DYNAMIC PRICING STRATEGIES IN COMPETITIVE RETAIL MARKETS

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Lay Abstract

Firms' pricing strategy is essential to achieving their objectives, especially in markets with little product differentiation. The dynamic conditions faced by firms in the market require dynamic strategies from retailers. Despite the prevalence of dynamic pricing strategies employed by firms in practice, there is a dearth of research investigating how retailers adjust their pricing strategies in response to external shocks. Furthermore, what kind of pricing routines do retailers employ in a competitive market with little product differentiation?

This dissertation examines the impact of specific external shocks, including wholesale price fluctuations and a carbon tax, on retailers' dynamic pricing strategies. It also identifies distinct pricing routines that retailers adopt in the gasoline market. The findings have implications for understanding retailers' pricing strategies in both theory and practice.

Abstract

In markets with minimal product differentiation, a firm's pricing strategy is essential to achieve its objectives. In competitive environments, instead of seeing prices converge to marginal cost, there is a noticeable variation in prices across different retailers and over time due to their dynamic pricing strategies. A considerable amount of research is built on analytical models that depend on a static market framework, viewing market conditions as stable and unchanging, where firms employ mixed strategies in equilibrium. However, real-world market conditions are quite dynamic and experience ongoing fluctuations because of external shocks. Additionally, the role of mixed strategies in explaining specific pricing paradigms in such markets is limited. Given that competitive markets are highly dynamic, this thesis aims to address the following questions: i) How does retailer pricing react to external cost shocks in a dynamic and competitive market? ii) In such markets, what pricing paradigms or routines are followed by retailers to adjust prices over time?

The first paper in this thesis examines the impact of two specific external shocks on retailer pricing in the retail gasoline market. We show that external shocks such as wholesale price increases and a carbon tax directly and indirectly affect retailer pricing. The direct effect of both results in higher prices charged by retailers. However, the indirect impact of these shocks works in contrasting ways. The imposition of the carbon tax increases consumers' search intensity, thereby making the market more competitive, while increases in wholesale prices have the opposite effect.

The second paper in the thesis studies the pricing paradigms or routines followed by retailers to adjust prices in the gasoline market. We first evaluate what constitutes the critical dimensions of retailers' pricing paradigms and find that they are price level, price variance, and

price adjustment frequency. We then identify three typical pricing paradigms in the gasoline market, going from high price, stable paradigms to low price, very volatile paradigms. We further find that the likelihood of retailers adopting a pricing paradigm is associated with gas station and market characteristics.

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Chapter 1 - Introduction

Price competition plays a fundamental role in retail product markets, particularly in highly competitive markets where products exhibit minimal differentiation. In such markets, the competitive advantage from non-price factors diminishes, magnifying the importance of price competition. Retailers strive to maximize their profits by strategically determining prices while considering their competitors' pricing strategies. Classical models of Bertrand competition suggest that in undifferentiated markets, prices should ideally converge to a uniform competitive price close to the marginal cost. However, in practice, we often observe price dispersion across markets rather than the convergence predicted by classical economic theory. The price dispersion is present in two key forms. Firstly, there is cross-sectional price dispersion—the prices set by retailers in the same market differ from each other at the same time. Secondly, there is intertemporal price variation—retailers change their prices frequently even when their wholesale prices remain constant. For instance, in the retail gasoline market in Hamilton, Ontario, gas stations typically change their prices two to three times daily. As measured by the standard deviation of gas prices across markets within Hamilton in Spring 2019, the price dispersion is about 3.25 cents per liter. The intertemporal price variation for a gas station, measured by the daily price variance, is 2.57 cents. Given that the average profit margin of a gas station in the Greater Toronto Area is approximately 3 cents per liter, the significance of this variation becomes apparent. The dynamic and divergent nature of gas station prices concerning competitor prices indicates that prices do not conform to the expected pattern of convergence to marginal cost. It has become common for gas stations to adjust their prices frequently, leading to cross-sectional price dispersion and intertemporal price variation in the market.

