**University of Alberta**

# Three Studies of Retail Gasoline Pricing Dynamics


by

Benjamin James Atkinson


A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy


Department of Economics


Edmonton, Alberta
Fall 2007

*Your file Votre référence*
*ISBN: 978-0-494-32911-5*
*Our file Notre référence*
*ISBN: 978-0-494-32911-5*

## Abstract

In many Canadian cities, retail gasoline prices appear to cycle, rising by large amounts in one or two days followed by several days of small consecutive price decreases. While many empirical studies examine such markets, certain questions cannot be properly answered without high frequency, station-specific price data for an entire market.

Thus, the first paper in this thesis uses bi-hourly price data collected for 27 stations in Guelph, Ontario, eight times per day for 103 days to examine several basic predictions of the Edgeworth cycle theory. The results are largely consistent with this theory. However, most independent firms do not tend to undercut their rivals' prices, contrary to previous findings. Furthermore, the timing, sizes and leaders of price increases appear to be very predictable, and a specific pattern of price movements has been detected on days when prices increase. These findings suggest that leading a price increase might not be as risky as one may expect.

The second paper uses these same data to examine the implications of an informal theory of competitive gasoline pricing, as advanced by industry and government. Consistent with this theory, stations do tend to set prices to match (or set a small positive or negative differential with) a small number of other stations, which are not necessarily the closest stations. Also, while retailers frequently respond to price changes within two hours, many take considerably longer to respond than is predicted by the theory. Finally, while price decreases do ripple across the market like falling dominos, increases appear to propagate based more on geographic location and source of price control than proximity to the leaders.

The third paper uses both these data and Guelph price data collected every 12 hours during the same 103 days from OntarioGasPrices.com to examine the sample selection biases that might exist in such Internet price data, as well as their implications for empirical research.

It is found that the Internet data tend to accurately identify features of cycles that can be distinguished using company-operated, major brand station prices, while features that require individual independent station data or very high frequency data might not be well-identified.

## Acknowledgements

I want to thank my supervisors, Andrew Eckert and Douglas S. West for their guidance, supervision, and continual encouragement during every stage of my education at the University of Alberta; Tim Brennan, Jeffrey Church, Richard Gilbert, Gernot Kofler, Stuart Landon, Robin Lindsey, Henry van Egteren, Moin Yahya, and seminar participants at the University of Alberta, the 40th and 41st Annual Meetings of the Canadian Economics Association (Montreal, Quebec and Halifax, Nova Scotia), the 53rd Annual North American Meetings of the Regional Science Association International (Toronto, Ontario), the Inaugural Gasoline and Oil Markets Research Conference (Berkeley, California), and the 5th Annual International Industrial Organization Conference (Savannah, Georgia), for helpful comments and suggestions; my parents, Raymond and Lila Atkinson for providing food, shelter, emergency loans for gas, the exclusive use of a vehicle, and the on-call availability of a back-up vehicle during the data collection process; my wife, Michaelle Tuz-Atkinson for collecting prices from OntarioGasPrices.com, and for her support during the 4+ months that we lived in different time zones; my friend, Mark Veilleux for being my "local contact" in Guelph, and for going out of his way to find answers to my questions when I was in another city; the City of Guelph for providing me with traffic flow data free-of-charge; and to the Competition Bureau (Industry Canada) for its generous support (financially and otherwise) during my four years on paid Education Leave. I remain solely responsible for any errors or omissions. The views expressed in this thesis are my own, and are not purported to be those of the City of Guelph, Industry Canada, the Competition Bureau or the Commissioner of Competition.

# Table of Contents

## List of Figures

## List of Tables

# Chapter 1

## Introduction

Economists tend to focus primarily on price as a mechanism to equate supply and demand, and thus to maximize welfare. Under the standard one-shot Bertrand model of duopolistic price competition, where firms have no capacity constraints and sell homogeneous goods, it is predicted that prices will be set equal to marginal cost. Of course, most markets are not characterized by these simple assumptions, and so prices are often set above marginal cost. As a result, economists are interested in identifying the conditions under which firms can profitably price above marginal cost, as well as the welfare implications of these supra-competitive prices.

Policymakers are also interested in understanding the conditions under which the price mechanism can function more efficiently. For example, the mission of competition authorities in countries such as Canada, the United States, and Australia is to encourage the development ofmore competitive market conditions. Consistent with this goal, when a competition authority examines a proposed merger, the key question is likely to be whether the merged firm (and possibly the non-merging firms) will be able to exercise greater market power after the merger, where market power refers to the ability of a firm to raise its price above marginal cost. These authorities also attempt to punish firms that use or extend their market power illegally, either criminally (e.g, price fixing), or under civil law (e.g., abuse of dominance). Thus, competition authorities need to be able to identify the various market conditions that might allow a firm to exercise greater market power, or which might reduce such power.

Retail gasoline appears to be a prime example of a product where a firm might set its price to equal marginal cost. In particular, gasoline seems to be a homogeneous good, and since prices are posted on large billboards at the side of the road, menu costs are likely negligible. The high degree of price visibility in this industry also suggests that commuters can observe the prices of many stations over a large distance with little to no search costs, and neighbouring competitors can also observe these prices with little effort. Thus, price changes might propagate across an entire city within a very short amount of time. For this reason, one might also expect that prices will tend to be uniform and stable across markets; a station will not lower its price because it will be "immediately" matched by its rivals, and it will not raise its price because this price increase will not be followed.

However, evidence provided in the empirical literature on retail gasoline price competition contradicts these expectations. For example, in many Canadian cities, including Vancouver, Ottawa, and cities in southern Ontario, retail gasoline prices have been observed to move in cycles during which they rise by large amounts in one or two days, followed by several days of small consecutive price decreases. There is evidence that these cycles exist even when costs are relatively stable. Such cyclical patterns have also been documented in retail gasoline markets in Australia and the mid-western United States. On the other hand, there are other cities where prices have been observed to be much more stable, and which do not appear to follow cyclical patterns. Given the importance of the price mechanism to clearing markets and maximizing social welfare, economists and policymakers are interested in understanding the conditions under which price cycles exist, as well as their implications.

Many academic papers and industry studies have been published in the area of retail gasoline price competition. Some papers explicitly control for differentiation between stations based on various station characteristics (e.g., demand complementarities, service levels, and brand loyalty), or by location (e.g., high- versus low-traffic areas). Cycles might also exist in one market, but not another, if the first market either has a higher concentration of independent retailers, or if it includes certain "maverick" retailers that price more aggressively than other retailers. However, to fully examine the implications of spatial and product differentiation, as well as the presence of certain types of competitors, one ideally requires high frequency, station-specific price data for all stations in a market.

The purpose of this thesis is to develop a clearer understanding of retail gasoline pricing dynamics, particularly with respect to the effects certain market conditions have on the sizes, frequencies, and timing of price increases and decreases. Such research is important, because it can provide economists and policymakers with guidance on the appropriate theoretical model to be adopted (or developed) to explain pricing dynamics in a given market, which can then be used to examine the welfare and antitrust implications of these pricing dynamics.

Given the above overall purpose, in Chapter 2, four theoretical literatures on retail gasoline pricing dynamics will be critically reviewed, to determine which one seems most appropriate for examining the price cycles that are observed in retail gasoline markets in Canada, the United States, and Australia. The empirical studies in Chapters 3 to 5 will be based on the theory that will be chosen in Chapter 2.[1]

Chapter 3 will empirically examine several basic predictions of the alternating-moves Edgeworth cycle theory, which has been used in previous empirical research to examine retail gasoline price cycles in several retail gasoline markets. These predictions will be examined

---

[1] Chapters 3 to 5 are written as three separate papers because they deal with different issues, and so can be read independently of one another. However, they inevitably contain some overlap in terms of empirical literature review, data description, and certain tables and figures.

using bi-hourly price data that have been collected (by personal observation) for 27 stations in Guelph, Ontario, eight times per day from August 14 to November 24, 2005. These data will allow a more detailed examination of these Edgeworth cycle predictions than other studies that use more limited data. Therefore, the Guelph data will provide economists and policymakers with greater insight into whether the Edgeworth cycle theory is most appropriate for examining the competitive implications of retail gasoline price cycles. These data will also provide an indication of any refinements that should be made to whichever theory is chosen by a researcher to study price cycles in a particular retail gasoline market.

Chapter 4 will also examine retail gasoline pricing dynamics using these data, but will focus in more detail on the interaction between specific stations in Guelph. Specifically, the implications of an informal theory of competitive gasoline pricing, which has been advanced by both industry and government, will be examined in this chapter. This analysis will complement the one in Chapter 3 by examining whether the prices of certain types of stations are more likely than others to be matched by other stations, as well as the speed with which a station will respond to the price change of a rival. Thus, Chapter 4 will provide insight into the appropriate timing restrictions that need to be incorporated into a theoretical model of retail gasoline pricing.

Chapter 5 will take a more proactive approach to studying retail gasoline pricing dynamics by considering the data that will be available for *future* research. While the bi-hourly price data for Guelph reveal important insights into retail gasoline price competition, they cannot be used to examine spatial price competition within larger cities, or to compare prices across cities. Thus, the purpose of Chapter 5 will be to examine the sample selection biases that might arise in data collected from Internet gasoline pricing sites, as well as their implications for empirical research. This study will be conducted using both the balanced panel used in

Chapters 3 and 4, as well as a set of Guelph retail gasoline price data collected every 12 hours from OntarioGasPrices.com during the same 103 days. The main contribution made by this chapter will be to provide researchers with some guidance on which questions are more likely than others to be answered with reasonable accuracy, thus expanding the potential scope of future research in retail gasoline price competition.

To anticipate results, after considering competing explanations for retail gasoline price cycles, the Edgeworth cycle theory appears to be the more appropriate for explaining the cycles observed in Guelph. However, certain refinements to this theory might make its predictions more accurate; these refinements include accounting for spatial and product differentiation, predictable demand fluctuations, and consumer search costs. Finally, researchers can likely make accurate conclusions using Internet pricing data as long as they do not require data for individual independent stations or very high-frequency data, and as long as they are not examining pricing dynamics in cities where gasoline prices follow daily cycles.

# Chapter 2

# Dynamic Pricing Models for Oligopolistic Markets: A Critical Survey of the Theoretical Literature

## 2.1 Introduction

The purpose of this chapter is to survey the relevant theoretical literature for theoretical models of dynamic pricing that might explain cycles observed in many retail gasoline markets. Section 2.2 summarizes some potential causes of price movements in an oligopolistic market. Section 2.3 reviews four theoretical literatures regarding pricing dynamics. These literatures are the sales literature, which predicts that cycles might arise as firms engage in intertemporal price discrimination; the (s, S) threshold literature, where cycles might exist when a firm faces "menu costs", which are the costs of changing the price; Edgeworth cycles, where prices are unstable in equilibrium, and adjust downward as firms battle for market share; and the (tacitly) collusive price war literature, which predicts that demand and cost shocks will lead to price wars. The endogenous price leadership literature is surveyed in Section 2.4, and Section 2.5 concludes.

## 2.2 Potential Causes of Price Movements

### *2.2.1 Demand and Cost Conditions*

Prices might move because demand or costs have changed for at least one of the firms in the market. The sizes and directions of the price movements could depend not only on the direction of the demand or cost shocks, but also the slopes of the demand and cost curves, and whether the firm faces menu costs. The sizes of the price movements might also depend on whether the firm is involved in a (tacitly) collusive agreement with its rivals, as will be seen in Section 2.3.

### *2.2.2 Intertemporal Price Discrimination*

Prices might move over time even when demand and cost conditions remain unchanged. For example, a firm might set its price relatively high to exploit consumers with high reservation prices, but periodically offer a sale to attract more patient consumers. After these customers buy the firm's product, it raises its price again until the next sale. As a result, prices move in cycles over time, and these sales might even be predictable, such as the Boxing Day sale.

### *2.2.3 Inventory Fluctuations*

In the macroeconomics literature, inventories are often cited as a reason for price rigidities. A firm might accumulate inventories in order to hedge against input price increases due to inflation, and thus maximize its long-term profit. Some researchers have studied the firm's inventory accumulation problem in terms of (s, S) threshold models, which focus on whether inventory investment is pro-cyclical. While the focus of this thesis is *price* movements, inventories might still help explain price movements, as demonstrated by Aguirregabiria (1999).

### *2.2.4 Non-stable Prices in Equilibrium*

While there are many external factors that lead to price movements in an oligopolistic setting, prices might simply be volatile because there is no stable equilibrium in the market. As will be seen in the theory of Edgeworth cycles, the equilibrium strategy of a firm might be to undercut its rivals until one of their prices reaches a lower bound, upon which the firm whose turn it is to move raises its price to a relatively high one, and the cycle is repeated. In this case, price undercutting is simply the equilibrium response in an unstable market environment.

### *2.2.5 Predation*

Integrated oil companies are often accused of engaging in predation, and some governments have been sympathetic to these complaints. For example, "divorcement" legislation has been passed in several U.S. states, which legally forbids upstream firms from directly operating their franchisees. In Canada, the governments of Nova Scotia, Quebec, and PEI set price floors in their provinces, possibly in response to the lobbying efforts of independent retailers who cite price wars as evidence of predatory conduct. The main theories of predation will therefore be reviewed in this section to examine whether predation might lead to price cycles.

Ordover and Saloner (1989) divide predation theories into three categories: long-purse (deep-pocket), reputation and signalling models. The long-purse scenario dates back to Telser (1966), who argues that a firm sustains losses for a sufficient period of time to drive its rival out of the market; this is possible because the predator has superior access to capital. The predator's price is expected to fall to a predatory level, and remain there until the rival leaves the market. After this rival exits the market, the predator raises its price again to a profit maximizing level. In other words, prices are not predicted to cycle.

A second reason why entry might be deterred is explored in reputation models of predation, where the dominant firm gains a reputation for aggressive behaviour against rivals, so potential entrants decide that entry is unprofitable. These models originated with Yamey (1972), and have since been given game-theoretic treatment by Milgrom and Roberts (1982), Kreps and Wilson (1982) and Kreps *et al.* (1982). Again, the predator's price is not expected to cycle, but instead falls to a predatory price and remains there until its rival exits the market. Such a reputation strategy might also be used to deter entry.

Signalling models of predation predict that the dominant firm will signal to its rival that it is a low-cost firm, or that demand is low, so that the rival will believe that remaining in the market is unprofitable. As with the other two sub-literatures, prices are not expected to cycle; they are predicted to fall to a predatory level until the rival exits the market, and then rise again.

### 2.3 Theoretical Dynamic Pricing Models

Four literatures have been found that make dynamic pricing predictions: sales, (s, S) thresholds, Edgeworth cycles, and price wars. These theories are the focus of the following subsections.[2]

#### *2.3.1 Intertemporal Price Discrimination and the Theory of Sales*

The typical assumptions in this literature are as follows. There are N homogeneous firms that offer an infinitely durable good for sale, which cannot be rented or resold. There are also a large number of consumers that the firms can separate into two groups based on some observable characteristic. A new and identical cohort of consumers enters the market each period, and each consumer demands one and only one unit of the good, subject to their reservation price (which is the same for both types of consumers). Each consumer remains in the market until a purchase is made, and then leaves the market forever. Finally, the firm with the lowest price serves all consumers, and if more than one firm has the lowest price, they split market demand evenly.

In his seminal article, Varian (1980) models a monopolistically competitive market where firms can differentiate consumers by the amount of information that they have. Informed consumers know the entire distribution of prices across the market, and therefore purchase their units from the lowest priced firm. Uninformed consumers, on the other hand, do not know the

---

[2] A discussion of the price leadership implications of these models will be delayed until Section 2.4, because leadership predictions only arise in the Edgeworth cycle literature.

distribution of prices, and so choose a retailer randomly. Prices are set randomly by the retailers in each period, and follow no particular pattern, cyclical or otherwise. Furthermore, Varian (1980) does not predict the timing of sales, nor does he indicate how long they will last.

Conlisk, Gerstner, and Sobel (1984) extend this model to show that the price level of a durable good monopolist moves cyclically when consumers can be differentiated by their tastes: a high-demand consumer has a relatively high reservation price, while a low-demand consumer has a lower reservation price. Each consumer's reservation price falls in each period that it remains in the market, since it prefers to buy the good sooner rather than later. The monopolist begins the cycle by setting its price equal to the high-demand consumer's reservation price, and then lowers its price in each successive period until it equals the low-demand consumer's reservation price. This "sale" lasts one period, after which the monopolist raises its price back to the high-demand consumer's reservation price. The cycle is then repeated.

These cycles do not appear to extend to the oligopoly case. Sobel (1984) finds that if consumers are differentiated by tastes in an oligopolistic market, then each firm typically sets its price just low enough to attract high-demand consumers. However, it occasionally and randomly lowers its price to the reservation price of the low-demand consumer for one period (it offers a sale). It then raises its price back to the high level until the next sale.

On the other hand, Fershtman and Fishman (1992) develop a dynamic search model to explain price cycles, where consumers are either patient or impatient. Each period, a consumer decides the intensity of search with the objective of minimizing the discounted cost of purchase, including search costs, and a firm's price is binding for one period. Before making a purchase, a consumer must solicit a price quotation from a firm; any number of prices may be solicited at the beginning of the period at a constant and positive cost per price quotation. An impatient consumer might sample more than one price in a given period, and therefore pay additional search costs. The authors predict that patient consumers will wait until the price is relatively low to make their purchases, so a firm's price slowly falls until it is low enough to attract these consumers (there is a demand "boom"). Once the sale is offered and the patient consumers buy their units, the firm's price rises back to a relatively high level, and the cycle is repeated.

In all of these models, a firm normally charges a high price to serve the consumers that have relatively inelastic demand curves, but periodically offers a low price to attract the other consumers, after which it raises its price again. In some models, there are price cycles, and in others, the sale is random and characterized by a jump in the price. However, none of them allow consumers to make repeat purchases, and so cannot be applied to retail gasoline markets.

While there are models that explain price movements in the context of repeat purchases, they do not predict volatile prices, and they particularly do not predict cyclical pricing. Nelson (1970; 1974) defines "experience goods" as ones where a consumer's demand becomes more inelastic as it learns that the product is of high quality. His theory, formalized by Milgrom and Roberts (1986), predicts that the firm will be willing to sacrifice profits in the short-run by charging a relatively low price (and spending more on advertising), in order to signal its product's high quality to consumers. Once the consumer learns that the product is high quality, the firm will raise its price, and there is no future volatility.[3] Thus, it appears that intertemporal price discrimination is not a sufficient explanation for price cycles in retail gasoline markets.[4]

---

[3] Also see Crémer (1984), Riordan (1986), and Bagwell and Riordan (1991) for other papers in this literature.

[4] It should be noted that a number of papers have been recently written which examine retail gasoline pricing dynamics using consumer search models. For example, Lewis (2005) develops a theoretical search model to explain asymmetric price adjustment, where prices rise

*2.3.2 (s, S) Threshold Models*

Nominal prices might remain rigid in a market over time, even when demand or cost conditions change, if the costs of price adjustment outweigh the additional profits from that adjustment. For example, a firm might keep its nominal price fixed until inflation lowers its real price below a threshold, denoted by "s", and then increase its nominal price to a target, denoted by "S". Thus, it is not nominal prices that move cyclically, but *real* prices. (s, S) models predict that nominal price changes will be infrequent, but when they do change, the change is relatively large.

While the above example assumes that inflation is the cause of price movements, other state variables might be more applicable, such as demand or costs. Furthermore, if the state variable can move in either direction, then there are upper and lower thresholds. If there are linear as well as fixed adjustment costs, then there are also upper and lower targets.

(s, S) threshold models have traditionally been studied by macroeconomists in the context of the inventory control problem,[5] but they have also been used to explain nominal price rigidities. For example, Sheshinski and Weiss (1977; 1983) study the effects of inflationary expectations on the formulation of pricing policies. However, the authors assume that the firm is a monopolist, and only two papers have been found that model competition between firms.[6]

In one of these two papers, Slade (1999) assumes that oligopolists are engaged in a state-space game, and that a firm faces menu costs in the context of stocks of consumer goodwill (instead of inflation), which it accumulates (loses) by choosing a low (high) price. The firm

---

quickly and fall slowly over time. However, he assumes that prices rise and fall in response to cost movements, which appears contrary to observations made in other cycling markets.

[5] For example, see Scarf (1960) and Blinder (1981).

[6] Other monopoly models are by Danziger (1984) and Ye and Rosenbaum (1994).

generates brand loyalty by consistently charging a low price, and so is hesitant to raise its price when there is a demand or cost shock. As with the monopoly models referenced above, the firm's nominal price is predicted to be rigid over time, and does not move cyclically.

However, Aguirregabiria (1999) does provide a model where nominal prices move cyclically when there are menu costs, in the context of a monopolistically competitive market.[7] He combines the inventory and price threshold models with the theory of sales, by assuming that the firms in the market have *two* choice variables: price and inventories. Before observing its periodic demand shock, which is identically and independently distributed (i.i.d.), a firm chooses these two variables each period to maximize its present-discounted stream of *real* profits. The author shows that given the probability of running out of stock, if fixed ordering costs are large relative to the menu costs, then the firm holds a sale when the order is placed; this price is maintained for a short period of time. The firm then raises its price infrequently until the next order, when it offers another sale and the cycle is repeated.

Aguirregabiria (1999) appears to offer the only model in the (s, S) threshold literature which not only models a non-monopolistic market, but also predicts price cycles. However, he predicts cycles that are opposite to those observed in some retail gasoline markets, where prices appears to rise sharply in a day or two, and then decline slowly over several days until the next price increase; instead, Aguirregabiria (1999) predicts that a firm's price will fall sharply at the beginning of the cycle, and then rise slowly over the course of this cycle until the next sale. A second drawback is that his results rely on the assumption of menu costs, which are likely insignificant in retail gasoline markets where prices on both the pumps and pricing signs tend

---

[7] Even though firms make zero profits in a monopolistically competitive market, this is a *long-run* condition. Thus, this model might have useful implications in the short-run.

to be changed electronically. Thus, models of pricing dynamics based on menu costs do not appear to be appropriate for examining retail gasoline price cycles.

### *2.3.3 Edgeworth Cycles*

In the standard model, two symmetric firms each maximize their present-discounted stream of profits by producing a homogeneous product over an infinite horizon. The firm with the lowest price captures the entire market, and in the event that both charge the same price, they split market demand evenly. Furthermore, marginal cost is common and constant, each firm has the same discount factor, and there are no fixed costs or capacity constraints. Price competition takes place in discrete time and prices are chosen sequentially over a finite grid, so a firm cannot price in units of less than a tenth-of-a-cent, for example. The firms play Markov strategies, where one's pricing decision depends only on the other's current price, as well as its own current price, so the solution concept employed in this model is the Markov Perfect Equilibrium (MPE).

These models differ from simultaneous-moves models in that they allow the firms to observe one another's pricing decisions *before* making their own decisions. The seminal article in this literature is written by Maskin and Tirole (1988), who assume that the time between consecutive periods is small because a firm can quickly change its price, so the discount factor is near one.[8] They prove that for a sufficiently fine price grid and a discount factor near one, both focal point equilibria and Edgeworth cycle equilibria exist.[9] With respect to Edgeworth

---

[8] This assumption is reasonable if menu costs are sufficiently small, which seems to be true with respect to retail gasoline markets (see Section 2.3.2).

[9] In the kinked demand curve story, a firm's price for the good in question is stable in the long-run at a "focal" price, because the firm fears that lowering its price will initiate a price war, while an increase in its price will not be followed by its competitors. See Sweezy (1939).

cycle equilibria, each firm undercuts the other's price until an intermediate price is reached, upon which the active firm lowers its price to marginal cost. There is then a war of attrition of indeterminate length as each firm waits with positive probability for its rival to restore the cycle at a single increment above the monopoly price; once one of the firms raises its price, the cycle is repeated. The authors prove that the average market price must be bounded away from the competitive price.[10] The length of the cycle depends on the firms' marginal cost and the size of the price grid, since firms undercut one another by a minimal amount.[11]

A drawback of the Maskin and Tirole (1988) model is that they do not predict when Edgeworth cycles will be observed instead of focal point equilibria. Eckert (2003) addresses this question by assuming that firms differ in size, which can be measured by the number of retail outlets operated by that firm, or the number of pumps; when both firms set the same price, their market shares are proportional to their sizes. They still have identical marginal cost curves and no capacity constraints. The author uses examples to demonstrate that the existence of each equilibrium depends on the firm's relative size: while focal point equilibria can only exist when firms are similar in size, Edgeworth cycle equilibria exist for a wide range of relative sizes.

Specifically, Eckert (2003) investigates three ranges of relative firm size. First, if the two firms are similar in size, then they undercut one another along the downward portion of the cycle until the market price is equal to marginal cost. There is then a war of attrition until one of them raises its price slightly above the monopoly price, and the cycle is repeated.

---

[10] In this survey of the Edgeworth cycle literature, the term "market price" refers to the lowest price in the market and the "active firm" is the firm whose turn it is to move.

[11] Note that the dynamic Edgeworth cycle theory does not rely on capacity constraints, which are the basis for the cycles demonstrated by Edgeworth (1925).

As the large firm grows increasingly larger than its rival, it is more tempted to match the market price on the downward portion of the cycle. As in the previous case, the small firm always undercuts the market price until it prices at marginal cost; then, in equilibrium, the large firm resets the cycle by setting its price above the monopoly price; there is no war of attrition. Intuitively, the small firm is more motivated than the large firm to follow an undercutting strategy because the market sharing rule is biased in favour of the large firm.

Finally, when the large firm is significantly larger than its rival, then it *always* matches the market price along the downward portion of the cycle; as usual, the small firm always undercuts the market price. This match-undercut phase continues until the small firm sets its price equal to marginal cost, and then the large firm does one of two things: it either resets the cycle with positive probability, or it matches the market price. If it does the latter, then the small firm definitely resets the cycle. Thus, in equilibrium, the lowest price in the cycle is expected to last no more than two periods, depending on whether or not the large firm resets the cycle.

With respect to the equilibrium length of the cycle, it is expected to grow as the relative size of the large firm rises. In other words, the greater the presence of small firms, the more volatile is the market price, and the closer the average market price is to the competitive ideal.

Noel (2006) computationally searches for Edgeworth cycles under a number of different conditions, while allowing for firm-specific discount factors and marginal costs that fluctuate within a given band (but are still identical across firms). The author finds that cycles still exist in equilibrium after making these modifications. Specifically, each firm undercuts the market price by one grid-length until price approaches marginal cost; they then undercut one another more aggressively to hasten the next restoration. If marginal cost is relatively high, then the active firm resets the cycle, and its rival is guaranteed to follow. Otherwise, the active firm might match the market price and wait for its rival to restore the cycle.

Noel (2006) also finds that market elasticities have little effect on the cycle, since the gains from undercutting are mainly from market stealing, not new customers. Furthermore, as the discount factor decreases (so firms are less patient), the cycle peak falls (but is still above the static monopoly price), and a firm more aggressively undercuts the market price while it is above the monopoly price. Once the market price falls below the monopoly price, undercuts return to one-unit increments. The result is that the entire cycle shifts vertically downward, as both the high and low prices of the cycle are lower than when firms have higher discount factors.

With respect to sharing rules, Noel (2006) finds that if the large firm has a significantly high market share at equal prices and a discount factor near one, then it tends to match high prices but aggressively undercuts intermediate ones, since it knows that the small firm will reset the cycle. As the discount factor falls closer toward 0.5, the large firm more frequently matches moderate prices; as its market share falls closer toward 0.5, it more frequently undercuts high prices by one notch. In all cases, Firm 2 continues to be the consistent price leader.

Noel (2006) also finds that Edgeworth cycles continue to exist when firms are capacity-constrained, or when there is product or spatial differentiation. However, if constraints become too tight, or differentiation is more than moderate, then focal price equilibria replace cycles.

Finally, Noel (2006) identifies Edgeworth cycle equilibria in a model with three firms. Specifically, firms undercut one another by one-unit increments until prices approach marginal cost, after which undercuts become more aggressive. They might then either match the market price or return to one-unit undercuts to encourage a rival to relent first. Eventually, one of the firms will attempt to lead a cycle restoration – "attempt" because it might not succeed.

For example, if marginal cost falls after the price increase, then there may be a "delayed response” as the second firm chooses to match or undercut the price of the third firm instead of following the leader’s increase. The leader might even abandon its restoration attempt, lowering its price back to the bottom of the cycle along with the other two firms; Noel (2006) calls these occurrences “false starts”. False and delayed starts indicate coordination problems during cycle restorations that do not exist in the two-firm model; they make resetting the cycle more costly, so market prices are pushed closer to marginal cost before a firm risks restoring the cycle again. They are also found to be more common as the discount factor falls further below one. An implication of these findings is that all firms can benefit if one of them assumes the role of consistent price leader, thus reducing the uncertainty that leads to such coordination problems.

Wallner (1999) considers the implications of the infinite-horizon Edgeworth cycle model by instead assuming *finite* horizons, where the length of the game is common knowledge, and future profits are *not* discounted. He finds that while there are no rigid-price equilibria, there are equilibria where reactions functions follow a three-period cycle. In the beginning of the cycle, Firm A’s price is fixed at the smallest amount above the monopoly price level, and Firm B undercuts it by setting its price at the monopoly level, which in turn is frozen for two periods. In the second period, Firm A sets a price sufficiently low to deter further undercutting, which induces Firm B to raise its price to slightly above the monopoly price in the third period. In response to Firm B’s restoration, Firm A begins a new cycle with the same behaviour but reversed roles. The market price never settles down, and is always above marginal cost. Only the last few periods do not follow the usual cycle, as the firms choose to act myopically.

Wallner (2001) extends this model further by allowing firms to discount future profits. He finds that while the three-period cycle remains when the discount factor is relatively high, for stronger discounting the firms instead follow two-period reaction function cycles, where the trigger and undercutting phases of the game are collapsed into one. Thus, firms continue to undercut one another's prices by small amounts until one decides to undercut by a larger amount to the trigger price. Its rival then raises its price back to just above the monopoly level. Wallner (2001) claims that product homogeneity is not crucial to the results.

### *2.3.4 Price War Models*

Concerns are often expressed by government officials and the general public that price cycles are an indication of collusion in the retail gasoline market. These accusations are largely based on the perception that price movements are synchronized across stations that operate under different brands. However, as will be demonstrated in this section, these accusations do not seem to be consistent with predictions made in the theoretical price war literature.

Most theories of tacit collusion use the supergame framework. Supergames are one-shot simultaneous-moves games repeated an infinite number of times. Unless stated otherwise, it is assumed that N identical firms sell a homogeneous good to a group of identical consumers. A firm maximizes its present-discounted stream of profits by strategically choosing its price level, subject to the common discount factor and the prices of its rivals. The firm with the lowest price serves the entire market; if multiple firms charge the lowest price, then they split market demand evenly. Finally, the models surveyed predict that in equilibrium, price wars erupt due to demand or cost shocks, as opposed to a firm cheating on the collusive agreement.

Green and Porter (1984) demonstrate that if firms cannot perfectly observe demand shocks (or rival price cuts), then a negative i.i.d. demand shock can lead to a price war.[12] This

[12] While Green and Porter (1984) actually assume Cournot (quantity) competition, Tirole (1988, 262-5) shows that the same implications arise in a price-setting game.

price war is characterized by an immediate downward "jump" of each firm's price to a punishment level (assumed to be Nash-reversion). It lasts for a fixed number of periods, after which all prices simultaneously return to the collusive level until the next price war. Price wars are infrequent relative to the number of periods of price stability, and are also unpredictable.[13]

Rotemberg and Saloner (1986) show that price wars can also break out during high-demand periods ("booms"), even when demand shocks are perfectly observable by all firms. They find that when there is a positive i.i.d. demand shock, the punishment is insufficient to deter cheating because demand is expected to fall back to its normal level in the future. Thus, prices are typically stable, but the firms agree to set a lower price during booms so that the gains from cheating on the agreement are eliminated.[14] Price wars are infrequent and unpredictable, and are characterized by immediate jumps from one collusive price level to another.[15]

Slade (1989) assumes that firms sell a differentiated product, and both rival prices and sales can be monitored. The firms are involved in a Bayesian game, where they use these observed prices and quantities as informative signals of the true state of demand. When there

---

[13] Abreu, Pearce, and Stacchetti (1986) modify this model to show that if firms base their decisions on the history of the game, then the length and severity of the punishment phase is not fixed. However, prices still do not cycle.

[14] As such, price wars do not actually occur in this model; rather, the collusive price varies over the business cycle.

[15] Haltiwanger and Harrington (1991) show that if the i.i.d. assumption is relaxed, so that positive (negative) demand shocks are expected to be followed by further positive (negative) demand shocks, then the most difficult part of the cycle is when demand is *falling*, since future losses from cheating will be lower than if it is rising. Thus, even though price wars can break out during booms, they are more likely to break out during recessions. However, for either of these demand cycle theories to explain the weekly price cycles observed in some retail gasoline markets, demand would need to rise substantially early in the week and then gradually fall each day as the week progresses toward the weekend, which seems unlikely.

is a demand shock, a price war is triggered, but in this model there are no price "jumps", nor are there any punishment phases. Instead, each firm adjusts its price every period based on the price choices of its competitors in the previous period. This process of adjustment continues each successive period until the "true" state of the market is learned, upon which each firm's new price remains stable until the next demand shock. The length of the war is not predictable, because it depends on the size of the demand shock. However, the model does predict that the larger the demand shock, the longer will be the process of adjustment. Finally, as with the previous models, price wars are infrequent, and there are no cycles in equilibrium.

In the above models, the cause of the price war has been a demand shock. Eckert (2004) extends the Maskin and Tirole (1988) framework to show that if marginal cost is stochastic without persistence (although it is still constant and identical across firms), then price wars can also erupt when cost shocks occur, where marginal cost is observed by the firms *before* they make their decisions. Marginal cost follows a Markov process, where in any period it can be high or low, and remains unchanged with probability $\alpha$. For example, if $\alpha = 0.99$ then the shock is essentially unexpected, but has long-run implications.

The implications are as follows. Price wars do not occur in equilibrium if demand or cost shocks are infrequent and near-permanent. In such a case, if the shock triggers a change from the low focal price to the high focal price, then one of the firms immediately lowers its price in order to induce the other firm to restore the higher focal price. However, if demand or costs are subject to shocks with *low* permanence, then the shock that increases the focal price could trigger a prolonged period of undercutting before the new focal price is established. Thus, prices are volatile in equilibrium after a shock, but price cycles are still not observed.[16]

In summary, the above price war models predict that price wars can occur when demand is rising or falling, and high or low. Demand shocks can be perfectly or imperfectly observable, and may or may not be i.i.d. Finally, price wars can occur if products are homogeneous or differentiated, or when marginal cost changes. Regardless of the assumptions, these theories never predict cycles, but instead predict several periods of price stability, briefly interrupted by relatively short price wars. In other words, as long as demand and costs are unchanged, the firms' prices will remain stable. Thus, these models do not seem to explain why prices cycle.

### 2.4 Endogenous Price Leadership Literature

The theories of endogenous price leadership typically fall into three categories: collusive price leadership, dominant-firm price leadership,[17] and barometric price leadership.[18] Rotemberg and Saloner (1990) examine a differentiated products duopoly under (tacit) collusion, where both firms have constant and identical marginal cost, and symmetric demand functions (with the

---

[16] In another extension of Maskin and Tirole (1988), Eaton and Engers (1990) propose an alternating-moves model with differentiated products and heterogeneous consumers, and find that there are two types of steady-state collusive equilibria: spontaneous equilibria, where the collusive price is stable in equilibrium without any threat of punishment; and disciplined equilibria, where the collusive price is sustained with the threat of punishment for deviation. However, price wars never occur in equilibrium in this model.

[17] In the models of dominant-firm price leadership discussed in this section, firms are not assumed to be price takers, contrary to dominant firm/competitive fringe models.

[18] Under barometric price leadership, the leader serves as a barometer of current market conditions for other firms in the industry. This leader possesses no power to coerce the other firms to follow its pricing decisions, but simply passes along information to them. Cooper (1997) argues that barometric leadership is not dependent on the existence of collusion or a dominant firm, but it also does not preclude their existence.

exception of the intercepts). Furthermore, the firms are asymmetrically informed, so while Firm 1 fully observes any given demand shock, Firm 2 only knows its distribution, as well as the history of prices and quantities (this assumption is critical to the results). In this game, Firm 2 is expected to follow Firm 1's lead, or the game infinitely reverts to the one-shot simultaneous moves game. Furthermore, there is no credible way for Firm 1 to better inform Firm 2. They show that even though the firms produce differentiated products, the firm with more information becomes the endogenous price leader, which serves to facilitate collusion.

The above model assumes that the firm with the informational advantage becomes the endogenous price leader under collusion. Cooper (1997) shows that the firms do not need to be colluding for the relatively informed firm to become the (barometric) price leader. He presents a price-setting differentiated products duopoly model, where both firms face a common demand shock, and each firm is able to purchase information about the magnitude of the shock. The cost of acquiring this information is assumed to be small, and after acquiring it, each firm can either set its price or wait to observe its rival's price choice. It is also assumed that they cannot credibly inform each other of their information. He finds that the only equilibrium that arises in pure strategies is where one firm becomes informed and the price leader, while the other firm remains uninformed and a price follower. He then shows that the firm with the lower cost of acquiring information purchases it in equilibrium.

