price adjustment delays during successful price increase episodes

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 or 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]."[20] The program most likely refers to Ultramar's LPG established in the summer of 1996, which commits it to be the lowest price in a neighborhood of each store.

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.

Figures 3a and 3b 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 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 discussed 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 5 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 dum-

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

Table 5: Regression result of adjustment delays on store and price characteristics

VARIABLES	(1) Victoriaville	(2) Thetford-Mines
Dissidents stations	146.7***	
	(38.96)	
Low-cost chains	145.4***	66.01***
	(23.86)	(9.874)
Followers stations	30.64*	13.68*
	(17.77)	(6.962)
Couche-Tard stations	16.10	-13.66***
	(24.46)	(4.372)
Distance to low-cost chains	9.026	-2.039***
	(10.64)	(0.745)
Distance to closest competitor	-14.81	-6.720***
	(16.29)	(2.180)
Proposed increase	-21.29***	-6.357***
	(3.887)	(1.974)
Current margin	-32.57***	-4.897***
	(3.215)	(1.465)
Observations	122	83
R-squared	0.614	0.523

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0. Dependent variable: Price adjustment delay in minutes. Stations in the reference group are part of the leader's network. Low-cost chains refer to Ultramar and the big-box stations.

mies 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.[21] 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 eventually agree to 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.[22] 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.

The coefficients on proposed price increases suggest a tradeoff between price differences and

[21]The actions of the two Thetford-Mines dissidents are never observed.

[22]Distances are calculated using the Euclidian distance between the latitude/longitude coordinates of stations.

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.

Lastly, the coefficients associated with current margins suggest that delays are shorter when the initial profit margins are high. This correlation is likely caused by observations from the early parts of the wire-tap period that were associated with low margins and a high level of disagreement among stations. Between January and March 2005, the Victoriaville price stayed close to the floor for several consecutive weeks, consistent with a price war episode punishing the behavior of one dissident that led to the newspaper article and the investigators' visits over Summer and Fall of 2004.[23]

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 are arranged such that all stations except Ultramar adjust overnight and then the next morning Ultramar surveys prices and increases once it had verified that all of the stations have 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 5:00 pm. 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. The next morning Ultramar surveys prices and increases once it had verified that all of the stations have gone along with the price increase.

4.2 Price decrease delays

Recall from above that Ultramar initiates twelve of the fourteen documented price decreases in Victoriaville and Thetford Mines. 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 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 probabil-

[23] 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.

Table 6: Results from regressions of the probability of being called during price decreases on store characteristics

VARIABLES	(1) Victoriaville	(2) Thetford Mines	(3) Pooled sample
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)
Nb. pumps			0.0150**
			(0.00591)
Full service			-0.138***
			(0.0446)
24 Hours			-0.473***
			(0.106)
Observations	210	84	250
R-squared	0.212	0.283	0.351

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Dependent variable: Dummy variable equal to one if station receive a warning. Low-cost chains refer to Ultramar and Big-box stations.

ity 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 price declines. Not all followers are warned of a price decline however; in the pooled sample followers are 25% 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.[24] It is interesting to note that stations associated with the group of more efficient stations (ie. 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.

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

5 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.

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, in particular to Ultramar and the Big-box retailer chains. 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".[25] 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. 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."[26]

The value of these delays is a function of consumers' responsiveness to prices. It is well documented that demand at the store level is very elastic since the stations are highly substitutable. Houde (2010) estimates this elasticity to be between -10 and -15 depending on store locations. Moreover, the short-run elasticities are likely to be higher because of the predictability of the pricing patterns. After an increase, prices tend to stay high for several weeks. If consumers are able to anticipate this pattern, they can easily save by filling up their tanks at stations that increase their prices later (see for instance Levin, Lewis, and Wolak (2009)). This form of inter-temporal substitution is known to increase the short-run purchasing price elasticity in other retail markets (see for instance Erdem, Imai, and Keane (2003) and Hendel and Nevo (2005)).

Our goal in this section is to measure the magnitude of the market share transfers associated with the observed recurrent temporary price differences. Since we observe market shares at the quarterly level, a somewhat naive approach is to measure the correlation between average market shares and the order of moves.

Table 7 presents the results of an OLS regression of the average sales volume of each store on the order of moves observed in the Competition Bureau document. We construct two measures of timing by calculating the median delay that each station was accorded during price increases, and a dummy variable equal to one if stations received a phone call warning them of an upcoming price cut more than 50% of the time. The number of observations reflects the number of stations surveyed by Kent Marketing (i.e. 25 in Victoriaville and 12 in Thetford Mines). Although these es-

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

[26] April 26th 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."

Table 7: Regression results of sales volume on station characteristics and order of play

VARIABLES	(1)	(2)
Median adjustment delay (minutes)	15.80	29.95**
	(12.83)	(11.78)
Price decrease call (dummy)	2,649**	3,882**
	(1,273)	(1,445)
Nb. pumps	632.1***	464.5**
	(151.4)	(191.7)
Dissident	15,623***	
	(2,299)	
Victoriaville	-492.4	
	(1,007)	
Streets FE		✓
Observations	27	27
R-squared	0.794	0.912

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Dependent variable: Volume per day during the second quarter of 2005.

timates cannot be interpreted as causal, they provide suggestive evidence that stations that were allowed to increase late or were warned of decreases early have larger sales volume. The second specification controls for street fixed-effects, and thus compares stations facing similar traffic volume. The first coefficient indicates that stations moving two hours after the leader sell nearly $3,600$ liters more per day, which represents 60% of the average volume. Similarly, stations that are called immediately following a price cut sell nearly $4,000$ liters more per day. Both coefficients combine the direct effect of order of play on size, and the fact that the leader tends to allocate delay and to communicate with more productive stations. In this sense, these estimates correspond to an upper bound on the value of timing.

Our second approach is to measure the short-run elasticity of demand at the station-level. For this, we use two additional data sources. First, we document an example of delayed price reactions by collecting price and traffic data at two neighboring stations in Montreal over the course of two evenings. Second, we use daily price and volume observations from a chain of stations in Québec city during a price war episode. We describe our analysis and results below. Additional details on the data and regression results can be found in Appendix C.