Existing literature has suggested that retail price dispersion results from retailers' dynamic pricing strategies. The most commonly used theory on retailers' dynamic pricing in competitive markets suggests that retailers exploit consumers' incomplete information about prices in the market and adjust prices to prevent consumers from identifying retailers offering the lowest price. In such a market, retailers play mixed strategies in equilibrium. A significant body of research in this domain relies on analytical models that assume a static market environment. These studies typically abstract away from external disruptions, treating market conditions as fixed and unchanging. However, market conditions are highly dynamic in practice and subject to continuous fluctuations due to external shocks. These shocks can take various forms, such as changes in taxation policies, sudden increases in wholesale prices driven by supply chain disruptions, or broader economic shifts. Such external disturbances compel retailers to adapt their pricing strategies, particularly when employing mixed-strategy pricing, as they must respond to evolving cost structures and competitive pressures. Moreover, these shocks influence consumer expectations and beliefs, altering their purchasing behavior and consequently, reshaping market equilibrium over time. Despite the clear empirical relevance of these dynamics, existing literature has yet to thoroughly examine how these external shocks interact with firms' strategic pricing decisions and consumer expectations in a dynamic market setting.

Furthermore, the role of mixed strategies is limited when explaining heterogeneous dynamic pricing patterns exhibited by firms in retail markets. The outcome of the most commonly used theories of dynamic pricing suggests retailers employ mixed strategies, which show up as random pricing patterns in the market. However, in practice, retailers often adopt different patterns to adjust their prices dynamically. These patterns can appear as price cycles that rise suddenly and drop slowly in specific markets, also known as "Edgeworth Cycles," while there may be an apparent lack of any clear pattern in others. In light of these issues regarding retailers' dynamic price competition strategies, there is room for further research and exploration in this domain, particularly in bridging the gap between academic understanding and business practices.

In this thesis, I focus on retailers' dynamic pricing strategies in the retail gasoline market, characterized by a market with a homogeneous good, inelastic demand, and little consumer stockpiling behavior. The first paper of the thesis examines the role of price competition when the market responds to external shocks. Specifically, how do external shocks reshape retailer pricing? Retailers can face different types of external shocks, such as taxes, changes in firms' cost structure, supply constraints, etc. I investigate the effects of a carbon tax on retailer pricing in the gasoline market and contrast it with the impact of another external influencing factor, i.e., the wholesale price. I developed a theoretical framework based on consumer search theory to understand retailers' pricing response when faced with the external shocks of a carbon tax and wholesale price. I argue that both the carbon tax and wholesale price change are external shocks that act to change consumers' search behavior in the market and have opposite effects on retailer pricing.

The carbon tax has a direct and indirect impact on retail prices. The direct effect increases the cost for retailers and drives up retail prices. The indirect impact of carbon tax acts through increased consumer search. Due to the imposition of the carbon tax, consumers anticipate price increases and are more inclined to search for the best price. Increased consumer search intensifies price competition among gas stations and limits the magnitude of their price increases in response to the carbon tax imposition. Moreover, this indirect effect is magnified by the number of competing gas stations in the local market. More competitors involve more pricing complexity, and consumers are more willing to investigate price variation when external shocks like carbon tax occur. The increased consumer search intensity increases price competition and reduces the tax passed through to the consumers compared to what it would have been without the change in consumer search.

In contrast, when wholesale prices increase, consumers view this change as routine, and a lower proportion of consumers are likely to be informed about such changes. Furthermore, consumers may anticipate the retail price increase to be reversed soon when wholesale prices drop. This expectation will reduce consumer search, allowing for a softening of price competition among firms. A higher number of competitors in a market that faces wholesale price changes strengthens such expectation, thereby softening price competition and allowing gas stations to raise retail prices further.

The empirical findings support the above theoretical analysis. Specifically, the results prove that while the carbon tax positively impacts retail gasoline prices, it intensifies consumer search, measured by the cross-sectional price dispersion in the local market, lowering the retail prices. The imposition of a carbon tax leads to a decline in price dispersion in the market. This contrasts with the impact of wholesale price increases, which results in a small but significant increase in the price dispersion, thereby implying a slight loosening of price competition intensity. The carbon tax and wholesale price increases both increase the gas stations' production cost, yet the effects on the gas stations' pricing are opposite due to consumers' search behavior. Our study echoes existing studies that state that the key to retailers' dynamic pricing is the intensity of consumer search. A change in this intensity drives changes in pricing strategy, resulting in a more competitive market for retailers.