Deneckere, Kovenock, and Lee (1992) extend Varian (1980) by assuming two firms and no entry, and that each firm produces a non-storable, differentiated product at constant unit cost. The firms play an alternating-moves game over an infinite horizon, and a firm's price is fixed for time of length N. This is similar to the Maskin and Tirole (1988) framework, except the time between successive price-setting periods is much shorter than the length of time that the price is fixed.[19] A finite number of consumers demands one unit of the good in each period (so it incorporates repeat purchases), given their (common) reservation price. Each consumer only purchases its unit from the firm to which it is loyal, where loyalty implies that the consumer's purchasing decision depends (partly) on non-price factors; if it has no loyalty, then it purchases its unit from the lowest-priced firm. No opportunity for price discrimination exists. The authors find that the firm with the higher proportion of loyal consumers is the endogenous price leader.

Deneckere and Kovenock (1992) provide game-theoretic support for the hypothesis that the dominant firm leads price movements. They make the same assumptions as Deneckere, Kovenock, and Lee (1992), except that the good is homogeneous and the dominant firm gains its advantage with a larger (exogenously-determined) capacity. They find that the dominant firm is the endogenous price leader when costs are identical. If costs differ between firms, then if the high-cost firm has the higher capacity, it always leads; if capacity is low and sufficiently small, the low-cost firm becomes the endogenous price leader. Thus, high costs promote price leadership, and when unit costs are negatively related to capacity, then size may not matter.[20]

van Damme and Hurkens (2004) also examine the effects of cost asymmetries on price leadership. They assume no capacity constraints, and that firms can move at any time. Products are differentiated but substitutable, and the more efficient firm has a lower marginal cost. They find that waiting is more risky for the low-cost firm, so it becomes the endogenous price leader.

---

[19] For example, if a firm has the opportunity to move every second period and N = 4, then if it changes its price in Period 2, it must wait until Period 6 to be able to set a new price.

[20] Similarly, Furth and Kovenock (1993) show that this result does not rely on the assumption that goods are homogeneous; assuming a differentiated goods duopoly with capacity constraints, the authors find that an endogenous leader does exist within certain ranges of asymmetric capacities, and that this leader is the firm with the highest capacity.

Van Cayseele and Furth (2001) attempt to determine which firm is the endogenous price leader when duopolists differ in both marginal costs and capacities. They find that the most efficient firm becomes the price leader, whether or not its rival has more capacity.

Kovenock and Widdows (1998) consider price leadership under asymmetric price rigidity for a differentiated goods duopoly with linear demands, and constant (and identical) marginal cost. The firms' prices are rigid when there are negative (and unanticipated) demand shocks, but flexible during demand booms. They conclude that the previous price leader always remains the leader for small positive demand shocks, as well as for a range of large negative shocks. However, if the shock is especially large, then the leader's identity is indeterminate.

The papers surveyed above predict that the same firm will always be the price leader; Pastine and Pastine (2004) show that there can be occasional changes in the leader's identity in a duopoly setting with differentiated products. Firms move whenever they want and time is continuous, but there is a fixed time lag. Thus, a firm cannot observe its rival's decision until a certain amount of time has passed. Consumers do not purchase from either firm until both prices are set, and once both firms have chosen their prices, the game ends and they compete on those prices over an infinite horizon. The authors find that in mixed strategies, the firms fight over who becomes the leader, but the one with the shorter reaction time (lower cost of delay) is the likely leader; larger firms are more likely to become the endogenous price leader. Finally, if the equilibrium is repeated for successive price changes, then occasional changes in the leader are predicted, because the probability of becoming the leader changes with the cost of delay.

In the Edgeworth cycle literature, two papers address the question of price leadership with respect to both price increases and decreases. Eckert (2003) finds that if the two firms are similar in size and each firm has a discount factor close to one, then either firm can lead price movements both on the upward and downward portions of the cycle; they both undercut the market price at all prices above marginal cost, and both reset the cycle with positive probability. As the large firm grows in size relative to the small firm, the role of leader changes in equilibrium depending on the market price: the small firm always undercuts the market price (as long as it is above marginal cost), and the large firm may either match or undercut its rival's price; the large firm *always* leads restorations, in equilibrium. Finally, when the large firm is significantly larger than its rival, then the small firm always undercuts the market price while the large firm always matches it, and either firm might lead restorations.

Noel (2006) demonstrates computationally that when marginal cost randomly fluctuates within a given band, and when discount factors are firm-specific, a consistent leader of price increases can emerge in a market. For example, in the simple Bertrand duopoly model, if the firms have different discount factors, then the more patient one will be the consistent leader of restorations; if only one is capacity-constrained, then the unconstrained firm always relents. The intuition behind this result is that even at a higher price, the unconstrained firm still serves the residual demand in the market Furthermore, when the two firms differ in terms of size (measured by their market shares when prices are equal), Noel (2006) predicts that the *small* firm will tend to be the consistent leader of price increases, even for intermediate ranges of the market share variable. This finding contradicts intuition, as well as the examples provided by Eckert (2003), which demonstrate that the large firm will tend to lead restorations, in equilibrium, as long as its market share is not too close to 0.5 or one.

Finally, Noel (2006) shows that when one of the firms is recognized by its rival to be a consistent leader of restorations, then the follower might engage in a "step-up" strategy at the bottom of the cycle. Specifically, in the simple Bertrand duopoly model, the follower undercuts aggressively along the downward portion of the cycle to hasten the next restoration; as its price approaches marginal cost, it prices more passively while it waits for its rival to relent. The follower might even "step up" at the bottom of the cycle, which means it raises its price slightly, so that it remains profitable while it waits for its rival to restore the cycle. Given this strategy, the recognized leader always raises its price first since it knows its rivals will never do so, so step ups are not observed in equilibrium.

In summary, the surveyed theoretical literature regarding endogenous price leadership always predicts that the leader has a certain advantage with respect to costs, information, brand loyalty, capacities, or size. All of these predictions are intuitive, but with the exception of the Edgeworth cycle theory, only Pastine and Pastine (2004) predict that the leader's identity can change over time (as the cost of delay changes). However, they do not predict that different types of firms will lead price changes in different directions, as might be expected in a retail gasoline market; a refiner brand that controls prices at several stations in the city might be relatively unwilling to lead prices down the cycle, but may be in a better position to coordinate restorations than an independent retailer that controls the price of one station in part of the city where less traffic flows. Thus, it is concluded that the Edgeworth cycle theory is likely the most appropriate theory to explain endogenous price leadership in retail gasoline markets.

### 2.5 Summary Remarks

After conducting an extensive survey of the theoretical economics literature regarding pricing dynamics, it is concluded that the Edgeworth cycle theory is most applicable for explaining the retail gasoline price cycles observed in various markets in Canada, the U.S. and Australia. First, it provides a more convincing explanation of why prices cycle in these markets than the sales, (s, S) threshold and price war literatures. Most of these alternative theories do not predict cycles, and those that do either predict cycles that are substantively different than those observed empirically, or make assumptions that cannot be applied to retail gasoline markets, such as a monopolist firm and/or a durable good.

Second, the Edgeworth cycle theory seems to make more realistic predictions regarding which stations will likely lead price movements, as it predicts that the identities of price leaders might differ depending on whether prices are rising or falling; of the remaining theories in the endogenous price leadership literature, only Pastine and Pastine (2004) predict changes in leaders, but they predict that the leader's identity will change as the cost of delay changes. In a retail gasoline market, where one brand might control prices at several stations across the city while another might control the price at only one or two stations, it is reasonable to expect that major brand stations that are price controlled by their head offices are relatively more likely to lead restorations, but are less willing than independents to lead prices down again.

## 2.6 References


Abreu, Dilip, David Pearce, and Ennio Stacchetti (1986), "Optimal Cartel Equilibria with Imperfect Monitoring," *Journal of Economic Theory* 39, 251-69.

Aguirregabiria, Victor (1999), "The Dynamics of Markups and Inventories in Retailing Firms," *Review of Economic Studies* 66, 275-308.

Bagwell, Kyle and Michael H. Riordan (1991), "High and Declining Prices Signal Product Quality," *American Economic Review* 81, 224-39.

Blinder, Alan S. (1981), "Retail Inventory Behavior and Business Fluctuations," *Brookings Papers on Economic Activity* 1981, 443-505.

Conlisk, John, Eitan Gerstner, and Joel Sobel (1984), "Cyclic Pricing by a Durable Goods Monopolist," *Quarterly Journal of Economics* 99, 489-505.

Cooper, David J. (1997), "Barometric Price Leadership," *International Journal of Industrial Organization* 15, 301-25.

Crémer, Jacques (1984), "On the Economics of Repeat Buying," *RAND Journal of Economics* 15, 396-403.

Danziger, Leif (1984), "Stochastic Inflation and the Optimal Policy of Price Adjustment," *Economic Inquiry* 22, 98-108.

Deneckere, Raymond and Dan Kovenock (1992), "Price Leadership," *Review of Economic Studies* 59, 143-62.

Deneckere, Raymond, Dan Kovenock, and Robert Lee (1992), "A Model of Price Leadership Based on Consumer Loyalty," *Journal of Industrial Economics* 40, 147-56.

Eaton, Jonathan and Maxim Engers (1990), "Intertemporal Price Competition," *Econometrica* 58, 637-59.

Eckert, Andrew (2003), "Retail Price Cycles and the Presence of Small Firms," *International Journal of Industrial Organization* 21, 151-70.

----- (2004), "An Alternating-Move Price-Setting Duopoly Model with Stochastic Costs," *International Journal of Industrial Organization* 22, 997-1015.

Edgeworth, Francis Ysidro (1925), "The Pure Theory of Monopoly," in *Papers Relating to Political Economy,* Volume 1 (London: MacMillan and Co., Limited), 111-42.

Fershtman, Chaim and Arthur Fishman (1992), "Price Cycles and Booms: Dynamic Search Equilibrium," *American Economic Review* 82, 1221-33.

Furth, Dave and Dan Kovenock (1993), "Price Leadership in a Duopoly with Capacity Constraints and Product Differentiation," *Journal of Economics (Zeitschrift für Nationalökonomie)* 57, 1-35.

Green, Edward J. and Robert H. Porter (1984), "Noncooperative Collusion under Imperfect Price Information," *Econometrica* 52, 87-100.

Haltiwanger, John and Joseph E. Harrington, Jr. (1991), "The Impact of Cyclical Demand Movements on Collusive Behavior," *RAND Journal of Economics* 22, 89-106.

Kovenock, Dan and Kealoha Widdows (1998), "Price Leadership and Asymmetric Price Rigidity," *European Journal of Political Economy* 14, 167-87.

Kreps, David M. *et al.* (1982), "Rational Cooperation in the Finitely Repeated Prisoners' Dilemma," *Journal of Economic Theory* 27, 245-52.

Kreps, David M. and Robert Wilson (1982), "Reputation and Imperfect Information," *Journal of Economic Theory* 27, 253-79.

Lewis, Matthew (2005), "Asymmetric Price Adjustment and Consumer Search: An Examination of the Retail Gasoline Market," Ohio State University Working Paper (July 26, 2005).

Maskin, Eric and Jean Tirole (1988), "A Theory of Dynamic Oligopoly, II: Price Competition, Kinked Demand Curves, and Edgeworth Cycles," *Econometrica* 56, 571-99.

Milgrom, Paul and John Roberts (1982), "Predation, Reputation, and Entry Deterrence," *Journal of Economic Theory* 27, 280-312.

----- (1986), "Price and Advertising Signals of Product Quality," *Journal of Political Economy* 94, 796-821.

Nelson, Phillip (1970), "Information and Consumer Behavior," *Journal of Political Economy* 78, 311-29.

---- (1974), "Advertising as Information," *Journal of Political Economy* 82, 729-54.

Noel, Michael (2006), "Edgeworth Cycles and Focal Prices: Computational Dynamic Markov Equilibria," UCSD Working Paper (April 10, 2006).

Ordover, Janusz A. and Garth Saloner (1989), "Predation, Monopolization, and Antitrust," in *Handbook of Industrial Organization,* Volume 1, Edited by Richard Schmalensee and Robert Willig (Amsterdam: North-Holland), 537-96.

Pastine, Ivan and Tuvana Pastine (2004), "Cost of Delay and Endogenous Price Leadership," *International Journal of Industrial Organization* 22, 135-45.

Riordan, Michael H. (1986), "Monopolistic Competition with Experience Goods," *Quarterly Journal of Economics* 101, 265-80.

Rotemberg, Julio J. and Garth Saloner (1986), "A Supergame-Theoretic Model of Price Wars during Booms," *American Economic Review* 76, 390-407.

----- (1990), "Collusive Price Leadership," *Journal of Industrial Economics* 39, 93-111.

Scarf, Herbert (1960), "The Optimality of (S, s) Policies in the Dynamic Inventory Problem," in *Mathematical Methods in the Social Sciences, 1959,* Edited by Kenneth J. Arrow, Samuel Karlin, and Patrick Suppes (Stanford, California: Stanford University Press), 196-202.

Sheshinski, Eytan and Yoram Weiss (1977), "Inflation and Costs of Price Adjustment," *Review of Economic Studies* 44, 287-303.

----- (1983), "Optimum Pricing Policy under Stochastic Inflation," *Review of Economic Studies* 50, 513-29.

Slade, Margaret E. (1989), "Price Wars in Price-Setting Supergames," *Economica* 56, 295-310.

----- (1999), "Sticky Prices in a Dynamic Oligopoly: An Investigation of (s, S) Thresholds," *International Journal of Industrial Organization* 17, 477-511.

Sobel, Joel (1984), "The Timing of Sales," *Review of Economic Studies* 51, 353-68.

Sweezy, Paul M. (1939), "Demand Under Conditions of Oligopoly," *Journal of Political Economy* 47, 568-73.

Telser, L.G. (1966), "Cutthroat Competition and the Long Purse," *Journal of Law & Economics* 9, 259-77.

Tirole, Jean (1988), *The Theory of Industrial Organization* (Cambridge, Massachusetts: MIT Press).

Van Cayseele, Patrick and David Furth (2001), "Two is not Too Many for Monopoly," *Journal of Economics (Zeitschrift für Nationalökonomie)* 3, 231-58.

van Damme, Eric and Sjaak Hurkens (2004), "Endogenous Price Leadership," *Games and Economic Behavior* 47, 404-20.

Varian, Hal R. (1980), "A Model of Sales," *American Economic Review* 70, 651-9.

Wallner, Klaus (1999), "Sequential Moves and Tacit Collusion: Reaction-Function Cycles in a Finite Pricing Duopoly," *Journal of Economic Theory* 84, 251-67.

----- (2001), "Price Wars in Finite Sequential Move Price Competition," CEPR Discussion Paper #2850.

Yamey, B.S. (1972), "Predatory Price Cutting: Notes and Comments," *Journal of Law & Economics* 15, 129-42.

Ye, Meng-Hua and David I. Rosenbaum (1994), "Stochastic (s, S) Pricing and the U.S. Aluminum Industry," *Eastern Economic Journal* 20, 107-15.

# Chapter 3

## Retail Gasoline Price Cycles: Evidence from Guelph, Ontario Using Bi-Hourly, Station-Specific Price Data

### 3.1 Introduction

In many Canadian cities, retail gasoline prices appear to move in cycles where they rise by large amounts in one or two days, followed by several days of small consecutive price decreases. Some consumers and politicians cite these cycles as evidence of anti-competitive behaviour, while other people, including economists and industry participants/experts, argue that such price volatility suggests that firms are engaged in intense competition. Thus, a clear understanding of the dynamics behind these cycles is important for both economists and policymakers.

The Edgeworth cycle theory, which will be reviewed in Section 3.2, has been often used to explain these cycles. Since prices have been observed to frequently change in several of these markets, and also since the theory makes predictions regarding inter-station price competition, proper testing of the Edgeworth cycle theory ideally requires high frequency, station-specific data for an entire market. Unfortunately, such data are not publicly available for an unregulated market, so researchers are typically restricted to using price data that are collected for a subset of stations in a market, and which might also be collected once every week and averaged across stations. As such, these data might generate misleading conclusions regarding which types of stations tend to lead price increases, which types tend to either match or undercut their rivals' prices, and even whether prices cycle at all.

Given these concerns with the relevant empirical literature, the purpose of this chapter is to examine the accuracy of several basic predictions of the Edgeworth cycle theory. Retail prices for 27 stations in Guelph, Ontario were observed every two hours (8:00AM to 10:00PM) from August 14 to November 24, 2005. Station characteristics were also collected, and wholesale (rack) price data were obtained for London, Ontario to approximate marginal costs.

To anticipate results, the Edgeworth cycle theory is supported by the data in many respects. However, discrepancies exist that would likely be overlooked with less complete data, and comprise two important contributions to the literature. First, it appears that independents do not generally tend to set the market minimum price, contrary to findings in previous studies. Instead, it appears that the minimum market price tends to be set by a single brand (Pioneer), which is partly owned by a refiner brand (Suncor) and which operates one station in Guelph. On the other hand, other independents in Guelph do not appear to be particularly aggressive; specifically, the "mom-and-pop" operations, which have low capacities, repair bays and no other ancillary operations, do not seem to closely follow the Guelph cycles, and might be more focussed on their repair businesses than gasoline sales.

Second, the leaders of price increases in Guelph are always identified to be among five specific stations, which are either known or believed to be price controlled by two specific brands. Furthermore, the peak prices set by these stations, as well as the timing of their price increases are quite predictable; this predictability might increase the probability that a station's price increase will be followed by its rivals, as well as increase the speed of rivals' responses. These findings do not contradict the predictions of the Edgeworth cycle theory, but do indicate certain refinements that might be made to the theory to make its predictions more accurate.

This chapter is organized as follows. The theoretical Edgeworth cycle literature and its testable implications are reviewed in the next section, as well as the relevant empirical literature. Section 3.3 discusses the data, while Section 3.4 examines the accuracy of the Edgeworth cycle predictions. Section 3.5 considers alternative explanations for cycles, Section 3.6 examines whether price movements following Hurricane Katrina are consistent with the Edgeworth cycle theory, and Section 3.7 concludes.

## 3.2 Literature Review

### *3.2.1 Edgeworth Cycles*

In the model developed by Maskin and Tirole (1988), two identical firms maximize their present-discounted stream of profits by setting prices for a homogeneous product over an infinite horizon. Marginal cost is constant, there are no fixed costs or capacity constraints, and the firm with the lowest price serves the entire market. If both firms charge the same price, then they split market demand evenly. Price competition takes place in discrete time, and prices are chosen over a finite grid. Finally, Maskin and Tirole (1988) restrict a firm's strategies to depend only on the most recent rival price set. Using this framework, the authors prove that for a sufficiently fine price grid and a discount factor near one, many Markov perfect equilibria exist, including Edgeworth cycles.[1]

The structure of an equilibrium cycle is shown graphically in Figure 3.1, and is described as follows. Beginning at the top of the cycle, a firm undercuts its rival's price by one unit; this strategy is played by the firm because it expects its rival to do the same in the next period, and because it can serve the entire market before its rival responds to this undercut. These one-unit undercuts continue until one firm lowers its price to marginal cost. There is then

---

[1] Noel (2006) extends this model to permit randomly fluctuating marginal cost, and shows computationally that if there is product or spatial differentiation, capacity constraints or three firms, then Edgeworth cycles can still exist in equilibrium.

a war of attrition of indeterminate length (as illustrated in Figure 3.1 by the difference in the lengths of the cycles) as each firm waits with positive probability for the other to initiate a cycle "restoration" by raising its price to the new cycle peak (each firm plays mixed strategies where the expected profits of waiting and relenting are equal); the cycle is then repeated. This reluctance to lead a restoration is not because it might not be followed, but rather due to the expectation that the follower will undercut this price by an incremental unit, causing the leader to make zero profits for two consecutive periods.[2] Furthermore, the leader sets a price *above* the monopoly price so that its profits will be closer to the monopoly level when it does have the opportunity to set its price again.

Eckert (2003) extends the basic model to allow the two firms to differ in size, which can be measured by the number of stations each one operates in the market, or by its number of pumps; if both charge the same price, their shares of market demand are proportional to their relative sizes. He uses examples to demonstrate that the large firm will tend to lead price increases, while the small firm is more likely to follow an undercutting strategy. Although there is no coordination problem in this model, intuitively, a large firm can more easily coordinate a restoration by simultaneously raising all of the prices that it controls.[3] On the other hand, the market sharing rule is biased against a small firm when both charge the same price; given the choice of either matching or undercutting its rival's price, the undercutting (matching) strategy

[2] The knowledge that leading a restoration will result in two consecutive periods of zero profits also deters firms from raising their prices before they equal marginal cost.

[3] Also, Noel (2006) shows that if a firm is a recognized leader of price increases, then followers might follow a "step-up" strategy where they raise their prices slightly at the bottom of the cycle to remain profitable. Given this strategy, the recognized leader always raises its price first since it knows its rivals will never relent, so step ups are not observed in equilibrium.

tends to be more profitable for the small (large) firm.

In summary, five structural and three behavioural predictions are examined in this chapter, where the structural predictions relate to the prices being set, while the behavioural predictions refer to how stations interact with their rivals (and so require station-specific data):[4]

(S1) Retail prices follow an asymmetric pattern, increasing by large amounts in a short amount of time, and falling over a longer amount of time with a series of much smaller price decreases (as demonstrated in Figure 3.1).

(S2) In theory, prices cycle even if marginal cost is constant. Thus, the pattern of retail price movements, where large single price increases are followed by many small price decreases are not expected to be observed in the rack price series.[5]

(S3) Theoretically, prices do not rise until a station's price falls to marginal cost, so it initiates a restoration when, and only when its price approaches marginal cost.

(S4) In theory, the cycle peak is above the monopoly price, and is a function of both demand parameters and marginal cost. Thus, peak price-cost margins might fluctuate as both demand and costs fluctuate.

(S5) The magnitudes of retail price decreases are expected to not vary with the cycle position. This prediction follows from the theoretical equilibria, in which firms undercut one another by minimal amounts in a battle for market share.[6]

---

[4] Identifying predictions as structural or behavioural is adopted from Noel (2007a).

[5] Noel (2006) demonstrates that in a model with three firms, if marginal cost falls after the leader raises its price, enabling its rivals to earn positive profits without raising their prices, then the leader might abandon the restoration attempt. Noel (2006) calls this a "false start".

[6] The minimum possible undercut in a retail gasoline market is 0.1 cents per litre. However, in reality, this minimum is expected to depend on its spatial location and other

(B1) Based on the examples provided by Eckert (2003) and intuition, the leaders of price increases in Guelph will tend to be the brands that individually control prices at more stations than any other brands (the majors).

(B2) The stations that undercut the market minimum price will tend to be brands that control prices at the fewest stations in Guelph (the independents).

(B3) The theory assumes that a station can temporarily increase its market share by undercutting its rivals' prices. Thus, when a station undercuts the entire market, its rivals should not be observed to match this new price immediately, even if they are geographically close to that station.

### *3.2.2 Empirical Studies*

Price data used in some studies of retail gasoline price cycles, such as Eckert (2002) and Noel (2007b), are averaged across stations and sampled once per week. Lewis (2006) also identifies price cycles in retail gasoline markets in the mid-western United States, using daily average retail prices. While the authors of these studies are able to examine price cycles in a number of ways, these data cannot be used to examine any of the three behavioural predictions because station-specific prices are not observed.

In order to test certain predictions of the Edgeworth cycle theory, Noel (2007a) collected station-specific price data for 22 stations in Toronto, every 12 hours for 131 days in 2001. Using econometric methods, the author finds support for all four predictions. However, two

---

characteristics. In fact, a station might effectively undercut a rival's price by setting a certain price-differential *above* it; for example, it might charge a premium for full-service gas.

potential issues arise in regard to his conclusions. First, many of the stations that are excluded from the sample are located within a few blocks of the sampled stations. Thus, it is unlikely that all stations in the relevant market have been included in the sample, suggesting that true price leaders might have been excluded from the sample. Second, these 22 stations are distributed along major city routes in a relatively small section of Toronto, and so might react to one another's price changes more quickly than every 12 hours. Thus, consistent leaders of price movements (if they exist) will unlikely be identified with twice-daily data.

While he does not specifically study the coordination problem that can exist in initiating a new cycle, Noel (2007a, 85) also finds evidence that both majors and independents tend to raise their prices to an "almost standard markup". Furthermore, he finds that restorations tend to be initiated early in the week, which is consistent with a claim of the Conference Board of Canada (2001, 28) that prices tend to rise early in the week (after the morning rush) when demand is relatively low. However, since he identifies several different firms as leaders, Noel (2007a) appears unable to identify which brands (if any) consistently raise their prices first, or a more specific time of day when restorations are initiated.

Although Eckert and West (2004a-b) cannot identify specific price leaders, they do identify specific brands that might be instrumental in driving prices down in cycling markets. Using station-specific price data collected from gasoline price websites in Ottawa and Vancouver, Eckert and West (2004a) find evidence that the existence of cycles seems to depend on the presence of suspected "maverick" retailers that prevent tacit collusion, such as Sunoco and Pioneer in Ottawa, and ARCO and Tempo in Vancouver.[7] Eckert and West (2004b) find

---

[7] The authors also note that Suncor owns both the Sunoco brand and 50% of Pioneer.

that price decreases in Vancouver appear to originate in regions where ARCO and Tempo are most highly concentrated, and restorations are usually initiated on Tuesdays and Wednesdays.[8] They also find that both the wholesale price and mode peak prices in their data are quite stable, implying that peak margins are relatively constant.

Wang (2006a) compiled a data set that includes every price change by every station in Perth, Australia from June 1, 2001 to October 31, 2003. The "24 Hour Rule" imposed by the Western Australian government requires firms to set their prices simultaneously and once per day, and all prices are simultaneously posted by the government on the Internet.[9] Given these timing constraints, Wang (2006a) examines the alternating-moves assumption of the Edgeworth cycle theory. He finds that despite the timing regulations, prices do cycle in Perth, and firms still stagger price increases through a system of price leadership. However, given the fact that the timing of price movements in this market is regulated, it is unclear whether these results could extend to an unregulated market.

Finally, in the basic duopoly model developed by Maskin and Tirole (1988), firms do not encounter a problem coordinating cycle restorations; in the period after one firm raises its price, its rival follows this price increase by slightly undercutting the leader's price. However,

---

[8] LECG Canada (2006) also attempts to evaluate the impact of local competition on retail gasoline prices. However, little evidence is provided in this study regarding the competitiveness of independents, since only five stations between Oshawa and Kitchener-Waterloo are sampled, covering a road distance of 150km; the market participants selected which stations were sampled, but provided no evidence that they are representative of other stations in their market(s); the timing of price changes is unobserved since the data range from average daily to monthly revenues per litre sold; and the operations of the two independents in the sample are not primarily focussed on gasoline sales.

[9] By 2:00PM each day, every retailer reports it price for the next day to the government, and all are posted simultaneously on the Internet by 2:30PM (http://www.fuelwatch.wa.gov.au; visited 2007-05-01). All prices are set at exactly 6:00AM and remain unchanged for 24 hours.

Noel (2006) demonstrates computationally that by adding a third firm, a coordination problem can arise, leading to false starts. Wang (2006b) empirically examines this problem in the context of a 2004 antitrust case involving gas stations in Ballarat, Australia, which were alleged to be parties to a price-fixing agreement in 1999 to 2000. In this case, phone records show that inter-station phone calls increased substantially on days when restorations were initiated, and these phone calls were allegedly initiated to coordinate price increases across the market.[10] However, Wang (2006b) does not address how gas prices might move in such a way as to facilitate the coordination of restorations in the absence of any collusive behaviour.

### 3.3 The Data

Regular-grade fuel prices in cents per litre (cpl) were collected every two hours (8:00AM to 10:00PM) from August 14 to November 24, 2005 for 27 stations in Guelph, a city in southern Ontario with an approximate population of 106,000.[11] All 27 prices were collected once in 45 minutes, on average. Station characteristics were also collected, including operating hours (24 hours or not), service levels (full-, self-, or split-serve), capacities (regular-grade nozzle counts), and other operations (repair bay, convenience store, car wash). Finally, daily rack price data for London, Ontario were obtained from MJ Ervin & Associates to approximate marginal costs.

Station locations are plotted in Figure 3.2, and numbered in the order that they were

---

[10] Wang (2006b) reports that four firms admitted to initiating calls with the purpose of coordinating restorations; the issue was whether the three contesting firms were also parties to the agreement. All three were convicted by the trial Court, but one conviction was reversed by the full Court on appeal.

[11] The last period during which prices were collected on November 24 began at 4:00PM.

collected.[12] Esso, Petro-Canada, Shell/Beaver and Sunoco are the vertically-integrated (major) brands in the city; Canadian Tire, 7-Eleven and Pioneer are among the independents in the market, where an independent is defined as a brand that is not 100% owned by a refiner brand. Selected characteristics for each station are provided in Table 3.1, where it can be seen that major brand stations tend to be 24-hour, self-serve stations with relatively high capacities, convenience stores and car washes, and no repair bays. Stations selling gas under the 7-Eleven, Canadian Tire and Pioneer brands are similar to these major brand stations in terms of capacities and other characteristics, while the other independents are full-serve stations with relatively low capacities, limited hours, and repair bays, but no other operations.

Intuitively, the ability of a firm to successfully initiate a restoration can depend on the number of stations' prices that it controls; a brand might attempt to lead a restoration by simultaneously raising all of the prices that it controls in the market. Thus, an attempt was made to determine whether each station's price is set by its manager or its supplier. Representatives of the above seven brands were contacted, and six reported that each station's price is company-controlled (Station 14's manager is permitted some control over that station's price); Esso refused to provide price control information. However, according to MJ Ervin & Associates Inc. (2006, Appendix A), 7-Eleven Canada controls prices at its Esso-branded stations, implying that Station 7's price is not controlled by Esso. Also, Station 17 has a Rainbow-branded car wash and variety store, and is described on an Esso-affiliated website as

---

[12] Esso Station 28 did not post its price, and so was excluded from the sample. However, prices collected once per night from its pump from August 14 to September 29, 2005 (excluding August 16) suggest that the other 27 stations were not basing their prices on its prices; on average, Station 28's price is observed to change every 9.0 days, versus every 1.0 to 2.0 days for each other station.

a family-operated dealer.[13] Finally, the empirical literature on station contracts suggests that a company is more likely to control prices at stations with longer hours, greater pump capacities, or convenience stores, and is more likely to delegate price-setting authority to stations that are full-serve and/or have repair bays.[14] Thus, Esso most likely controls prices at Stations 19, 21, and 26.[15] Based on these conclusions, major brand stations are divided in Table 3.1 by the likely source of price control, where Group A stations' prices are either known or believed to be controlled by the head office of the brand, and Group B stations' prices are not. Independents are also divided by size (station-specific nozzle counts), where Group C stations have relatively more regular-fuel nozzles than Group D stations.

In order to examine the behavioural predictions, all relevant competitors of each station should be included in the sample. With this in mind, the 10 nearest stations to Guelph have been identified; all are located between 3.0 and 10.3 km from their nearest Guelph neighbours, and the area between them and Guelph is non-residential. Thus, if consumers patronize stations near their homes,[16] then it is reasonable to expect that they do not view these 10 stations as

---

[13] See "Esso Rebecca Run for SMA" (http://www.rebeccarun.com/esso_dealers/rainbow.html; visited 2007-05-01).

[14] For example, see Shepard (1993), Slade (1998), and Taylor (2000).

[15] These criteria also suggest that Stations 9, 11, 20 and 27 are lessee dealers; however, both Suncor (which markets the Sunoco brand) and Shell Canada (which markets the Shell and Beaver brands) reported that they control all of their Guelph stations' prices. Furthermore, MJ Ervin & Associates Inc. (2006, Appendix A) reports that all full-serve Suncor marketed Sunoco stations, and all Beaver stations are price controlled by Suncor and Shell Canada, respectively.

[16] For example, in his Affidavit for the case of *Director of Investigation and Research v. Imperial Oil Limited*, dated July 24, 1989, Exhibit A at paragraph 14, Professor M. Trebilcock writes that "industry data suggest that up to 70% of consumers tend to buy most of their gasoline within two miles of their homes." This quote also appears in the Reasons and Decision for the case (pp. 22-23).

relevant alternatives to Guelph stations. By the same argument, stations in Kitchener, Waterloo and Cambridge (these cities are visible in the south-west corner of Figure 3.3) are even less likely to be direct competitors of Guelph stations.

## 3.4 Empirical Examination of the Basic Theoretical Predictions

### *3.4.1 Structural Predictions*

#### 3.4.1.1 Basic Patterns in Retail Price Changes

The purpose of this subsection is to demonstrate that retail gasoline prices in Guelph follow an asymmetric pattern, increasing by large amounts in a short amount of time and then falling over a longer amount of time with a series of much smaller price decreases. Evidence of such a cyclical pattern would provide support for Prediction (S1) of the Edgeworth cycle theory.

Table 3.2 contains summary statistics regarding retail price movements over the entire sample. On average, an individual station's price decreases 116 times and increases 21 times. With respect to daily prices, the market mean price rises on 25 (24.5%) days and decreases on each of the other 77 days on which a change can be measured. The market mode price exhibits similar asymmetries. Thus, retail prices clearly rise much more frequently than they fall.

Table 3.2 also demonstrates that the magnitudes of price increases tend to be much larger than decreases. On average, individual stations are observed to raise their prices by 7.3 cpl in one period, but lower them by only 1.4 cpl at a time. On a market-wide basis, the average daily price increase is 3.8 cpl, while the average daily price decrease is 1.3 cpl. The asymmetry in the mode price is even more pronounced: the average daily increase (decrease) in the mode price is 7.7 cpl (1.9 cpl). The relative infrequency and large magnitudes of market price increases are shown graphically in Figure 3.4, in which the bi-hourly mode price is plotted with the daily London rack price and a daily price of crude oil.[17]

Next, it can be established that all 27 stations tend to raise their prices within the same two-day period, which is defined as the restoration phase of the cycle. Modifying the approach of Eckert and West (2004b), an attempted restoration day (Day 0) is defined as a day when the bi-hourly market mode price rises after a station raises its price to that mode price.[18] The following days are Days 1, 2, etc.

Applying this methodology yields 16 restoration attempts. The 31 Days 0 and 1 identified in the data account for 91.5% of the 575 observed price increases.[19] Also, for 13 restorations, all 27 stations increase their prices during the same two days, on average, while only a subset of stations raise their prices during the other three restorations. Two of these three restorations appear to be false starts;[20] on average, only 21 stations raise their prices, and most increases are completely reversed by the end of Day 1. With respect to the third restoration,

---

[17] Daily crude oil price data (par Edmonton) were obtained from Natural Resources Canada (http://www2.nrcan.gc.ca/es/erb/prb/english/View.asp?x=476; visited 2007-05-01).

[18] Mode price increases in a single period are occasionally observed after a station lowers its price, causing a higher price to be more frequently observed. These are clearly not restoration attempts. Also, on September 22, 10 stations in Guelph are observed to raise their prices from below 105.0 cpl to as high as 130.9 cpl. However, these increases appear to be responses to a demand shock; queues of approximately 10 to 20 vehicles were observed at most stations in Guelph for the entire day, which began before the first price increase, and all but one were reversed by the next morning. Similar queues (and larger price increases) were reported in the media for stations across southern Ontario, and were attributed to consumer fears that gas prices would rise due to Hurricane Rita. The Competition Bureau also concludes that a demand shock led to price increases on this day; see "Competition Bureau Concludes Examination into Gasoline Price Spike Following Hurricane Katrina" (http://www.competitionbureau.gc.ca/internet/index.cfm?itemID=2047&lg=e; visited 2007-05-01).

[19] Restoration attempts are identified on both August 30 and 31, so August 31 is a Day 0 *and* a Day 1.

[20] See Noel (2006), *supra* note 5.

seven stations are observed to increase their prices to ones that are less than or equal to the pre-restoration prices of 14 of the remaining stations.

The findings of this subsection can now be summarized. On average, a gasoline retailer in Guelph lowers its price 5.5 times more often than it increases it, and it also raises its price by a magnitude that is 5.2 times greater than for its price decreases. Similarly, the market-wide daily mean price increases much less frequently than it falls, and by much larger amounts.

#### 3.4.1.2 Basic Patterns in Rack Price Changes

According to Prediction (S2) of the Edgeworth cycle theory, the cyclical price movements described in the previous subsection are not driven by rack price movements; in other words, the rack price is not expected to follow the cyclical patterns exhibited in the retail price series. Therefore, the purpose of this subsection is to explore whether this prediction is supported by the data collected in Guelph. If so, then these results will suggest that the Edgeworth cycle theory is more appropriate than cost-based theories of asymmetric price movements for explaining the retail price cycles observed in Guelph.

First, as shown in Table 3.2, it does not appear that increases in the London rack price are much more common than rack price decreases. First, the rack price decreases 1.4 times more often than it increases (39 vs. 28 times), compared to 4.3 times for the daily mode retail price, and 5.5 times for the average individual station. Similarly, on average, rack price increases are 1.1 times greater in magnitude than rack price decreases (2.4 cpl vs. 2.1 cpl), compared to 4.1 times for the daily mode retail price and 5.2 times for the average individual station. These summary statistics suggest that while the London rack price does exhibit some asymmetry, it does not follow the highly asymmetric cycles observed in Guelph retail prices.

It can next be established that while retail price changes in each direction tend to be followed by price decreases, there is no strong pattern with respect to which direction the rack price changes. Table 3.3 contains a transition matrix, which shows the proportion of price changes in each direction that are followed by price increases and decreases. Proportions are provided for both the daily retail and rack price series, and retail price changes are only calculated on days when the rack price is set, to permit direct comparison between the two series. For example, according to this table, 7.1% of retail price increases are followed in the next price change by a retail price increase, while 42.9% of rack price increases are followed in the next change by a rack price increase.