5.1 Ultramar experiment

We collected price and traffic data from two neighboring stations in Montreal over the course of two evenings, one of which featured a price increase of 11 cpl. More specifically, on subsequent Mondays in the Spring of 2010 (April 26th and May 3rd) we counted the number of vehicles filling up between 7 and11 pm at an Esso station and an Ultramar station on opposite sides of the street.

These stations had been observed to often increase their prices around this time early in the week and to follow price adjustment patterns similar to those in the target markets: the Esso station increases its price and the Ultramar station followed after a period of delay (around two hours).

Using the change in the observed traffic at each station before and after Esso's sudden price increase, we estimate an own-price elasticity of -10.8, and a cross-price elasticity of 7.8. These estimates imply sizable increases in demand for Ultramar. For instance, when one store increases its price by 11 cpl (from 100), its competitor receives around 117 extra vehicles by delaying its action by two hours. To get a rough idea of the increase in daily volume this represents, we assume that the average customer buys 20 liters of gasoline. If we assume that the average station sells 7000 liters of gasoline per day (see Table 2), on average stations serve 350 vehicles per day. The two hour delay would translate into a 33% increase in daily volume.

There are certain caveats with this experiment. The first is of course that we have only two stations and eight observations. The second is that it is for Montreal and not for one of the target markets. Nonetheless we think that it does provide some idea of the potential benefit of a predictable temporary price difference. Also, the fact that a similar pattern can be found in Montreal (where we would expect collusion, at least on a broad scale, to be difficult to sustain) suggests that Ultramar's low-price guarantee is an important factor in explaining the observed delay.

5.2 Québec City price war

Next we use daily volume data from a chain of gasoline stations in Québec City to quantify the volume loss associated with posting a price above the minimum market price. In 2000, Québec City experienced a city-wide gasoline price war. Starting in February 2000, the vast majority of the 285 stations posted a price equal to the floor. In December, the government investigated the market for violation of the price-floor regulation, which effectively put an end to the price war. During the investigation, the largest chain of independent stations, Eko, published daily volume records for its network of 32 stores in the region as evidence that all local markets experienced zero or negative markups for most of the period.

Using these records we find that stations posting prices between one half and two cents above the minimum-observed price sell between 11% and 25% less gasoline than their daily average volume, while stations posting prices more than two cents above the minimum lose between 35% and 47% of their daily volumes. Furthermore, stations with large capacity tend to be more affected (i.e. up to 56%).

These results are consistent with previous results found in the literature that the short-run price elasticity of demand at the station level is very large. To translate these estimates into volume losses associated with being a first mover during price increase episodes, we would need to know something about the length of time associated with the price differences observed in the Eko data-set. Assuming that the observed price differences lasted a full business day, these results suggest that afternoon-long price differences would represent nearly 25% of average daily volumes. However, since the market was experiencing a price war, it is unlikely that the price differences that we observe in Québec city lasted more than a few hours. If this is the case, we can directly translate the regression coefficients into volume losses. That is, a station increasing its price first by more than two cents, loses between 35% and 50% of its daily volume (i.e. between 1,506 and 2,152 liters in the Eko sample).

5.3 Profitability of delay

To get a sense of the value of delay, we calculate the change in sales and profits associated with the observed transfer scheme over the 2002 to 2005 period, using the estimates of short-run station-level elasticities described above. We perform these calculations assuming that each price change results in a market share transfer, and that aggregate demand is inelastic. Moreover we hold fixed total demand and its distribution using the observed distribution of quarterly sales volume in the second quarter of 2005, denoted by q_j for all stations j active during the wire-tap period.

The magnitude of market share transfers is proportional to the fraction of daily sales that firms give-up by raising their price early, or decreasing it late. Using the estimates from above, we assume that delays during price increases lead to a 50% volume decrease (i.e. 7.14% weekly), while delays during price cuts lead to a 5% volume decrease (i.e. 0.71% weekly). Since aggregate demand is inelastic, this loss in volume is automatically transferred to stations moving late during price increases and early during price decreases. To simplify the calculation we assume that Ultramar and the Big-box chains receive transfers during price increases, and that only Ultramar stations benefit from price cuts. This assumption tends to over estimate the size of volume transfers, since there is some heterogeneity in the observed timing of move within early movers. However, by assuming an inelastic demand, we are also ignoring the possible demand-expansion effect associated with price changes, which would under-estimate transfers.

Using these assumptions, we sort stations in three groups: Ultramar, Big-box, and Others. To evaluate the total profit of each station, we calculate for each week between 2002 and 2005 the total fraction of sales given up by stations moving early during price increases, and the implied revenue increase for stations moving late (and vice-versa for price decreases). We further assume that the total transfer is split between Ultramar/Big-box stations according to their fixed market shares. Notice, that the value of this transfer is a function of the current and lagged price levels, and the current common cost level c_t.

The following equation formalizes this calculation:

$$\Pi_j(\alpha) = \begin{cases} \sum_{t=1}^{T}(p_t - c_t)q_j\left(1-\alpha_t\right) + (p_{t-1}-c_t)\omega_{jt}\left(\sum_{k\in J_t}\alpha_t q_k\right) & \text{If } j \in \text{Ultramar or Big-Box} \\ \sum_{t=1}^{T}(p_t - c_t)q_j\left(1-\alpha_t\right) & \text{If } j \in \text{Other} \end{cases}$$

Table 8: Estimated change in volume and profits associated with the observed transfer scheme

Markets	Freq. Increase / Decrease (%)	Players	Volume differences × 1000 L.	%	Profit differences × 1000 $	%
Sherbrooke	23/42	Ultramar	250.72	3.21	5.58	1.02
		Big-Box	118.62	2.34	0.05	0.01
		Others	-137.33	-1.95	-14.11	-2.84
Thetford Mines	18/35	Ultramar	141.16	3.24	2.70	0.86
		Others	-69.35	-1.53	-7.94	-2.43
Victoriaville	16/27	Ultramar	350.94	4.85	15.10	2.90
		Big-Box	588.14	2.87	5.78	0.39
		Others	-90.41	-1.34	-11.38	-2.34

where α_t, the fraction of volume lost, is equal to 0.0714 during increases and 0.00714 during decreases, J_t denotes the set of firms providing the transfer in week t (i.e. J_t is empty if $p_t = p_{t-1}$), and ω_{jt} is the share of the transfer allocated to station j (i.e. $\omega_{jt} = q_j / \sum_{k \notin J_t} q_k$). We perform a similar calculation to quantify the total sales volume over the same period. To evaluate the gain/loss in profit and sales we perform a similar calculation setting $\alpha_t = 0$ for all t. This eliminates the transfers, but holds fixed the observed pricing patterns.