My second study focuses on the gas stations' dynamic pricing strategies. Retail pricing in gasoline markets is highly dynamic, with prices fluctuating multiple times daily based on market conditions such as demand and price competition. Gas stations often adhere to various paradigms to adjust their prices over time. However, existing literature has not recognized or examined these dynamic pricing paradigms. My study uses a data-driven approach to provide metrics to measure retailers' pricing behaviors. We take hourly pricing of regular-grade gasoline for all the gas stations in Hamilton, Ontario, from February to December 2019 and extract nine features from the pricing series of each gas station. We then use factor analysis to summarize these nine features in 3 dimensions. These dimensions are *price level, price variance*, and *price adjustment frequency*. Using unsupervised machine learning, clustering is used to group gas stations along these three dimensions. Retailers exhibit three distinct paradigms in these pricing dimensions. The first cohort has a high average price but low price variance and low price adjustment frequency (named Everyday High Price or EDHP in my study). The second cohort has a low average price but high price variance and high price adjustment frequency (Volatiles). The third cohort is in the middle along all three dimensions (called Centrals). Gas stations' choice of a pricing paradigm is related to the station and market characteristics they face. Firms facing more competitors are likely to adopt a volatile paradigm rather than a central or EDHP paradigm. Gas stations near highways, those in higher-income neighborhoods, and the ones belonging to chain stations are likely to adopt a volatile pricing paradigm. The metrics developed in this paper offer a unique approach to understanding retailers' dynamic pricing process, an area not well explored in existing literature.

The next chapter examines the relevant literature on retailers' dynamic pricing competition strategies from Economics and Marketing. In Chapter 3, I present the paper on carbon tax shock to the retail gasoline markets, while Chapter 4 discusses the research on using a data-driven approach to identify pricing patterns in the retail gasoline market.

Chapter 2 - Literature Review

This thesis examines price competition in markets characterized by minimal product differentiation. In this chapter, I review the relevant literature, beginning with the classical Bertrand competition model and progressing to more recent studies that incorporate incomplete information and dynamic strategic interactions.

Static Bertrand Competition with Complete Information

Static Bertrand competition describes a setting where firms compete by simultaneously setting prices, assuming homogenous products, identical marginal costs, and complete consumer information. The classical model (Bertrand 1883; Tirole 1988) assumes that firms make one-shot, optimizing decisions without knowledge of competitors' actions. In equilibrium, the firm with the lower price captures the entire market, incentivizing both firms to price at marginal cost to avoid being undercut. This yields a perfectly competitive outcome with zero economic profits. However, empirical observations contradict this prediction; real-world markets often exhibit persistent price dispersion (Baye, Morgan, and Scholten 2006). Moreover, static pricing is infrequently applied in practice—e.g., hotels maintain fixed markups on mini-bar items over extended periods.

Static Bertrand Competition with Incomplete Price Information

A substantial body of literature extends the Bertrand competition framework by incorporating the role of consumers' incomplete price information in shaping firms' pricing strategies. In markets where prices change frequently, consumers face challenges in maintaining up-to-date knowledge, and only those who actively search can identify the lowest-priced option. In such environments, price dispersion can persist as firms strategically obscure their prices to deter consumer learning. The theoretical foundation for this phenomenon originates in consumer search theory, beginning with Stigler (1961), who argued that acquiring price information is costly in markets with homogeneous products and imperfect transparency. Consumers weigh the marginal cost of obtaining additional price quotes against the marginal benefit of finding a better price, which governs the extent of their search.

One influential class of models formalizing this idea is the *fixed sample search* framework. These models assume that consumers decide in advance how many price quotes to collect, with each additional quote incurring a cost. This approach is particularly relevant for high-involvement purchases where centralized pricing information is unavailable. However, early models such as Stigler (1961) focused solely on consumer behavior, neglecting firms' strategic pricing decisions. Diamond (1971) showed that when firm responses are omitted, even small search costs can drive all firms to set monopoly prices—contradicting the widespread empirical observation of price dispersion. Rothschild (1973) addressed this by introducing reservation prices: consumers abandon search only if offered prices fall below their individual thresholds. Weitzman (1979) formalized an optimal stopping rule for search, suggesting that consumers continue searching until the marginal cost of an additional quote exceeds its marginal benefit.