In summary, Table 3.3 shows that rack price increases are followed in the next price change by further increases 6.0 times more often than mode retail price increases are followed by increases (42.9% vs. 7.1%). Also, rack price decreases are followed by increases 1.5 times more often than mode retail price decreases are followed by increases (40.5% vs. 26.5%). Thus, it seems that while retail prices tend to fall during the cycle, rack prices exhibit no similarly strong pattern in either direction.[21]

#### 3.4.1.3 The Timing of Restoration Attempts

The purpose of this subsection is to consider Prediction (S3) of the Edgeworth cycle theory, which is that restorations will be initiated when, and only when at least one firm's price falls to

---

[21] Mode retail price changes are calculated for Table 3.3 instead of averages because it typically takes two days for all stations in the market to raise their prices during restorations, so consecutive average daily price increases are common in the data. Therefore, the results provided for mode retail prices are more representative ofthe results for each individual station.

marginal cost; this is empirically examined using the retail-rack margin.[22] However, one should first understand the possible role played by both demand and prices in other cities in the region.

First, consistent with the findings of studies cited in Section 3.2, restorations tend to be observed early in the week when gasoline demand is expected to be relatively low; 13 (81.3%) restoration attempts are observed between Monday and Wednesday (six on Tuesday). Also, the first stations to raise their prices to their peaks always do so between noon and 2:00PM, which is when the number of commuters is relatively low in Guelph.[23]

Second, cycle restorations appear to be initiated *regionally*. Price data were collected for gasoline stations in Kitchener, Cambridge, and Waterloo every day at noon and midnight from an Internet gasoline pricing website.[24] It has been discovered that the 12-hourly mode and average prices in all three cities tend to fall (sometimes at different rates) until a restoration is identified in Guelph, after which these prices rise by several cents per litre; by the morning of Day 1, the mode peak price observed in Guelph is also reported on this site for multiple stations in each city. Since a brand might delegate its price-setting authority across the region to a single district manager, this finding is not inconsistent with the Edgeworth cycle theory.

---

[22] The retail-rack margin is calculated to be the retail price minus the current London rack price, the Ontario provincial gas tax (14.7 cpl), the federal gas tax (10.0 cpl), and the federal Goods and Services Tax (7%), which is levied on both the price and the excise taxes.

[23] See Paradigm Transportation Solutions Limited *et al.* (2005, 20). Travel demand is likely a reasonable proxy for gasoline demand, because consumers travel to buy gas.

[24] Consumers voluntarily post the brands, locations and prices of gasoline retailers on this site (http://www.ontariogasprices.com; visited 2007-05-01). Both the nickname of the "price spotter" and the time of their post are also listed. Membership is free and anonymous (but not required), and members earn 150 points per posted price (up to 750 points per day) which can be used to participate in raffles for prizes such as U.S.$250 gas cards. Additional points are earned for participating in other features of the site, such as voting in opinion polls and posting messages on a forum.

Given these two findings, the relationship between the timing of restoration attempts and the proximity of prices to the London rack price will be clearer. In the data, restorations are always initiated within two weekdays of the mode retail-rack margin becoming non-positive in at least one of the four cities; the mode margin in Guelph is calculated for every period during which prices were collected, and the mode margins in the other three cities are calculated for every 12-hour period.[25] It is found that restorations are never initiated in the data on weekends or weekdays after 2:00PM, even if the mode retail-rack margin is several cents below zero. Particularly when the mode margin becomes non-positive in at least one city on a weekday (11 times), then the restoration is either initiated on that day or on the next weekday; when it turns non-positive on a weekend (five times), then a restoration is initiated either on the following Monday or Tuesday. Restorations are also never observed when mode margins in all four cities are positive. These results can be contrasted with those generated if Guelph is isolated from the other three cities: only 12 restorations are initiated when the mode retail-rack margin is non-positive, while the pre-increase mode margins are 1.0 to 6.4 cpl on the other four Days 0.

The relationship between the timing of restoration attempts and the London rack price is shown graphically in Figure 3.4, where each Day 0 is marked with a vertical line; these lines tend to be farther apart (closer together) when the rack price is falling (rising). Specifically, when the rack price is relatively stable, the durations between restoration attempts tend to approximate the 6.6 day average in Table 3.2; seven occur six to eight days after the previous Days 0. However, after Hurricanes Katrina and Rita and the subsequent increases in the

[25] A margin is considered non-positive if it is strictly lower than 0.1 cpl, since it equals zero if it is rounded down to the nearest tenth. Also, modes are calculated instead of means because they are representative of the posted prices of the first stations to raise their prices.

London rack price, three restorations follow previous ones in one to three days; the three longest durations of 10 to 14 days occur while the London rack price falls.

3.4.1.4 The Predictability of Cycle Peaks

Next, Prediction (S4) will be considered, which is that the peak price of a cycle will be set above the monopoly price, and therefore the peak retail-rack margins are expected to fluctuate with demand and costs. However, as discussed in Section 3.2, both Eckert and West (2004b) and Noel (2007a) find that the mode peak margins in their data for Vancouver and Toronto tend to follow relatively constant markups. Thus, this section will investigate whether peak margins in Guelph can be approximated using the London rack price.

Consistent with the above studies, the data show that the mode cycle peak margins in Guelph can be approximated using the London rack price. Particularly, 14 (87.5%) of all mode peak prices can be calculated by adding 7.0 cpl and all taxes to the current London rack price, and then rounding the result either to the nearest "5" or the nearest "9".[26] Therefore, while the peak retail-rack margin does fluctuate over time as predicted by the basic Edgeworth cycle theory, it is much more predictable than one might intuitively expect from the large fluctuations of the London rack price. This predictability is of particular interest because it can facilitate both the speed and success of restoration attempts; the current rack price is likely observable to all players in the market, so if the mode peak price is roughly predictable, then a station's rivals

[26] With respect to the other two restorations, the mode peak price on November 4 is rounded down further to end in "5", while the mode peak margin on August 31 is 9.2 cpl. The latter restoration coincides with a 15.2 cpl increase in the London rack price following Hurricane Katrina; see Section 3.6 for a more detailed examination of price movements in Guelph following Hurricane Katrina.

can more easily distinguish its restoration attempt from a temporary inventory shortage or a glitch with its electronic price sign.[27]

3.4.1.5 The Relationship Between Retail Price Decreases and Rack Prices

Prediction (S5) of the Edgeworth cycle theory will next be tested, which is that the magnitudes of retail price decreases will tend to be constant during a cycle, with the possible exception of periods toward the end of the cycle when a firm might attempt to hasten a restoration. It is important to test whether the data are consistent with this prediction, because a key assumption of the Edgeworth cycle theory is that firms undercut one another's prices in a battle for market share, rather than in response to cost fluctuations. If it is instead found that price movements in Guelph are strongly responsive to cost movements, then a different theory of pricing dynamics might be more appropriate for explaining price cycles in this market.

The model to be estimated is based on equations estimated by Eckert (2002) and Noel (2007c), using data for Windsor and Toronto, respectively. The effects of retail and rack prices, among other factors, on the magnitudes of retail price changes are estimated using data collected during undercutting phases. The model, which is explained below, is as follows:

$$\Delta p_t = \alpha_0 + \alpha_1 p_{t-1} + \alpha_2 r_t + \alpha_3 \Delta p_{t-1} + \alpha_4 \Delta r_{t-1} + \alpha_5 t + \beta D_t + v_t$$

---

[27] A question that arises from this result is whether a demand function exists such that a 7.0 cpl markup can alway be above the monopoly price, regardless of cost fluctuations. One such inverse demand function is $p = A - k \ln(q)$, where A and k are demand parameters and q is the quantity demanded. If marginal cost is assumed to be c (a constant), then the monopoly price is $p^M = c + k$; the monopoly markup (k) is constant, even when A and c fluctuate. Thus, it is possible that a constant markup over the London rack price will always result in a price above the monopoly price, because the monopoly markup is also constant. However, it should be noted that k will *not* equal 7.0 cpl under the basic Edgeworth cycle theory, which predicts that the leader will raise its price *above* the monopoly price. It has not been demonstrated that a firm would indeed set a constant markup over this monopoly price, in equilibrium.

where $\Delta p_t$ is the change in the average daily retail prices in Guelph (excluding taxes) from Time *t-1* to Time *t*,[28] $r_t$ is the London rack price at Time *t*, $D_t$ is a vector of six day-of-the-week dummies (Wednesday to Monday), *t* is a linear time trend, and $v_t$ is a random error term.[29]

Since the purpose of this subsection is to examine the magnitudes of price *decreases*, the 31 restoration days (Days 0 and 1) are omitted from the data (but price increases might still be observed on non-restoration days). Data for November 24 are also excluded from the analysis, because only five periods were sampled that day; this exclusion does not change any of the qualitative results discussed below. Furthermore, tests regarding lag lengths of the dependent and rack price variables, as well as for stability and serial correlation are explained in the technical appendix (Section 3.8).

With respect to the explanatory variables that are included in the above regression equation, they are as follows. First, the lagged average retail price and the current rack price are included because the magnitudes of retail price changes during an undercutting phase might depend on rack price movements and the current position of the cycle. The lagged changes in the average retail and rack price series are also included to control for the possibility that

---

[28] Eckert (2002) takes the logarithm of the dependent variable, because the assumption of normal errors implies that price increases can be predicted over the decreasing part of the cycle. However, as predicted by Noel (2006), and as observed in the Guelph data, firms might follow a "step-up" strategy during an undercutting phase, implying price increases might occasionally be observed during undercutting phases when prices are not in equilibrium.

[29] Eckert (2002) also estimates a probit equation, from which he calculates the Inverse Mills Ratio to control for sample-selection bias. However, a similar probit equation cannot be estimated using the Guelph data; restoration attempts are never observed on weekends, so day-of-the-week effects cannot be incorporated into the probit estimation. However, as found in Section 3.4.1.3, the timing of restorations appears to be (at least partly) determined by exogenous factors, including the day of the week and prices in other cities, which could reduce any sample selection bias present in the model.

average retail price changes might reflect recent changes in the average retail and rack prices other than through the current retail-rack margin. The basic Edgeworth cycle theory predicts that if statistically significant, the coefficients on these variables will be estimated such that price decreases grow in absolute size as the average retail price approaches the rack price.

Second, the Conference Board of Canada (2001) claims that stations tend to lead restorations early in the week when demand is relatively low, and evidence to support this claim was provided in Section 3.4.1.3 above. This implies that stations might undercut less aggressively on these days, because there are relatively fewer consumers for which to compete. Therefore, six dummies for days of the week are included in the regression to control for day-of-the-week demand factors; Tuesday is omitted since it is a Day 0/1 for 10 (62.5%) restorations.

The results of this regression are provided in Table 3.4. First, the coefficient on $p_{t-1}$ is negative and statistically significant at the 1% level of significance, while the coefficient on $\Delta p_{t-1}$ is positive and statistically significant at the 10% level of significance. Also, the coefficient on $r_t$ is positive and significant at the 1% level of significance, while the coefficient on $\Delta r_{t-1}$ is negative and significant at the 10% level of significance. Furthermore, the null hypothesis that the coefficients of $p_{t-1}$ and $r_t$ are equal but opposite in sign is not rejected at the 5% (or 10%) level of significance. Taken together, these results suggest that while the size of an average retail price change does not statistically depend on the position of the cycle (measured by the current retail-rack margin), the average retail price does tend to fall by larger increments the higher is the previous average retail price and the lower is the current rack price, and that larger average retail price decreases in the current period are followed by even larger decreases in the next period. Finally, all six day-of-the-week dummies are individually- and jointly-insignificant at the 5% level of significance, suggesting the sizes of price decreases do not significantly depend on the day of the week.[30]

It is important to realize that these results are not necessarily inconsistent with the Edgeworth cycle theory, which predicts that a firm will lead a restoration by raising its price slightly above the monopoly price. The basic theory assumes that marginal cost is constant, and therefore each firm's profit margin falls until a restoration attempt. However, if marginal cost is permitted to rise substantially, such that a firm's margin rises above the monopoly margin, then the firm might lower its price more aggressively in order to return to the monopoly margin. Since the results in Section 3.4.1.4 suggest that the mode monopoly margin in Guelph might be slightly below 7.0 cpl, it is possible that the results shown in Table 3.4 reflect particularly aggressive pricing during days when the mode retail-rack margin rose above this level due to large rack price decreases. Evidence to support this expectation is found in Pearson correlation coefficients between the retail-rack margin and $\Delta p_t$ during non-restoration days: the coefficient is -0.61 (N = 26) when the margin is above 7.0 cpl, and -0.11 for all other days (N = 44).

To examine this relationship econometrically, a dummy has been created that equals one when the margin is above 7.0 cpl and zero otherwise. This dummy has been added to the above regression; two interaction terms that equal either $p_{t-1}$ or $r_t$ multiplied by this dummy are also included. Furthermore, using the testing-down procedure described in the technical appendix, $\Delta p_{t-1}$ and $\Delta r_{t-1}$ are no longer included in the regression. The results of this alternative specification are that none of the coefficients (including the constant) are significant at the 10%

---

[30] To test if Hurricane Katrina had a significant impact on the size of price decreases in Guelph, a dummy was added to the above regression that equals one between August 30 and September 17, inclusively; these dates were chosen because Katrina hit the U.S. on August 29, and September 17 is the day on which the first advisory of Hurricane Rita was issued, so the effects of Katrina and Rita will not be mixed. No qualitative results change as a result of including this dummy, which is not statistically significant at the 10% level of significance.

level of significance. These results are consistent with the argument that the mean price in Guelph tends to fall at a relatively constant rate when the (lagged) mode retail-rack margin is below the pre-rounded peak markup of 7.0 cpl, and falls at a greater rate otherwise.[31]

### *3.4.2 Behavioural Predictions*

#### 3.4.2.1 Cycle Restorations and Firm Size

The first behavioural prediction to be considered is that large firms tend to lead price increases, where size is measured by the number of stations price controlled by each brand. The purpose of this subsection is to identify which brands and stations tend to lead price increases, and to consider the extent to which these firms are indeed the largest firms in the Guelph market.

For this subsection, two different methodologies are used to identify restoration leaders. The first identifies which brands and stations are the first to increase their prices on each Day 0. However, a problem with this methodology is that some leaders raise their prices slightly more than enough to make their retail-rack margins positive, and then raise them to their cycle peaks later in the day. This suggests that they might be following a "step-up" strategy.[32] Thus, the second methodology only identifies a station as a leader if it is among the first to raise its price to its cycle peak on Day 0.

The leaders identified by these two methodologies are listed in Table 3.5, along with the number of times each is observed to be a leader. As predicted by the Edgeworth cycle theory,

---

[31] If mode price changes are examined instead of mean price changes, then the testing-down procedure described in the technical appendix leads to a decision to include no lags of $\Delta p_t$ and $\Delta r_t$ in any of the three regressions estimated in this section; the qualitative results found in the three mean price regressions are also found in their corresponding mode price regressions.

[32] See Noel (2006), *supra* note 3.

both methodologies tend to identify major brand stations as leaders. However, they also tend to be five specific major brand stations: Petro-Canada Stations 5, 18 and 25, and Esso Stations 19 and 26, all of which are either known or believed to be price controlled by their head offices. Specifically, the only Petro-Canada station not identified in this table is Station 14, and it is known that its manager has limited price control. Similarly, Stations 19 and 26 are two of the Esso stations identified as most likely to be price controlled by Esso. Finally, the three Sunoco stations are rarely identified as leaders of price increases, while no Shell Canada station is ever identified as a leader, despite it being a national refiner brand.[33]

Thus, the findings in this section go further in identifying leaders of price increases than could have been possible using data that only includes prices for a subset of stations in the market, or for prices that were only collected twice per day. For example, Noel (2007a) uses econometric techniques to identify leaders of price increases in Toronto, and finds that major brands, in general tend to lead them. In the Guelph data, even though every major brand is known or believed to control three stations' prices each, two are identified as leaders of almost every restoration, while two are rarely, if ever leaders.[34]

---

[33] One issue that arises in the identification of price leaders is that, because it took 45 minutes to collect prices from all 27 stations each period, stations observed toward the end of each trip are more likely to be identified as leaders than stations observed earlier in the drive. Therefore, a third methodology has been considered, where stations are also identified as leaders if they are observed to raise their prices to their cycle peaks one period later than the leaders identified in the second methodology, but might have actually raised their prices first. It is found that the results using the second and third methodologies are not substantively different; no new stations are identified as leaders, while Stations 3 and 4 are each identified as price leaders twice, the three Sunoco stations two to four times each, the Esso stations 10 to 12 times each, and the Petro-Canada stations 14 to 16 times each.

[34] Note that the data are consistent with the argument that Petro-Canada has assumed the role of leader of price increases, and Esso Stations 19 and 26 are typically quick followers. Specifically, Stations 5, 18 and 25 are always observed to set the mode peak price by 2:00PM,

These results suggest that the size of a firm is not the only characteristic that can influence whether it is a leader of price increases; otherwise, Sunoco and Shell Canada should be identified as leaders more often. Another potential influence is the spatial location of the firm. First, each of the other 22 stations are located within 3.5km of at least one of these five leaders (on a crow-flies basis), implying that each rival can more quickly observe the initiation of a restoration by one of these leaders than if the leaders were isolated near the edges of the city. Second, all five leaders are located either within one block of a mall or in the downtown core where large numbers of consumers are expected to converge. Intuitively, since each consumer represents a potential source of revenue, stations near these high-traffic areas have an incentive to compete directly with these five leaders, rather than with stations that are not on commuting routes. For both reasons, price increases initiated by these five stations might be observed by their rivals more quickly than price increases of stations where fewer consumers travel; this relative visibility might reduce the risk that a price increase will not be followed, which could increase the likelihood that a station will be willing to take this risk. It might also explain why Petro-Canada and Esso chose to control these particular stations, and not the others.[35]

---

while the first price increases of Esso Stations 19 and 26 are observed after 2:00PM on three and four dates, respectively. Also, of the three Esso stations that are believed to be price controlled by their head office, only those with Group A Petro-Canada stations as their closest competitors are ever observed to lead price increases; Esso Station 21 is never identified as a leader, even when its nearest competitor, Sunoco Station 20 is one. On the other hand, all three Group A Petro-Canada stations are typically identified as leaders, even though Petro-Canada Station 5's nearest competitor, Esso Station 6 is never a leader.

[35] Noel (2006) does present a numerical example in which the existence of cycle equilibria depends on the degree of spatial differentiation, but does not examine the effects of spatial differentiation on the likelihood that a station will lead an increase. Thus, extending the theory to explore the effects of spatial differentiation on the identity of leaders may be a valuable contribution to the literature.

3.4.2.2 Price Decreases and the Aggressiveness of Independents

Next, Prediction (B2) will be considered, which is that small firms (measured by the number of stations price controlled by the same price setter) are more likely to undercut their rivals' prices than larger firms. This subsection will identify which brands and stations tend to undercut the entire market, and also consider whether they tend to be independently price controlled.

For each period in which the market minimum price falls, a station is identified as setting the minimum price in the city if it is the only station observed to set this price; if more than one station is observed to set the minimum price in a period, then it is unclear if it was the first to set this price. Using this methodology, Table 3.6 lists the number of times each station is identified as setting the minimum price, excluding those that are never identified as doing so.[36] According to this table, Pioneer Station 23 sets the minimum price in 39.2% of all such cases, followed by a major brand station, Petro-Canada Station 25, which clearly sets the minimum price 15.7% of the time. Furthermore, the other nine large and small independent stations identified in Table 3.1 only set the minimum price 9.8% of the time *combined*, suggesting that they do not initiate city-wide price decreases as frequently as suggested by the theory.

Also, while Pioneer Station 23 appears to be the main price cutter in this market, the "small" independents in Guelph appear to be generally out of touch with the cycles. This can first be demonstrated by comparing the average number of times independents lower their prices

---

[36] In the data, Sunoco Stations 9 and 20 contemporaneously set their prices 0.4 cpl above the price of Sunoco Station 22 with 90.9% and 56.9% of their prices decreases, respectively, possibly reflecting a premium for full-service operations. Thus, these two stations are considered to undercut the market minimum if they price above the previous minimum price by less than 0.4 cpl. If this assumption is not made, then the only substantive change to Table 3.6 is that Station 20 is never observed to undercut the market; of the (now) 139 cases where a single station undercuts the entire market, Pioneer is this station 45.3% of the time. The other 25 stations's totals rise by zero to two times each.

during the sample: the four "large" independents lower their prices an average of 120 times over the sample, which is four more times than the overall average in Table 3.2. The average "small" independent, on the other hand lowers its price only 46 times, or once every 2.2 days.

Second, the small independents appear much more likely than other stations to violate the theoretical prediction that a firm raises its price to its cycle peak with a single increase. For each of the 16 restorations, while the major brand and "large" independent stations rarely, if ever reach their peaks in multiple steps, four of the six "small" independents account for 56.8% of the 37 observations where a station took multiple increases to reach its cycle peak, for an average of over five times each.

One might then question why Pioneer seems to have a greater incentive to undercut its rivals than the small independents. In fact, the six small independents price *above* the mode price set by the 12 Group A stations in the previous period with a weighted-average of 71.1% of their price decreases. One potential explanation is that, as seen in Table 3.1, small independents can only serve two to four consumers at once due to limited nozzle counts, while Pioneer has eight regular-fuel nozzles. Thus, a small independent is relatively less able to accommodate the extra demand that it might attract by pricing aggressively.

Pioneer Station 23 also seems to be relatively more focussed on gasoline sales than the small independents for two reasons. First, it is open 24 hours and operates self-serve pumps, which potentially allow it to serve more customers than the small independents that only have full-serve pumps (and so can serve fewer customers at a time) and which close every night. Second, Pioneer operates a convenience store, which not only might attract more consumers to its pumps due to demand complementarities, but also give it an incentive to set its gas prices more aggressively, because lower gasoline profits can be offset by higher store profits. On the other hand, the small independent stations have no ancillary operations other than repair bays, and might compete less aggressively for gasoline sales because these repair businesses are their primary operations. This argument is consistent with an observation made by Wang (2006a, 9), that small independents in Perth tend to be focussed more on repair businesses than gasoline sales, and thus do not follow cycles very closely.

However, this does not explain why Pioneer appears to undercut the market more often than stations operated by Canadian Tire and 7-Eleven, which also operate convenience stores and six to eight self-serve pumps, and are typically open 24 hours. A possible explanation is that Pioneer is partly owned by Suncor, and according to Eckert and West (2004a, 41-42), Sunoco and Pioneer might follow an undercutting strategy in order to maximize gasoline sales and refinery utilization rates of Suncor. In other words, Pioneer is unique from other independent stations in Guelph because it is partially vertically integrated, and therefore can internalize part of the double marginalization externality by pricing near marginal cost.

#### 3.4.2.3 The Alternating-Moves Assumption

The alternating-moves assumption of the Edgeworth cycle theory, Prediction (B3) will be considered next. Maskin and Tirole (1988) incorporated this assumption into their model to capture the idea that reactions are based on short-run commitment, which provides stations with an incentive to undercut their rivals to temporarily increase market share. Thus, the purpose of this subsection is to demonstrate that stations in Guelph indeed do not respond quickly to price undercuts by other stations, where quickly can be defined as within one or two periods.

This analysis includes 49 of the 60 cases where Pioneer is observed to undercut the entire market; the other 11 are omitted from the calculations because they are observed on the mornings of Days 0, leaving the other 26 stations no more than six hours to respond before the next restoration attempt. In the following discussion, the "response time" refers to the median number of hours taken by a station to match or undercut the minimum price set by Pioneer.

The earliest response time to Pioneer on weekdays (N = 32) is six hours, while 18 (69.2%) stations take at least 12 hours to respond. On weekends (N = 17), the earliest response is in eight hours, while 25 stations take 22 to 86 hours to respond. Also, the response times of Pioneer's closest competitor based on road distance, Sunoco Station 22 are 10 (24) hours on weekdays (weekends); the response times of its closest non-Sunoco competitor, Esso Station 26 are six and 22 hours on weekdays and weekends, respectively. While an examination of the reasons why these response times are so large is beyond the scope of this chapter, these results demonstrate that stations do not respond immediately to rival price reductions.

### *3.4.3 The Coordination Problem*

The purpose of this section is to combine evidence generated in Sections 3.4.1 and 3.4.2 to explain how the coordination problem, which is expected to exist during cycle restorations, appears to be less of an issue in the Guelph retail gasoline market. First, it will be demonstrated in Section 3.4.3.1 that the timing and magnitudes of price increases, as well as the identities of the price leaders are quite predictable, and therefore one can recognize the initiation of a restoration relatively quickly and unambiguously. In Section 3.4.3.2, it will be demonstrated that during the first day of each restoration attempt, the prices of some of the first stations to raise their prices follow a specific pattern, which is consistent with the explanation that in order for a firm to be willing to assume the leadership role during restorations, it would not only need to avoid the losses that would be incurred by temporarily charging the highest price in the market, but also avoid creating a reputation as a high-priced firm in the market.

3.4.3.1 The Predictability of Restorations

Cycle restorations in Guelph are observed to be very predictable in terms of the timing and size of price increases. First, it was shown in Section 3.4.1.3 that restorations are typically initiated early in the week and between noon and 2:00PM, implying that one can predict with reasonable accuracy the timing of a restoration attempt. Second, the mode peak price tends to be roughly predictable based on the current London rack price (see Section 3.4.1.4), suggesting a restoration attempt can be distinguished from a station-specific anomaly, such as a temporary fuel shortage or an electronic error in its pricing sign.

Furthermore, as argued by Noel (2006, 32-33), "The emergence of a consistent price leader ... is important for reducing these coordination problems when there are more than two firms." Such consistent leaders were identified in Section 3.4.2.1 where Group A stations of two specific brands were almost always identified as leaders of price increases (Petro-Canada Stations 5, 18 and 25, and Esso Stations 19 and 26). Each of these five stations typically sets the mode peak price between noon and 2:00PM on every restoration day in the data, and each is located in areas of the city where they appear relatively more likely to be quickly observed by their competitors. Thus, the predictability of these stations' price movements, as well as their spatial characteristics suggest that consistent leaders have arisen in this market, which can lead to reduced coordination problems during cycle restorations.[37]

---

[37] Note that the predictability of price cycles can also be advantageous to consumers. For this reason, the Australian Competition and Consumer Commission (ACCC) regularly updates its website with historical price data for the five largest metropolitan cities in Australia (http://www.accc.gov.au/ content/index.phtml/itemId/280309; visited 2007-05-01).

#### 3.4.3.2 Sub-cycles

By consistently being among the first stations to raise their prices on restoration days, Petro-Canada and Esso might not only sacrifice profits to their competitors while they wait for them to raise their prices, but they could also generate a negative reputation among consumers as the high-priced brands in the city. Thus, the purpose of this subsection is to demonstrate how prices during each restoration move in such a way that these problems are less likely encountered.

During all 16 restorations, a sub-cycle is observed where some of the first stations to raise their prices on Day 0 lower them back to (and sometimes below) their cycle troughs within two to four hours, and remain there until at least 8:00PM, after which they raise them again to their peaks. Only then do they begin to gradually lower their prices. A total of 67 sub-cycles have been observed, and while the identities of the stations are not always the same, every participant initially raises its price by 4:00PM. Three representative sub-cycles are visually displayed in Figure 3.5, using bi-hourly price data for Petro-Canada Station 18, where sub-cycles were observed for 13 (81.3%) restorations.

Table 3.7 lists all of the brands and stations that have been observed to follow this sub-cycle, along with the number of times each was observed. The five Petro-Canada and Esso stations identified as leaders in Table 3.5 are among the top six stations in this table. Also, nine of the 10 leaders identified in Table 3.5 under Methodology 2 are observed to sub-cycle at least as often as any other station in Table 3.7. These results suggest that leading a price increase might not be as risky as one might expect, because the first stations to raise their prices do not necessarily remain the highest-priced stations in the city during a restoration phase.[38]

---

[38] The Conference Board of Canada (2001, 28) argues that if a restoration attempt is not followed quickly enough, then it might be abandoned before the evening rush. Evidence found

### 3.5 Alternative Explanations of Price Cycles

The purpose of this section is to consider competing explanations of price cycles, and to explore whether they might explain the cycles observed in Guelph more accurately than the Edgeworth cycle theory. First, the oligopolistic "sticky" pricing theories cited by Borenstein, Cameron, and Gilbert (1997) predict that positive (negative) retail price changes will be triggered by positive (negative) cost changes. Also, since the oligopolists have market power, they respond more quickly to cost increases than to decreases, which implies that prices rise faster than they fall in response to cost changes. However, as discussed in Section 3.4.1, the large price increases observed during restorations are not preceded by similarly large rack price increases, and when margins are not exceptionally high, the sizes of retail price decreases seem to be insensitive to rack price movements.[39]

Second, prices might cycle in markets where demand cycles. Rotemberg and Saloner (1986) and Haltiwanger and Harrington (1991) predict that firms will price counter-cyclically to prevent the breakdown of a (tacitly) collusive agreement. Thus, gasoline retailers are expected to lower their prices during high-demand periods when demand is *expected* to fall, and raise them when demand is currently low, but expected to rise in the future. However, if these theories explain the weekly cycles observed in Guelph, then demand should rise substantially at roughly the same time each week, and fall gradually as the week progresses. While the Conference Board of Canada (2001) does observe that demand tends to be lowest early in the

---

in this chapter suggests that these abandonments might have actually been part of sub-cycles.

[39] While some stations might receive volume discounts off the rack price that are not received by other stations, whether or not these discounts influence retail price cycles cannot be explored because the specific contract terms for each station are not publicly available.

week when restorations are often observed, no evidence has been found to suggest that demand falls by roughly constant increments on each successive day before the next restoration attempt. Furthermore, if it is believed that demand does follow such weekly cycles, then these theories do not explain why cycle restoration attempts are observed approximately once every two weeks during October 2005, or why they are observed three times in four days between August 30 and September 2. However, as demonstrated in this chapter, all 16 restoration attempts observed in Guelph occur after the mode retail-rack margin falls below 0.1 cpl in at least one city in the region, which is consistent with Prediction (S3) of the Edgeworth cycle theory.

A third possibility is that inventory fluctuations cause price cycles. Using a monopolistically competitive, (s, S) threshold model where firms choose prices and inventory levels, Aguirregabiria (1999) predicts that prices will rise slowly until inventories are replenished and then fall rapidly, which is the reverse of the cycles observed in Guelph. Furthermore, brand representatives contacted by e-mail reported that gasoline deliveries can occur three to four times per week and on no particular days, and that inventory deliveries can be made within a couple of hours after being ordered, simply by rerouting the delivery trucks. Thus, inventory deliveries appear to be too frequent and reliable to explain weekly price cycles.

It might instead be argued that retail gasoline price cycles arise due to intertemporal price discrimination. In other words, a retailer begins the cycle with a relatively high price that the most impatient consumers are willing to pay, and then gradually lowers its price to attract more patient consumers. However, while theories have been found in the sales literature which predict such cycles, they make crucial assumptions that cannot be applied to retail gasoline markets. For example, Conlisk, Gerstner, and Sobel (1984) assume a durable good monopolist; this assumption is inapplicable to retail gasoline markets, and the result does not appear to extend to an oligopoly setting (see Sobel, 1984). On the other hand, Fershtman and Fishman (1992) predict cycles similar to those observed in Guelph, using a dynamic oligopolistic search model where consumers base their purchasing decisions on prices observed in the market; the number of prices observed is a function of search costs. However, as with Conlisk, Gerstner, and Sobel (1984) and Sobel (1984), the authors assume a durable good that is purchased once by each consumer and never again, which does not apply to retail gasoline markets.[40]

Finally, a drawback of all of these explanations is that none predict that certain types of firms will lead price changes in either direction; they assume that firms do not observe their rivals' current prices before making their own pricing decisions. This assumption not only contradicts evidence provided in this chapter with respect to price leadership and the coordination problem, but also evidence identified in other studies of retail gasoline markets.

### 3.6 Price Movements Following Hurricane Katrina

After the impact of Hurricane Katrina on the United States, retail gasoline prices across Canada and the U.S. rose substantially; in Guelph, the mode price rose by 36.3 cpl between August 30 and September 2, 2005, while the London rack price rose by 30.6 cpl during these same days, as can be seen in Figure 3.4. Following the price increases across these two countries, there were numerous allegations by both politicians and the general public of "gouging" by the players in these markets, and calls for government intervention. Therefore, the purpose of this section is to examine price movements in Guelph following Hurricane Katrina, to find evidence

[40] Lewis (2005) also develops a theoretical search model to explain asymmetric price adjustment. However, he assumes that prices rise and fall in response to wholesale price movements, which does not appear to be true in the Guelph data.

that is either consistent with the basic Edgeworth cycle predictions, or which suggests that other theories and hypotheses might more accurately explain these price movements.

For the purposes of this section, the "Katrina" period is defined to include all dates from August 30 to September 17, 2005, inclusively. These dates were chosen to ensure that the price effects of Hurricanes Katrina and Rita would not be mixed; Katrina hit the U.S. on August 29, so its effects are expected to begin on August 30 at the earliest, while the first advisory of Hurricane Rita by the U.S. National Hurricane Center was made on September 17.[41]

As can be seen in Figure 3.4, both the mode retail price and London rack price follow very similar patterns during these 19 days, as both series exhibit several large increases between August 31 and September 2, and then fall gradually from September 3 to 17. These similarities appear to suggest that contrary to Prediction (S2), retail price cycles in Guelph might have been directly influenced by rack price movements, and so another dynamic theory of price movements might more accurately explain these price movements. However, it appears that the data are indeed consistent with the other seven basic Edgeworth cycle predictions, as well as the overall results of this chapter. Evidence to support this conclusion is broken down by prediction as follows:

(S1) On average, individual stations lower their prices 4.2 times more often than they increase them, and price increases are 4.2 times larger than price decreases. Similarly, the city-wide mode price is observed to decrease 6.0 times more often than it increases, and mode price increases are 6.0 times larger than price decreases, on average.

---

[41] National Hurricane Center (http://www.nhc.noaa.gov; visited 2007-05-01).

(S3) Every restoration is observed within two days of the retail-rack margin falling below 0.1 cpl in at least one of the four cities in this region, and never on weekends, consistent with the results in Section 3.4.1.3. Figure 3.4 also shows that cycle restorations tend to be initiated relatively frequently when the London rack price is rising (three times between August 30 and September 2), and less frequently when the rack price is falling (once between September 3 and 17).

(S4) Three (75.0%) mode peak prices are consistent with the simple approximation described in Section 3.4.1.4. The markup on the fourth restoration day (August 31) is 9.2 cpl, which might reflect disequilibrium behaviour following the Hurricane Katrina shock; the London rack price rose another 12.0 cpl over the following two days, leading to another restoration on September 2 when the markup is consistent with the cost-based approximation.

(S5) As discussed in Section 3.4.1.5, adding a dummy to the regression which equals one on these 19 dates does not change any qualitative results in Table 3.4, and the dummy is not statistically significant at the 5% level of significance. Specifically, the average daily retail price falls by small and decreasing increments as the cycle progresses.

(B1) At least two of Stations 5, 18, 19, 25 and 26 are identified as leaders of each restoration under Methodology 2. Also, Petro-Canada Stations 5, 18 and 25 always set the city-wide mode peak price between noon and 2:00PM on Day 0. Finally, sub-cycles are observed during every restoration, similar to those described in Section 3.4.3.2.

(B2) Pioneer is observed to set the market minimum price much more often than any other station; out of 36 cases where a station is observed to solely set the market minimum price, Pioneer is this station 16 (44.4%) times, followed by Sunoco Station 20 (four times) and Petro-Canada Station 25 (three times). The other 24 stations are observed to solely set the minimum price zero to two times each.

(B3) It takes approximately 24 hours for all stations in the city to raise their prices during restorations. As for price decreases, of the 14 times that Pioneer is observed to undercut all 26 other stations, and where the price cut is not observed on a Day 0, the first station to match or undercut Pioneer at the median is Canadian Tire Station 24 (four hours), while 18 stations take 18 to 48 hours to match or undercut Pioneer's price decreases.

In summary, examining data for the 19 days following Hurricane Katrina and preceding the announcement of Hurricane Rita, it appears that retail gasoline price movements in Guelph during this period are consistent with price movements observed in Guelph during the non-Katrina days, as well as with the basic predictions of the Edgeworth cycle theory.

### 3.7 Conclusions

While many authors have used retail gasoline price data to test certain predictions made by the Edgeworth cycle theory, no study has been found which uses price data that were collected with a high frequency for all stations in a market, which describes an ideal data set for such tests. Thus, the purpose of this chapter was to examine the several basic predictions of the Edgeworth cycle theory using price data collected eight times per day for 103 days from 27 stations in Guelph, Ontario; in the process, an investigation was conducted into whether previous studies might have overlooked certain cycle characteristics due to data restrictions.

It was found that many of the basic theoretical predictions are confirmed by the data, such as the basic shape of the cycle, the weak relationship between retail and rack price movements, the strong relationship between the timing and restoration attempts and the retail-rack margin, and the assumption that firms play an alternating-moves game; it was also found that major brand stations do tend to lead price increases, while the minimum price in the city is frequently set by an independent station, which are both consistent with the theory. However, certain discrepancies between the theoretical predictions and these results have been identified, which lead to two important contributions to the literature.

First, it appears that while one independent station does tend to set the market minimum price more frequently than any major brand station, this finding does not extend to independents, in general, contrary to findings in previous studies. Instead, price decreases tend to be led by a single independent brand (Pioneer) which is partly owned by a refiner brand (Suncor), and which operates one station in Guelph. On the other hand, the other independents in Guelph do not appear to be particularly aggressive. A potential reason for this finding is that, compared to the "mom-and-pop" operations, Pioneer is relatively more focussed on gasoline sales than repair operations. It might also be more aggressive than other large independents because Suncor has been reported to follow a capacity-utilization maximization strategy.