Table 8 presents the results. Note that the numbers are aggregated at the station level, and therefore the estimated transfers do not reflect heterogeneity in network size. The differences across markets reflect both heterogeneity in market structure (e.g. market share of Ultramar stations), as well as differences in the frequency and magnitude of price changes. Our estimates of the transfers correspond to an increase of between 3.2% and 4.85% in total volume over three years for Ultramar, and about 2.5% for the Big-box retailers. In comparison, the average station moving early during price increases gives up less than 2% of total volume.

The increases in profits are smaller than the percentage increases in sales since late movers earn relatively lower margins during price increase periods. The reason is that price increases are triggered by cost increase and so late movers are being transferred increased volume, but at relatively low margins. The value of these transfers for Ultramar is between $\$3,000$ and $\$15,000$ per station over three years. However, this calculation ignores differences in cost across stations, and the indirect benefits associated with an increase in sales, such as volume discounts or profits from complementary products. In that sense, the profit differences correspond to a lower bound in the actual profit gains.

It is important to note that the length of the delay and therefore the size of the transfer is influenced by two features of the economic environment. First, the floor that is in place in Québec may lessen the impact of cost asymmetries by reducing the incentive of stronger retailers to deviate, which decreases the size of the transfers necessary to sustain collusion. Of course, it is also the case that by making punishments less severe, all but the lowest-cost stations with marginal costs below the regulated price-floor are more likely to deviate from the collusive agreement.

Second, the large number of heterogenous competitors constrains the size of transfers. The leader of the cartel may agree to a transfer of a certain size, but this could violate the incentive constraints of stronger followers that move early. For instance, we observe a few instances in Sherbrooke and Victoriaville where proposed price increases failed to be implemented. This breakdown is very often the result of long delay on the part of dissidents. In these cases, some of the cartel members, most often Couche-Tard, will decide that the delay being accorded is too long and will lower their prices. Couche-Tard is a convenience-store chain for which the volume losses associated with excessive delays are relatively more costly than for other cartel members. In Appendix B we provide a theoretical example that rationalizes this behavior, and shows that the presence of a strong competitor among firms issuing transfers can limit the length of delays.

6 Conclusion and discussion

Our analysis of the functioning of four retail 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 temporary price differences can be used to sustain collusion. In this section we conclude the paper by discussing the role of coordination costs in shaping the collusive agreement, and the implications of our results for the detection of collusion in other markets.

6.1 The role of coordination costs

The transfer mechanism that we described implements transfers based on adjustment delays, and operates mainly during price increases. This creates large temporary price differences, which lead to significant volume gains for late movers.

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 between the stations: even small price differences induce sizable 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).

Our analysis of the phone conversations suggests 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.[27] To implement transfers through delays, the cartel must therefore invest in significant monitoring and communication efforts to increase the probability of detecting laggers. This is costly, both in terms of time, and because explicit communication increases the risk of being caught by antitrust authorities.

Ultramar's LPG policy is helpful in this respect. This role is consistent with the theory literature initiated by Salop (1986) that associates price-matching policies with facilitating practices. While these papers focus 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 Fisher (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 (due to the volatility of costs), which would translate into more frequent delays, and possibly higher coordination costs.

6.2 Policy implications

When trying to identify collusive behavior antitrust authorities often seek evidence of: (i) parallel price changes, and (ii) stable profit margins. Both behaviors are clearly not on display here, despite the fact that these firms appear to have been explicitly colluding: markups are highly volatile, and firms move sequentially in a fixed and pre-determined order. 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.

The pricing patterns we document in the collusive markets are also present in a large number of other retail gasoline markets throughout Québec. In Figure 4, we illustrate this point by plotting the joint density of margins and the price adjustment ratio.[28] Recall that the adjustment ratio is about three in the collusive markets, and that median margins are seven cents. Looking along

[27] 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.

[28] The figure is constructed using the Régie price survey, and includes 128 stations located in all regions of the Province and observed between 2002 and 2006. The adjustment ratio is calculated as the median increases over decreases adjusted for the ratio of median cost changes.

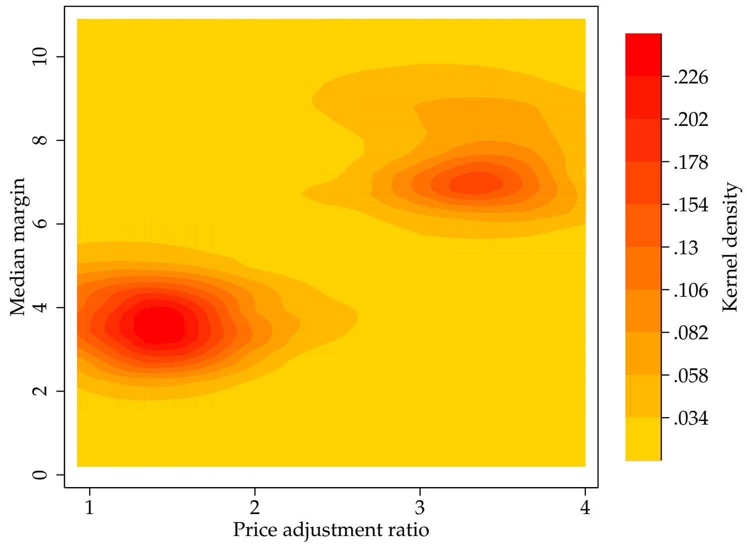


Figure 4: Joint density of price adjustment ratio and margins in Québec between 2002 and 2005

the horizontal axis it is clear that the distribution of adjustment ratios is bi-modal: about 30% of stations surveyed exhibit asymmetries equal to or greater than the cartels, while the remaining group adjust their prices more symmetrically. The same is true for margins, and the figure suggests a strong positive association between the two variables.