Subsequent work incorporated both consumer and firm optimization under incomplete information. Salop and Stiglitz (1977) modeled a market where some consumers search and others do not, causing firms to set prices between competitive and monopoly levels. Stahl (1989) generalized these results by examining how the equilibrium distribution of prices depends on the share of informed consumers. Burdett and Judd (1983) introduced a model in which identical firms and consumers interact in a steady-state setting with frictions in the timing of consumer search. They showed that even minimal variation in consumer search intensity can result in equilibrium price dispersion. These models demonstrate that price dispersion can arise without requiring product or firm heterogeneity even in static or stationary Bertrand environments.

A parallel stream of research focuses on *clearinghouse search* models, which assume that consumers can observe all prices in the market by incurring a one-time, fixed search cost. This framework captures centralized search environments—such as price comparison websites—where informed consumers face no marginal cost for additional quotes. Varian (1980) offers the most influential clearinghouse-style model. He considers a market where some consumers are fully informed while others are uninformed and choose sellers randomly. In equilibrium, firms adopt ***mixed pricing strategies***: they randomize prices to attract informed consumers while maintaining higher prices for uninformed ones. This model shows that equilibrium price dispersion can persist even among identical firms and homogeneous products due to asymmetric consumer information. Although Varian's model does not explicitly include a physical clearinghouse, it is conceptually aligned with that literature because informed consumers effectively observe the entire price distribution at zero marginal cost.

Rosenthal (1980) also contributes to this line of research, showing that firm-specific consumer preferences can generate price dispersion even when some consumers are fully informed. Spulber (1995) extends Varian's model to settings where firms possess private information about their marginal costs but not about competitors', showing that price dispersion persists even if consumers have symmetric information. Baye and Morgan (2001) further enrich the clearinghouse framework by introducing a platform that charges firms to post their prices. Even with symmetric firms and consumers, equilibrium price dispersion arises due to platform participation frictions.

Together, these analytical models provide a comprehensive understanding of how informational frictions—whether due to consumer search costs, asymmetric information, or platform constraints—prevent price convergence. Across both fixed sample and clearinghouse frameworks, the dominant theoretical insight is that firms adopt mixed pricing strategies in equilibrium, sustaining price dispersion even in otherwise competitive environments.

The development of theoretical price dispersion models has inspired a substantial empirical literature that tests their predictions and explores how retailers implement dynamic pricing strategies. A prominent body of work has validated the existence of mixed strategy pricing in the retail gasoline market. Multiple studies show that gas stations adjust prices in ways consistent with randomization: they change their relative positions in the price distribution and exhibit non-stationary transition probabilities (Hosken, McMillan, and Taylor 2008; Lach and Moraga-González 2017). Chandra and Tappata (2011) introduce a novel empirical test for detecting mixed pricing strategies by observing how prices switch from low to high (and vice versa) across station pairs within a market. Nishida and Remer (2018) further support this finding by demonstrating that such bidirectional price switching provides direct evidence of price randomization. Collectively, these studies offer strong empirical support for the theoretical prediction that firms in the gasoline retail market adopt mixed pricing strategies in equilibrium.

Complementing this line of research, a large empirical literature investigates the determinants of price dispersion in gasoline markets, linking it to heterogeneities in consumer behavior and firm characteristics—as predicted by search models. Factors such as local demographics (e.g., income and education levels) influence the likelihood that consumers are informed, while competitive conditions (e.g., the number of nearby stations) shape firms' incentives to target informed versus uninformed consumers (Marvel 1976). Additional market-level drivers include cost heterogeneity, spatial differentiation, brand reputation, competition intensity, and demand elasticity. Baron, Taylor, and Umbeck (2004), Eckert and West (2005), and Clemenz and Gugler (2006) document a negative relationship between the number of competitors and station-level prices, consistent with competitive pressure reducing prices. In contrast, Hosken et al. (2008) find no significant association between local competition and price levels, suggesting variation in how competition translates to pricing across markets.