Second, the coordination problem inherent in leading price increases does not appear to be as significant a problem as one might expect. In particular, stations that are price controlled by Petro-Canada and Esso are found to be consistent leaders of price increases. These stations are located in relatively high-traffic areas, and all other stations are located within 3.5km of at least one of these five leaders. Furthermore, a sub-cycle has been identified during every restoration, which appears to enable stations to lead price increases without incurring the negative consequences of raising their prices before their rivals, including temporary losses in business and reputation effects with consumers.

These results have several implications for both researchers and the competition authority. First, to accurately study inter-station price dynamics in cycling markets like Guelph, prices should be collected very frequently from all stations in the market; the sub-cycles would be overlooked with data collected every 12 hours, and price leaders would be difficult to identify. Second, the source of price control and spatial proximity to areas where traffic converges, such as malls and downtown cores, appear to be important characteristics to be included in any analysis of retail gasoline price competition. Finally, independent brand competition might not be as important as one might expect; rather, existing competition from certain types and brands of independents might provide a better indication of the relative competitiveness between two markets.

Alternative theories of price cycles were also examined in this chapter, and they do not seem to explain these cycles as well as the Edgeworth cycle theory. However, certain extensions of the Edgeworth cycle theory might prove worthwhile. First, since restorations seem to be triggered by both proximity to marginal cost and demand conditions, a possible extension involves allowing for predictable demand fluctuations. Second, evidence found for this chapter, as well as by Eckert and West (2004b) imply that more formal attention should be committed to extending the theory to allow for spatial and non-spatial product differentiation, particularly as it relates to predicting price leaders.

### 3.8 Technical Appendix

*Determination of Lag Lengths*

A testing-down procedure was used to determine the number of lags to be included in the regression for both the average retail and London rack price changes. Beginning with seven lags of each series, the last lag of each one was deleted until the null hypothesis that these last lags are jointly insignificant at the 5% level of significance is rejected. This procedure chooses one lag of each change variable. A similar testing-up procedure chooses the same model, and while the Akaike information criterion (AIC) chooses two lags of each variable, the value of the AIC is only slightly larger for one lag of each variable (198.3 vs. 198.2). Therefore, one lag for each variable is chosen for parsimony.

*Tests for Stability*

Following Eckert (2002), Augmented Dickey-Fuller (ADF) tests were conducted for the average retail and rack price series, using all 102 full days in the sample; the number of lags were chosen to be the largest significant lags in either the autocorrelation function or the partial autocorrelation function (seven lags for the average retail price series, and six lags for the rack price series). With a 5% critical value of -3.41, the null hypothesis of a unit root was tested against the alternative hypothesis of a deterministic trend, and the test statistics are -3.56 for the rack price series and -3.36 for the average retail price series. Thus, the null hypothesis of a unit root is rejected for the rack price series but not for the retail series.

However, the critical value is very close to the test statistic for the average retail price series, and therefore the null hypothesis is also close to being rejected. Furthermore, Kennedy (2003, 351) writes that "Because the traditional classical testing methodology accepts the null unless there is strong evidence against it, unit root tests usually conclude that there is a unit root. This problem is exacerbated by the fact that unit root tests generally have low power." Thus, the conclusion of a unit root in the average retail price series is unlikely to be a major concern.[42]

*Test for Autocorrelation*

Popular tests for autocorrelation such as the Durbin-Watson *d* test cannot be conducted using time series data with missing observations. However, applying a Runs Test (see Gujarati, 1995, 419-20) to the regression in Table 3.4, for 29 runs (34 positive residuals and 36 negative residuals), the 95% confidence interval is (27.8, 44.1). Thus, the null hypothesis of random disturbances is not rejected at the 5% level of significance.

---

[42] Conducting the same ADF test for the *mode* retail price series, the test statistic for seven lags is -3.65, so the null hypothesis of a unit root (against the alternative hypothesis of a deterministic trend) is rejected at the 5% level of significance for the mode price series.

Figure 3.1

Example of a Theoretical Edgeworth Cycle, Assuming MC = 0 and Constant Demand

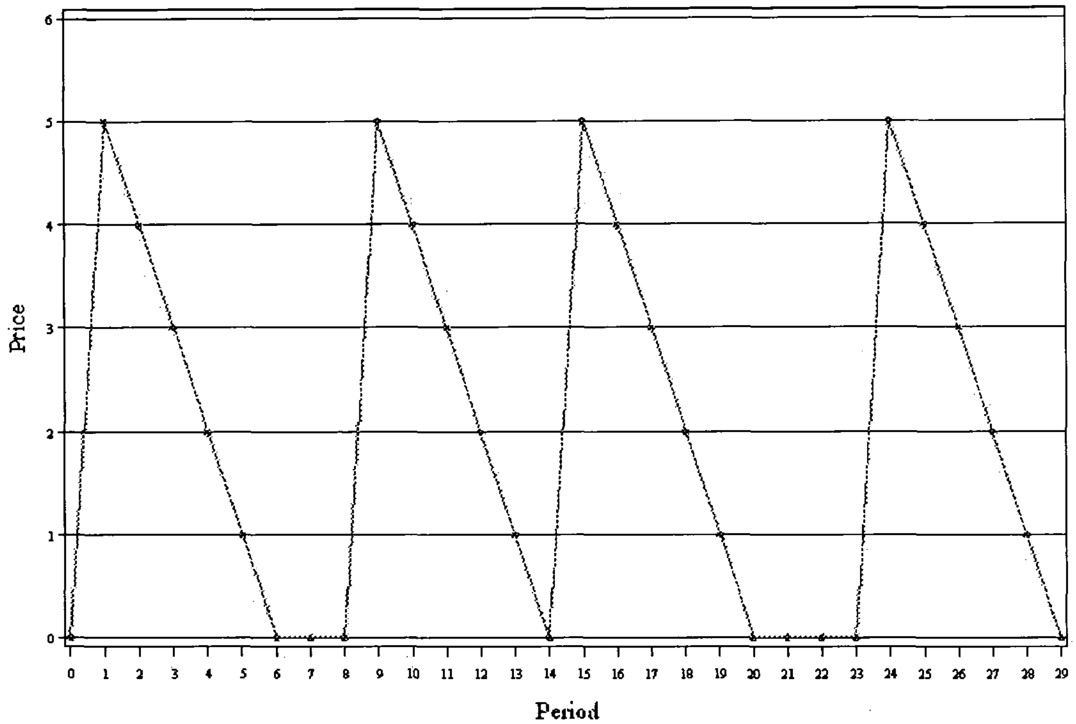


Figure 3.2: Station Locations

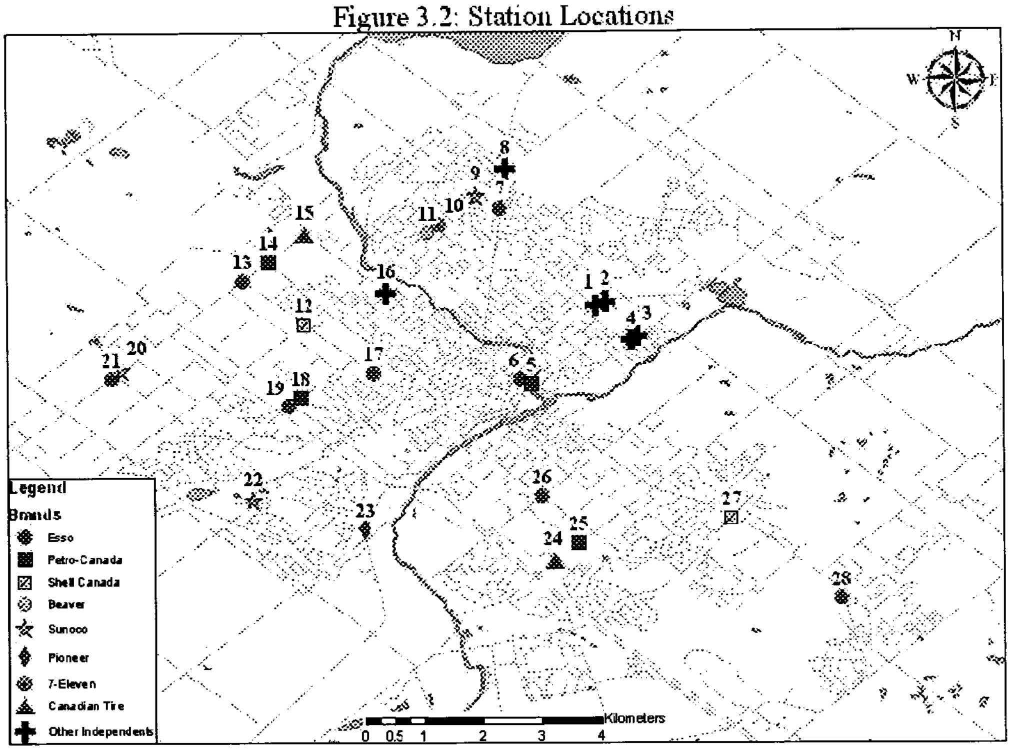



Figure 3.3 Nearest Outside Competition

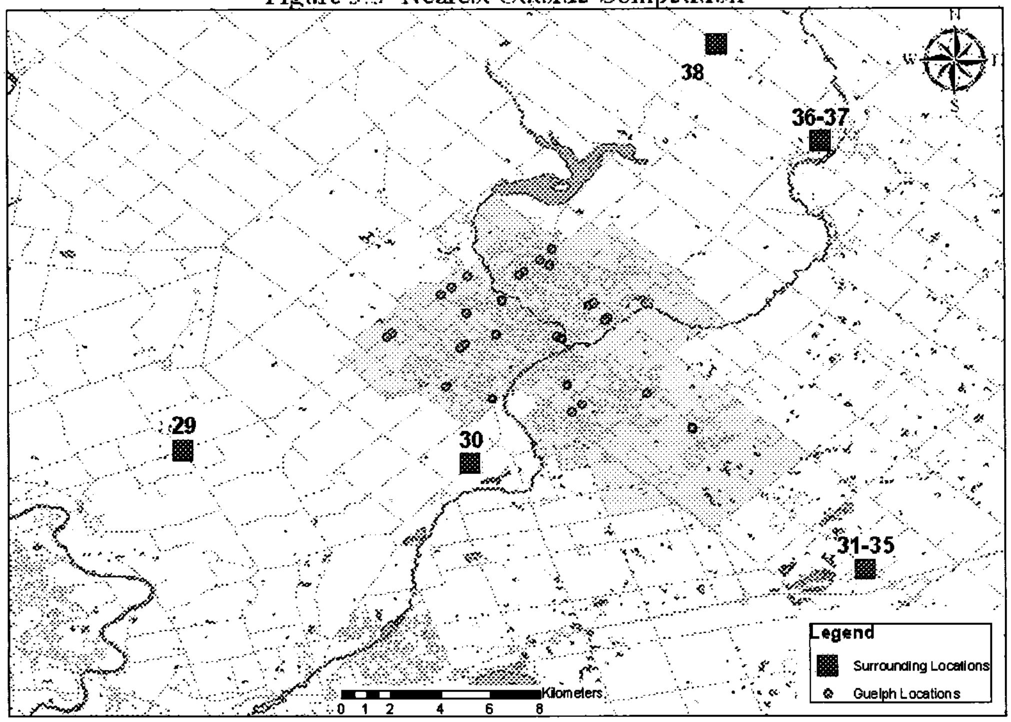
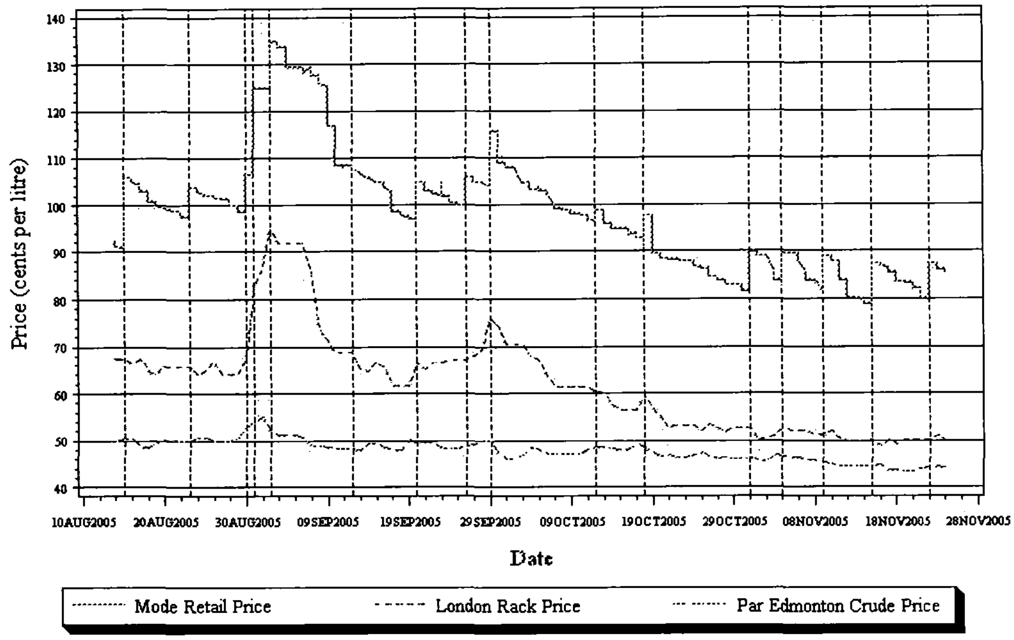


Figure 3.4

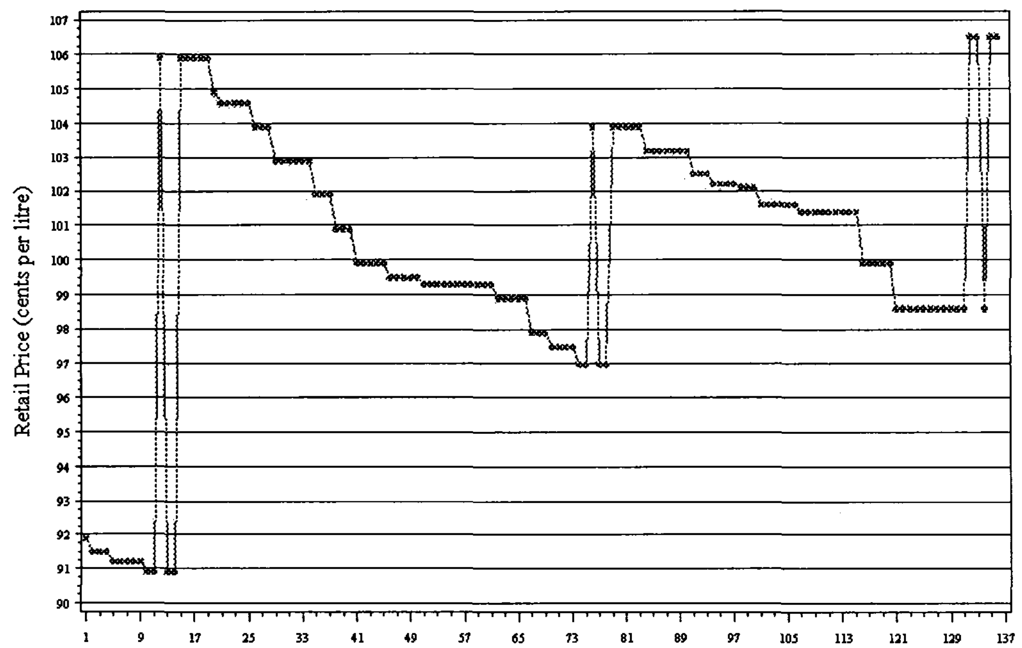
**Upstream Prices and Mode Retail Price for Guelph, Ontario**




Note: Each vertical line represents a day when a restoration was attempted.

Figure 3.5

**Representative Examples of Sub-cyclical Pattern (Petro-Canada Station 18, August 14 to 30, 2005)**




**Period (= "1" on August 14 at 8:00AM, "9" on August 15 at 8:00AM, etc.)**

Table 3.1: Selected Station Characteristics*

| Brand | ID | Nozzle Count | 24 Hrs | Self-Serve | Store | Car Wash | Auto |
|---|---|---|---|---|---|---|---|
| *Group A* | | | | | | | |
| Esso | 19 | 12 | ✓ | ✓ | ✓ | ✓ | |
| Esso | 21 | 10 | ✓ | ✓ | ✓ | ✓ | |
| Esso | 26 | 8 | ✓ | ✓ | ✓ | | |
| Petro-Canada | 5 | 8 | | ✓ | ✓ | | |
| Petro-Canada | 18 | 8 | ✓ | ✓ | ✓ | ✓ | |
| Petro-Canada | 25 | 8 | ✓ | ✓ | ✓ | ✓ | |
| Shell | 12 | 8 | ✓ | ✓ | ✓ | | |
| Shell (Mac's) | 27 | 8 | ✓ | ✓ | ✓ | | |
| Shell (Beaver) | 11 | 6 | | | | | ✓ |
| Sunoco | 9 | 6 | | | | ✓ | |
| Sunoco | 20 | 4 | | | | | |
| Sunoco | 22 | 8 | ✓ | ✓ | ✓ | ✓ | |
| *Group B* | | | | | | | |
| Esso (Norm's Garage) | 6 | 4 | | | | | ✓ |
| Esso (7-Eleven) | 7 | 8 | ✓ | ✓ | ✓ | | |
| Esso (Gas-Up Carwash) | 13 | 4 | | ✓ | | ✓ | ✓ |
| Esso (Rainbow) | 17 | 6 | ✓ | ✓ | ✓ | ✓ | |
| Petro-Canada | 14 | 8 | | ✓ | ✓ | | |
| *Group C* | | | | | | | |
| 7-Eleven | 10 | 8 | ✓ | ✓ | ✓ | | |
| Canadian Tire | 15 | 8 | | ✓ | ✓ | | ✓ |
| Canadian Tire | 24 | 6 | ✓ | ✓ | | ✓ | |
| Pioneer | 23 | 8 | ✓ | ✓ | ✓ | | |
| *Group D* | | | | | | | |
| Amco | 1 | 4 | | | | | ✓ |
| Cango | 2 | 3 | | | | | ✓ |
| Hilton Group Gas | 3 | 4 | | | | | ✓ |
| Maple Leaf Gas and Fuels | 4 | 4 | | | | | ✓ |
| CAN-OP | 8 | 2 | | | | | ✓ |
| Quik-N E-Zee Gas & Snacks | 16 | 2 | | | | | ✓ |

* Petro-Canada Station 18 is the only station with both full- and self-serve pumps; since the self-serve price is observed, only those pumps are counted. Also, a "store" means a convenience store, except for Canadian Tire Station 15 where it is a Canadian Tire department store.

Table 3.2: Summary Statistics

| Station-Specific Bi-Hourly Data | |
|---|---|
| Average price increase | 7.3 cpl |
| Average price decrease | 1.4 cpl |
| Average number of price increases per station | 21 |
| Average number of price decreases per station | 116 |
| **Market-Level Daily Data*** | |
| Average increase in city-wide mean price | 3.8 cpl |
| Average increase in city-wide mode price | 7.7 cpl |
| Average decrease in city-wide mean price | 1.3 cpl |
| Average decrease in city-wide mode price | 1.9 cpl |
| Number of increases (mean price) | 25 |
| Number of increases (mode price) | 16 |
| Number of decreases (mean price) | 77 |
| Number of decreases (mode price) | 68 |
| Average number of days between attempted restorations | 6.6 |
| **Daily London Rack Price Data** | |
| Average increase | 2.4 cpl |
| Average decrease | 2.1 cpl |
| Number of increases | 28 |
| Number of decreases | 39 |

* The mean price rises more frequently and by smaller amounts than the mode price, since it typically takes two days for all stations in the city to raise their prices during restorations.

Table 3.3: Transition Matrix of Daily Mode Retail, Rack Price Movements*

| Retail Prices | $\Delta p_t > 0$ | $\Delta p_t < 0$ |
|---|---|---|
| $\Delta p_{t-1} > 0$ (N = 14) | 7.1% | 92.8% |
| $\Delta p_{t-1} < 0$ (N = 49) | 26.5% | 73.5% |
| **Rack Prices** | $\Delta r_t > 0$ | $\Delta r_t < 0$ |
| $\Delta r_{t-1} > 0$ (N = 28) | 42.9% | 57.1% |
| $\Delta r_{t-1} < 0$ (N = 37) | 40.5% | 59.5% |

* To enable comparison of these results between retail and rack prices, retail price changes are calculated once per day, and only on days when the rack price is set (i.e., excluding Sundays, Mondays, and the Tuesdays following Labour Day and the Canadian Thanksgiving Day). Mode prices are examined instead of mean prices, because the results are more representative of price movements of individual stations, which tend to rise once followed by several decreases.

Table 3.4: Regression Results (Dependent Variable: $\Delta p_t$)

| Variable | Coefficient | | t-ratio |
|---|---|---|---|
| $p_{t-1}$ | -0.25560 | * | -5.50 |
| $r_t$ | 0.26223 | * | 4.67 |
| $\Delta p_{t-1}$ | 0.11284 | *** | 1.99 |
| $\Delta r_{t-1}$ | -0.13749 | *** | -1.73 |
| $SUNDAY_t$ | -0.07730 | | -0.14 |
| $MONDAY_t$ | -0.28569 | | -0.52 |
| $WEDNESDAY_t$ | 0.09274 | | 0.15 |
| $THURSDAY_t$ | 0.23934 | | 0.40 |
| $FRIDAY_t$ | 0.01913 | | 0.03 |
| $SATURDAY_t$ | -0.50962 | | -0.91 |
| t | -0.00388 | | -0.57 |
| CONSTANT | 0.29048 | | 0.17 |

**F-stat for joint significance of day-of-week dummies**
0.62 with 6 and 58 df (p-value = 0.717)

**F-stat for $H_0$: $p_{t-1} + r_t = 0$**
0.11 with 1 and 58 df (p-value = 0.746)

N = 70 Adjusted $R^2 = 0.40$

* Statistically significant at the 1% level of significance (two-tail)
*** Statistically significant at the 10% level of significance (two-tail)

Table 3.5: Observed Leaders of Price Increases for 16 Restorations*

| Brand | ID | Group | Count (Methodology 1) | Count (Methodology 2) |
|---|---|---|---|---|
| Petro-Canada | 25 | A | 11 | 15 |
| Petro-Canada | 5 | A | 8 | 12 |
| Petro-Canada | 18 | A | 7 | 11 |
| Esso | 19 | A | 8 | 10 |
| Esso | 26 | A | 6 | 9 |
| Sunoco | 22 | A | 1 | 2 |
| Sunoco | 9 | A | 2 | 1 |
| Sunoco | 20 | A | 0 | 1 |
| Hilton Group Gas | 3 | D | 2 | 1 |
| Maple Leaf Gas and Fuels | 4 | D | 0 | 1 |
| Quik-N E-Zee Gas & Snacks | 16 | D | 2 | 0 |

* See Section 4.2.1 for definitions of each methodology. As multiple stations are usually observed to raise their prices in a single period, the total counts do not add to 16.

Table 3.6: Number of Times Stations Undercut Entire Market (N = 153)*

| Brand | Station ID | Group | Count | Proportion |
|---|---|---|---|---|
| Pioneer | 23 | C | 60 | 39.2% |
| Petro-Canada | 25 | A | 24 | 15.7% |
| Sunoco | 20 | A | 23 | 15.0% |
| Esso (Rainbow) | 17 | B | 11 | 7.2% |
| 7-Eleven | 10 | C | 6 | 3.9% |
| Hilton Group Gas | 3 | D | 5 | 3.3% |
| Petro-Canada | 14 | B | 5 | 3.3% |
| Shell (Mac's) | 27 | A | 5 | 3.3% |
| Esso (7-Eleven) | 7 | B | 3 | 2.0% |
| Esso | 26 | A | 3 | 2.0% |
| Petro-Canada | 5 | A | 2 | 1.3% |
| Quik-N E-Zee Gas & Snacks | 16 | D | 2 | 1.3% |
| Petro-Canada | 18 | A | 2 | 1.3% |
| Maple Leaf Gas and Fuels | 4 | D | 1 | 0.7% |
| Canadian Tire | 24 | C | 1 | 0.7% |

* Only stations observed to solely set the market minimum price at least once are included in this table. Also, Sunoco Stations 9 and 20 are considered to have undercut the market if their prices are strictly less than 0.4 cpl above the previous minimum price (see footnote 36).

Table 3.7: Stations Observed to Follow Sub-Cycle for 16 Restorations

| Brand | Station ID | Group | Count |
|---|---|---|---|
| Esso | 19 | A | 14 |
| Petro-Canada | 18 | A | 13 |
| Petro-Canada | 5 | A | 11 |
| Hilton Group Gas | 3 | D | 5 |
| Maple Leaf Gas and Fuels | 4 | D | 4 |
| Sunoco | 9 | A | 4 |
| Petro-Canada | 25 | A | 4 |
| Esso | 26 | A | 4 |
| Esso (Rainbow) | 17 | B | 2 |
| Sunoco | 22 | A | 2 |
| Shell | 12 | A | 1 |
| Esso | 21 | A | 1 |
| Pioneer | 23 | C | 1 |
| Canadian Tire | 24 | C | 1 |

### 3.9 References

Aguirregabiria, Victor (1999), "The Dynamics of Markups and Inventories in Retailing Firms," *Review of Economic Studies* 66, 275-308.

Borenstein, Severin, A. Colin Cameron, and Richard Gilbert (1997), "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?," *Quarterly Journal of Economics* 112, 305-39.

Conference Board of Canada (2001), *The Final Fifteen Feet of Hose: The Canadian Gasoline Industry in the Year 2000.*

Conlisk, John, Eitan Gerstner, and Joel Sobel (1984), "Cyclic Pricing by a Durable Goods Monopolist," *Quarterly Journal of Economics* 99, 489-505.

Eckert, Andrew (2002), "Retail Price Cycles and the Response Asymmetry," *Canadian Journal of Economics* 35, 52-77.

----- (2003), "Retail Price Cycles and the Presence of Small Firms," *International Journal of Industrial Organization* 21, 151-70.

Eckert, Andrew and Douglas S. West (2004a), "A Tale of Two Cities: Price Uniformity and Price Volatility in Gasoline Retailing," *Annals of Regional Science* 38, 25-46.

----- (2004b), "Retail Gasoline Prices Cycles Across Spatially Dispersed Gasoline Stations," *Journal of Law & Economics* 47, 245-73.

Fershtman, Chaim and Arthur Fishman (1992), "Price Cycles and Booms: Dynamic Search Equilibrium," *American Economic Review* 82, 1221-33.

Gujarati, Damodar N. (1995), *Basic Econometrics*, Third Edition (New York: McGraw-Hill, Inc.).

Haltiwanger, John and Joseph E. Harrington, Jr. (1991), "The Impact of Cyclical Demand Movements on Collusive Behavior," *RAND Journal of Economics* 22, 89-106.

Kennedy, Peter (2003), *A Guide to Econometrics*, Fifth Edition (Cambridge, Massachusetts: The MIT Press).

LECG Canada (2006), "What Determines the Profitability of a Retail Gasoline Outlet? A Study for the Competition Bureau of Canada," Independent Expert Report.

Lewis, Matthew (2005), "Asymmetric Price Adjustment and Consumer Search: An Examination of the Retail Gasoline Market," Ohio State University Working Paper (July 26, 2005).

----- (2006), "Temporary Wholesale Gasoline Price Spikes Have Long-Lasting Retail Effects: the Aftermath of Hurricane Rita," Ohio State University Working Paper (August 16, 2006).

Maskin, Eric and Jean Tirole (1988), "A Theory of Dynamic Oligopoly, II: Price Competition, Kinked Demand Curves, and Edgeworth Cycles," *Econometrica* 56, 571-99.

MJ Ervin & Associates Inc. (2006), "National Retail Gasoline Site Census 2005," Annual survey of retail gasoline representation in Canada (June 9, 2006).

Noel, Michael (2006), "Edgeworth Cycles and Focal Prices: Computational Dynamic Markov Equilibria," UCSD Working Paper (April 10, 2006).

----- (2007a), "Edgeworth Price Cycles: Evidence from the Toronto Retail Gasoline Market," *Journal of Industrial Economics* 55, 69-92.

----- (2007b), "Edgeworth Price Cycles, Cost-Based Pricing and Sticky Pricing in Retail Gasoline Markets," *Review of Economics and Statistics* 89, 324-34.

----- (2007c), "Asymmetric Cost Passthrough in Cycling Retail Gasoline Markets: Analysis under the Correct Counterfactual," UCSD Working Paper (March 21, 2007).

Paradigm Transportation Solutions Limited, Tottem Sims Hubicki Associates, and GSP Group Incorporated (2005), "Guelph-Wellington Transportation Study: July 2005 Final Report," Transportation study jointly undertaken by the City of Guelph and the County of Wellington.

Rotemberg, Julio J. and Garth Saloner (1986), "A Supergame-Theoretic Model of Price Wars during Booms," *American Economic Review* 76, 390-407.

Shepard, Andrea (1993), "Contractual Form, Retail Price, and Asset Characteristics in Gasoline Retailing," *RAND Journal of Economics* 24, 58-77.

Slade, Margaret E. (1998), "Strategic Motives for Vertical Separation: Evidence from Retail Gasoline Markets," *Journal of Law, Economics & Organization* 14, 84-113.

Sobel, Joel (1984), "The Timing of Sales," *Review of Economic Studies* 51, 353-68.

Taylor, Beck A. (2000), "Retail Characteristics and Ownership Structure," *Small Business Economics* 14, 157-64.

Wang, Zhongmin (2006a), "Endogenous Timing in Oligopoly Pricing: Evidence from a Repeated Game in the Field," Northeastern University Working Paper (October 2006).

----- (2006b), "Cartel Communication and Pricing Coordination: A Case Study," Northeastern University Working Paper (December 2006).

# Chapter 4

# Price Matching and the Domino Effect in a Retail Gasoline Market[1]

## 4.1 Introduction

For many years, there have been competition concerns regarding how retail gasoline prices are set in the U.S. and Canada. In several U.S. states, including Delaware, Maryland, Nevada and Virginia, such concerns gave rise to divorcement legislation, under which refiners are not permitted to own or operate gas stations.[2] Concerns have also been raised in the U.S. regarding zone pricing. A company that owns and operates gasoline stations might define price zones where prices for all of its stations in the zone are the same. It has been suggested that zone pricing is a form of price discrimination, and thus is an indicator of market power. It has also been argued that zone pricing can be used in an anti-competitive fashion to coordinate pricing, and to deter entry through localized price cutting.[3]

In Canada, consumers have complained about the perceived uniformity of retail gas prices in some markets, and the perception that retailers raise their prices at the same time. Consumers have also been troubled by the observation that retail gasoline prices in some

[1] A version of this chapter, which is co-written with Andrew Eckert and Douglas S. West, has been submitted for publication.

[2] See Barron and Umbeck (1984) and Blass and Carlton (2001) for empirical analyses of the efficiency effects of divorcement laws.

[3] See Meyer and Fischer (2004) for a detailed discussion of price zones and some of their alleged anti-competitive effects; and Kleit (2003) for pro-competitive arguments for them.

markets rise faster than they fall.[4] Concerns have also been voiced regarding inter-jurisdictional differences in retail prices that do not appear to be cost-based, indicating to consumers that retail gasoline markets are not competitive.[5]

Possibly in response to public concerns, Canada's gasoline industry has advanced a competitive theory of gasoline pricing to explain certain perceived features of gas pricing that lead to allegations of collusion or anti-competitive behaviour. Under this theory, it is assumed that gas is a homogeneous good, consumers are willing to drive long distances to save small amounts of money on gas, and prices are perfectly observable by consumers and nearby competitors. Based on these assumptions, it is argued that intra-market prices tend to uniformity, individual stations quickly match price changes by certain competitors, and price changes pass through an entire market almost immediately, in a domino fashion.[6]

While many complaints have been made regarding how retail gas prices are set and the gasoline industry has offered explanations, there are almost no publicly available studies of how prices actually change in urban retail gasoline markets, using complete station-specific data on intra-day price changes over a long period of time. Such data are simply not available for most urban markets, and can only be collected through personal observation of prices, or possibly via subpoena of retailers' pricing records in the course of a formal investigation. Even here, price

[4] Such asymmetry seems to be typical of other goods as well. Peltzman (2000), studying a wide range of products, finds that over two-thirds of the markets examined exhibit prices that respond more quickly to input cost increases than to input cost decreases.

[5] While no single study catalogues all anxieties about retail gasoline pricing, the Conference Board of Canada (2001) attempts to provide explanations for most of the gasoline pricing phenomena that bother consumers.

[6] A detailed discussion of the competitive theory as developed in industry and government documents is given in Section 4.2.

data may not be complete. Yet, without such data there exists no formal evidence that the stylized facts which the competitive theory attempts to explain are indeed facts, and that pricing behaviour is consistent with a theory of anti- or pro-competitive conduct. The purpose of this chapter is to use gasoline station price data collected eight times per day for 103 days, for 27 gas stations in Guelph, Ontario to evaluate the accuracy of the received wisdom regarding gas prices and the implications advanced by the informal theory of competitive gas pricing.

While the informal competitive theory seems to have been accepted by governments in many instances, some jurisdictions remain unconvinced. For example, the sense that consumers' concerns regarding gasoline pricing were not being addressed led the House of Legislative Assembly of Nova Scotia to establish an all-party committee to investigate gasoline pricing in that province. In its report, the Committee made a number of strong recommendations, such as retail divorcement (or price regulation if divorcement is rejected), a prohibition of petroleum product sales below acquisition cost, and that refiners must charge the same rack price to all customers.[7] These recommendations are clearly motivated by anxieties regarding possible anti-competitive conduct, which may or may not be supported by a detailed analysis of retail gasoline pricing data.

The competitive market model of retail gas pricing in Canada has been the focus of some of our earlier research. However, Eckert and West (2005) investigate the price uniformity prediction, and not the price response dynamics that are also proposed in the model. Other published studies of retail gas price movements use weekly or monthly prices averaged across stations or prices for a small number of stations, and cannot study price response dynamics (see,

---

[7] See Nova Scotia Select Committee on Petroleum Product Pricing (2004, 32-35).

for example, Borenstein, Cameron, and Gilbert, 1997; Borenstein and Shepard, 1996; Sen, 2003; and Noel, 2007).[8] Some studies try to explain station-level pricing using station characteristics, location, and local competition, but do not study responses to price changes (e.g., Plummer, Haining, and Sheppard, 1998; Barron, Taylor, and Umbeck, 2000; and Hastings, 2004). Some studies use station-specific prices, but either the price data are cross-sectional (e.g., Shepard, 1991), surveyed no more than once per week (e.g., Haining, 1983; Plummer, Haining, and Sheppard, 1998; and Barron, Taylor, and Umbeck, 2000), or for a jurisdiction (Western Australia) which regulates the timing of gasoline price changes (Wang, 2006).

To anticipate results, to our knowledge, this chapter offers the first convincing evidence that for at least one Canadian market, to a large extent, stations do set prices to match (or set a small differential with) a small number of other stations. However, these stations are not necessarily the closest stations. In addition, we document that while stations frequently match price changes within two hours, many take considerably longer to respond than claimed in industry and government documents and predicted by the competitive theory. Finally, while price decreases do ripple across the city like falling dominos, increases appear to propagate across the city based more on geographic location and source of price control than proximity to the leaders of these increases. Overall, this study provides evidence that commonly accepted stylized facts regarding gasoline pricing in Canada, which have given rise to a competitive theory to explain them, are true to a certain extent. However, they are in many ways oversimplifications which hide details that can guide the development of theory which might provide a better understanding of conduct in these markets.

---

[8] While Slade (1992) studies responses by stations to rival price changes using a small subset of stations in a city, she is unable to examine how price changes move across a city.

In the next section, the theory of retail gasoline pricing in Canadian markets is presented, as well as some reasons to believe that it will not be entirely supported by the data. Section 4.3 describes the data. Section 4.4 presents the identities of principal price matches for each gasoline station in Guelph, and contains results related to station responses to price changes. Section 4.5 examines the so-called domino effect that is alleged to be present in retail gasoline markets. Section 4.6 discusses station price responses during price cycle restorations. Section 4.7 provides a summary and some concluding remarks.

### 4.2 The Theory of Retail Gasoline Pricing in Canadian Markets

In Canada, there have been frequent allegations of anti-competitive conduct among gasoline retailers, and multiple investigations of pricing in the retail gasoline industry.[9] There have also been mergers over the past 25 years affecting vertically-integrated oil companies that were among the largest gasoline retailers. This has led to the development of a competitive theory of retail gasoline pricing that has been advanced by the petroleum industry to defend observed pricing behaviour. The origins of the theory cannot be determined, and it has not been formalized. However, the elements of the theory are clear, and its implications are supposed to be the conduct that is generating the competition complaints.

As it appears in industry documents and studies, and some government documents, the informal competitive theory makes four assumptions:

(1) Retail gasoline is a homogeneous product, so consumers are unwilling to pay

---

[9] See the Competition Bureau's "Consumer Fact Sheet on Gasoline Prices", September 2005 (http://www.competitionbureau.gc.ca/internet/index.cfm?itemid=1906&lg=e; visited 2007-05-01).

higher prices for a station's brand of gasoline.[10] Price differentials between stations might be tolerated for full-serve versus self-serve gasoline, or if a station offers some product or service that is superior to that of its rivals.[11]

(2) Consumers are extremely price-sensitive when it comes to purchasing gasoline. They will travel large distances (e.g., a mile) to save two-tenths of a cent on a litre of gas, or 10 cents for a fill-up.[12] There are apparently no capacity constraints (in terms of pump counts, tank size, or otherwise) that might prevent consumers from taking advantage of price differentials.