Similar pricing patterns have also been documented by researchers in other gasoline markets, but have mostly been rationalized by the non-cooperative model of Maskin and Tirole (1988) (see in particular Eckert (2002) and Noel (2007)). According to this model cycles emerge because of a market friction that forces players to move sequentially. In one equilibrium, firms repeatedly under-cut each other in order to gain market share until margins are close to zero, at which point they randomly choose to restart the cycle by raising their price.

Not only do we observe firms explicitly coordinating their actions, some key predictions of the Maskin-Tirole model do not hold. In particular, the identities of the firms increasing and decreasing prices are invariant and known to all, suggesting that firms are not alternatively undercutting each other. We also do not find any evidence to support the type of menu costs or information lags that are necessary to generate the alternative move structure that is at the heart of the Maskin-Tirole model. Instead, while firms do move sequentially, information about price changes is easily transmitted, and the time lag between gasoline price changes is an outcome of the collusive agreement rather than the result of a market friction. Other researchers studying price cycles have also documented the fact that the identity of the firms restarting the cycle is often invariant (see Wang (2009) and Lewis (2010)), suggesting that ours may not be the only markets where price adjustments are explicitly coordinated.

In a companion paper, Clark and Houde (2011), we provide empirical evidence that the high margins and asymmetric adjustments documented here can be linked with collusion. We show that both the degree of price asymmetry and the level of margins decreased substantially in the four cartel cities after the collapse of the cartels, triggered by the execution of the search warrants (see also Erutku and Hildebrand (2010)). In addition, we find that the group of stations in the upper-right quadrant of Figure 4 (i.e. high margins and asymmetric pricing), also reacted to the announcement by posting lower prices and reducing the importance of asymmetries (relative to stations in the lower-left quadrant).

References

Asker, J. (2010). A study of the internal organization of a bidding cartel. *American Economic Review 100*(3), 724–762.

Athey, S. and K. Bagwell (2001, Autumn). Optimal collusion with private information. *RAND Journal of Economics 32*(3), 428–465.

Blanchard, O. and S. Fisher (1989). *Lectures on macroeconomics*. MIT Press.

Borenstein, S., A. C. Cameron, and R. Gilbert (1997, Feb.). Do gasoline prices respond asymmetrically to crude oil price changes? *The Quarterly Journal of Economics 112*(1), 305–339.

Carranza, J. E., C. Clark, and J.-F. Houde (2009, April). Price controls and competition in gasoline retail markets. Working paper, University of Wisconsin-Madison.

Clark, C. R. and J.-F. Houde (2011). The effect of explicit communication on pricing: Evidence from a gasoline price-fixing case.

Connor, J. (2001). *Global Price Fixing: Our Customers are the Enemy*. Kluwer Academic Publishers.

Eckert, A. (2002). Retail price cycles and response asymmetry. *Canadian Journal of Economics 35*(52-77).

Erdem, T., S. Imai, and M. P. Keane (2003). Brand and quantity choice dynamics under price uncertainty. *Quantitative Marketing and Economics 1*, 5–64.

Erutku, C. and V. Hildebrand (2010). Conspiracy at the pump. *Journal of Law & Economics 53*.

Genesove, D. and W. P. Mullin (2001, Jun.). Rules, communication, and collusion: Narrative evidence from the sugar institute case. *American Economic Review 91*(3), 379–398.

Graham, D. A. and R. C. Marshall (1987). Collusive bidder behavior at single-object second-price and english auctions. *The Journal of Political Economy 95*(6), 1217–1239.

Harrington, J. (1991). The determination of price and output quotas in a heterogeneous cartel. *International Economic Review 32*, 767–792.

Harrington, J. and A. Skrzypacz (2010). Private monitoring and communication in cartels: Explaining recent collusive practices. *American Economic Review (Forthcoming)*.

Hendel, I. and A. Nevo (2005). Measuring the implications of sales and consumer stockpiling behavior. forthcoming, Econometrica.

Houde, J.-F. (2010, November). Spatial differentiation and vertical mergers in retail markets for gasoline. working paper, University of Wisconsin-Madison.

Jacquemin, A. and M. Slade (1989). Cartels, collusion, and horizontal merger. In R. Schmalensee and R. Willig (Eds.), *Handbook of Industrial Organization*, Volume 1, Chapter 7, pp. 415–473. North Holland and Co.

Levenstein, M. and V. Y. Suslow (2006). What determines cartel success? *Journal of Economic Literature 44*.

Levin, L., M. Lewis, and F. Wolak (2009). High frequency evidence on the demand for gasoline. working paper, Ohio State University.

Lewis, M. (2010). Price leadership and coordination in retail gasoline markets with price cycles. working paper, Ohio State University.

Lewis, M. (2011, July). Odd prices at retail gasoline stations: Focal point pricing and tacit collusion. working paper, Ohio State University.

Marshall, R. C. and L. Marx (2008). Explicit collusion and market share allocations. Fuqua School of Business, Duke University.

Maskin, E. and J. Tirole (1988). A theory of dynamic oligopoly, ii: Price competition, kinked demand curves, and edgeworth cycles. *Econometrica: Journal of the Econometric Society 56*(3), 571–599.

Noel, M. (2007). Edgeworth price cycles, cost-based pricing and sticky pricing in retail gasoline retail markets. *Review of Economics and Statistics 89*(2), 324–334.

Pesendorfer, M. (2000, Jul.). A study of collusion in first-price auctions. *Review of Economic Studies 67*(3), 381–411.

Porter, R. H. (1983, Autumn). A study of cartel stability: The joint executive committee, 1880-1886. *The Bell Journal of Economics 14*(2), 301–314.

Porter, R. H. and J. D. Zona (1993, Jun.). Detection of bid rigging in procurement auctions. *Journal of Political Economy 101*(3), 518–538.

Roller, L.-H. and F. Steen (2006). On the workings of a cartel: Evidence from the norwegian cement industry. *American Economic Review 96*(1), 321–338.

Rotemberg, J. J. and G. Saloner (1986, Jun.). A supergame-theoretic model of price wars during booms. *The American Economic Review 76*(3), 390–407.

Salop, S. C. (1986). Practices that (credibly) facilitate oligopoly co-ordination. In J. Stiglitz and F. Mathewson (Eds.), *New developments in the analysis of market structure*, pp. 265–291.

Scott-Morton, F. (1997). Entry and predation: British shipping cartels 1879-1929. *Journal of Economics and Management Strategy 6*(4), 499–516.

Slade, M. (1987). Interfirm rivalry in a repeated game: An empirical test of tacit collusion. *Journal of Industrial Economics 35*, 499–516.

Slade, M. E. (1992). Vancouver's gasoline-price wars: An empirical exercise in uncovering supergame strategies. *The Review of Economic Studies 59*(2), 257–276.

Wang, Z. (2008). Collusive communication and pricing coordination in a retail gasoline market. *Review of Industrial Organization 32*(1), 35–52.

Wang, Z. (2009). (mixed) strategy in oligopoly pricing: Evidence from gasoline price cycles before and under a timing regulation. *Journal of Political Economy 117*(6).

A Competition Bureau document appendix

As mentioned in the text, our understanding of the facts with respect to the allegations of the Competition Bureau is based on the documents submitted by the Competition Bureau to the Superior Court. The wire taps 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. In this Appendix we describe in further detail the content of the Annexes along with the sequence of price changes that we uncover from the court documents.

For each price adjustment attempt that is documented the Competition Bureau documents list the phone calls along with an extract or a summary of the individual conversations (including information about who made the call, who received the call, and the time of the call). For example, pages 27 and 41 of Annex A represent a typical entry for a price adjustment attempt. The annex makes reference to a 4 cent per liter price increase attempt on April 6th 2005 in Victoriaville. The Competition Bureau explains that the increase was initiated by two players and that twenty-three gas stations were involved. The annex lists these stations, and then summarizes eighty-eight telephone conversations which took place between 6:44 am and 3:42 pm. The summaries explain that the price increase was to take place at 9:15 am. Finally, in the annex the bureau concludes that according to observations in the field, the agreement had been executed. Figure 5 provides an example of the type of information contained in the conversations. The example comes from an entry for the price increase attempt in Victoriaville on April 6th 2005.

Table 9a describes the price increases that occurred in Thetford Mines and Victoriaville during the period. The table presents information from the court documents on the initial price, the target price, and the price following the adjustment, along with information on whether the adjustment was successful (in the sense that all cartel members had adjusted their price by the end of the attempt). In Thetford Mines there were five price increase attempts during this period, all of which were successful. In Victoriaville there were six successful price increase attempts. In Sherbrooke/Magog, there were seventeen price increase attempts during the two wire tap periods, of which twelve were at least partially successful (we denote partial success by P). Table 9b describes these price increases.

Table 10 describes the periods between coordinated price increases in Victoriaville and Thetford Mines. In between the large price increases that occur there are typically a series of small price decreases (1 to 2 cents) along with periods of stability (of between 5 and 9 days). In Victoriaville there are three such periods during the wire-tap, while in Thetford Mines there are two. There are no entries describing coordinated price decreases in the Competition Bureau documents (although in the entries for two price increases, the price decreases that preceded them are discussed).

B A model of tacit collusion with asymmetric retailers

Consider a market with 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. 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_H. This leads to different incentive constraints, which increases the minimum discount factor that can sustain collusion. The two following equations illustrate the difference in the incentive constraints when punishments are infinite:

$$\text{IC}^H : \frac{D(\bar{p})(\bar{p}-c)}{2(1-\delta)} \geq D(p_j^d)(p_H^d - c),$$

$$\text{IC}^L : \frac{D(\bar{p})\bar{p}}{2(1-\delta)} \geq D(p_j^d)p_L^d + \delta\frac{D(c)}{1-\delta},$$

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

Similarly, network size affects firms' incentives to participate in a collusive agreement because of the lack of differentiation between locations. If firms have common costs, but operate networks of different sizes, when colluding on a common price, market shares are roughly proportional to the number of retail

Figure 5: Wire-tap conversation: Victoriaville April 6 2005

Annexe 2 : Le 6 avril 2005 à Victoriaville

à 8h43 :	André Bilodeau laisse un message à Céline Bonin demandant de le rappeler.
à 8h50 :	André Bilodeau laisse un message à France Benoit ***(Les Pétroles Therrien Inc.)*** demandant de le rappeler le plus tôt possible.
à 8h52 :	André Bilodeau téléphone à Jean-Yves Plourde (Olco) et lui dit "98.9, 9h15". André Bilodeau lui demande de téléphoner à la station-service Crevier (Dépanneur du Rond-Point Victoriaville). Jean-Yves Plourde répond : "o.k.".
à 8h53 :	André Bilodeau appelle la station-service de Tomas Fréchette et indique au préposé : 98.9¢ à 9h15. Ce dernier répond qu'il va s'en occuper.
à 8h53 :	Jean-Yves Plourde (Olco) appelle la station-service Crevier et indique à l'employé que c'est Jean-Yves Plourde et que le prix de l'essence sera à 98.9¢, à 9h15. L'employée répond que c'est bien beau et qu'elle va augmenter le prix en conséquence.
à 8h54 :	André Bilodeau téléphone à Daniel Drouin (Sonerco). Ce dernier demande si tout le monde est prêt. André Bilodeau répond oui. Daniel Drouin répond : o.k. c'est beau. Et ajoute qu'il va faire ses tournées.
à 8h56 :	André Bilodeau appelle Martin Fréchette (Coopérative Agricole des Bois-Francs) et lui dit : « ... on s'en va à 98.9¢ à 9h15...tu vas t'en occuper? » Martin Fréchette répond oui.
à 8h57 :	André Bilodeau dit à Marc Létourneau (Sonerco) à 9h15, 98.9¢. Marc Létourneau (Sonerco) répond o.k. André Bilodeau ajoute qu'il n'est pas obligé de contacter les Paul Ouellette, Lyne Caouette et Manon Brasseur car Daniel Drouin(Sonerco) lui a dit qu'il s'en occuperait.
à 9h00:	Céline Bonin (Couche-Tard) téléphone à André Bilodeau. Ce dernier lui dit de changer le prix à 9h15, pour 98.9¢, ce à quoi elle acquiesce. Céline Bonin demande pour combien de temps. André Bilodeau répond qu'ils vont immédiatement voir si cela fonctionnera.
à 9h10 :	Marc Létourneau (Sonerco) téléphone à la station-service de Paul Ouellette (Sonerco) et instruit la préposée d'augmenter le prix de l'essence à 98.9¢, à 9h30. Elle répond que c'est déjà fait.
à 9 h10 :	Marc Létourneau (Sonerco) appelle Ghislain Lallier (Esso) pour l'aviser que le prix de l'essence avait changé à 98.9¢.