(3) Retail gasoline prices are clearly posted on large signs, allowing consumers to easily compare prices. This allows gas retailers to easily monitor their nearby rivals' prices.[13]

---

[10] *Id.*

[11] See Conference Board of Canada (2001, 26).

[12] Shell Canada claims that "People will drive across town for as little as two tenths of a cent a litre – a savings of a dime on a 50-litre fill-up." See Shell Canada Limited, "Shell's Gasoline and Diesel Prices" (http://www.shell.ca/home/Framework?siteId=ca-en&FC2=/ca-en/html/iwgen/faq/zzz_lhn.html&FC3=/ca-en/html/iwgen/pricing/gasoline_today_shared/energy_gasoline.html#5; visited 2007-05-01). In its "Gasoline Pricing: Frequently Asked Questions" (http://www.imperialoil.ca/Canada-English/News/Issues/N_I_GasQuestions.asp; visited 2007-05-01), Imperial Oil refers to consumer price sensitivity to a two-tenths of a cent price difference, as does Petro-Canada in its FAQs (http://retail.petro-canada.ca/en/independent/2065.aspx; visited 2007-05-01). The Conference Board of Canada (2001, 25) refers to consumers switching stations for differences of a fraction of a penny, while Browne (1997, 46) refers to the industry suggestion that "the average consumer will drive across the street if another dealer is selling gasoline 0.2¢ per litre cheaper." He also notes that no empirical evidence was presented to support this assertion. The Standing Committee on Industry, Science, and Technology (2003, 21-22) states that industry officials have claimed that consumers are very price-conscious, "travelling great distances to save a fraction of a cent per litre, even though this may amount to a saving of only 10¢ or 20¢ on an average fill-up."

[13] Reference to consumers observing gasoline prices as they drive by a station at 60 km/h is made by the Canadian Centre for Energy Information in its "Gasoline Q & A"

(4) Implicit in the theory is the assumption that individual gasoline retailers set prices non-cooperatively. There is some recognition that price zones exist (see the Conference Board of Canada, 2001, 27), but their sizes vary according to competitive conditions.

These four assumptions are taken by proponents to yield the following implications:

(1) Retail gas prices tend to uniformity (with perhaps very small differentials for service quality differences) in a market, as large positive deviations from the mode price are unsustainable. Stations charging prices higher than the mode price will experience a substantial loss in business and market share over a short period of time.[14]

(2) Retail gasoline price changes move rapidly and pervasively through the market.[15] There is some variation in the interpretation of the word "rapidly". The most extreme view is advanced by the Canadian Centre for Energy Information: "Of course, there can only be one lowest price, so everyone who wants to sell gasoline has to match the lowest price in the region within minutes

---

(http://www.centreforenergy.com/silos/GasolinePrices/faqAnswers.asp#9; visited 2007-05-01); and by the Conference Board of Canada (2001, 25) and the Standing Committee on Industry, Science, and Technology (2003) in summarizing industry views. The Canadian Petroleum Products Institute (1995), an association representing the major petroleum producers, states that gasoline is "the only product you can price shop at 40 kph – exposure to large number of retail outlets – price signs highly visible."

[14] See Imperial Oil, *supra* note 12. See also MJ Ervin & Associates Inc. (1997, 21) and the Committee to Review Gasoline Prices in British Columbia (1999, 26).

[15] The Consent Order Impact Statement (1989, 21-22) in the case of *Director of Investigation and Research v. Imperial Oil Limited* states that "the many alternative sources available to price sensitive consumers ensure that price changes move both rapidly and pervasively through most large metropolitan areas and smaller centres."

– hours at most – or face a dramatic drop in sales."[16] One can find reference to responses to price changes that are either "immediate"[17], "quick"[18], "extremely quick"[19], or "almost immediate"[20].

(3) Gas stations respond to prices set by a small number of other stations or "key competitors". There is some question regarding how to interpret the term "key competitor". The Conference Board of Canada (2001, 25-26) notes that:

> Most of the majors and regional refiner-marketers employ a set of tactics to ensure that each of their retail outlets remains competitive within their local markets. The following steps are generally taken before initiating a price change: Each outlet identifies the key competitors within a particular market (usually two or three) and then price relationships are established with respect to these key competitors. The relationship depends on the characteristics of the key competitors.

According to the Standing Committee on Industry, Science, and Technology (2003, 21-22), it is the view of industry officials that "Consumers have proven to be very price conscious, travelling great distances to save a fraction of a cent per litre. ... Retailers are aware of this extreme shopping behaviour by motorists,

---

[16] See the Canadian Centre for Energy Information, *supra* note 13.

[17] See the Canadian Petroleum Products Institute, "Gasoline Pricing Facts and Myths" (http://www.cppi.ca/Q_A_s.html; visited 2007-05-01).

[18] See Shell Canada Limited, *supra* note 12, and MJ Ervin & Associates Inc. (1997, 21).

[19] See Imperial Oil, *supra* note 12.

[20] See the Conference Board of Canada (2001, 25). The Standing Committee on Industry, Science, and Technology (2003, 1) also refers to a possible competitive explanation for gasoline pricing, where price changes are "rapid and pervasive". The Committee (at page 21) appears to accept that when a retail outlet changes its price, " competitors in the immediate vicinity follow in lockstep within minutes". Natural Resources Canada (2005, 19) refers to stations that watch their competitors and "match the lower price almost immediately."

and must therefore keep an eye on their immediate rivals' prices for fear of losing sales." It is unclear whether distance is the primary determinant of a station's key competitors or immediate rivals, but it is likely an important determining factor.

(4) Price reductions will radiate outwards from the initial source, like a falling sequence of dominos. This view is captured in the characterization of rival stations' responses to a price reduction, as advanced by an expert in the Imperial Oil/Texaco merger case:

> While industry data suggest that up to 70% of consumers tend to buy most of their gasoline within two miles of their homes, the structure of this market ensures that price changes move both rapidly and pervasively through most large metropolitan areas. This is because each consumer's two mile radius overlaps with the next consumer's such that a net of interlocking submarkets spans the city. Any price decrease in one area of the city is transmitted by a domino effect, to other areas of the city through these interlocking submarkets ...[21]

The Canadian Petroleum Products Institute (1995) also refers to prices that "move rapidly and pervasively through large urban areas – the domino effect." No evidence in support of such a domino effect has been presented.

These are the major assumptions and implications that have been made in the informal theory of gasoline pricing in Canadian markets. Essentially, if a station reduces its price in a retail gasoline market, then this price change is matched quickly through the market, like a falling series of dominos. Consumer price sensitivity and posted retail prices ensure that price

---

[21] This quote appears in the Reasons and Decision for the case of the *Director of Investigation and Research v. Imperial Oil Limited*, pp. 22-23. The passage was obtained from the Affidavit of Professor Trebilcock dated July 24, 1989, Exhibit A at paragraph 14.

differentials cannot be sustained.

At the same time that the competitive theory of gasoline pricing is proposed, there is some recognition in some industry documents, as well as in the Conference Board of Canada (2001) report that a retail gasoline market might be characterized by a price cycle. For example, Petro-Canada has suggested that because consumers are price-sensitive, "a retailer may lower their price to gain a temporary advantage to attract more customers. ... As prices in the market decline to a point where a retailer feels profitability is unacceptable, that retailer may increase their price back to a profitable level." If other retailers follow, "the market is restored to a higher price level and the cycle then repeats itself."[22] The recognition of the price cycle, however, does not seem to affect either the industry's basic statement of the competitive theory or the implications that industry is prepared to derive from it.

There are several reasons why the informal competitive theory might not be supported by the data in a particular market. First, gas stations are not identical, and are differentiated by location and other characteristics, such as a convenience store or car wash. The competitive theory of gasoline pricing recognizes that retail gasoline markets are spatial, but seems to assume that consumers incur little or no transportation costs in shopping for gas.

Second, the competitive theory ignores the structure of retail gasoline markets, and the incentive that firms might have to tacitly coordinate pricing in highly-concentrated markets. It also does not consider the effect that the ownership structure of gas stations might have on how price adjustments are made. Retail gasoline markets in Canada typically contain three types of

[22] See Petro-Canada, *supra* note 12. Similar descriptions are in the Canadian Centre for Energy Information, *supra* note 13 at 5; Imperial Oil, *supra* note 12 at 1; Canadian Petroleum Products Institute, *supra* note 17 at 2; and the Conference Board of Canada (2001, 27-29).

stations: branded stations of vertically-integrated oil companies with a national presence, branded stations of vertically-integrated oil companies with a regional presence, and independents that are either singletons or part of a small chain, or stations affiliated with another retailer like a supermarket or department store. The Conference Board of Canada (2001) and data reported in *Octane Magazine* indicate that the relationship between vertically-integrated branded gasoline suppliers and their retailers largely takes one of three forms:

(1) dealer-operated (or commission-dealer) station: the supplier owns the gas station and inventory, and sets the pump price, but the station is managed by a dealer that is paid a commission based on the volume of gas sold;

(2) lessee-operated station: the supplier owns the gas station, but the station is leased to and managed by a lessee/dealer that purchases gasoline from the supplier and resells it to consumers at a price determined by the lessee;

(3) independent dealer-operated station (or branded independent): an independent dealer owns the station, purchases gas from the supplier, and resells it to consumers at a price determined by the independent dealer.

It is then possible that a vertically-integrated company might have its dealer-operated stations change their prices in a market at the same time, while its lessee-operated and branded independent dealers may not change their prices simultaneously. Stations could then be seen adjusting prices at different locations in a city in a way that does not resemble a domino effect.

Third, independents could have different objectives than the vertically-integrated majors, affecting the way in which they respond to price changes. Some independents might consider automotive repair to be their primary business and devote little effort to monitoring gasoline prices. Other independents could focus on market share maintenance in order to sell complementary goods and services, leading them to undercut rather than match price reductions. Some retailers (e.g., Sunoco and Pioneer) might undercut instead of price-match in order to maximize gasoline sales and refinery utilization rates of the parent company.[23]

Fourth, in a market with a price cycle, it is unclear whether prices will be set in a way suggested by the competitive theory. Economic theories of price cycles have yet to be modified to incorporate spatial elements and vertical relations among stations and their suppliers, so it is unknown whether the modified theory would make the same pricing predictions as the competitive market model.

In what follows, the implications of the informal theory of gasoline pricing will be examined using price data from Guelph, Ontario. We shall also consider whether alternative explanations for retail gasoline pricing might explain the failure of an implication to hold.

### 4.3 The Data

Regular-grade gasoline prices in cents per litre (cpl) were collected bi-hourly (8:00AM to 10:00PM) from August 14 to November 24, 2005 for 27 stations in Guelph, a city in southern Ontario with an approximate population of 106,000.[24] Each period, approximately 45 minutes were typically required to collect prices at all stations. Station characteristics were also collected, including operating hours (24 hours or not), service level (full-, self-, or split-service), number of regular-grade nozzles, and other operations (repair bay, convenience store, car wash).

Station locations are plotted in Figure 4.1, and are numbered in the order in which they

[23] See Eckert and West (2004a, 41-42), who also note on page 31 that Suncor owns both the Sunoco brand and 50% of the Pioneer brand.

[24] The last period during which prices were collected on November 24 began at 4:00PM.

were collected. Esso, Petro-Canada, Shell/Beaver and Sunoco are the vertically-integrated (major) brands in the city; Canadian Tire, 7-Eleven and Pioneer are among the independents.[25] Station characteristics are provided in Table 4.1, where it can be seen that major brand stations tend to be 24-hour self-serve stations with relatively high capacities, convenience stores and car washes, and no repair bays. Stations from the largest independents are similar to these majors in terms of capacities and characteristics, while the other independent stations have lower capacities and no ancillary operations other than repair bays.

An attempt was made to determine whether the price of each station is set by its manager or its supplier. Six of the above seven brands reported that each station's price is company-controlled (Station 14's manager is permitted limited price control). Esso refused to provide price control information. However, according to MJ Ervin & Associates Inc. (2006, Appendix A), 7-Eleven Canada controls prices at its Esso-branded stations, implying that Station 7's price is not controlled by Esso. Also, Station 17 has a Rainbow-branded car wash and variety store, and is described on an Esso-affiliated website as a family-operated dealer.[26] Finally, the empirical literature on station contracts suggests that a company is more likely to control prices at stations with longer hours, greater pump capacities, or convenience stores, and is more likely to delegate price-setting authority to stations that are full-serve and/or have repair bays.[27] Based

---

[25] Esso Station 28 was excluded because its price was not posted, but prices collected once per night from the pump from August 14 to September 29 suggest that prices at the other stations move independently of this station's price. Also, Beaver is a regional brand that is owned by Shell Canada, and is therefore counted as a Shell station.

[26] See "Esso Rebecca Run for SMA" (http://www.rebeccarun.com/esso_dealers/rainbow.html; visited 2007-05-01).

[27] See Slade (1998), Shepard (1993), and Taylor (2000).

on these conclusions, major brand stations are divided in Table 4.1 by the likely source of price control, where Group A stations' prices are either known or believed to be controlled by the head office of the brand, and Group B stations' prices are not. Independents are also divided into two categories based on size (station-specific nozzle counts), where Group C stations have more regular-fuel nozzles than Group D stations.

Stations in Guelph tend to be separated geographically by source of price control. Looking at Figure 4.1, if a line is drawn connecting Stations 4, 16 and 13, then only two of the 12 Group A stations are located on or above this line, while 11 of the 15 stations in Groups B to D are in this same area. Thus, it will be difficult to distinguish between the effects of location versus different supplier contracts.

A basic examination of the data reveals that over the 103 days in the sample, on average each station raised its price 21 times, and lowered it 116 times. There is little difference in the average number of increases across the four groups in Table 4.1, which range from 17 to 23. However, there is a substantial difference across groups with respect to the average number of decreases; on average, Group A stations lowered their prices 162 times, while Group B stations lowered them 84 times. The difference between the two groups of independent stations is also large: the Group C stations lowered their prices an average of 120 times over the sample, while the Group D stations lowered them 46 times. Location also seems to be associated with how often a station lowers its price: on average, stations below the previously-defined line lowered their prices 157 times, compared to 71 times for other stations.

The data also suggest that retail gasoline prices in Guelph move in a cyclical pattern observed in many Canadian cities, and acknowledged in industry documents.[28] During the cycle, retail prices increase rapidly and decrease over one or more weeks, even when wholesale prices are stable. For Guelph, this is demonstrated in Figure 4.2 where the mode retail price is plotted, along with the London, Ontario rack price and the par Edmonton price of crude oil.[29] In the alternating-moves, infinite-horizon, price-setting duopoly model developed by Maskin and Tirole (1988), an "Edgeworth cycle" equilibrium exists in which each firm slowly undercuts its rival's price until prices fall near marginal costs. At this point, one of the firms will raise its price, initiating a new cycle. Empirical studies of retail gasoline markets (e.g., Eckert, 2002; Noel, 2007; Eckert and West, 2004b; and Wang, 2006) have found evidence to support the theory.[30] Since price increases and decreases have separate implications for the structure of these cycles, as well as the behaviour of firms in these cycling markets, price increases and decreases will be treated separately in this chapter.

### 4.4 Price Uniformity, Price Matching, and the Speed of Price Response

In this section, we examine Implications 1 to 3 from the competitive theory of gasoline pricing, that retail prices tend to uniformity, that stations match a small number of other stations, and

---

[28] See *supra* note 22.

[29] Daily rack price data for London, Ontario were obtained from MJ Ervin & Associates, and daily crude oil price data (par Edmonton) were collected from Natural Resources Canada's website (http://www2.nrcan.gc.ca/es/erb/prb/english/View.asp?x=476; visited 2007-05-01).

[30] While Wang (2006) studies cyclic prices in Perth, Australia, using daily station-specific data, the data pertain to a regulated market; in Perth, stations are permitted to change prices at most once per day, and prices are posted daily on a government website so that firms are fully informed about rival prices. Thus, Wang's data cannot be used to address our main questions of interest, such as how quickly firms respond to the price changes of rivals.

that retail price changes quickly move across the market. Whether stations match geographically close stations is also considered, as well as whether small price differentials are quickly eliminated. This section focusses on price decreases; increases are considered in Section 4.6.

*4.4.1 Price Uniformity*

Our first observation is that prices do not tend to uniformity across all of Guelph. Excluding the first two days of each cycle when stations are raising their prices, on average, only 8.0 out of 27 stations charge the mode price in any given period, while each station's price each period is the same as 3.5 other stations, on average. Thus, while there appears to be some price-matching, rather than matching a market-wide price, stations tend to match a small number of other stations. Also, it is not the case that at a given point in time, prices vary by only a few tenths of a cent. Indeed, excluding the first two days of each cycle, 47% of prices are at least one-half of a cent above or below the current mode price.[31]

*4.4.2 Price Matching*

The next question is whether stations tend to match the prices of particular other stations, as predicted by the industry and government literature described in Section 4.2.[32] As a first approach to this question, Table 4.2 lists the station that each station contemporaneously

---

[31] The statistics reported in this paragraph do not take into account that stations may not match rivals, but might instead undercut or price above rivals by a fixed margin, reflecting service or quality differentials. This possibility is considered in the remainder of this section.

[32] The procedures used in the section identify which competitors a station matches most often over the sample period. These competitors might differ from those that a station monitors, but to which it rarely responds.

matches (or prices within a fixed margin of) most frequently when it lowers its price. It also lists the percentage of price decreases for which it matches this station or establishes the fixed margin, and the margin set. For example, Pioneer Station 23 undercuts Station 20 by exactly 0.7 cpl with 46% of its price decreases; there is no other station that it matches or sets a fixed margin with more frequently.[33] The last column of Table 4.2 lists the frequency with which a station matches its closest neighbour when it reduces its price.

First, note from Table 4.2 that for many stations, the degree to which it contemporaneously matches (or establishes a fixed margin with) another station's price is high.[34] Across all stations, a station matches the same other station with a weighted average of 60% of its price decreases, while only two stations match a single station with less than 35% of their decreases.[35] These findings provide preliminary support for the hypothesis that stations lower prices in order to match specific stations.

Second, of the 17 major brand stations, eight most frequently match the price of a station in the same chain, the most striking example being Sunoco Station 9; it sets a price exactly 0.4 cpl above that of Sunoco Station 22 with 91% of its price decreases, despite Station 22 being the fourth-furthest station in the sample from Station 9.[36] Strong price-matching is also observed across all three Sunoco stations, and across three of the seven Esso stations in the sample (19,

---

[33] Recall that Suncor owns 50% of Pioneer. See *supra* note 23.

[34] For presentation purposes, from this point forward, we will use "matching" to refer to setting the same price as a rival *or* establishing a fixed differential with that rival.

[35] Defining a station's secondary match as the station that it contemporaneously matches with the second-highest frequency, across all stations, a station matches its secondary match with a weighted average of 49% of its price decreases.

[36] Note that while Station 9 is a full-serve station, Station 22 is self-serve. Hence, 0.4 cpl may represent a differential for the level of service.

21 and 26). The main exception is Petro-Canada, as three of its four stations tend to match the three Group A Esso stations. These results suggest more direct price control by Esso for Stations 19, 21 and 26 than for the other four Esso stations, and that Petro-Canada Station 14 is a branded independent, supporting arguments made in Section 4.3.

The evidence regarding geographic proximity is mixed. Based on road distance, only seven stations match their closest station most frequently, and for only 11 is the station identified in Table 4.2 one of the three closest. Therefore, same-chain effects and geographic proximity account for the identity of the station being matched from Table 4.2 for 70% of the stations.[37]

Of the five stations that match another station with at least 80% of their price decreases, four involve stations either across the street or within a block of each other. In each of these cases, one station in the pair tends to lead the other; in particular, Station 2 leads Station 1, Station 3 leads Station 4, and Station 10 leads Station 11. In other cases where stations are located in close proximity to one another, evidence that they match the current prices of their close rivals is weaker. Finally, on average, a station matches its closest competitor with 40% of price decreases, compared to 60% as given above.

A problem with looking at whether a station matches the price being charged in the same period by a rival is that we do not know which station established the price first. As well, a purpose of this chapter is to address how price changes propagate across the city, which requires considering how stations respond to past price changes. To that end, we next consider to what

[37] If Table 4.2 is reconstructed under the restriction that a Group A station cannot list another Group A station of the same brand as the station that it matches with the highest frequency, then the evidence regarding geographic proximity is strengthened; under this restriction, 10 of the 27 stations match their closest rivals most frequently, and the rival that is matched the most often is one of the three closest stations for 16 of the 27 stations.

degree stations match prices charged by a small number of stations in the previous period.

To answer this question, three principal matches are identified for each station using the following methodology. For each station, we identify the differential it sets with the lagged price of each competing station with the highest frequency – this differential is zero if it sets the same price as the competing station. Then, consider each possible combination of three competing stations, and choose the combination that maximizes the number of price decreases with which a station matches (or sets the specified fixed margin with) the lagged price of at least one station. Principal matches identified by this methodology are listed in Table 4.3, and are designated primary, secondary, and tertiary matches.[38] For example, Table 4.3 identifies Station 5's principal matches as Stations 26, 24 and 23 – it matches their lagged prices with 60%, 34% and 28% of price decreases, respectively. There is no other combination of three stations that Station 5 matches (with a lag) with higher frequency.

For each principal match, Table 4.3 reports the fraction of price decreases with which the station matches that principal match or sets a fixed margin, and the margin that it sets (its price less the price of the principal match). Principal matches are sorted by the frequency with which the station matches them. The last column reports the percentage of price decreases explained by matching or setting a fixed margin with at least one of the principal matches. For example, Station 5 matches at least one of its principal matches with 81% of its price decreases.

Two comments should be made regarding methodology. First, principal matches are not computed for Stations 1, 4, and 11, which as discussed earlier seem to simply match the

[38] Three principal matches are considered due to the reference to two or three key competitors by the Conference Board of Canada (2001, 25-26), as quoted in Section 4.2 above. The analysis in this section was also carried out identifying only two principal matches for each station, with similar results.

price of the closest station. Likewise, they are not permitted to be principal matches. Second, our methodology does not identify a unique set of principal matches for eight stations.[39] In Table 4.3, we list for those stations the principal matches that are closest to the station in question. For example, there are two possible sets of principal matches for Station 7: Stations 5, 6 and 17; and Stations 25, 6 and 17; the first set is chosen since Station 5 is closer to Station 7 than is Station 25. Two stations (Stations 6 and 16) are excluded from Table 4.3 because a large number of principal match lists are identified (seven and six, respectively). Also, the frequency with which Station 16 matches lagged station prices is very low compared to other stations, suggesting it pursues a different strategy, so principal matches cannot be identified.[40]

The first observation from Table 4.3 regards the number of price reductions for each station that can be counted as matching at least one of the primary, secondary, or tertiary matches. The frequency with which a station matches a price charged in the previous period by at least one of its principal matches ranges from 56% to 91%, with an average across stations of 66%. On average, a station matches its primary match with a weighted average of 37% of price decreases.

With respect to the geographic proximity of principal matches, the results are mixed. For 10 of the 22 stations listed in the table, none of the principal matches are one of the three

---

[39] One reason for this was that, as discussed above, certain stations within the same chain tend to change prices simultaneously and price uniformly. Therefore, our method identified for certain stations different sets of principal matches, using different stations from the same chain.

[40] Note that there is little difference between the number of price decreases that the list of principal matches in Table 4.3 explains for a particular station, and the number explained by the "second-best" list of principal matches. However, similar conclusions were obtained with principal match lists based on other criteria. See the end of this section for further comments on other methodologies.

closest stations. On average, a station's primary match is its sixth-closest; the range is from first to 19th. Also, a station in Table 4.3 matches one of its three closest stations with a weighted average of 44% of its decreases, as opposed to 66% of its decreases that are explained using its three principal matches. Coupled with the results from Table 4.2, it appears that while in many cases stations tend to peg their prices to those of their nearest stations, in others cases the principal matches are determined by factors other than proximity.

Finally, certain stations are principal matches for many different stations. In particular, Pioneer Station 23 is a principal match for 12 stations, and the primary match for three; Esso Station 26 is a principal match for six stations and the primary match for five. Also, 47% of all price decreases (except Stations 19, 21, 23 and 26) match the lagged price of Stations 23 or 26, or price 0.3 cpl above Station 23. More discussion of the role of these stations in leading price reductions is given in Section 4.5.[41]

*4.4.3 Speed of Price Response*

Another important prediction made by government and industry is that stations respond quickly to price reductions by a small number of rival stations, "immediately" eliminating differences beyond a small margin. To consider this prediction, Table 4.4 presents, for each station, the

---

[41] A concern with Table 4.3 is that prices are collected over roughly 45 minutes. Thus, if Table 4.3 identifies one of a station's principal matches to be a station whose price was collected later, it is possible that this principal match set its price after the station in question. Examination reveals only two cases where a station's primary match was typically collected at least 20 minutes after the station in question (Stations 5 and 9, both listing Station 26 as their primary match). However, for both stations, Station 26's price was in place for more than one period for 45% of the times that it was matched by Stations 5 and 9, providing further evidence that these stations follow Station 26. Thus, the timing of price collection does not appear to be a serious concern regarding the identities of the principal matches.

distribution of the length of time between when a station's primary match sets a price and when the station matches it, excluding observations where the station is closed and so cannot respond in that period. For example, a value of one at the $50^{th}$ percentile means that for 50% of observations where a station's primary match lowers its price and is matched by the station in question, that station matches it within one period.[42] For each row, the sample includes all price decreases that match or set the fixed margin with the primary match.

According to Table 4.4, seven stations match the prices of their primary match by the next period with a frequency of at least 50%; for the stations reported in Table 4.4, 40% of price decreases that match the price of a station's primary match do so in the period after the price was established. While in many cases a station responds within a single period to its primary match, the claim that price differentials beyond a few tenths of a cent will be eliminated "immediately" is not supported by the data.

Table 4.4 also suggests that whether a station responds quickly to its primary match is related to both its identity and type. Stations with either Esso Stations 19 or 26 as their primary match make up seven of the 11 fastest stations to respond. Those stations that respond quickly to their primary match also tend to be major brand stations, while the slowest stations to respond to primary matches tend to be independents, as well as Esso Stations 19 and 26.

The observation that independents seem less likely to respond quickly to their principal matches has different potential explanations. First, Group D stations tend to change their prices infrequently. Gas sales might not be the main business of Group D stations, which also operate service bays, so these station operators may be less concerned with monitoring rivals.

---

[42] Station 8 is excluded from Table 4.4, as it matches its primary match only six times.

Note that if a station's practice is not to match (or establish a fixed margin with) a few principal matches, but rather to follow some other rule, then Table 4.3 will not identify those competitors upon which a station bases its price. One observation that suggests that this could be a possibility is that Group D stations tend to set particular price endings. For example, Station 2 ends all prices with the digit "5", while Station 3 ends 96% of its prices with "7". Since Station 6 ends all prices with "9", it could appear that Stations 2 and 3 peg their prices to a fixed differential with Station 6, when all three stations just rely on certain price endings.

To address this concern, we look next at the relationship between whether a station lowers its price and the last-period differentials between its price and prices being charged by rival stations. The intuition of government and industry arguments is that a station is more likely to lower its price if it is higher, as opposed to lower than its rival's price. If a station's decreases are highly correlated with the difference between lagged prices at it and a particular competitor, then this suggests that the station may be basing its price on that of this competitor.

To this end, we construct for each station a dummy variable that equals one when it lowers its price, and compute the correlation coefficient between this variable and the previous-period difference between the station's price and the price of a rival station. This is done for all rival stations. Table 4.5 lists, for each station from Table 4.3, the station that yields the highest Spearman correlation coefficient. Days when restorations are initiated are excluded, as well as periods when the station is closed.

The list of matches in Table 4.5 is remarkably similar to the list of primary matches in Table 4.3. Of the 22 stations listed in Tables 4.3 and 4.5, 11 (50%) have the same primary matches; for five stations, the primary match in Table 4.3 is the station with the second- or third-highest correlation coefficient. The main difference between the primary matches identified in

Tables 4.3 and 4.5 is that from Table 4.5, Esso Station 26 is the primary match for eight stations, while Stations 19 or 21 are primary matches for another four stations. Thus, Table 4.5 provides further evidence that many stations in the market peg their prices to a small number of Esso stations.

The main findings of this section can now be summarized. As suggested by industry and government, to a large extent stations do set prices to match or establish a small differential with a select list of stations. However, certain stations do not seem to be engaged in price-matching behaviour, instead changing their prices infrequently and relying on certain price endings, while for some other stations, only around half of decreases can be described as matching one of three other stations. Also, the role of geographic distance in determining the identities of these principal matches is smaller than anticipated – in practice, many stations seem to peg their prices either to Pioneer Station 23 or to major brand stations operating near Pioneer. Finally, while in many cases stations respond to their principal matches within a period, many take longer to respond, particularly independents and stations not targeting Esso.

### 4.5 The Domino Effect

In this section, the fourth implication of the competitive theory of gasoline pricing, that price reductions radiate outwards from the initial source like a falling sequence of dominos, is examined. Specifically, the amount of time that it takes a station to respond to a price cut by Pioneer Station 23 is calculated, where a station is considered to respond to this price cut when it matches or undercuts Pioneer's price; fixed price differentials are not considered.[43]

---

[43] Exceptions are Sunoco Stations 9 and 20, which tend to price 0.4 cpl above Sunoco Station 22, as discussed above. These two stations are considered to have responded to Pioneer

The focus on undercuts by Pioneer is justified by the observation that it frequently undercuts the entire market: Pioneer Station 23 accounts for 39% of the 153 cases where one station is observed to undercut all others in Guelph. This proportion is over twice that of the next most frequent undercutter, Petro-Canada Station 25, which sets 16% of these minima. Excluding 11 observations where Pioneer's decrease is on a day when a restoration is initiated, the following analysis is based on 49 observations where it undercuts the entire market.

Response times have been calculated and ranked across stations based on three measurements. First, the order in which stations respond to Pioneer's price cuts is ranked from 1 to 26. The second measurement ranks stations on a scale of 0 to 3 based on whether they respond to Pioneer on the same day as its price decrease ("0"), overnight (10:00PM to 8:00AM) ("1"), the next day ("2"), or beyond the next day ("3"). The third measurement calculates the number of hours elapsed between observing Pioneer's price cut and the station's response.

The results for each of these three measurements are provided in Table 4.6, and are illustrated graphically in Figures 4.3 and 4.4. They are divided into weekday and weekend observations, where a weekend is defined to begin at 6:00PM on Friday (after the afternoon rush). There are 32 weekday and 17 weekend observations. However, certain stations do not always respond to Pioneer's price decrease before the next cycle restoration, so their statistics are calculated over fewer observations.

The results are broadly consistent with the claim that stations respond to Pioneer's price cuts in a domino fashion. Visually, Figures 4.3 and 4.4 illustrate that on both weekdays and weekends, stations in the southwest corner of the city containing Pioneer tend to meet or beat

---

if they price 0.4 cpl above Pioneer, or lower.

Pioneer's price before most stations elsewhere in the market. However, a station's road distance to Pioneer does not provide a complete explanation of its speed of response to Pioneer's price decreases. Statistically, the Pearson correlation coefficient between the road distance to Pioneer and the number of hours to respond to Pioneer's decrease, taken from Table 4.6, is 0.44 for weekdays and 0.41 for weekends.

In comparison, the response time to Pioneer seems to be more highly correlated with contract type. If a variable is constructed that assigns a value of "1" to Group A stations, "2" to Group C stations, "3" to Group B stations, and "4" to Group D stations, then the Pearson correlation coefficient between this variable and the median number of hours to respond to Pioneer is 0.81 on weekdays and 0.67 on weekends.[44] An example of where contract type seems to dominate proximity in determining response time is given by Sunoco Station 9, which tends to respond to Pioneer on the same day as Pioneer undercuts the market, despite being on the other side of the city and the fourth-furthest station from Pioneer. Similarly, Station 17, which is considered a branded independent, tends to respond to Pioneer the day after a price decrease, despite being closer to Pioneer than many of the Group A stations that respond on the same day.

The results also seem to be consistent with the results from Table 4.3 regarding principal matches. In Table 4.3, Pioneer is identified as a principal match of 12 stations, 11 of which are among the first 12 to respond to its price decreases in Table 4.6.[45] Those stations which do not list Pioneer as a principal match tend to follow afterwards.

---

[44] Spearman correlation coefficients are 0.78 and 0.73. Taken over all 129 cases where a single station undercuts the entire market, but not on a day when a restoration is initiated, and not dividing the sample into weekdays and weekends, the Pearson coefficient falls to 0.75.

[45] The exception is Station 8, whose principal matches are questionable, as noted above.

While the results do suggest the basic existence of a domino effect, the speed of response is not as fast as claimed in the informal theory. Table 4.6 shows that only nine stations respond to Pioneer's price decreases on the same day on weekdays, and the median response time of the fastest stations is six hours. The majority of stations tend to take over 24 hours to respond to Pioneer, while some stations take nearly three days. The ranking of response times on weekends is similar; the Pearson correlation coefficient between weekday and weekend hours to respond to Pioneer is 0.88. However, Table 4.6 shows that stations wait longer to respond to Pioneer's price cuts on weekends. Only one station responds on the same day that Pioneer lowers its price on a weekend, while other stations tend to take 22 to 86 hours to match Pioneer's price.

A potential explanation for the slower response times on weekends is that on weekdays, consumers pass many stations during their commutes and can compare prices across these stations before making purchases. However, they might remain close to home on weekends and buy gas as part of multi-purpose shopping trips. Thus, gasoline retailers might be more sensitive to price differences with their rivals on weekdays. This might also explain why price cuts take several hours to reach even the closest stations on weekdays: between rush hours, consumers may observe fewer prices and are less price-sensitive. These observations are similar to those of Slade (1992), whose findings are consistent with weekday commuters being more price-sensitive than Saturday consumers.

Finally, an implication of the competitive theory is that, despite how a price decrease propagates across a market, price decreases should be quickly adopted by most stations. This appears to be true for only certain categories of stations. Of the 160 times that a new minimum price is established in the city by one or more stations, and which are not observed on a day when a restoration is initiated, only 39% of these new minimum prices are eventually matched or beaten by all stations before the next restoration. If Group D stations are excluded, then this percentage increases to 58%; excluding Groups B and D, it rises to 77%, while for Group A alone it is 80%.[46] Thus, while a new minimum price usually does not spread across all stations, it does typically propagate across stations in Groups A and C. However, even in these cases, it takes a long time for the price to move across the market. The average time for a new minimum price to be met or beaten by all other stations (when this happens ) is 81 hours; on average, it takes the new price 44 hours to be matched or beaten by all stations in Groups A and C. Of course, given the association between contract and geographic location, these results might reflect the distance from the setter of the new minimum price, instead of the contract.

### 4.6 Price Increases

In this section, the pattern of price movements during cycle restorations will be described and compared to the results in Section 4.5. Sixteen attempted restorations are identified where the bi-hourly mode price increases after one or more stations raise their prices to that mode price. However, two restorations are excluded from this analysis, because 11 or more stations did not raise their prices on these dates.

It should first be noted that in every cycle restoration, a sub-cycle has been observed where some of the first stations to raise their prices lower them back to (or near) their pre-increase levels within four hours of the initial increase. Then, between 8:00PM and 8:00AM the next morning, these stations are consistently observed to raise their prices back to the tops

[46] Looking only at the 49 price decreases initiated by Pioneer, the results are similar. Thirty-nine percent of these new minimum prices are matched or undercut by all other stations; excluding Group D stations, this figure rises to 67%, and it rises further to 82% if only Groups A and C stations are included in the analysis.

of their cycles, after which they begin to fall slowly over the course of the main cycle. While the identities of these stations are not always the same, they are always among the first stations to raise their prices in the early afternoon.

A possible explanation for this sub-cycle is that these stations use the first price increase to initiate the restoration while travel demand is at its midday low,[47] and then lower their prices before the afternoon rush, after which they wait for their rivals to raise their prices. The second increase does not occur until travel demand falls again after the afternoon rush. In light of this pattern, a station's ranking is based on when it raises its price to its cycle peak the first time. Also, if it raises its price multiple times in small increments before reaching its cycle peak, then the timing of the final increase is used to rank that station among its rivals.

Table 4.7 reports that all stations tend to raise their prices to their individual peaks within 24 hours of the initial increase, and 16 reach their peaks on the first day. This can be contrasted with the results in the previous section, where some stations are observed to take over two days to respond to price decreases by Pioneer; only 10 typically respond on the same day.

However, despite the finding that most stations tend to raise their prices on the first day, they are not observed to raise them within a few hours of one another. Table 4.7 shows that while five stations consistently lead restorations (Stations 5, 18, 19, 25 and 26),[48] only three follow these leads within two to four hours, while eight stations wait until the end of the night.

---

[47] See Paradigm Transportation Solutions Limited *et al.* (2005, 20).

[48] These five stations are either within one block of a mall or are in the downtown core, and so are highly visible to both consumers and their competitors. Furthermore, they account for five of the six Petro-Canada and Esso Group A stations. These results suggest that both the location of stations and the source of price control are important in identifying which stations are relatively more able to coordinate restorations, and will therefore raise their prices first.

As with price decreases, Figure 4.5 shows that south-western stations tend to follow the leaders' price increases on the first day, while the north-eastern stations tend to wait until the next day to raise their prices. However, the association between proximity to the price leaders and the time taken to increase price is again weak. Statistically, the Pearson correlation coefficient between the number of hours a station takes to set its cycle peak price and the road distance to its nearest leader is 0.35, excluding the five consistent leaders of price increases.

Again as with price decreases, the source of price control appears to be associated with the timing of price increases. Excluding the five consistent leaders, the Pearson correlation coefficient between the number of hours taken for a station to increase its price and the contract variable constructed in the previous section is 0.75. As examples, Stations 9 and 11, which are price controlled by Sunoco and Shell Canada, respectively, tend to reach their cycle peaks by the end of the first night, even though their nearest neighbours (which are open 24 hours) raise their prices the following day.

### 4.7 Conclusions

The purpose of this chapter was to examine the accuracy of implications of an informal theory of competitive gasoline pricing, using price data collected eight times per day for 103 days from 27 stations in Guelph, Ontario. The four main implications that were examined, and that represent commonly accepted stylized facts regarding gasoline pricing in Canada, are that retail gas prices tend to uniformity, that each station matches the prices of a small set of other stations, that retail gasoline price changes move quickly through the market, and that price reductions radiate outwards from the initial source like a falling sequence of dominos. The theory suggests that gasoline retailers compete aggressively with one another, and thus exercise very little individual market power when setting prices. While this model has been advanced by industry and government, no empirical evidence has been offered to support its main predictions.

To our knowledge, this chapter offers the first evidence regarding the accuracy of the accepted stylized facts which, coincidentally, emerge as implications of the competitive theory. We find that, as commonly claimed, many of the stations in our sample do tend to set prices to match (or set a small differential with) a small number of other stations. However, these stations are not necessarily the closest ones. Instead, price movements of stations within the same chain are often highly correlated, suggesting that certain stations' prices are only indirectly dependent on rival stations' prices. Also, while some stations often respond to price changes of another station within two hours, many take considerably longer to respond than predicted by the competitive theory and claimed in industry documents. Finally, while price decreases do ripple through the market like falling dominos, the order in which stations increase prices appears to be more strongly associated with location and source of price control than proximity to leaders.

These results suggest that the stylized facts which the competitive theory was designed to explain are an oversimplification of how retail gasoline prices are actually set. This indicates that competition authorities should be hesitant to accept the competitive model of gasoline pricing without a full analysis of pricing in other retail gasoline markets.

A remaining question is whether the model proposed by industry can be extended to account for discrepancies between the accepted stylized facts and actual pricing behaviour, or whether alternatives need to be considered. For example, one possible explanation for the variation in how long it takes a station to respond to a price change is suggested in Section 4.4. If consumer price sensitivity is lower on weekends when consumers observe fewer prices and purchase gas as part of a multipurpose shopping trip, then retailers may have less incentive to respond rapidly to rival prices. This may also suggest that stations respond more quickly near the afternoon rush hour than earlier in the day. A more realistic model of gas pricing would also need to account for the fact that gas stations are differentiated by spatial location, station characteristics, and supplier contracts, and that gasoline pricing might have the characteristics of an Edgeworth cycle. Whether an extended model that accounts for these factors, as well as variations in consumer price sensitivity, can yield predictions that match the more complex behaviour observed in this study is a subject of future research.

Figure 4.1: Station Locations

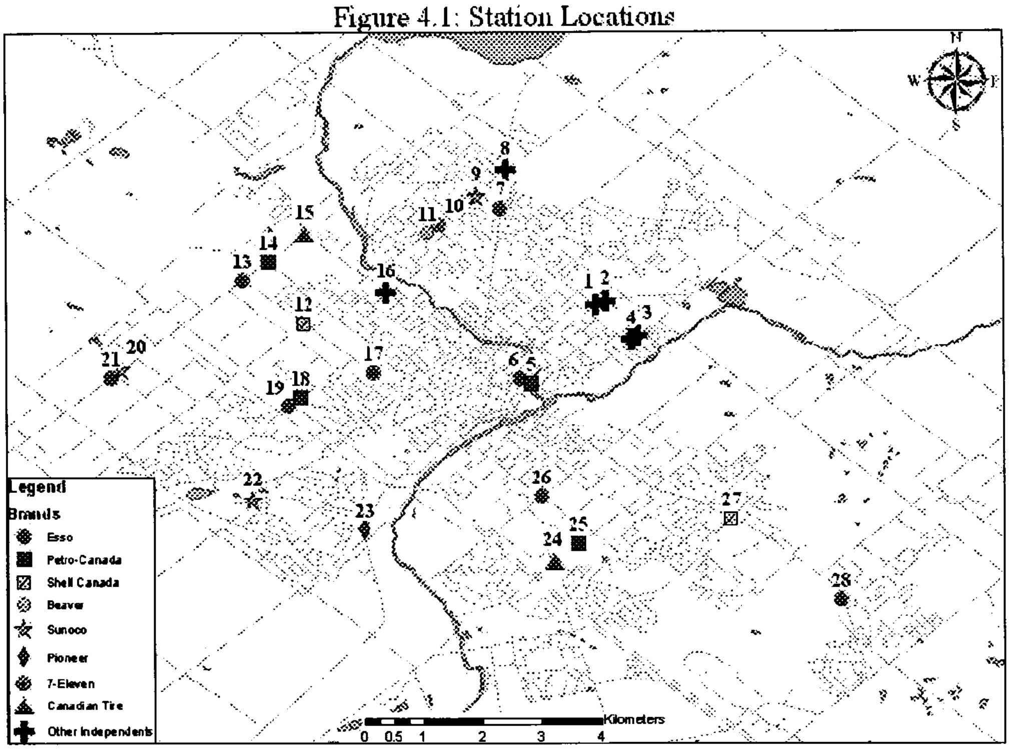



Figure 4.2

Upstream Prices and Mode Retail Price for Guelph, Ontario

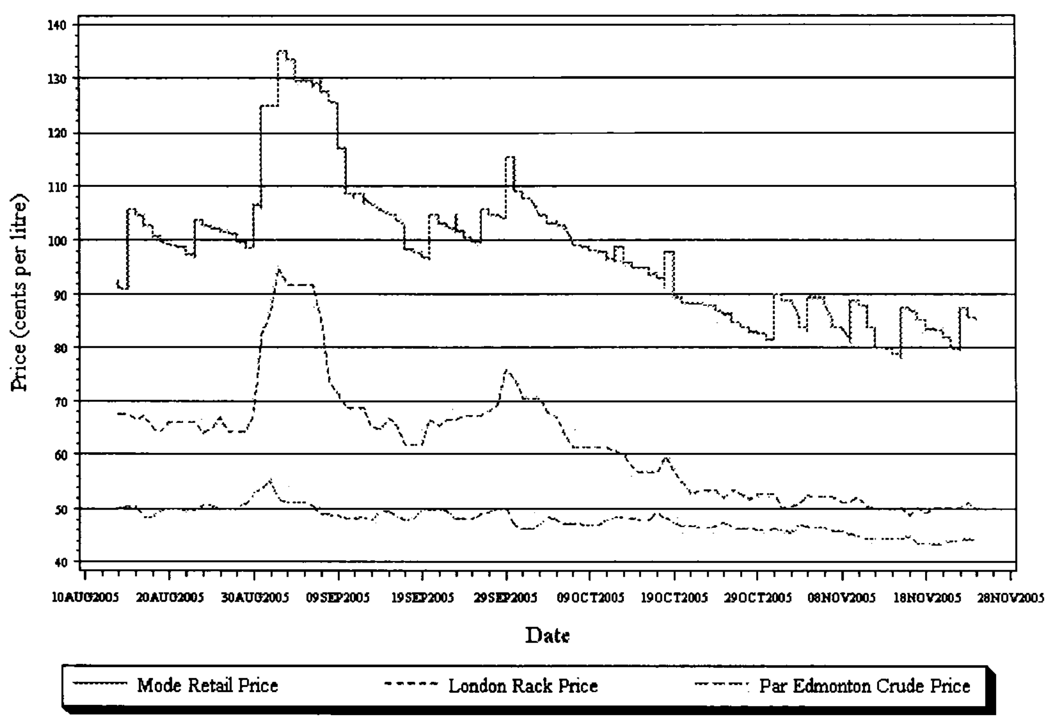
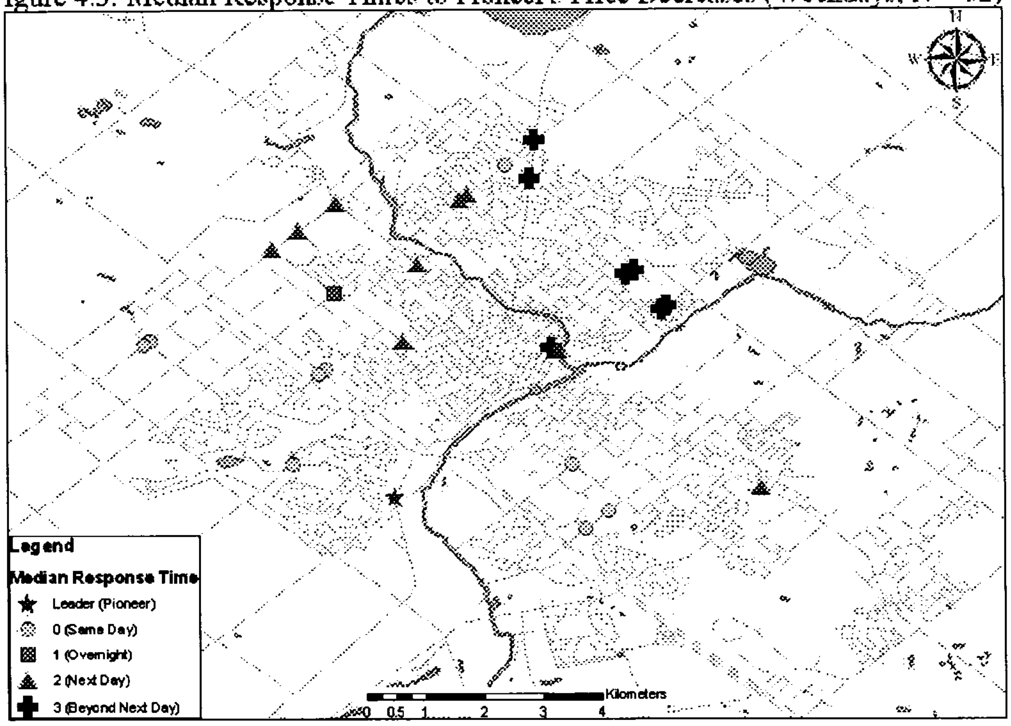
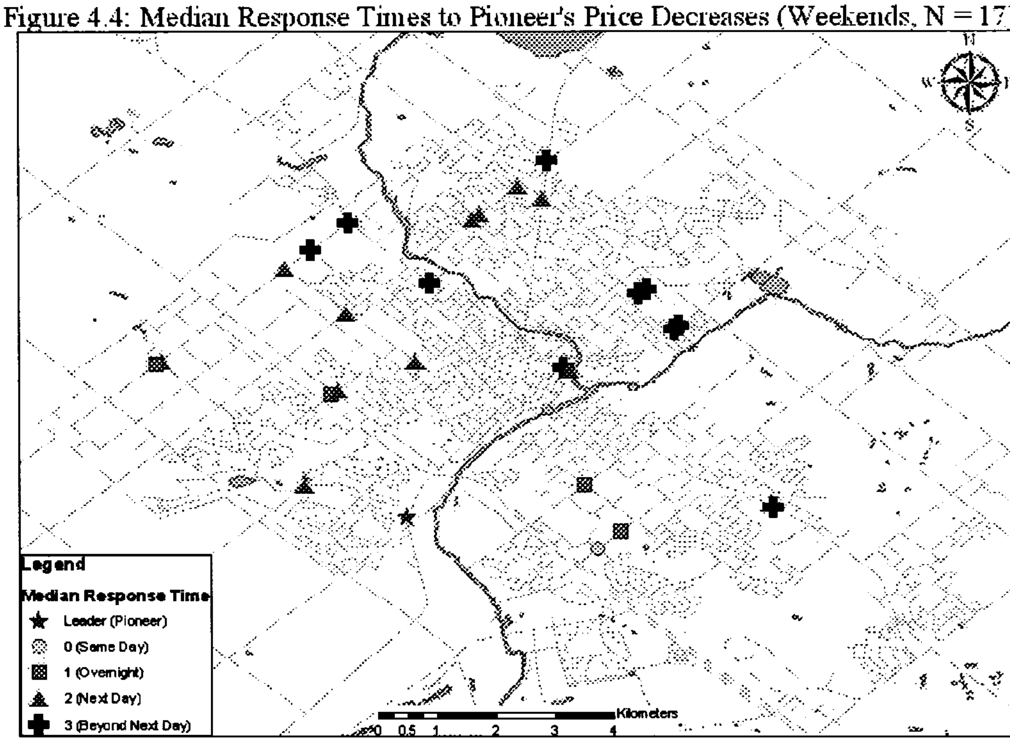


Figure 4.3: Median Response Times to Pioneer's Price Decreases (Weekdays, N = 32)*



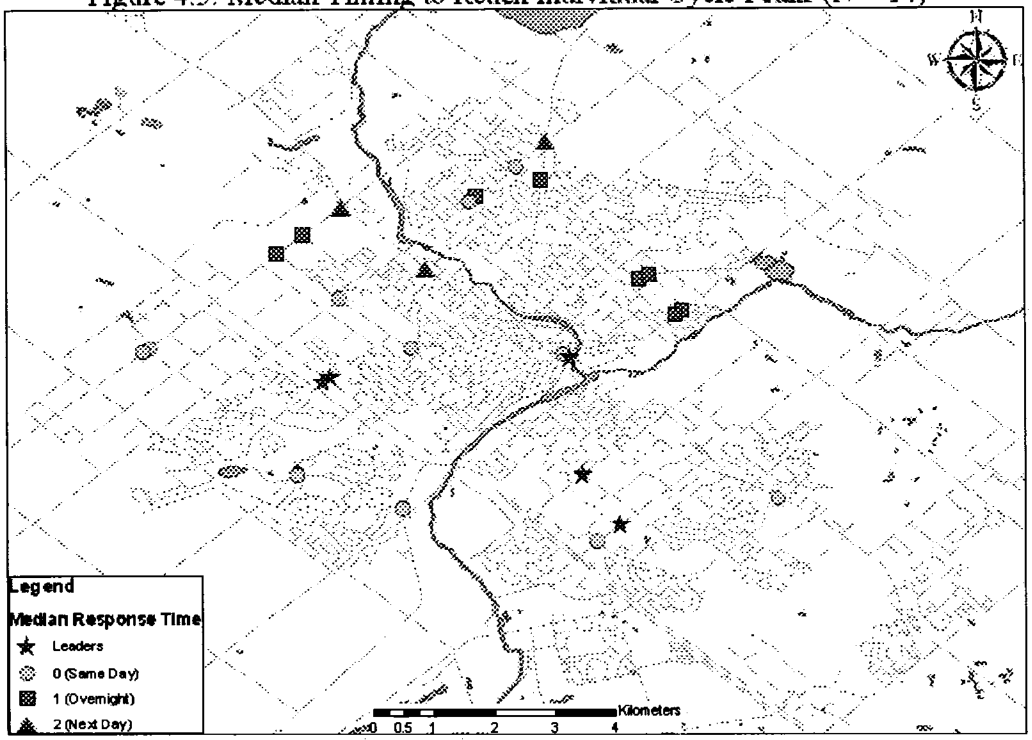

* N is reduced for a station by one each time it does not respond to a price decrease before the next restoration.

Figure 4.4: Median Response Times to Pioneer's Price Decreases (Weekends, N = 17)*




* N is reduced for a station by one each time it does not respond to a price decrease before the next restoration.

Figure 4.5: Median Timing to Reach Individual Cycle Peaks (N = 14)*




* Stations 8 and 16 only raised their prices during 13 of these restorations, while Station 14 did so during 12 of them.

Table 4.1: Selected Station Characteristics*

| Brand | ID | Nozzle Count | 24 Hrs | Self-Serve | Store | Car Wash | Auto |
|---|---|---|---|---|---|---|---|
| *Group A* | | | | | | | |
| Esso | 19 | 12 | ✓ | ✓ | ✓ | ✓ | |
| Esso | 21 | 10 | ✓ | ✓ | ✓ | ✓ | |
| Esso | 26 | 8 | ✓ | ✓ | ✓ | | |
| Petro-Canada | 5 | 8 | | ✓ | ✓ | | |
| Petro-Canada | 18 | 8 | ✓ | ✓ | ✓ | ✓ | |
| Petro-Canada | 25 | 8 | ✓ | ✓ | ✓ | ✓ | |
| Shell | 12 | 8 | ✓ | ✓ | ✓ | | |
| Shell (Mac's) | 27 | 8 | ✓ | ✓ | ✓ | | |
| Shell (Beaver) | 11 | 6 | | | | | ✓ |
| Sunoco | 9 | 6 | | | | ✓ | |
| Sunoco | 20 | 4 | | | | | |
| Sunoco | 22 | 8 | ✓ | ✓ | ✓ | ✓ | |
| *Group B* | | | | | | | |
| Esso (Norm's Garage) | 6 | 4 | | | | | ✓ |
| Esso (7-Eleven) | 7 | 8 | ✓ | ✓ | ✓ | | |
| Esso (Gas-Up Carwash) | 13 | 4 | | ✓ | | ✓ | ✓ |
| Esso (Rainbow) | 17 | 6 | ✓ | ✓ | ✓ | ✓ | |
| Petro-Canada | 14 | 8 | | ✓ | ✓ | | |
| *Group C* | | | | | | | |
| 7-Eleven | 10 | 8 | ✓ | ✓ | ✓ | | |
| Canadian Tire | 15 | 8 | | ✓ | ✓ | | ✓ |
| Canadian Tire | 24 | 6 | ✓ | ✓ | | ✓ | |
| Pioneer | 23 | 8 | ✓ | ✓ | ✓ | | |
| *Group D* | | | | | | | |
| Amco | 1 | 4 | | | | | ✓ |
| Cango | 2 | 3 | | | | | ✓ |
| Hilton Group Gas | 3 | 4 | | | | | ✓ |
| Maple Leaf Gas and Fuels | 4 | 4 | | | | | ✓ |
| CAN-OP | 8 | 2 | | | | | ✓ |
| Quik-N E-Zee Gas & Snacks | 16 | 2 | | | | | ✓ |

* Petro-Canada Station 18 is the only station with both full- and self-serve pumps; since the self-serve price is observed, only those pumps are counted. Also, a "store" means a convenience store, except for Canadian Tire Station 15 where it is a Canadian Tire department store.

Table 4.2: Principal Matches Identified by Contemporaneous Matching

| Station ID | Principal Match | Frequency | Differential* | Frequency with Nearest Station |
|---|---|---|---|---|
| 1 | 2 | 100% | 0.0 | 100% |
| 2 | 1 | 81% | 0.0 | 81% |
| 3 | 6 | 36% | -1.2 | 31% |
| 4 | 3 | 88% | 0.0 | 88% |
| 5 | 26 | 49% | 0.0 | 12% |
| 6 | 3 | 45% | 0.2 | 25% |
| 7 | 10 | 57% | 0.0 | 13% |
| 8 | 6 | 39% | 0.0 | 13% |
| 9 | 22 | 91% | 0.4 | 14% |
| 10 | 17 | 46% | 0.0 | 42% |
| 11 | 10 | 80% | 0.0 | 80% |
| 12 | 18 | 68% | 0.0 | 15% |
| 13 | 14 | 53% | 0.0 | 53% |
| 14 | 15 | 35% | -1.0 | 33% |
| 15 | 14 | 63% | 0.0 | 63% |
| 16 | 6 | 18% | 0.0 | 10% |
| 17 | 6 and 10 (tie) | 26% | -2.0, -1.0 | 13% |
| 18 | 19 | 68% | 0.0 | 68% |
| 19 | 21 | 73% | 0.0 | 57% |
| 20 | 22 | 57% | 0.4 | 54% |
| 21 | 19 | 78% | 0.0 | 53% |
| 22 | 20 | 68% | -0.4 | 36% |
| 23 | 20 | 46% | -0.7 | 32% |
| 24 | 23 | 56% | 0.0 | 36% |
| 25 | 26 | 44% | 0.0 | 31% |
| 26 | 21 | 63% | 0.0 | 32% |
| 27 | 12 | 35% | 0.0 | 32% |

* The price of the station less the price of the principal match.

Table 4.3: Principal Matches, Based on Lagged Matching*

| Station ID | Primary Match | | | Secondary Match | | | Tertiary Match | | | Frequency |
|---|---|---|---|---|---|---|---|---|---|---|
| | Station | Frequency | Differential | Station | Frequency | Differential | Station | Frequency | Differential | |
| 2 | 6 | 53% | -1.4 | 3 | 49% | -0.2 | 7 | 42% | -0.4 | 84% |
| 3 | 6 | 38% | -1.2 | 2 | 26% | -0.8 | 20 | 18% | -0.2 | 64% |
| 5 | 26 | 60% | 0.0 | 24 | 34% | 0.0 | 23 | 28% | 0.3 | 81% |
| 7 | 17 | 39% | 0.0 | 5 | 29% | 0.0 | 6 | 28% | -1.0 | 67% |
| 8 | 14 | 30% | 0.0 | 6 | 30% | -1.0 | 23 | 22% | 1.3 | 70% |
| 9 | 26 | 49% | 0.4 | 18 | 42% | 0.4 | 23 | 25% | 0.7 | 73% |
| 10 | 17 | 49% | 0.0 | 15 | 25% | -1.0 | 9 | 24% | -0.4 | 66% |
| 12 | 18 | 76% | 0.0 | 19 | 69% | 0.0 | 23 | 24% | 0.3 | 91% |
| 13 | 14 | 48% | 0.0 | 18 | 47% | 0.0 | 17 | 42% | 0.0 | 87% |
| 14 | 15 | 39% | -1.0 | 17 | 33% | 0.0 | 18 | 27% | 0.0 | 69% |
| 15 | 14 | 59% | 0.0 | 20 | 33% | 0.0 | 12 | 24% | 0.0 | 83% |
| 17 | 19 | 28% | 0.0 | 10 | 26% | -1.0 | 12 | 12% | -1.0 | 58% |
| 18 | 20 | 28% | -0.4 | 23 | 25% | 0.0 | 25 | 22% | 0.0 | 59% |
| 19 | 23 | 26% | 0.0 | 20 | 20% | -0.4 | 25 | 19% | 0.0 | 56% |
| 20 | 26 | 26% | 0.4 | 23 | 21% | 0.3 | 25 | 16% | 0.0 | 56% |
| 21 | 20 | 25% | -0.4 | 23 | 24% | 0.0 | 25 | 23% | 0.0 | 61% |
| 22 | 19 | 39% | 0.0 | 24 | 28% | 0.0 | 23 | 24% | 0.3 | 67% |
| 23 | 20 | 37% | -0.7 | 25 | 21% | -0.3 | 13 | 17% | -1.3 | 58% |
| 24 | 23 | 46% | 0.0 | 25 | 26% | 0.0 | 26 | 25% | -0.3 | 78% |
| 25 | 26 | 35% | 0.0 | 23 | 21% | 0.0 | 13 | 15% | -1.0 | 58% |
| 26 | 23 | 30% | 0.0 | 25 | 18% | 0.0 | 18 | 16% | -0.4 | 58% |
| 27 | 26 | 35% | 0.0 | 18 | 35% | 0.0 | 6 | 17% | -1.4 | 60% |

* In ties, the smallest differential in absolute value is reported.

Table 4.4: Distribution of Response Times to Primary Matches

| Station ID | Primary Match | Percentiles | | | Percentage of Responses by the Next Period |
|---|---|---|---|---|---|
| | | 75% | 50% | 25% | |
| 20 | 26 | 2 | 1 | 1 | 67% |
| 22 | 19 | 2 | 1 | 1 | 59% |
| 9 | 26 | 3 | 1 | 1 | 55% |
| 5 | 26 | 2 | 1 | 1 | 55% |
| 17 | 19 | 3 | 1 | 1 | 53% |
| 24 | 23 | 3 | 1 | 1 | 52% |
| 25 | 26 | 3 | 1 | 1 | 51% |
| 21 | 20 | 3 | 2 | 1 | 45% |
| 18 | 20 | 3 | 2 | 1 | 40% |
| 12 | 18 | 3 | 2 | 1 | 38% |
| 27 | 26 | 3 | 2 | 1 | 32% |
| 13 | 14 | 4 | 2 | 1 | 31% |
| 23 | 20 | 4 | 3 | 1 | 29% |
| 26 | 23 | 4 | 2 | 1 | 28% |
| 15 | 14 | 5 | 3 | 2 | 14% |
| 19 | 23 | 4 | 3 | 2 | 17% |
| 10 | 17 | 6 | 4 | 2 | 17% |
| 14 | 15 | 10 | 7 | 2 | 14% |
| 7 | 17 | 7 | 5 | 2 | 11% |
| 3 | 6 | 11 | 6 | 2 | 9% |
| 2 | 6 | 8 | 6 | 5 | 4% |

Table 4.5: Primary Matches, Identified Using Correlation Coefficients

| **Station ID** | **Primary Match** |
|---|---|
| 2 | 17 |
| 3 | 18 |
| 5 | 26 |
| 7 | 17 |
| 8 | 25 |
| 9 | 26 |
| 10 | 17 |
| 12 | 18 |
| 13 | 19 |
| 14 | 21 |
| 15 | 14 |
| 17 | 26 |
| 18 | 26 |
| 19 | 26 |
| 20 | 26 |
| 21 | 20 |
| 22 | 26 |
| 23 | 21 |
| 24 | 23 |
| 25 | 26 |
| 26 | 23 |
| 27 | 19 |

Table 4.6: Median Timing of Responses to Pioneer's Undercuts*

| Station ID | Ranking of Stations by Order of Responses | | Respond Same Day (0), Overnight (1), Next Day (2), Beyond Next Day (3) | | Number of Hours to Respond to Pioneer | |
|---|---|---|---|---|---|---|
| | Weekdays (N = 32) | Weekends (N = 17) | Weekdays (N = 32) | Weekends (N = 17) | Weekdays (N = 32) | Weekends (N = 17) |
| 24 | 1 | 1 | 0 | 0 | 6 | 8 |
| 26 | 2 | 3 | 0 | 1 | 6 | 22 |
| 20 | 2 | 5 | 0 | 2 | 6 | 22 |
| 21 | 3 | 4 | 0 | 1 | 6 | 22 |
| 19 | 3 | 4 | 0 | 1 | 8 | 22 |
| 18 | 4 | 4 | 0 | 2 | 8 | 22 |
| 25 | 6 | 2 | 0 | 1 | 12 | 16 |
| 22 | 6 | 7 | 0 | 2 | 10 | 24 |
| 9 | 7 | 10 | 0 | 2 | 10 | 24 |
| 5 | 8 | 7 | 2 | 2 | 22 | 24 |
| 17 | 11 | 12 | 2 | 2 | 20 | 26 |
| 12 | 11 | 11 | 1 | 2 | 22 | 28 |
| 14 | 12 | 13 | 2 | 3 | 24 | 36 |
| 27 | 13 | 15 | 2 | 3 | 30 | 44 |
| 13 | 15 | 13 | 2 | 2 | 26 | 30 |
| 10 | 15 | 10 | 2 | 2 | 28 | 26 |
| 15 | 16 | 17 | 2 | 3 | 30 | 48 |
| 11 | 16 | 15 | 2 | 2 | 26 | 32 |
| 7 | 18 | 16 | 3 | 2 | 46 | 34 |
| 3 | 18 | 17 | 3 | 3 | 46 | 42 |
| 16 | 20 | 21 | 2 | 3 | 32 | 46 |
| 6 | 21 | 22 | 3 | 3 | 48 | 70 |
| 2 | 21 | 20 | 3 | 3 | 50 | 48 |
| 1 | 21 | 20 | 3 | 3 | 68 | 60 |
| 4 | 22 | 18 | 3 | 3 | 48 | 44 |
| 8 | 25 | 24 | 3 | 3 | 70 | 86 |

* N is reduced for a station by one each time it does not respond to a price decrease before the next restoration; also, weekends are defined to begin at 6:00PM on Friday (after the afternoon rush).

Table 4.7: Median Timing to Reach Individual Cycle Peaks (N = 14)*

| Station ID | Station Rank by Order of Increases | Reach Peak First Day (0), Overnight (1), Next Day (2) | Number of Hours to Reach Cycle Peak |
|---|---|---|---|
| 5 | 1 | 0 | 0 |
| 18 | 1 | 0 | 0 |
| 19 | 1 | 0 | 0 |
| 25 | 1 | 0 | 0 |
| 26 | 1 | 0 | 0 |
| 27 | 6 | 0 | 2 |
| 24 | 8 | 0 | 2 |
| 12 | 9 | 0 | 4 |
| 9 | 9 | 0 | 8 |
| 22 | 9 | 0 | 8 |
| 20 | 10 | 0 | 8 |
| 21 | 10 | 0 | 8 |
| 23 | 10 | 0 | 8 |
| 6 | 12 | 0 | 8 |
| 11 | 12 | 0 | 8 |
| 17 | 13 | 0 | 8 |
| 3 | 15 | 1 | 18 |
| 4 | 15 | 1 | 20 |
| 10 | 16 | 1 | 18 |
| 1 | 18 | 1 | 18 |
| 2 | 18 | 1 | 18 |
| 7 | 18 | 1 | 18 |
| 14 | 18 | 1 | 18 |
| 13 | 18 | 1 | 20 |
| 16 | 22 | 2 | 20 |
| 15 | 24 | 2 | 20 |
| 8 | 24 | 2 | 22 |

* Stations 8 and 16 only raised their prices during 13 of the 16 restorations, while Station 14 did so during 12 of them.

### 4.8 References


Barron, John M., Beck A. Taylor, and John R. Umbeck (2000), "A Theory of Quality-Related Differences in Retail Margins: Why There is a 'Premium' on Premium Gasoline," *Economic Inquiry* 38, 550-69.

Barron, John M. and John R. Umbeck (1984), "The Effects of Different Contractual Arrangements: The Case of Retail Gasoline Markets," *Journal of Law & Economics* 27, 313-28.

Blass, Asher A. and Dennis W. Carlton (2001), "The Choice of Organizational Form in Gasoline Retailing and the Costs of Laws Limiting that Choice," *Journal of Law & Economics* 44, 511-24.

Borenstein, Severin, A. Colin Cameron, and Richard Gilbert (1997), "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?," *Quarterly Journal of Economics* 112, 305-39.

Borenstein, Severin and Andrea Shepard (1996), "Dynamic Pricing in Retail Gasoline Markets," *RAND Journal of Economics* 27, 429-51.

Browne, Dennis M. (1997), *Gasoline Prices and the Public Interest: The Consumer Advocate's Report on Gasoline Prices in the Province of Newfoundland and Labrador.*

Canadian Petroleum Products Institute (1995), "Sector Competitiveness Framework: Refined Petroleum Products," Presentation on Gasoline Pricing to the Standing Committee on Natural Resources.

Committee to Review Gasoline Prices in British Columbia (1999), "Report on Gasoline Prices in British Columbia," Submitted to the Attorney General of British Columbia.

Conference Board of Canada (2001), *The Final Fifteen Feet of Hose: The Canadian Gasoline Industry in the Year 2000.*

Eckert, Andrew (2002), "Retail Price Cycles and the Response Asymmetry," *Canadian Journal of Economics* 35, 52-77.

Eckert, Andrew and Douglas S. West (2004a), "A Tale of Two Cities: Price Uniformity and Price Volatility in Gasoline Retailing," *Annals of Regional Science* 38, 25-46.

----- (2004b), "Retail Gasoline Prices Cycles Across Spatially Dispersed Gasoline Stations," *Journal of Law & Economics* 47, 245-73.

----- (2005), "Price Uniformity and Competition in a Retail Gasoline Market," *Journal of Economic Behavior & Organization* 56, 219-37.

Haining, Robert (1983), "Modeling Intraurban Price Competition: An Example of Gasoline Pricing," *Journal of Regional Science* 23, 517-28.

Hastings, Justine S. (2004), "Vertical Relationships and Competition in Retail Gasoline Markets: Empirical Evidence from Contract Changes in Southern California," *American Economic Review* 94, 317-28.

Kleit, Andrew N. (2003), "The Economics of Gasoline Retailing: Petroleum Distribution and Retailing Issues in the U.S.," Available at http://www.api.org (December 2003).

Maskin, Eric and Jean Tirole (1988), "A Theory of Dynamic Oligopoly, II: Price Competition, Kinked Demand Curves, and Edgeworth Cycles," *Econometrica* 56, 571-99.

Meyer, David W. and Jeffrey H. Fischer (2004), "The Economics of Price Zones and Territorial Restrictions in Gasoline Marketing," Federal Trade Commission Working Paper.

MJ Ervin & Associates Inc. (1997), "Canadian Retail Petroleum Markets Study," Joint initiative of Industry Canada, Natural Resources Canada, and the Canadian Petroleum Products Institute.

----- (2006), "National Retail Gasoline Site Census 2005," Annual survey of retail gasoline representation in Canada (June 9, 2006).

Natural Resources Canada (2005), "Overview of the Canadian Downstream Petroleum Industry," Report Prepared by the Oil Division.

Noel, Michael (2007), "Edgeworth Price Cycles: Evidence from the Toronto Retail Gasoline Market," *Journal of Industrial Economics* 55, 69-92.

Nova Scotia Select Committee on Petroleum Product Pricing (2004), "Report of the Nova Scotia Select Committee on Petroleum Product Pricing," August 31, 2004.

Paradigm Transportation Solutions Limited, Tottem Sims Hubicki Associates, and GSP Group Incorporated (2005), "Guelph-Wellington Transportation Study: July 2005 Final Report," Transportation study jointly undertaken by the City of Guelph and the County of Wellington.

Peltzman, Sam (2000), "Prices Rise Faster than They Fall," *Journal of Political Economy* 108, 466-502.

Plummer, Paul, Robert P. Haining, and Eric Sheppard (1998), "Spatial Pricing in Interdependent Markets: Testing Assumptions and Modeling Price Variation. A Case Study of Gasoline Retailing in St. Cloud, Minnesota," *Environment and Planning A* 30, 67-84.

Sen, Anindya (2003), "Higher Prices at Canadian Gas Pumps: International Crude Oil Prices or Local Market Concentration? An Empirical Investigation," *Energy Economics* 25, 269-88.

Shepard, Andrea (1991), "Price Discrimination and Retail Configuration," *Journal of Political Economy* 99, 30-53.

----- (1993), "Contractual Form, Retail Price, and Asset Characteristics in Gasoline Retailing," *RAND Journal of Economics* 24, 58-77.

Slade, Margaret E. (1992), "Vancouver's Gasoline-Price Wars: An Empirical Exercise in Uncovering Supergame Strategies," *Review of Economic Studies* 59, 257-76.

----- (1998), "Strategic Motives for Vertical Separation: Evidence from Retail Gasoline Markets," *Journal of Law, Economics & Organization* 14, 84-113.

Standing Committee on Industry, Science, and Technology (2003), "Gasoline Prices in Canada," Fifth report of the Committee, presented to the Canadian House of Commons.

Taylor, Beck A. (2000), "Retail Characteristics and Ownership Structure," *Small Business Economics* 14, 157-64.

Wang, Zhongmin (2006), "Endogenous Timing in Oligopoly Pricing: Evidence from a Repeated Game in the Field," Northeastern University Working Paper (October 2006).

# Chapter 5

## On Retail Gasoline Pricing Websites: Potential Sample Selection Biases and Their Implications for Empirical Research

### 5.1 Introduction

Over the past several decades, a considerable amount of empirical research has been published in which retail gasoline price movements are examined. However, researchers are typically restricted by data that are limited both in terms of frequency and level of aggregation; for example, some studies use prices that are averaged across stations and collected once per week, while others use station-specific data that are collected as frequently as every 12 hours, but only for a small subset of stations in the market. While these data are useful for examining certain issues regarding price movements in retail gasoline markets, they cannot be used to examine price competition between stations across large geographic areas. This is particularly true when prices in a market follow weekly cycles, rising quickly by large amounts over one or two days, and then frequently falling by relatively small increments during the next several days. High frequency, station-specific data for an entire market are ideal in these cases, but the costs of collecting such data can be very high, both in terms of time and money.

However, retail gasoline price data for certain jurisdictions are publicly available on the Internet at little to no monetary cost, which might be sufficient for answering some questions that cannot be adequately addressed by other publicly available retail gasoline price data. For example, GasBuddy.com is a network of over 173 gasoline price information sites across Canada and the United States, which operate under location-specific domain names such as OntarioGasPrices.com and ClevelandGasPrices.com. Consumers ("price spotters") voluntarily post the brands, locations and prices of gasoline retailers, and members are identified by their nicknames; non-members are identified as "visitor". Each post is also time-stamped, but the time that the price is actually observed by the spotter is typically not provided. Membership is free and anonymous, and members earn points for each posted price that can be used to participate in raffles for such prizes as U.S.$250 gas cards. Additional points are earned for participating in other features of the site, such as opinion polls and message forums.

There are a number of scenarios in which data collected from such websites (henceforth referred to as the "Internet data") are expected to provide reliable results for researchers. For example, one might construct a data set that includes prices for stations in a market, as well as certain product and spatial characteristics for each station, such as the number of pumps, traffic flows, service levels, and other (non-gasoline) operations; one could then examine how these characteristics might influence the general direction in which price increases and decreases tend to propagate across the market, and whether certain brands tend to price higher or lower than other brands in the market. One could likely also examine how price uniformity and volatility are influenced by a major structural change in the market, such as the entry or exit of certain players in the market, or a merger between two key players. A researcher might even collect data for multiple markets, and use them to examine how certain features of price competition differ across the markets depending on local concentration, and the presence or absence of certain types and brands of stations.