outlets. Everything else being equal, the firm with the smallest network (e.g. $n_H > n_L = 1$) has the largest incentive to deviate from the agreement and increase their volume:

$$\text{IC}^H : \frac{n_h D(\bar{p})\bar{p}}{(1+n_H)(1-\delta)} \geq D(p^d)p_H^d,$$
$$\text{IC}^L : \frac{D(\bar{p})\bar{p}}{(1+n_H)(1-\delta)} \geq D(p^d)p_L^d.$$

That is, the firm with the smallest network can capture the whole market by deviating, but receives only a share $1/(n_H+1)$ when it cooperates.

B.1 Temporary price differences as transfers

In Table 11a we provide a numerical example illustrating an inter-temporal transfer scheme based on temporary price differences in a market with heterogeneous costs: Firms agree on setting a common price $\bar{p}$, and on allowing the low-cost firm to hold a sale at price $p^d < \bar{p}$ every $T+1$ periods. This strategy implies that the high-cost firm agrees to give-up one period of sales every cycle. When negotiating the agreement, firms face a tradeoff between colluding on a higher price, and increasing the frequency of sales. We use a Nash bargaining solution in which firms' threat points are determined by the value of deviating to solve this tradeoff.

Table 9: Price increases

(a) Thetford Mines and Victoriaville

Date	Before	Target	After	Calls	Success
			Thetford Mines		
8-Mar	86.4	94.4	94.4	30	yes
6-Apr	94.4	98.4	98.4	52	yes
26-Apr	93.4	99.4	99.4	24	yes
3-Jun	92.4	97.4	97.4	41	yes
22-Jun	97.4	99.4	99.4	32	yes
			Victoriaville		
4-Mar	83.9	85.9	85.9	7	no
8-Mar	85.9	94.9	86.9	25	no
15-Mar	86.7	89.9	89.9	28	yes
30-Mar	89.9	94.9	94.9	89	yes
6-Apr	94.9	98.9	98.9	88	yes
26-Apr	94.9	99.9	99.9	70	yes
3-Jun	89.9	97.9	96.9	84	yes
22-Jun	94.9	99.9	94.9	69	no
23-Jun	94.9	99.9	99.9	85	yes

(b) Sherbrooke and Magog

Date	Before	Target	After	Calls	Success
21-Apr	93.4		96.4	6	yes
27-May	91.4	95.4	91.4	87	no
1-Jun	91.4	96.9	91.4	57	no
3-Jun	91.4	97.4	91.4	8	no
7-Jun	91.4	98.4	98.4	30	yes
15-Jun	91.4	99.4	97.4	56	yes
21-Jun	97.4	99.9	97.4	12	no
27-Jun	97.4	102.4	99.4	33	yes
16-Aug	106.4		110.4	n/a	P
6-Dec	92.4		96.4	n/a	P
4-Jan	98.4	104.4	104.4	23	yes
22-Jan	92	96.9	96.4	42	yes
10-Mar	96.4	99.4	99.4	99	yes
15-Mar	99.4	107.4	107.4	92	yes
31-Mar		110.4	110.4	74	yes
12-Apr	108.4	113.4	113.3	73	yes
18-Apr		115.4	115.4	32	n/a

The middle columns illustrate the changes in the collusive arrangements as the cost asymmetry increases. With small asymmetries (i.e. $c = 0.1$), collusion is feasible without transfers. However, since firms disagree on the optimal collusive price, the high-cost firm is willing to transfer market shares to its opponent every 3 periods in order to collude on a higher price, relative to the collusive price without transfers. With larger asymmetries, the agreements involve both higher prices and shorter cycles. In the last two rows, the asymmetries are too large to sustain collusion even with transfers.

B.2 The role of the price floor and competition

A second constraint on collusion that becomes relevant in our context is the presence of the price-floor regulation that exists in the Province. In general, price floor regulations can have two competing effects when binding in the punishment phase: (i) to raise the punishment revenues, and (ii) to reduce the market shares of the most efficient stores. The overall effect on collusion is thus ambiguous, and depends on the source of heterogeneity between firms.

When firms have symmetric costs, the market share effect is not present, and a binding floor simply reduces the severity of the punishments. Similarly, high-cost firms strictly benefit from a price floor policy, since their value of deviating is increased.

When cost asymmetries are present, a binding price floor can reduce the value of deviating for the low-cost firm. For instance, consider the previous example in which a price floor, like in the Québec case, is set to protect the least efficient store: $p_f = c + \mu$. In this case, for small values of μ, the value of deviating for type L is nearly cut in half:

$$\lim_{\mu \to 0^+} V_L^d(\mu) = D(p_L^d)p_L^d + \delta \frac{D(c)c}{2(1-\delta)} > D(p_L^d)p_L^d + \delta \frac{D(c)c}{(1-\delta)} = V_L^d(\mu = 0).$$

Therefore, for a moderately small price floor that is larger than or equal to the high-cost marginal cost, collusion is easier to sustain since the floor eliminates cost asymmetries in the punishment phase. This is not the case when asymmetries are solely in terms of network size, in which case a price floor strictly reduces the likelihood of collusion.