However, Internet data might not permit answers to empirical questions that require prices for stations that are relatively less likely to be reported on these sites, or which require very high frequency data. For example, it is unlikely that the data can accurately identify either the specific leaders of price increases, which stations are more likely than others to set the minimum price in the market, or the order in which stations change their prices, because all stations are not observed in the Internet data each period; some stations might be sampled two or three times per day, while others might be spotted once every two or three weeks, on average. Thus, the first stations to change their prices are not necessarily identified in the Internet data.

While the potential benefits of Internet price data are evident, no studies have been found which examine the sample selection biases that can arise in these data, or their implications for empirical research. Thus, the first purpose of this chapter is to examine the extent to which prices reported on OntarioGasPrices.com are a random sample, and then identify those factors that make a particular price or station more or less likely to be reported. These results will then be used to identify which features of price movements can and cannot be accurately identified using these data. These goals will be achieved by studying price movements in a market where prices appear to cycle, using two different data sets: one consisting of bi-hourly price data collected from 27 stations in Guelph, Ontario, eight times per day for 103 days; and the other an unbalanced panel of 12-hourly price data collected from OntarioGasPrices.com for Guelph during the same 103 days. Thus, this case study will provide guidance to researchers regarding when they can use Internet data with reasonable confidence, and when a more complete data set should be compiled instead.

To anticipate results, it is found that retail gasoline consumers in Guelph report prices of major brand stations that are price controlled by their head offices significantly more often than other stations, particularly those of small independent stations. Potential explanations for these biases relate to spatial and product differentiation. However, it does not appear that they tend to post a station's price more often as it falls relative to its rivals' prices. Consistent with these results, it is found that the Internet data tend to accurately identify features of cycles that can be distinguished using company-operated major brand station prices (e.g., the existence of a cycle, as well as its period, height, approximate starting days, asymmetry, etc.), while features that require individual independent station data or very high frequency data might not be well-identified (e.g., the identities of price leaders and the order in which stations change their prices). Also, daily mode prices tend to be more accurately measured in the Internet data than daily mean prices, in part because the small non-branded independents that tend to price above the city-wide mode price are under-represented in the Guelph data. However, daily mean prices are still well-measured by the Internet data. Finally, the daily mode and mean prices are sometimes approximated much less accurately on days when new cycles are initiated with large price increases, because it can take two days for these increases to be fully reflected in these prices. Therefore, depending on the city under examination and the questions being asked, a researcher can likely use Internet data to accurately compare prices both within and between cities.

This chapter is organized as follows. Section 5.2 reviews the relevant theoretical and empirical literatures regarding retail gasoline price cycles, and which stations' prices are relatively most likely to be reported by consumers. Section 5.3 introduces the data, which are used in Section 5.4 to econometrically examine certain station characteristics that might influence which prices are reported on the Internet, such as spatial and product differentiation, and relative prices. Based on these conclusions, Section 5.5 uses both data sets to empirically examine the extent to which any biases that exist in the Internet data influence the pricing patterns observed in the Guelph market. Section 5.6 concludes.

## 5.2 Literature Review

### *5.2.1 Factors That Might Influence Which Prices Are Reported*

The quality of price data collected from Internet pricing sites depends importantly on whether the same conclusions would be made with a random sample of data collected by more scientific means. However, a number of factors might affect the probability that a station's price will be sampled, which could raise issues regarding sample selection biases. These factors, which are explained below, have been divided into three categories: spatial differentiation, product differentiation, and price differentials.

#### 5.2.1.1 Spatial Differentiation

First, a station's geographic location can affect the probability that a station's price will be reported by consumers. For example, Sheppard, Haining, and Plummer (1992) theoretically examine spatial pricing in interdependent oligopolistic markets, in which retail prices vary with consumer price sensitivity, the choice sets available to consumers, and consumers' awareness of prices at different stations. In an empirical examination of this and related theories, Plummer, Haining, and Sheppard (1998) find evidence that the geographic location of a station is very important to consumers in St. Cloud, Minnesota. Specifically, through consumer surveys, the authors find that consumers tend to buy gas during work and shopping trips, which suggests that stations along major commuting routes will likely be most visible to consumers, and might therefore be most likely to be reported. It also suggests that if a station is located along a major commuting route, then its price will be more visible than other stations on weekdays, while a station that is near a shopping centre might also be more visible than others on weekends.

#### 5.2.1.2 Product Differentiation

A station's particular characteristics might also influence whether its price is more or less likely to be observed than prices at other stations. Stations can be divided into four groups, as follows. Groups A and B stations operate under refiner (major) brand labels; Group A stations are price controlled by their respective brands' head offices, while Group B station managers have some independent price control. On the other hand, Groups C and D stations (independents) do not operate under a major refiner brand label; in this chapter, Group C stations are distinguished from Group D stations by their relative size (higher regular-grade nozzle counts), and might also be more recognized by consumers for non-gasoline retail offerings, such as convenience items, groceries and other merchandise.

There are a number of reasons why consumers might be relatively more likely to observe the prices of stations in a certain group during their commutes. For example, they might be more inclined to report Groups A and B stations' prices in order to draw attention to their pricing practices, because they believe that the major refiner brands are "price gouging", or possibly involved in an illegal price-fixing agreement. Eckert and West (2004b) find evidence of such a perception in the comments that were posted by Vancouver consumers along with the stations' prices. On the other hand, consumers might be relatively more likely to post prices of certain "maverick" Group C stations, which tend to price closer to the wholesale price of gas, to further draw attention to differences between their prices and prices of major brand stations.

A consumer might also be relatively more likely to observe prices at stations that have other operations, such as convenience stores and car washes, which can attract their attention due to demand complementarities. As noted above, many Group C stations are in this category.

Finally, stations can be divided both across and within groups based on brand loyalty (see Kleit, 2003, 15), which can be created using brand loyalty programs.[1] Empirical evidence in this regard is provided by Plummer, Haining, and Sheppard (1998), who find that the most important characteristics of a gas station to consumers surveyed in St. Cloud, Minnesota are quality of service, brand, and extra services, respectively.

5.2.1.3 Relative Ranking of a Station's Price

Perhaps the most obvious reason why a consumer might report a certain station's price is that this price is higher or lower than prices of other stations. For example, the expressed purpose of GasBuddy.com is for consumers to report the lowest prices in their markets. Consistent with this goal, Eckert and West (2004b) note that some consumers who post Internet prices for Vancouver leave messages indicating that they are attempting to point out relatively low prices. However, other consumers in their data appear to be trying to identify relatively high prices, while others appear to be attempting to demonstrate price uniformity across stations.

### *5.2.2 Edgeworth Cycle Theory*

In the model developed by Maskin and Tirole (1988), two identical firms non-cooperatively maximize their present-discounted stream of profits by setting prices for a homogeneous product over an infinite horizon. Marginal cost is constant, there are no fixed costs or capacity constraints, and the firm with the lowest price serves the entire market. If both firms charge the same price, then they split market demand evenly. Price competition takes place in discrete

---

[1] For example, Petro-Canada, Esso, and Shell have Petro-Points, Esso Extra, and Air Miles loyalty programs, respectively; Sunoco has a "Swipe and Save" program for Canadian Automobile Association (CAA) members; and Canadian Tire, 7-Eleven, and Pioneer have cash-back programs in the form of special currencies that can only be used in their stores.

time, and prices are chosen over a finite grid. Finally, Maskin and Tirole (1988) restrict a firm's strategies to depend only on the most recent rival price set. Using this framework, the authors prove that for a sufficiently fine price grid and a discount factor near one, many Markov perfect equilibria exist, including Edgeworth cycles.

The structure of an equilibrium cycle is described as follows. Beginning at the top of the cycle, a firm undercuts its rival's price by one unit; this strategy is played by the firm because it expects its rival to do the same in the next period, and because it can serve the entire market before its rival responds to this undercut. These one-unit undercuts continue until one firm lowers its price to marginal cost. There is then a war of attrition of indeterminate length as each firm waits with positive probability for the other to initiate a cycle "restoration" by raising its price to the new cycle peak, which is one unit above the monopoly price (each firm plays mixed strategies where the expected profits of waiting and relenting are equal). This reluctance to lead a restoration is not because it might not be followed, but rather due to the expectation that the follower will undercut this price by an incremental unit, causing the leader to make zero profits for two consecutive periods.[2] The cycle is then repeated.[3]

Eckert (2003) extends the basic model to allow the two firms to differ in size, which can be measured by the number of stations each one operates in the market, or by its number of pumps; if both charge the same price, their shares of market demand are proportional to their

---

[2] The knowledge that leading a restoration will result in two consecutive periods of zero profits also deters firms from raising their prices before they equal marginal cost.

[3] Noel (2006) extends this model to permit randomly fluctuating marginal cost, and shows computationally that if there is product or spatial differentiation, capacity constraints or three firms, then Edgeworth cycles can still exist in equilibrium. He also demonstrates that with three firms, one might abandon its attempt to lead a restoration if one or both of its competitors do not follow this lead quickly enough; Noel (2006) calls these failed attempts "false starts".

relative sizes. He uses examples to demonstrate that the large firm tends to lead price increases, while the small firm is more likely to undercut its rival's price, because the market sharing rule is biased against it when both charge the same price; given the choice of either matching or undercutting its rival's price, the undercutting strategy tends to be more profitable for the small firm, while the matching strategy tends to be more profitable for the large firm.

### *5.2.3 Empirical Studies of Cycling Markets*

Many studies of retail gasoline markets use price data that are averaged across all sampled stations. For example, Eckert (2002) and Noel (2007a) use weekly average price data to examine retail gasoline price cycles in Canadian cities, while Lewis (2006) uses daily average price data to identify cycles in the mid-western United States. Depending on the durations of cycles, such data can be useful for studying certain structural cycle characteristics, but they cannot be used to study the price movements of particular stations, particularly spatial patterns.

Recognizing the deficiencies of weekly average price data, Noel (2007b) collected station-specific price data for 22 stations in Toronto, every 12 hours for 131 days in 2001. The author finds that these prices do follow cycles consistent with the Edgeworth cycle theory, that major brand stations tend to lead price increases, and that independents tend to lead price decreases. However, the fact that these 22 stations are all located within a small section of the city implies that the author is unable to examine spatial pricing patterns between stations, such as whether price decreases tend to be initiated in sections of Toronto where certain brands are relatively highly concentrated.

Since publicly available data are too limited to spatially examine intra-city retail gasoline price competition, Eckert and West (2004a-b; 2005) collected station-specific price data from Internet gasoline price sites for Vancouver and Ottawa. Eckert and West (2004a) find that the existence of cycles seems to depend on the presence of aggressive "maverick" retailers that prevent tacit collusion, such as Sunoco and Pioneer in Ottawa, and ARCO and Tempo in Vancouver. Eckert and West (2004b) find that price decreases in Vancouver appear to originate in regions where ARCO and Tempo are most highly concentrated, and restorations are usually initiated on Tuesdays and Wednesdays. Finally, Eckert and West (2005) examine whether prices in Vancouver tend to be uniform across stations, consistent with a competitive theory of gasoline pricing advanced by industry participants. While these data arguably generate reliable results for the authors' purposes, no studies have been found which empirically investigate which types of questions can be reasonably studied using Internet gasoline prices. Such an investigation would ideally compare data collected from the Internet for a set of stations in a market to a "complete" balanced panel for the same stations during the same time period.[4]

## 5.3 The Data

### *5.3.1 Balanced Panel of Bi-Hourly, Station-Specific Price Data*

Regular-grade fuel prices in cents per litre (cpl) were collected every two hours (8:00AM to 10:00PM) from August 14 to November 24, 2005 for 27 stations in Guelph, a city in southern Ontario with an approximate population of 106,000.[5] Station characteristics were also

---

[4] Other empirical studies of retail gasoline markets that use Internet data include Wang (2006) and Lewis and Marvel (2007). Wang (2006) collected prices from a website operated by the Western Australian government (which regulates the timing of price changes) to study Edgeworth cycles in Perth. Lewis and Marvel (2007) use U.S. price data collected from GasBuddy.com to examine the relationship between consumer search behaviour and retail gasoline price movements.

[5] The last period during which prices were collected on November 24 began at 4:00PM.

collected, including operating hours (24 hours or not), service levels (full-, self-, split-serve), capacities (regular-grade nozzle counts), and other operations (repair bay, variety store, car wash). In order to quantify a station's visibility to consumers, traffic flow data were obtained from the City of Guelph for major intersections from 2003-05, which include the estimated annual number of cars that travel in each direction relative to an intersection; the most recent data for each station's nearest available intersection are used. Finally, daily rack price data for London, Ontario were obtained from MJ Ervin & Associates to approximate marginal costs.

Station locations are plotted in Figure 5.1, and the approximate collection times for each station are also provided with this figure; for example, Station 12's price was collected at approximately 14 minutes after the hour.[6] Esso, Petro-Canada, Shell/Beaver and Sunoco are the vertically-integrated (major) brands in the city, while Canadian Tire, 7-Eleven and Pioneer are among the independents. Selected station characteristics are provided in Table 5.1, where major brand stations tend to be 24-hour, self-serve stations with relatively high capacities, convenience stores and car washes, and no repair bays. Stations selling gasoline under the 7-Eleven, Canadian Tire and Pioneer brands are similar to these major brand stations in terms of capacities and other characteristics, while the other independents are full-serve stations with relatively low capacities, limited hours and repair bays, but no other operations.

As argued in Section 5.2.1, a consumer might be more likely to report a station's price if it is price controlled by a refiner brand. Thus, an attempt was made to determine whether each station's price is set by its manager or its supplier. Representatives of the above seven brands were contacted, and six reported that each station's price is company-controlled (Station

---

[6] Esso Station 28 is excluded from the sample because it did not post its price; its price was also never observed on OntarioGasPrices.com during these 103 days.

14's manager is permitted some control); Esso refused to provide price control information. However, according to MJ Ervin & Associates Inc. (2006, Appendix A), 7-Eleven Canada controls prices at its Esso-branded stations, implying that Station 7's price is not controlled by Esso. Also, Station 17 has a Rainbow-branded car wash and convenience store, and is described on an Esso-affiliated website as a family-operated dealer.[7] Finally, the empirical literature on station contracts suggests that a company is more likely to control prices at stations with longer hours, greater pump capacities, or convenience stores, and is more likely to delegate price-setting authority to stations that are full-serve and/or have repair bays.[8] Thus, Esso most likely controls prices at Stations 19, 21, and 26. Based on these conclusions, major brand stations are divided in Table 5.1 by the likely source of price control: Group A stations' prices are either known or believed to be controlled by the head office of the brand, and Group B stations' prices are not. Independents are also divided by size (station-specific nozzle counts): Group C stations have relatively more regular-fuel nozzles than Group D stations.

### *5.3.2 Unbalanced Panel of Twice-Daily, Station-Specific Price Data*

During these same 103 days, price data were also collected twice per day (noon and midnight) for Guelph from OntarioGasPrices.com. These data include the brand and location of each station, the nickname of each price spotter ("visitor" for non-members), and the time that each price was posted on the site. Prices remain on the site for up to 24 hours on weekdays and 36 hours on weekends; if someone reports a price for a particular station, then the previously posted

---

[7] See "Esso Rebecca Run for SMA" (http://www.rebeccarun.com/esso_dealers/rainbow.html; visited 2007-05-01).

[8] For example, see Shepard (1993), Slade (1998), and Taylor (2000).

price for that station is eliminated, unless the consumer enters the address differently. Therefore, more than one price report is sometimes observed for a single station in a given period. A total of 2,101 price observations are included in the data set;[9] visual comparisons of the city-wide daily mode and mean price series across the two data sets are provided in Figures 5.2a and 5.2b, respectively, where it can be seen that the Internet trends coincide quite well with their corresponding balanced panel trends.

The reliability of the Internet data depend, in part, on the accuracy of the prices reported by each spotter. Thus, each report has been categorized based on its accuracy as follows. Using the collection times reported with Figure 5.1, each price included in this unbalanced panel is compared to the prices observed in the bi-hourly periods immediately preceding and following the price report. If the reported price equals one of these two prices, then the reported price is considered to be "correct". However, if the reported price is observed no earlier than 10:00PM on the previous evening, then it is labelled as "outdated".[10] If it is instead observed no later than 8:00AM the next morning, then the post is flagged as being reported "early".[11] It is otherwise

---

[9] One price posted on November 14 is excluded from the data, because the same spotter reported the same price for the same station two minutes earlier. Also, 11 "prank" posts have been omitted from the data, as they are for non-existent (and usually obscene) locations. Finally, the specific station being identified by a spotter is reasonably assumed for 24 price reports, based either on knowledge of the road network or the locations of stations reported concurrently by the same spotter; such ambiguities include identifying a location that applies to two different stations (e.g., Esso on Edinburgh Road N.), identifying a nearby intersection (e.g., Petro-Canada on Willow & Edinburgh instead of Willow & Silvercreek), and identifying the wrong brand for the listed intersection (e.g., identifying the station as Cango instead of Canadian Tire or Can-Op).

[10] Note that six of these outdated reports are observed between midnight and 1:00AM, but are treated as being posted before midnight to assess their correctness.

[11] This category was created to consider the possibility that market participants might use this site to signal price changes to their competitors, or as a way to advertise their prices to

labelled "wrong".[12] Based on this methodology, 1,502 (71.5%) prices in the unbalanced panel are considered correct, while 138 (6.6%) are outdated. Another 14 (0.7%) are flagged as early, and 447 (21.3%) are considered wrong. In summary, 1,655 (78.8%) of all 2,101 price reports are either known or believed to have been charged some time during that day.

Next, there is a question of the degree to which prices are wrong. It might be that errors tend to be lower than a cent per litre, because consumers tend to ignore the last digit of the price; they might assume it is zero (for example, see Schindler and Kirby, 1997) or a frequently observed ending, such as "9" or "5" (e.g., Basu, 2004). It is found that of the 461 wrong/early price reports, the integer parts of 274 (59.4%) of them are accurate at some point of the day prior to the price post. Furthermore, the average absolute difference between the reported price and the closest price charged prior to that posting is 1.1 cpl, which is larger than the 0.9 cpl maximum predicted by the focal price explanation.[13] These statistics suggest that while consumers might tend to pay less attention to price endings, there may be other explanations for why errors are made, such as expectations based on prices observed at other stations or simple carelessness on the part of certain price spotters.

---

consumers. There does not appear to be any evidence in the data to support this hypothesis.

[12] Note that until its signs were amended to display four-digit prices, Station 13 rounded its $1+ prices down to the nearest cent on its signs; for example, when it charged 101.9 cpl, it posted "101". Similarly, Station 15 always rounded its $1+ prices *up* to the nearest cent, so when it charged 102.5, for example, it posted "103". For these stations, the actual prices being charged were read directly from a pump each period. Both the posted and actual prices were considered when assessing the accuracies of the reported prices for these two stations.

[13] Note that this proportion includes two "visitor" posts on September 13 that seem to be pranks; they are for real stations (Stations 21 and 24), but are approximately 30 and 60 cpl lower than all other prices observed in both data sets. If these two posts are omitted from the analysis, then this bias falls to 0.9 cpl. Thus, a researcher using Internet price data should examine the data for any such outliers.

Finally, the Guelph site is dominated by a few spotters, and therefore any biases held by these spotters might influence the degree to which the overall data are biased. In particular, there are 81 specific price spotters in the data who post 2,033 of these prices (the other 68 prices are reported by "visitor"), the majority (50.8%) of all 2,101 price reports are made by four spotters, and two particular spotters are responsible for 858 (40.8%) of all price reports. Also, 292 (63.3%) of all 461 wrong/early price reports are made by these two spotters. This disproportionately high number of errors suggests that regular spotters are not necessarily more conscientious of the accuracy in their price reports.

## 5.4 The Randomness of the Sample

The purpose of this section is to examine the extent to which prices reported on this site are not simply a random sample, and then identify those factors which make a particular station's price more likely to be reported. As argued in Section 5.2.1, stations might be more or less likely to be spotted based on spatial and product differentiation, as well as relative prices. Therefore, two potential sources of bias will be examined in this section: biases based on groups of stations and biases based on price differences.

### *5.4.1 Biases Across Groups of Stations*

It was argued in Section 5.2.1 that Groups A and C stations might be more likely to be reported in Internet data than other stations; if this is true, then a researcher likely should not use these data to study issues that require individual Group D station prices, such as the speed with which these stations respond to rival price movements, or whether they tend to set the minimum price in the market on a daily basis.

An examination of this prediction uses Table 5.2, which lists the average number (and proportion) of days that each station's price is observed in the Internet data (averaged by group), both before and after omitting price reports for the two most frequent spotters. In both cases, the counts for Groups A and C stations are higher than for other stations, especially Group D stations. This conclusion is strengthened statistically by constructing a variable ($GROUP_i$) that equals "1" for Group A stations, "2" for Group C stations, "3" for Group B stations, and "4" for Group D stations; the correlation coefficient between $GROUP_i$ and the number of days (out of 103) that Station i is spotted ($COUNT_i$) is -0.75 if all spotters are included in the data, and -0.63 after excluding the two most frequent spotters.[14]

It was also argued in Section 5.2.1 that spatial location might be an important determinant of whether a station's price is observed by consumers. To examine this prediction graphically, Figure 5.3 differentiates stations based on how many days (out of 103) they are observed in the Internet data (including all spotters). This figure suggests that a spatial bias does exist in regard to which stations tend to be spotted; while stations in the northwest portion of the city (Stations 18 to 23) are all spotted on at least 80% of the 103 days in the sample, northeastern stations (Stations 1 to 11) are spotted less frequently, particularly Group D stations. If the two most frequent spotters are excluded from the data (not shown in the map), then all 11 northeastern stations are reported less than 20% of the time. Thus, it seems that whether a specific station's price is observed can depend largely on a single spotter.

In order to quantify spatial differences across stations, the estimated number of cars that pass each station every year has been calculated, and are summarized by group in Table 5.2.

[14] All correlation coefficients reported in this chapter are Pearson correlations.

It can be seen that in addition to being spotted more often, Groups A and C stations tend to have higher traffic flows than both Group B and (especially) Group D stations. Statistically, the correlation coefficient between a station's traffic flows ($TRAFFIC_i$) and the number of days that it is spotted is 0.53, which suggests that traffic flows might influence whether a station's price is spotted in the Internet data. Intuitively, a station with higher traffic flows might be more frequently reported for two reasons: first, because more people observe its price; and second, because the report will potentially benefit more drivers than a report for a more isolated station.

Therefore, based on the statistical analysis conducted in this section, it is concluded that there does appear to be a bias in the data toward Groups A and C stations, which tend to not only have other non-gasoline operations which can act as demand complementarities, but also tend to be located along relatively high-traffic routes where they are likely visible to more consumers than other stations.[15]

### *5.4.2 Biases Based on Relative Prices*

As argued in Section 5.2.1, a consumer might be more likely to report a station's price if it falls relative to the prices of competing stations. Consistent with this prediction, the correlation coefficient between the mean retail-rack margin (as summarized by group in Table 5.2) and $COUNT_i$ is -0.65 using all observations, and -0.67 after excluding the two most frequent

---

[15] While an econometric model could be formulated where $COUNT_i$ is regressed on three group dummies (Groups A to C) and $TRAFFIC_i$, there is a potential endogeneity problem with this regression, because a refiner brand might separate its stations into Groups A and B based on traffic flows at each station. Consistent with this argument, the correlation coefficient between $GROUP_i$ and $TRAFFIC_i$ is -0.64. However, this model was estimated both with and without $TRAFFIC_i$ using GeoDa™ (available at https://www.geoda.uiuc.edu; visited 2007-05-01), which controls for spatial autocorrelation; the results are that Groups A and C stations are reported statistically significantly more often than Groups B and D stations.

spotters, implying that stations with relatively high margins are reported less often than stations with lower margins.[16] If consumers are indeed more likely to report a station's price as its relative price falls (rises), then not only will station-specific price data be biased (as concluded in Section 5.4.1), but market mode and mean prices will also tend to be too low (high).

Thus, an important question to address is whether a station's price is more likely to be reported as its price falls relative to the market mode; if this null hypothesis is rejected, then a possible alternative explanation is that consumers tend to report prices based on other factors, such as spatial and product differentiation. To econometrically test this null hypothesis, the following probit regression has been estimated using a balanced panel of 2,781 observations (one per day for each station):

$$COUNT_{it} = \alpha + \beta DIFF_{it} + \gamma DAY0_t{*}DIFF_{it} + \delta NOPOST_{it} + \lambda STATION_i + \sigma DAY_t + v_{it}$$

where $COUNT_{it}$ is a dummy that equals one when Station i's price is observed in the Internet data on Day t, $DIFF_{it}$ equals the difference between Station i's mode price and the market mode price on Day t, $DAY0_t$ is a dummy that equals one on a day when a restoration attempt is observed in the balanced panel, $NOPOST_{it}$ is a dummy that equals one if Station i's price is not posted on its pricing sign on at least four periods on Day t, $STATION_i$ is a vector of 26 station-specific dummies, $DAY_t$ is a vector of 102 daily dummies, and $v_{it}$ is a random error term.

The model specification is based on the literature review in Section 5.2.1. Specifically, modes are chosen to define $DIFF_{it}$ because these are the prices that are most often observed on a given day. It might be predicted that this variable's coefficient will be negative, because

---

[16] The retail-rack margin is calculated to be the retail price minus the current London rack price, the Ontario provincial gas tax (14.7 cpl), the federal gas tax (10.0 cpl), and the federal Goods and Services Tax (7%), which is levied on both the price and the excise taxes.

consumers may be more likely to report a station's price as it falls relative to the market mode; on the other hand, consumers might be more likely to report a station's price as it *rises* relative to the market mode, in which case this coefficient would be positive. Furthermore, to control for the possibility that consumers might change their focus from low prices to high prices on days when restorations are attempted, the interaction term, $DAY0_t*DIFF_{it}$ is included in the regression, where a restoration day (Day 0) is defined to be a day when the bi-hourly market mode price rises in the balanced panel after at least one station raises its price to this mode.[17]

Next, $NOPOST_{it}$ is included to control for days when a station did not post its price for at least four periods (half the day); its coefficient is predicted to be negative. Finally, 26 station-specific dummies are included to control for differences across stations, such as product and spatial differentiation, while 102 daily dummies are included to control for unusual circumstances on specific days, such as bad weather or temporary city-wide demand shocks. These daily dummies indirectly control for day-of-the-week effects, as well, such as fewer reports on weekends when consumers are not commuting to work.[18]

The results of this regression are provided in the second and third columns of Table 5.3. First, it is shown that the LR test statistic for the overall significance of the model is 1,144.4624, so the null hypothesis that all 131 coefficients simultaneously equal zero is rejected at the 1%

---

[17] Note that while this definition differs from the one used in Section 5.5 (which is based on *daily* mode price increases to permit direct comparison between the two data sets), it is appropriate for this analysis because consumers are expected to notice when more than 50% of the stations in the market raise their prices by several cents per litre during the afternoon/evening of a single day, even if these increases are not enough to raise the daily market mode price.

[18] The excluded dummies are $STATION19_i$ (as it is one of the stations that often did not post a price) and $DAY96_t$ (which is considered to be a typical day as no restorations were observed, and no unusual conditions were evident with respect to traffic, weather, queues, etc.).

level of significance. Also, the estimated coefficients were used to obtain the predicted probability that a station's price will be spotted. If it is predicted that Station i's price will be reported if this probability exceeds 0.5, then the probit correctly predicts the dependent variable 76.7% of the time (66.9% for $COUNT_{it} = 0$ and 83.6% for $COUNT_{it} = 1$). Compared to the success rate of the naive prediction that every station's price will be reported every day (58.4%), the model appears to fit the data reasonably well.

Next, the estimated coefficients for $DIFF_{it}$ and $DAY0_t{*}DIFF_{it}$ are positive but not statistically significant from zero at the 5% level of significance, suggesting that a station's price is not significantly more likely to be reported if its price falls relative to the market mode price. On the other hand, $NOPOST_{it}$ is negative and significant at the 5% level, indicating that Station 19 is significantly less likely to be reported when it does not post its price on its pricing sign.

Since $NOPOST_{it}$ is statistically significant, the partial effects of a change from Station i posting its price to not posting it on the probability of that station's price being reported have been calculated for Stations 10 and 19; they are -13.4% and -5.7%, respectively.[19] An interpretation of these effects is that Group C stations tend to be reported less often than Group A stations, as found in Section 5.4.1, and thus might be more likely to be omitted from the Internet data when they do not post their prices; an alternative explanation is that stations in the northeastern section of the city tend to be reported less frequently than stations in the northwestern section of the city, as shown in Figure 5.3.[20]

---

[19] The partial effect for Station 19 is calculated by initially setting $NOPOST_{it}$ equal to zero, all other dummies always to zero and $DIFF_{it}$ to its sample mean (-0.0798993); for Station 10's partial effect, $STATION10_i$ is also always set equal to one (its coefficient is -0.64423).

[20] Several alternative model specifications have also been estimated to examine the robustness of these general results, i.e., that CONSTANT is positive and significant at the 1%

Finally, to examine whether the results are robust to different measurements of price differences across stations, this probit has been re-estimated using daily mode price rankings instead of differences between a station's daily mode price and the daily market mode price. Specifically, stations are ranked on a 27-point scale, where a higher ranking indicates a higher mode price for the station in question; if more than one station has the same daily mode price, then they are all ranked equally. For example, if two stations are tied for the lowest mode price, then they are both ranked number one, and the next-lowest priced station is ranked third.

The results of this alternative regression are displayed in the last two columns of Table 5.3; as with the first probit regression, the constant is positive and statistically significant at the 1% level of significance, while the coefficient for $NOPOST_{it}$ is negative and significant at the 5% level. However, an important difference between the results in the two models is that the variable used to compare prices across stations ($MODERANK_{it}$) is negative and statistically significant at the 5% level, meaning a station's price is significantly more likely to be reported as its ranking falls along the 27-point scale.

However, it appears that the methodology used in the first regression is more appropriate than in the second regression, because the ranking system can overestimate price differences across stations. To demonstrate this possibility, in the balanced panel, seven to eight stations

---

level, the coefficient for $NOPOST_{it}$ is negative and significant at the 5% level, and neither the coefficient for $DIFF_{it}$ nor the one for $DAY0_t*DIFF_{it}$ is significantly different from zero at the 10% level. First, six alternative definitions of $DIFF_{it}$ are the differences between Station i's daily mean/minimum/ maximum price and the city-wide daily mode/mean price; a seventh is the difference between Station i's daily mode price and the city-wide daily mean price. Regardless of the definition used, none of the main conclusions of this analysis changes. These conclusions also remain unchanged if $NOPOST_{it}$ is modified such that it equals one on Day t iff Station i's price is not posted for at least j periods during that day (j = 2, ..., 8). If j = 1, then the coefficient for $NOPOST_{it}$ is significant at the 1% level for all eight definitions of $DIFF_{it}$.

have the same daily mode price on an average day. Therefore, since the ranking system assigns all of these stations the same rank, if Station x's daily mode price rises by as little as 0.1 cpl in one day, while all other station's daily mode prices remain unchanged, then Station x's ranking will jump by six to seven points. In other words, the significance of the ranking variable in Table 5.3 might be due to the ranking system, rather than because a station's price is more likely to be reported as its daily mode price falls relative to other stations.[21]

In summary, an implication of the findings in this section is that using the Internet data should not bias a researcher's results regarding the pricing of a particular station. In other words, it does not appear that a particular station's price is more likely to be reported if it rises or falls relative to other stations. This finding is consistent with the argument that price spotters tend to report the prices of the same stations along their daily commuting routes, regardless of the prices being charged by those stations.

### 5.5 Implications of Sample Selection Biases for Empirical Research

In Section 5.4, it was demonstrated econometrically that while it does not appear that a particular station's price is reported more often as its mode price falls relative to the market mode price, there appears to be a sample selection bias with respect to which types of stations

---

[21] If rankings are based on mean daily prices, which are less likely to be identical across stations (three to four per day, on average), and therefore less prone to large jumps in a station's ranking, then the rank variable is *not* statistically significant at the 5% level of significance. This result is consistent with the argument that a change in a station's price relative to other stations will not significantly influence the probability that it will be spotted. Similarly, if rankings are based on maximum daily prices, then the rank variable is not significant at the 5% level. Finally, while the rank variable is significant at the 5% level if minimum daily prices are used, minimum price rankings have a similar drawback to mode rankings: on average, seven to eight stations have the same daily minimum price.

are reported: Groups A and C stations are reported significantly more often than Groups B and D stations. These results suggest that these data might be reliable if a researcher wants to analyse retail gasoline markets using daily mode prices (assuming a clear mode price exists in the market). However, they likely cannot provide clear answers to questions that rely on the pricing dynamics of particular stations, especially Groups B and D stations.

The purpose of this section is to explore these expectations further, by examining some basic predictions of the Edgeworth cycle theory. Consistent with the approach of Eckert and West (2004b) who examine mean and mode price movements in Internet data for Vancouver, duplicate price reports for the same station on the same day are excluded from the data, leaving 2,005 price observations; these deletions are made to avoid double-counting a station's price.

### *5.5.1 The Timing of Restorations*

In Section 5.4.2, a Day 0 was defined to be a day when the periodic (bi-hourly) market mode price rises after at least one station raises its price to this mode price; the next day is labelled Day 1, and so on. However, a problem with applying this definition to the Internet data is that every station's price is not reported in every 12-hour period, so determining whether a station increases or decreases its price is not always clear. Thus, a modified version of the methodology of Eckert and West (2004b) will be used to define Days 0: first, identify every day when the daily city-wide mode price rises by at least 4.0 cpl. If the first station-specific occurrence of this mode price is observed on this day, then this is Day 0; if it is the previous day, then that is Day 0. Using this methodology, both data sets identify 13 Days 0.

Comparing the 13 dates identified in each data set, it appears that the Internet data reasonably approximate the days on which restoration attempts are made, provided they are not "false starts",[22] and as long as restoration attempts are not made on consecutive days. Specifically, 12 of the 13 restorations identified in each data set are identified in both data sets, but five are identified one day apart. This is because it typically takes 24 hours for all stations in Guelph to raise their prices to their cycle peaks in the balanced panel, so it might take an additional day to observe an increase in the daily mode price in either data set. Given this lag, if a restoration attempt is abandoned on Day 1 (implying it is a false start), then a daily mode price increase might never be identified in the Internet data. Thus, while the balanced panel identifies a restoration attempt on October 18, the Internet data never identify it.

It should be noted that while the Internet data might identify restoration attempts with a lag of one day, the same problem is faced by the balanced panel when restorations are identified based on daily mode price changes. For example, during the days following the impact of Hurricane Katrina on the United States, three daily mode price increases are observed in the Internet data over four days (August 31 to September 3), but since the first two mode price increases are observed on consecutive days, the balanced panel identifies one large restoration instead. These results indicate that while the Internet data can overlook false starts and restorations that occur on consecutive days, this problem is not unique to this type of data. Furthermore, unless the market being studied follows daily cycles, the number of restoration attempts missed by the Internet data are likely to be relatively rare anomalies.[23]

---

[22] See Noel (2006), *supra* note 3.

[23] Note that the definition of Days 0 used in Section 5.4.2 identifies 16 Days 0, which include the 14 days identified between the two data sets in the current section. The other two are identified on September 12 and October 12, during which the market mode prices in the balanced panel are observed to increase by no more than 2.7 cpl, at least 11 stations are not observed to raise their prices at all, and most price increases are completely reversed by the end of Day 1. The finding that these two restoration attempts are not identified in the Internet data

A second implication of these results is also relevant for more general applications of these data. If the market being studied is characterized by such highly asymmetric cyclical pricing patterns, then even if mode and/or mean price movements tend to be accurately portrayed by the Internet data, they might be highly underestimated on days when restorations are initiated. Thus, a researcher should take this possibility into account when using mode or mean prices to study retail gasoline markets where prices cycle. The biases that can arise from the inclusion of Days 0 will be further demonstrated below.

### *5.5.2 Basic Patterns in Retail Price Changes*

This subsection examines whether basic patterns in retail price changes, in terms of daily mode and mean prices, can be reasonably approximated using data collected from the Internet. The results of this section will be used to evaluate arguments made in previous sections that while one might be advised to not base their analysis on Internet data for particular stations, results based on mode (and possibly also mean) price movements might be reasonable. The results are summarized in Table 5.4, and when appropriate, are divided into those for the Balance Panel ("BP") and the Internet data.

It is first found that the Internet data more accurately characterize "true" price movements if mode prices are studied instead of mean prices. Specifically, the daily city-wide average price decreases 2.5 (3.1) times more often than it increases in the Internet (BP) data, while the city-wide daily mode price decreases 4.2 (4.3) times more often in the Internet (BP)

---

(using the 4.0 cpl threshold) is consistent with the conclusion that Internet data can reasonably approximate the timing of restoration attempts as long as the price increases are sustained for longer than a day.

data. Similarly, city-wide average price increases are 2.4 (2.9) times greater in magnitude than decreases using the Internet (BP) data, while city-wide mode price increases are 4.1 times greater in magnitude than decreases, regardless of which data set is used.

Further evidence regarding the relative accuracy of the mode price in the Internet data is found by examining the proportion of times that the daily mode and mean prices are exactly identical across data sets. Table 5.4 shows that while the mode price is identical across data sets on more than 50% of all 103 days, the mean prices are identical less than 10% of the time. One potential explanation for the relative accuracy demonstrated in the mode series is that Group D stations are under-represented in the Internet data. On average, the daily mode price for a Group D station equals the daily city-wide mode price in the balanced panel on 5.7% of all 103 days, so the under-representation of Group D stations is unlikely to affect the mode price. Also, it was statistically demonstrated in Section 5.4.1 that Group D stations tend to have higher margins than Group A stations. Thus, the low number of price reports for Group D stations appear to contribute to the Internet data's frequent underestimation of the mean daily city-wide price (65.0% of all 103 days), but are less likely to affect the calculated mode price.

However, while daily mean prices do not tend to be exactly accurate, they do tend to be *almost* accurate. According to summary statistics and correlations provided in Table 5.4, including all 103 days in the sample, the Internet data underestimate the "true" daily mean price by 0.3 cpl, on average, while the correlation coefficient between the two daily mean price series is quite high at 0.998. On the other hand, if the mean sample margins are calculated *for each station* using both data sets, then the correlation coefficient between these two mean series is 0.640. Therefore, if the questions being studied by a researcher do not require exact average prices, then the Internet data might be suitable for these purposes, even though one likely should not base any conclusions on station-specific prices.

Next, an interesting observation made from the statistics in Table 5.4 is that even though the daily mode price tends to be exactly accurate more than 50% of the time, overall, it is still less accurate than the average price series; specifically, the Internet data underestimate the true daily mode price by 0.6 cpl, on average, while the correlation coefficient between the two mode price series is 0.973. A possible explanation for this result goes back to Section 5.5.1, where it was argued that the mode and mean prices might be less accurate on days when restoration attempts are made; it typically takes 24 hours for all stations to raise their prices, and therefore the mode price increase might be observed with a lag. To examine this possibility, the statistics in the previous paragraph have been re-computed after excluding all 14 Days 0 identified in Section 5.5.1.[24] It is found that both the mean and mode price series become more accurate after the exclusion of these 14 days, particularly the mode series: the Internet data underestimate the daily mode and mean prices by 0.1 and 0.2 cpl, respectively, while the correlation coefficients between the two data sets are 0.994 for the modes and 0.999 for the means.

The findings of this subsection can be summarized visually using Figures 5.2a and 5.2b, where the daily city-wide mode and mean prices are plotted for each data set. Both the mode and mean prices computed from the Internet data roughly overlap the corresponding series computed using the balanced panel. However, the Internet data tend to approximate daily mode prices more accurately than daily means, with the primary exception of Days 0. The overall results are consistent with conclusions made in Section 5.4, which are that a researcher can likely generate reliable results using mode and mean prices that are calculated from Internet

---

[24] When one data set identifies a Day 0 one day later than the other data set, only the first day is counted for these computations.

data, but one should take into account the possibility that these prices might be highly underestimated on days when restorations are attempted.

*5.5.3 Price Leadership*

The purpose of this section is to demonstrate that empirical analyses that rely on price data for specific stations likely should not be conducted using Internet data. One reason for this argument is that only a subset of the stations in a market are sampled each period, which can change every period. Also, there are some stations, particularly those in Group D, that are sampled as infrequently as once every few weeks; an extreme example is Station 8, which is spotted in the data nine times over the entire 103 days. Finally, stations' prices are unlikely to be observed in the order that they actually change.

To demonstrate the problems that can arise from relying on prices for particular stations, the leaders of price increases are defined in both data sets to be the first stations observed to raise their prices to the mode peak price on Day 0. The balanced panel identifies six specific major brand stations as leaders at least twice as often as the other 21 stations in the city: Petro-Canada Stations 5, 18 and 25 are identified as leaders of five to six restorations, while Esso Stations 17, 19, and 26 are identified as leaders four to five times each; the remaining 21 stations are identified as leaders no more than twice each. On the other hand, the Internet data identify four of these major brand stations as leaders no more often than two Group C stations: Pioneer Station 23 and Canadian Tire Station 24.

Similar conclusions are made regarding price decreases, in general. Using each data set, a station is identified as setting the minimum daily price in Guelph if it is observed to set this price before the other 26 stations in the city. At first glance, the Internet data seem to be quite reliable, as Pioneer Station 23 is consistently observed to set the daily minimum price much more frequently than all other stations. In the balanced panel, it sets the minimum 22 times, which is at least 2.7 times more often than all other stations; in the Internet data, Pioneer sets the minimum price 20 times, or at least four times more often than all other stations. However, the results are less accurate for the remaining 26 stations. Specifically, the balanced panel identifies 10 other stations as setting the market minimum at least once, while the Internet data identify 18 stations after Pioneer. Furthermore, seven of these new stations are identified at least as often as eight of the stations identified in the balanced panel.

Nonetheless, one can still likely use these data to determine whether prices tend to decrease in certain areas of a market, or whether certain brands might be more or less aggressive than other brands. For example, Eckert and West (2004a) compare the prices of each sampled station in Vancouver and Ottawa to the mode market price for each day; they find evidence that is consistent with the argument that certain brands in each city (such as Pioneer) are mavericks, because they tend to price below the daily market mode price. To examine whether these same conclusions might have been made if the authors used balanced panel data for each city, daily mode prices are calculated for Guelph using both data sets. Next, for each data set, the mode price for a given day is subtracted from all prices observed on that same day. The resulting differentials are then averaged across the entire sample for each brand, and displayed in the top section of Table 5.5.

According to this table, regardless of which data set is used, two key conclusions are made. First, Pioneer sets its price equal to the mode price with a relatively low frequency, and also tends to undercut the market mode by more than any other brand; this is consistent with the argument that Pioneer is a maverick brand in Guelph. Second, the Group D stations also rarely price at the mode, but tend to price well above the mode price, suggesting that they do not price as aggressively as one might expect.

In the last column of Table 5.5, the amounts by which the Internet data overestimate the mean brand differentials are listed, which range between 0.1 and 1.0 cpl. However, as was argued in previous sections, these differentials are likely to be smaller if restoration days are excluded from the calculations, because the mode price can be highly underestimated on these days. Thus, the numbers provided in Table 5.5 have been recomputed after omitting the 14 Days 0 identified in Section 5.5.1. The results, which are displayed in the bottom section of Table 5.5, are similar to those in the top section, i.e., that Pioneer appears to be a maverick in the market, while the Group D stations tend to price above the mode price. Finally, the numbers in the last column demonstrate that the amounts by which the Internet data overestimate the mean brand differentials are all smaller than when all 103 days are included in the analysis. The absolute differential is also smaller for every brand, except Canadian Tire which is 0.2 cpl larger than when all 103 days are included in the calculations.[25]

## 5.6 Conclusions

While the benefits of using high frequency, station-specific data to study retail gasoline price competition are not in dispute, data of such quality can usually only be obtained at a high cost, both in terms of time and money. Furthermore, while station-specific data are available from Internet gasoline pricing sites such as GasBuddy.com, no studies appear to exist which examine

[25] However, if the apparent prank post attributed to Canadian Tire Station 24 (see *supra* note 13) is omitted from the Internet data, then Canadian Tire's absolute differential also shrinks; its "Mean Diff" is 0.2 for all days and -0.0 on non-Days 0. The "Mean Diff" statistics for Esso are unchanged after excluding the apparent prank post attributed to Esso Station 21.

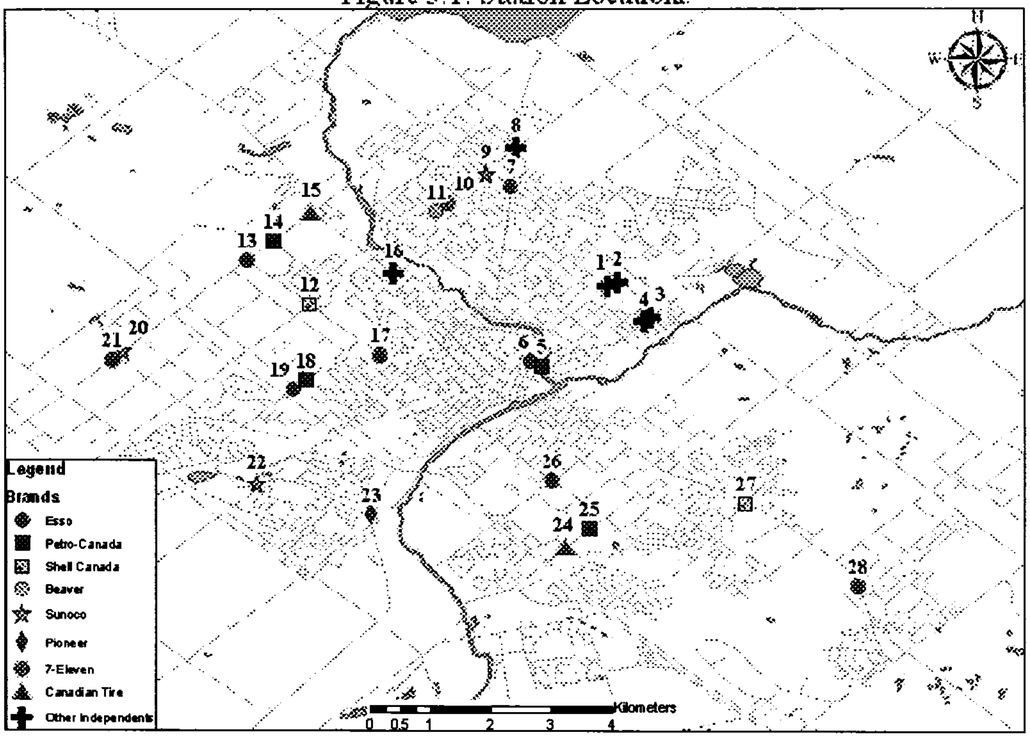
the conditions under which such data can be reliably used by a researcher. Thus, two data sets were constructed for stations in Guelph, Ontario to fill this gap in the literature: one consisting of a balanced panel of data collected bi-hourly from 27 stations, eight times per day for 103 days; and the other including prices collected every 12 hours from OntarioGasPrices.com during the same 103 days. These data were used to first identify certain sample selection biases that might arise in these Internet data sets, and the extent to which they can influence a researcher's results. These biases were then explored in more detail by examining some basic predictions of the Edgeworth cycle theory, using both data sets.

The main results of this chapter are as follows. First, consistent with predictions in the relevant literature, it appears that consumers tend to be relatively motivated to report the prices of major brand stations that are price controlled by their head offices; they are also relatively unlikely to report prices for small independent stations. Potential explanations for these biases include spatial and product differentiation between stations. However, it seems that consumers do not tend to report a station's price more often if its price rises or falls relative to competitors' prices in the city. Thus, the Internet data tend to accurately identify features of cycles that can be distinguished using company-operated major brand station prices (e.g., the existence of a cycle, its period, height, approximate starting days, asymmetry, etc.), while features that require individual independent station data or very high frequency data might not be well-identified (e.g., the identities of price leaders and the order in which stations change their prices).

Furthermore, for markets such as Guelph where a clear city-wide mode price tends to exist, daily mode prices tend to be more accurately measured in the Internet data than average prices, in part because the small non-branded independents that tend to price above the city-wide mode price are under-represented in these data for Guelph. However, the daily mean prices calculated by each data set are still almost perfectly correlated with one another, indicating that these data might still provide reliable results for a researcher, depending on the questions being asked. Finally, the mode and mean price series are found to be less accurately measured by the Internet data on days when restorations are initiated, because it typically takes two days for these price increases to be fully reflected in the data.

These results have important implications for economic researchers, because depending on the market and the questions being asked, they suggest that these data can be reliably used to examine retail gasoline price competition under a number of different scenarios. In particular, when combined with station characteristic data, including capacities, traffic counts, and other non-gasoline operations, these data can be used to examine spatial price competition, both within and across markets. Such studies are not usually possible using data that are publicly available, because these data tend to either be averaged across stations, or for a limited number of stations in a market. Furthermore, these data can be collected for free from the Internet, and are therefore widely available to researchers regardless of available funding. In summary, this chapter's results suggest that the availability of this relatively new source of data can open up new avenues for research that were previously unavailable due to data restrictions.

Figure 5.1: Station Locations




| Approximate Collection Times | | | |
|---|---|---|---|
| **Station ID** | **Collection Time** | **Station ID** | **Collection Time** |
| 1 | :00 | 15 | :17 |
| 2 | :00 | 16 | :21 |
| 3 | :01 | 17 | :24 |
| 4 | :01 | 18 | :26 |
| 5 | :03 | 19 | :26 |
| 6 | :03 | 20 | :30 |
| 7 | :08 | 21 | :30 |
| 8 | :09 | 22 | :35 |
| 9 | :11 | 23 | :36 |
| 10 | :12 | 24 | :40 |
| 11 | :12 | 25 | :40 |
| 12 | :14 | 26 | :42 |
| 13 | :15 | 27 | :45 |
| 14 | :16 | 28 | N/A |

Figure 5.2a
**Daily Mode Retail Prices for Guelph, Ontario**

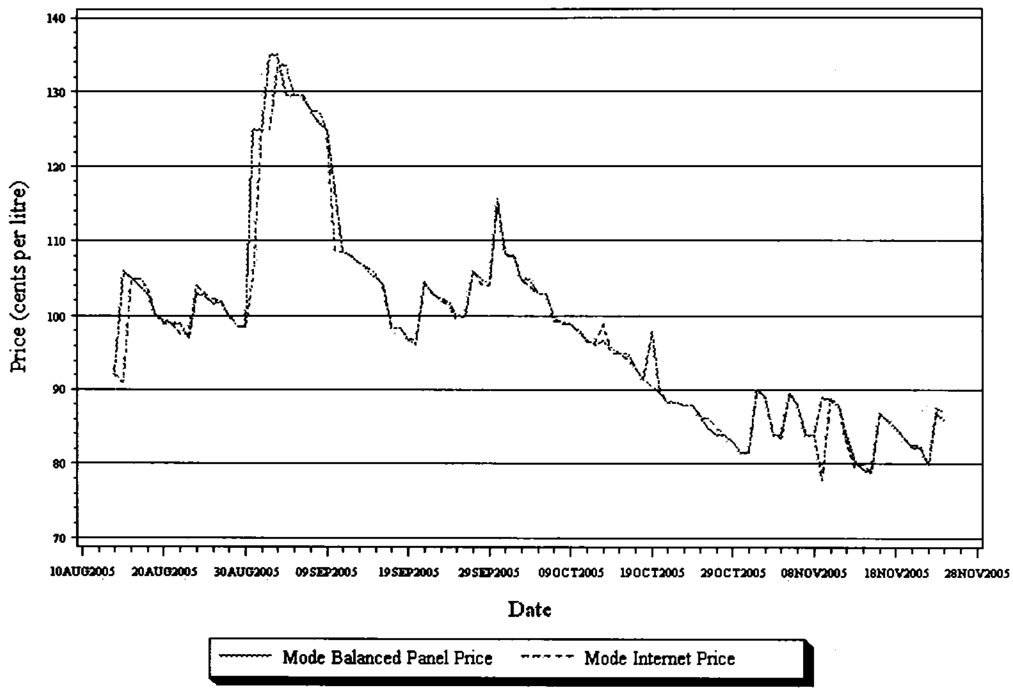



Figure 5.2b
**Daily Mean Retail Prices for Guelph, Ontario**

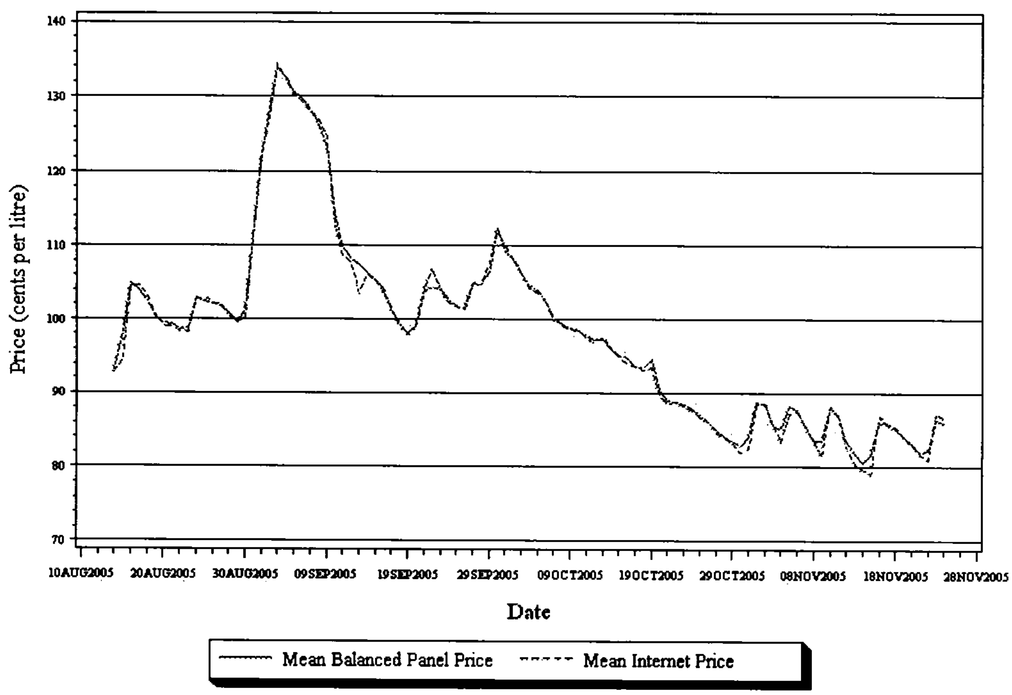


Figure 5 3: Proportion of Dates Each Station is Reported (N = 103)

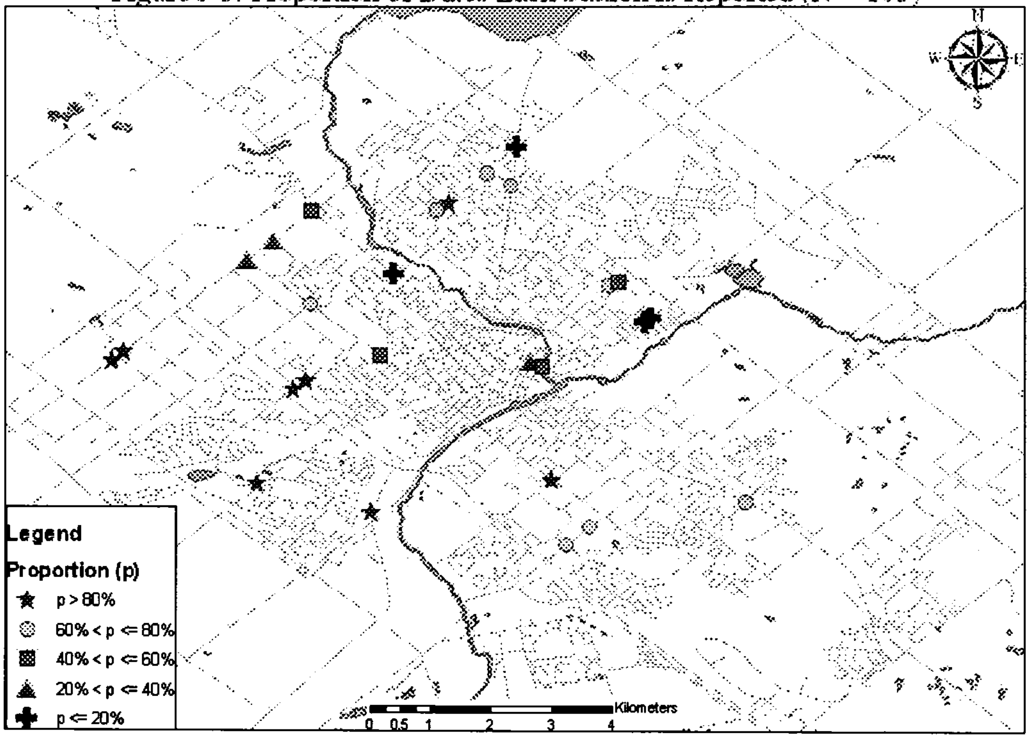


Table 5.1: Selected Station Characteristics*

| Brand | ID | Nozzle Count | 24 Hrs | Self-Serve | Store | Car Wash | Auto |
|---|---|---|---|---|---|---|---|
| *Group A* | | | | | | | |
| Esso | 19 | 12 | ✓ | ✓ | ✓ | ✓ | |
| Esso | 21 | 10 | ✓ | ✓ | ✓ | ✓ | |
| Esso | 26 | 8 | ✓ | ✓ | ✓ | | |
| Petro-Canada | 5 | 8 | | ✓ | ✓ | | |
| Petro-Canada | 18 | 8 | ✓ | ✓ | ✓ | ✓ | |
| Petro-Canada | 25 | 8 | ✓ | ✓ | ✓ | ✓ | |
| Shell | 12 | 8 | ✓ | ✓ | ✓ | | |
| Shell (Mac's) | 27 | 8 | ✓ | ✓ | ✓ | | |
| Shell (Beaver) | 11 | 6 | | | | | ✓ |
| Sunoco | 9 | 6 | | | | ✓ | |
| Sunoco | 20 | 4 | | | | | |
| Sunoco | 22 | 8 | ✓ | ✓ | ✓ | ✓ | |
| *Group B* | | | | | | | |
| Esso (Norm's Garage) | 6 | 4 | | | | | ✓ |
| Esso (7-Eleven) | 7 | 8 | ✓ | ✓ | ✓ | | |
| Esso (Gas-Up Carwash) | 13 | 4 | | ✓ | | ✓ | ✓ |
| Esso (Rainbow) | 17 | 6 | ✓ | ✓ | ✓ | ✓ | |
| Petro-Canada | 14 | 8 | | ✓ | ✓ | | |
| *Group C* | | | | | | | |
| 7-Eleven | 10 | 8 | ✓ | ✓ | ✓ | | |
| Canadian Tire | 15 | 8 | | ✓ | ✓ | | ✓ |
| Canadian Tire | 24 | 6 | ✓ | ✓ | | ✓ | |
| Pioneer | 23 | 8 | ✓ | ✓ | ✓ | | |
| *Group D* | | | | | | | |
| Amco | 1 | 4 | | | | | ✓ |
| Cango | 2 | 3 | | | | | ✓ |
| Hilton Group Gas | 3 | 4 | | | | | ✓ |
| Maple Leaf Gas and Fuels | 4 | 4 | | | | | ✓ |
| CAN-OP | 8 | 2 | | | | | ✓ |
| Quik-N E-Zee Gas & Snacks | 16 | 2 | | | | | ✓ |

* Petro-Canada Station 18 is the only station with both full- and self-serve pumps; since the self-serve price is observed, only those pumps are counted. Also, a "store" means a convenience store, except for Canadian Tire Station 15 where it is a Canadian Tire department store.

Table 5.2: Selected Statistics, Averaged Across Stations by Group

| Group | Number (%) of Days "Spotted" | | Mean Sample Margin (cpl)* | Annual Traffic Flows (Cars, '000s) |
|---|---|---|---|---|
| | Including All Spotters | Excl. Two Most Frequent Spotters | | |
| A | 79 (76.7%) | 50 (48.5%) | 4.8 | 25.664 |
| B | 45 (43.7%) | 32 (31.1%) | 5.0 | 20.661 |
| C | 70 (68.0%) | 47 (45.6%) | 4.5 | 24.196 |
| D | 29 (28.2%) | 10 (9.7%) | 6.0 | 10.627 |

* The mean sample margin for each station is calculated using the balanced panel data set.

Table 5.3: Probit Regressions (Dependent Variable: $COUNT_{it}$; N = 2,781)

| Variable† | Price Differentials | | Price Rankings | |
|---|---|---|---|---|
| | Coefficient | $\chi^2$ Stat | Coefficient | $\chi^2$ Stat |
| $MODEDIFF_{it}$ | 0.00012 | 0.00 | ----- | ----- |
| $MODERANK_{it}$ | ----- | ----- | -0.00982 ** | 4.16 |
| $DAY0_t$*$MODEDIFF_{it}$ | 0.00261 | 0.01 | ----- | ----- |
| $DAY0_t$*$MODERANK_{it}$ | ----- | ----- | 0.00447 | 0.19 |
| $NOPOST_{it}$ | -0.54350 ** | 5.74 | -0.53544 ** | 5.57 |
| CONSTANT | 1.90989 * | 28.29 | 1.97055 * | 30.03 |
| LR Test Statistic (df= 131) | 1,144.4624 | | 1,148.7847 | |

† Results for the 26 station-and 102 daily-dummies are not reported for presentation purposes.
* Statistically significant at the 1% level of significance (two-tail)
** Statistically significant at the 5% level of significance (two-tail)

Table 5.4: Inter-Data Set Comparisons of Prices and Price Correlations*

| Inter-Data Comparisons of Cycle Characteristics | Internet Data | Balanced Panel |
|---|---|---|
| Average increase in city-wide average price | 3.6 cpl | 3.8 cpl |
| Average increase in city-wide mode price | 7.8 cpl | 7.7 cpl |
| Average decrease in city-wide average price | 1.5 cpl | 1.3 cpl |
| Average decrease in city-wide mode price | 1.9 cpl | 1.9 cpl |
| Number of increases (average price) | 29 | 25 |
| Number of increases (mode price) | 16 | 16 |
| Number of decreases (average price) | 73 | 77 |
| Number of decreases (mode price) | 67 | 68 |
| Average number of days between attempted restorations | 7.5 | 7.8 |
| **Daily Price Comparisons** | | |
| Number (%) of days when mode daily prices are equal | | 52 (50.5%) |
| Number (%) of days when mean daily prices are equal | | 8 (7.8%) |
| Average difference between Balanced & Internet mode prices (all days) | | 0.6 cpl |
| Average difference between Balanced & Internet mean prices (all days) | | 0.3 cpl |
| Average difference between Balanced & Internet mode prices (non-Days 0) | | 0.1 cpl |
| Average difference between Balanced & Internet mean prices (non-Days 0) | | 0.2 cpl |
| **Pearson Price Correlations** | | |
| Between daily city-wide mode prices (all days) | | 0.973 |
| Between daily city-wide mean prices (all days) | | 0.998 |
| Between daily city-wide mode prices (non-Days 0) | | 0.994 |
| Between daily city-wide mean prices (non-Days 0) | | 0.999 |
| Between station-specific sample mean prices (all days) | | 0.640 |

* Note that the mean price rises more frequently and by smaller amounts than the mode price, because it typically takes two days for all stations in the city to raise their prices during restorations. Also, a Day 0 is a day when a restoration attempt is observed; if one data set identifies a restoration one day earlier than the other, then only the first day is counted for the purpose of the bottom two sections of this table.

Table 5.5: Comparisons of Station Prices to Daily Market Modes by Brand

| Brand | Internet Data* | | Balanced Panel | | Internet - Balanced Mean Diff |
|---|---|---|---|---|---|
| | Mean Diff | % Diff = 0 | Mean Diff | % Diff = 0 | |
| **Including All 103 Days** | | | | | |
| Esso | 0.3 | 36.5% | -0.1 | 32.2% | 0.4 |
| Petro-Canada | 0.7 | 39.1% | -0.3 | 34.5% | 1.0 |
| Shell | 0.9 | 25.8% | 0.3 | 28.9% | 0.6 |
| Sunoco | 0.3 | 23.2% | -0.3 | 23.5% | 0.6 |
| 7-Eleven | 0.3 | 33.3% | -0.2 | 36.2% | 0.5 |
| Canadian Tire | -0.3 | 26.2% | -0.4 | 31.1% | 0.1 |
| Pioneer | -0.6 | 17.2% | -1.1 | 13.4% | 0.5 |
| Other | 1.5 | 4.6% | 1.1 | 5.5% | 0.4 |
| **Excluding Days 0** | | | | | |
| Esso | 0.1 | 35.9% | 0.1 | 32.9% | 0.0 |
| Petro-Canada | 0.1 | 41.0% | -0.3 | 35.8% | 0.4 |
| Shell | 0.5 | 26.2% | 0.4 | 29.8% | 0.1 |
| Sunoco | 0.2 | 22.3% | -0.1 | 23.8% | 0.3 |
| 7-Eleven | 0.2 | 32.3% | 0.3 | 37.4% | -0.1 |
| Canadian Tire | -0.6 | 27.0% | -0.3 | 30.5% | -0.3 |
| Pioneer | -0.7 | 16.5% | -0.9 | 15.4% | 0.2 |
| Other | 1.6 | 4.9% | 1.4 | 5.6% | 0.2 |

* Note that Canadian Tire appears much less aggressive if the apparent prank post attributed to Station 24 (identified in footnote 13) is omitted from the Internet data; after omitting this post, its "Mean Diff" is 0.2 for all days, and -0.0 on non-Days 0. The "Mean Diff" statistics for Esso are unchanged after excluding the apparent prank post attributed to Esso Station 21.

## 5.7 References

Basu, Kaushik (2004), "Consumer Cognition and the Pricing in the 9's in Oligopolistic Markets," Harvard Institute of Economic Research Discussion Paper Number 2053.

Eckert, Andrew (2002), "Retail Price Cycles and the Response Asymmetry," *Canadian Journal of Economics* 35, 52-77.

--- (2003), "Retail Price Cycles and the Presence of Small Firms," *International Journal of Industrial Organization* 21, 151-70.

Eckert, Andrew and Douglas S. West (2004a), "A Tale of Two Cities: Price Uniformity and Price Volatility in Gasoline Retailing," *Annals of Regional Science* 38, 25-46.

----- (2004b), "Retail Gasoline Prices Cycles Across Spatially Dispersed Gasoline Stations," *Journal of Law & Economics* 47, 245-73.

----- (2005), "Price Uniformity and Competition in a Retail Gasoline Market," *Journal of Economic Behavior & Organization* 56, 219-37.

Kleit, Andrew N. (2003), "The Economics of Gasoline Retailing: Petroleum Distribution and Retailing Issues in the U.S.," Available at http://www.api.org (December 2003).

Lewis, Matthew (2006), "Temporary Wholesale Gasoline Price Spikes Have Long-Lasting Retail Effects: the Aftermath of Hurricane Rita," Ohio State University Working Paper (August 16, 2006).

Lewis, Matthew S. and Howard P. Marvel (2007), "When Do Consumers Search?," Ohio State University Working Paper (March 2007).

Maskin, Eric and Jean Tirole (1988), "A Theory of Dynamic Oligopoly, II: Price Competition, Kinked Demand Curves, and Edgeworth Cycles," *Econometrica* 56, 571-99.

Noel, Michael (2006), "Edgeworth Cycles and Focal Prices: Computational Dynamic Markov Equilibria," UCSD Working Paper (April 10, 2006).

----- (2007a), "Edgeworth Price Cycles, Cost-Based Pricing and Sticky Pricing in Retail Gasoline Markets," *Review of Economics and Statistics* 89, 324-34.

---- (2007b), "Edgeworth Price Cycles: Evidence from the Toronto Retail Gasoline Market," *Journal of Industrial Economics* 55, 69-92.

Plummer, Paul, Robert P. Haining, and Eric Sheppard (1998), "Spatial Pricing in Interdependent Markets: Testing Assumptions and Modeling Price Variation. A Case Study of Gasoline Retailing in St. Cloud, Minnesota," *Environment and Planning A* 30, 67-84.

Schindler, Robert M. and Patrick N. Kirby (1997), "Patterns of Rightmost Digits Used in Advertised Prices: Implications for Nine-Ending Effects," *Journal of Consumer Research* 24, 192-201.

Shepard, Andrea (1993), "Contractual Form, Retail Price, and Asset Characteristics in Gasoline Retailing," *RAND Journal of Economics* 24, 58-77.

Sheppard, Eric, Robert P. Haining, and Paul Plummer (1992), "Spatial Pricing in Interdependent Markets," *Journal of Regional Science* 32, 55-75.

Slade, Margaret E. (1998), "Strategic Motives for Vertical Separation: Evidence from Retail Gasoline Markets," *Journal of Law, Economics & Organization* 14, 84-113.

Taylor, Beck A. (2000), "Retail Characteristics and Ownership Structure," *Small Business Economics* 14, 157-64.

Wang, Zhongmin (2006), "Endogenous Timing in Oligopoly Pricing: Evidence from a Repeated Game in the Field," Northeastern University Working Paper (October 2006).

# Chapter 6

## General Discussion and Conclusions

The three papers that comprise this thesis each make an important contribution to the academic literature regarding retail gasoline price competition, not only with respect to price cycles, but also retail gasoline markets, in general. The high quality of the data that have been collected for this city has generated a number of interesting discoveries, which could not have been made using publicly available data for unregulated markets.

First, it was demonstrated in Chapter 3 that certain characteristics of price cycles in Guelph tend to be quite predictable, including the timing of restoration attempts, the leaders of price increases, and the sub-cyclical patterns observed at the beginning of each restoration attempt. It was also demonstrated that the minimum price in the city is frequently set by a single independent brand and station, Pioneer, while the other independent stations in the market do not appear to be particularly aggressive price setters.

Second, it was found in Chapter 4 that price movements do not tend to propagate across Guelph as quickly as predicted by an informal theory of retail gasoline price competition. Consistent with the findings in Chapter 3, it was also found that small independent stations tend to be among the last stations to match or undercut minimum prices set by Pioneer. The slow propagation of price decreases also appears to be inconsistent with the basic assumption of the Edgeworth cycle theory that one firm responds to the other as quickly as possible.

Finally, Chapter 5 provided evidence that data collected from OntarioGasPrices.com can be used by researchers of retail gasoline price competition, provided their questions do not require price data for independent stations, or high frequency data for individual stations. It also provides evidence to support predictions derived from the empirical literature that consumers tend to be biased toward certain stations based on factors such as spatial location, demand complementarities, and brand loyalty. It is expected that these results are robust to other cities of similar or greater size than Guelph, because price spotters in these cities are also likely to be biased toward major brand and large independent stations in relatively high-traffic areas. Also, the daily mean and mode prices in Guelph were approximated rather accurately, despite the fact that a large proportion of price reports were made by two spotters, who were also responsible for a disproportionately high number of errors.

In general, the results of this thesis suggest that the Edgeworth cycle theory is relevant for explaining the price cycles observed in many retail gasoline markets. However, certain refinements are likely warranted. First, the theory should be extended to allow for spatial and product differentiation across firms, and possibly to also account for consumer search costs. As argued above, the identities of price leaders appear to be determined not only by firm size, but also by the characteristics of the brands and stations themselves. Furthermore, the finding that price decreases do not propagate quickly across Guelph might also be explained by spatial and product differentiation, as well as costs that consumers would incur by searching for lower prices at stations located off their main commuting routes.

Second, one might refine the theory to allow for predictable demand fluctuations. It was found in Chapter 3 that prices tend to rise early in the week and during the middle of the day, which is when demand is expected to be relatively low. If one could extend the Edgeworth cycle theory to allow for such demand factors, then more accurate predictions might be made with respect to price leaders.

This thesis also has a number of important implications for competition authorities. In the case of a merger review, it seems that spatial location and other characteristics of retail gasoline stations might be important determinants of market power, and that a higher concentration of independents does not necessarily imply less market power on the part of the major brands. With respect to "gouging" complaints, large price increases can be part of regular cyclical patterns that are not indicative of either a "long weekend effect" or changes in retailer strategies following natural disasters. Finally, the high predictability of cycle restorations observed in the data suggest that retailers do not need to be involved in an illegal price-fixing agreement for prices to rise across a market "overnight". Instead, patterns in price movements can non-cooperatively facilitate the coordination of cycle restorations.

Finally, the results of this thesis provide motivation for future empirical research. First, the results of Chapter 3 and 4 suggest that even if cycles are more likely to exist in cities where there is a higher concentration of independents, price decreases in these cycling cities are not necessarily led by these independents. Thus, using Internet data collected for various non-regulated cities across Canada and the United States, one could examine whether price decreases tend to begin in certain areas of the city where independents are more highly concentrated, as well as the characteristics of these independent stations (e.g., whether they are believed to be mavericks). Such research would be a relevant extension of Chapters 3 and 4, because it could provide insight into the competitive effects of independent brand stations after controlling for their station characteristics, as well as population, geographical layout and market structure. As such, this research would provide some indication of why price cycles tend to be observed in certain cities and regions, such as Vancouver, southern Ontario, and the U.S. mid-west, but not in other locations, such as cities in the Canadian prairie provinces.

A second question that could be addressed using Internet data, but not with other sources of publicly available data, is whether prices in a given city become more or less volatile and uniform following different types of supply shocks. For example, it was demonstrated in Chapter 3 that following the supply shocks caused by Hurricanes Katrina and Rita, which led to greater capacity constraints in the United States, prices rose substantially in Guelph but continued to cycle. However, following an Imperial Oil refinery fire in February 2007 that led to tighter capacity constraints in southern Ontario, Internet data that I have continued to collect for Guelph, Kitchener, Cambridge, and Waterloo indicate that prices in these cities temporarily ceased to cycle, and instead became rather stable and uniform.

The temporary disappearance of cycles in Guelph following this fire is demonstrated visually in Figure 6.1, where prices follow regular cycles from November 2005 to February 2007; then, for several weeks, the mean price in Guelph rose multiple times, but the typical downward pricing trend is not observed in this figure between price increases. By late March, the regular cyclical patterns begin to be observed once again. Thus, a careful analysis of the Internet data that I have collected for Guelph since November 2004 (and for the other three cities since August 2005) could provide empirical evidence regarding whether tighter capacity constraints can actually lead to *less* cyclical behaviour, depending on the characteristics of the supply shock. Such findings would contradict the classic prediction by F.Y. Edgeworth that capacity constraints will lead to price cycles, but would be consistent with Michael Noel's computational findings, discussed in Chapter 2. These and other questions will be the likely focus of future empirical research.

Figure 6.1
Daily Mean Retail Prices for Guelph, Ontario (2005/11 to 2007/06)