The last three columns of Table 11a illustrate the impact of the price floor on the collusive agreement when cost asymmetries are present. As the last column shows, a market with a floor can sustain collusion

Table 10: Price decrease periods – Victoriaville and Thetford Mines

Period	**Numb Decreases**	**Avr size**	**Days Between Decreases**	**Numb calls**
Victoriaville				
April 6 - April 26	3	1.3 cents	5	26
April 26 - June 3	6	1.6 cents	5.4	36
June 3 - June 22	1	2 cents	9.5	25
Thetford Mines				
April 6 - April 26	2	2.5 cents	6.7 days	18.5
April 26 - June 3	4	1.75 cents	7.6 days	13.5

without transfer for a larger range of asymmetries (i.e. up to 0.3 in the example). The relative bargaining position of the two firms also changes because V_L^d is lowered. In the first three cases this means either a higher collusive price, and/or a longer cycle length (i.e. smaller transfers). For large asymmetries, the length of the cycles can implement equilibria that would not be feasible with a constant price, or without the price floor regulation. In the last two examples, firms agree on high prices and frequent periods of sales (i.e. every two periods).

The next two examples in Table 11b consider a similar situation, but add a third competitor with marginal cost $c_M \leq c$. Intuitively, when the number of firms making transfers increases, the cost of allowing frequent sales can be large enough to violate the incentive constraint of the intermediate competitor(s). For competition to constrain the frequency of transfers in this way, the third competitor must be relatively more efficient than the high-cost firm.

In the middle columns, we add a competitor that has the same cost structure as the high-cost firm. In this case, the participation constraint of this middle firm is irrelevant, and adding the third firm tends to decrease the value of deviation and facilitate collusion. Next, we consider an example in which the middle competitor is more efficient (i.e. $c_H > c_M = 0.1$). In this case, adding the third competitor changes the nature of the agreement if its participation constraint binds. In our example, this occurs for intermediate and large cost asymmetries. For $c = 0.25$ the presence of the third firm constrains the frequency of transfers to be larger than 2, which leads to a lower equilibrium price. When we increase the cost asymmetries, the length of the cycles is further increased, and the equilibrium price is actually decreasing in c.

C Value of delay

In this appendix we provide further information on the data and empirical approach used to measure the value of delay.

C.1 Ultramar experiment

On April 26th the Esso station increased its price by 11 cpl at 9 pm. The Ultramar station only adjusted its price just before 11 pm, and so between 9 and 11 pm there was an 11 cpl difference between the two

Table 11: Equilibrium collusive agreements for different levels of cost asymmetries and market structure

(a) Duopoly example

Asymmetry Largest c	Monopoly price (max)	No Price floor $\bar{p}$	No Price floor T	No Price floor Enforceable	Price floor = c $\bar{p}$	Price floor = c T	Price floor = c Enforceable
0.1	0.55	0.526	2	1	0.527	4	1
0.15	0.575	0.542	1	0	0.542	3	1
0.2	0.6	0.538	1	0	0.56	2	1
0.3	0.65	.NaN	.NaN	0	0.607	1	0
0.4	0.7	.NaN	.NaN	0	0.646	1	0

(b) Three firms example

Asymmetry Largest c	Monopoly price (max)	Inefficient competitor $\bar{p}$	Inefficient competitor T	Inefficient competitor Enforceable	Efficient competitor ($c_m = 0.1$) $\bar{p}$	Efficient competitor ($c_m = 0.1$) T	Efficient competitor ($c_m = 0.1$) Enforceable
0.2	0.6	0.569	2	1	0.569	2	1
0.25	0.625	0.601	1	0	0.586	2	0
0.3	0.65	0.622	1	0	0.592	3	0
0.35	0.675	0.644	1	0	0.582	6	0
0.4	0.7	0.668	1	0	0.563	12	0

Each $\bar{p}$ and T entries are the outcomes of the Nash bargaining game between the lowest and highest cost firm, subject to the agreement being enforceable by all firms. The maximum monopoly price is the monopoly price of the highest cost firm. *Enforceable* is a dummy variable indicating whether or not collusion is feasible at the lowest monopoly price without transfers. The discount factor is set to 0.98 and the lowest marginal cost is equal to 0. Entries with .NaN are not enforceable for any cycle length or prices. In the three-firm case, we assume that the high-cost and low-cost firms negotiate the agreement among themselves, subject to an enforceability constraint that must be satisfied for all three firms. In the *Inefficient competitor* example, the marginal cost of the middle firm is equal to c. In the *Efficient competitor* example, the marginal cost of the middle firm is constant and equal to 0.1. All examples assume a linear demand function: $D(p) = 1 - \min\{p_L, p_H\}$.

prices. On May 3rd there was no price increase at all and so we can use this evening's traffic volume to provide us with information about what demand on a typical Monday evening looks like. Details on the price adjustment and the traffic flows are provided in Table 12

We estimate the following relationship between vehicle traffic (Q_{iht}) and own and rival prices (P_{iht} and P_{-iht} respectively):

$$\log Q_{iht} = \underset{(11.199)}{18.399} \times \alpha + \underset{(1.269)}{-10.824} \times \log P_{iht} + \underset{(1.269)}{7.813} \times \log P_{-iht} + \mu_i + \theta_h + \tau_t + \epsilon_{iht}. \quad (1)$$

The econometric specification includes station fixed effects μ_i, hour fixed effects θ_h, and date fixed effects τ_t.

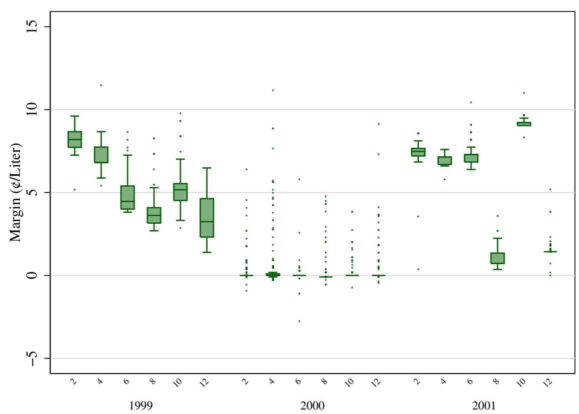
The estimated own-price elasticity is -10.8, while the cross-price elasticity is 7.8. Using these results we can calculate a back-of-the envelope estimate of the extra volume gained by Ultramar from being the low-price option for two hours when Esso has increased its price. To do so we compare the volume for each firm when they set the same price (we suppose 100 cpl), to the volume when one of them sets 11 cpl more than the other (as occurred on April 26th, 2010). We find that when both set 100 cpl traffic is 93.36 vehicles during a two-hour period. If instead we suppose that one firm sets 111 cpl while their rival sets 100, traffic is 210.78 and 30.14 at the low- and high-price stations respectively. In other words, in this case the benefit to setting a price 11 cpl below a rival's price is an increase in traffic of around 117 vehicles.

Table 12: Asymmetric price adjustment experiment

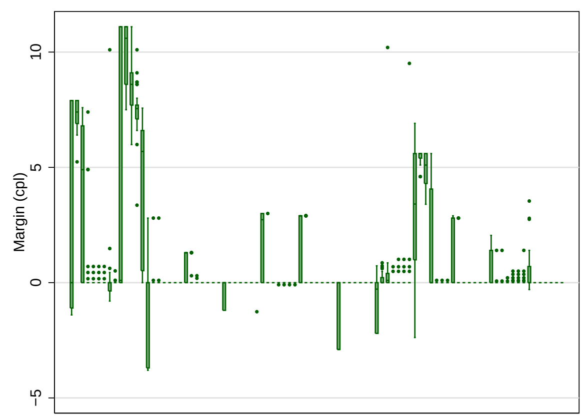
		26-Apr		3-May	
		7-9 pm	9-11 pm	7-9 pm	9-11 pm
Ultramar	Price	102.4	102.4	104.9	104.9
	Nmb vehicles	92	134	87	65
Esso	Price	102.4	113.4	104.9	104.9
	Nmb vehicles	82	20	99	64

Figure 6: Distribution of margins relative to the price floor in Québec City from 1999 to 2000

(a) Bi-Monthly margins among all stations



(b) Daily margins among Eko stations between September and December 2000



C.2 Québec City price war

In 2000, Québec City experienced a city-wide gasoline price war. Figure 6a illustrates the distribution of prices in Québec every two months between 1999 and 2001. Starting in February 2000, the vast majority of 285 stations posted a price equal to the floor. In December, the government investigated the market for violation of the price-floor regulation, which effectively put an end to the price war. During the investigation, the largest chain of independent stations, Eko, presented daily volume records for its network of 32 stores in the region as evidence that all local markets experienced zero or negative markups for most of the period. This data-set includes sales volume and prices for every Eko station on 90 consecutive days between September and December 2000. We matched the location of these stations with data from Kent Marketing to measure their characteristics.

Table 13 summarizes the prices, volumes, and sizes of the Eko stations, and Figure 6b illustrates the distribution of retail margins per day. On average, Eko stations tend to be smaller than those in the four cartel cities. Notice also that for most of the periods, the data exhibit zero close to price dispersion. However, nearly 20% of the posted price observations are higher than the minimum Eko price on a given day. Our objective is to use episodes during which stores priced above this minimum to measure the loss of sales associated pricing above the market price. This exercise is of course subject to the caveat that we do not observe the prices and volumes of other stations in the city. However, since the whole market exhibited very little price dispersion due to the ongoing price war, it is safe to assume most other stations in the city were setting a price equal to the minimum Eko price that we observe.

Table 13: Descriptive statistics on Eko stations in Québec City between Aug. and Dec. 2000

VARIABLES	Mean	Std-Dev.
Total volume (day/liters)	4304	2560
Unleaded price (cpl)	75.3	2.86
Dispersion: $P_j - \min(P_j)$	0.644	1.63
$D^2 : 0 < P_j - \min(P_j) \leq 2$	0.083	0.276
$D^{2+} : P_j - \min(P_j) \geq 2$	0.117	0.321
Nb. Pumps	5.41	2.55
Islands	1.52	.933

Table 14: The effect of temporary price differences on daily sales volume

VARIABLES	(1) Day FE	(2) Week FE	(3) Day FE	(4) Week FE
$1(0 < P_j - \min(P_j) \leq 2)$	-0.111***	-0.259***	-0.0995***	-0.249***
	(0.0293)	(0.0273)	(0.0330)	(0.0327)
$1(P_j - \min(P_j) \geq 2)$	-0.358***	-0.468***	-0.309***	-0.421***
	(0.0271)	(0.0244)	(0.0301)	(0.0288)
$1(0 < P_j - \min(P_j) \leq 2)$ X Large stations			-0.0334	-0.0314
			(0.0442)	(0.0534)
$1(P_j - \min(P_j) \geq 2)$ X Large stations			-0.144***	-0.140***
			(0.0375)	(0.0449)
Observations	2,639	2,639	2,639	2,639
R-squared	0.447	0.199	0.450	0.202
Number of ekoid	29	29	29	29

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

More specifically, we estimate the following linear regression model:

$$\log Q_{it} = \alpha_1 D_{it}^2 + \alpha_2 D_{it}^{2+} + \mu_i + \tau_t + u_{it}, \tag{2}$$

where D_{it}^2 is an indicator variable equal to one if store i was posting a price within $1/2$ cent and 2 cents per liter above the minimum price, and D_{it}^{2+} is an indicator variable equal to one for price differences larger than 2 cents per liter. The econometric specification includes station fixed effects μ_i, and period fixed-effects τ_t. We estimate two versions of the model in which we control for week or day fixed-effects. In the first specification, sales volume for a high-price station is compared to the average sales during the corresponding week, while in the second specification we are comparing the volume of high-price stations to the distribution of sales volume in the market within the same day. The former measures strictly the substitution across locations, while the latter allows for inter-temporal effects due to the fact that consumers can massively fill-up their thanks when price differences are important (i.e. future demand can can be lower).

Table 14 summarizes the regression results. Stations posting prices between one half and two cents above the minimum-observed price sell between 11% and 25% less gasoline than their daily average volume, while stations posting prices more than two cents above the minimum lose between 35% and 47% of their daily volumes. Furthermore, stations with large capacity tend to be more affected (i.e. up to 56%).