Further refining the role of market structure, Iyer and Seetharaman (2008) show that gas stations in more concentrated markets—where direct competition is intense—exhibit greater price variability than those in more diffuse markets. Brand identity also plays a key role in shaping pricing behavior. Lewis (2008) finds that branded gas stations engage in frequent price adjustments and that these fluctuations vary significantly by brand. Focusing on Austria, Pennerstorfer (2009) observes that branded stations consistently charge higher prices than independents. Interestingly, the presence of independent competitors appears to constrain branded stations' ability to raise prices, suggesting that independents serve as a disciplining force in local markets.

Together, these empirical findings confirm several key predictions of the theoretical literature: that price dispersion is sustained by firm and consumer heterogeneity, and that strategic price randomization is an equilibrium response to informational frictions and local market structure.

Dynamic Bertrand Competition

Firms typically do not compete in a single time period but continuously. In dynamic Bertrand competition, firms compete in price over multiple periods. Each firm’s pricing decision takes into account not only current market conditions but also anticipated future responses from rivals. This repeated-game structure introduces the need for dynamic pricing strategies that evolve over time. As in the static setting, early dynamic models often assume fully informed consumers, yet yield rich predictions regarding observed pricing patterns.

One of the most prominent empirical patterns arising from dynamic price competition is known as ***Edgeworth cycles***, which have been observed in gasoline markets across several U.S. and Canadian cities. These cycles are characterized by prices that decline gradually over time and then jump sharply upward, repeating in a cyclical manner. Maskin and Tirole (1988) offer the leading theoretical explanation. In their model, two identical firms compete by undercutting each other's prices to gain market share. This phase of mutual undercutting continues until profit margins approach zero. At this point, firms face a coordination problem: both would benefit from raising prices, but neither wants to move first. The resolution involves mixed strategies, with one firm eventually raising prices randomly, triggering a new cycle. The incentive is to restore profitability after a prolonged period of minimal margins.

Eckert (2002) argues that price increases in such settings function as a public good, restoring profits for all firms. Eckert (2003) extends the theory by incorporating firm asymmetries, predicting that smaller firms are more likely to undercut, while larger firms are more likely to lead price increases—a prediction supported empirically by Noel (2007). Further studies explore the conditions under which Edgeworth cycles arise. Noel (2008) shows that the pattern weakens when more than two firms are present, often resulting in delayed or failed price jumps. Atkinson (2009) interprets Edgeworth cycles as a form of tacit collusion, with one firm serving as a price leader. Doyle, Muehlegger, and Samphantharak (2010) find that cycles most commonly occur in markets with a medium level of competition. Lewis and Noel (2011) observe that in cycling markets, cost shocks pass through to retail prices more quickly than in non-cycling markets. Noel (2018) shows that supply-side disruptions, such as temporary refinery closures, can interrupt these pricing cycles.

Dynamic competition under incomplete information also helps explain a related pricing pattern—***asymmetric price adjustment***, or the "***Rockets and Feathers***" phenomenon. In this pattern, retail prices rise quickly in response to wholesale price increases (rockets) but fall more slowly when wholesale prices decline (feathers). This asymmetry has been widely observed across industries (Peltzman 2000), including gasoline. Several explanations have been proposed, including inflation expectations (Ball and Mankiw 1994), inventory lags (Borenstein, Cameron, and Gilbert 1997), market power (Borenstein and Shepard 2002), and consumer search frictions (Johnson 2002), with the latter receiving the most empirical support.

Yang and Ye (2008) argue that asymmetric pricing results when consumers react quickly to price increases but slowly to decreases, allowing firms to raise prices without immediate loss in demand. Tappata (2009) adds that rational consumers reduce search when prices are high—since expected gains are small—leading to weaker competitive pressure during price increases. Conversely, search intensifies when prices fall. Cabral and Fishman (2012) further argue that price increases and decreases send different signals to consumers, leading to asymmetric search responses.

Although the data used in this study do not exhibit the rockets and feathers pattern, the literature highlights how upstream cost changes can produce asymmetric retail pricing responses. In Chapter 3, we show that gas stations respond differently to cost increases stemming from wholesale price changes versus those driven by carbon taxes. These differences reflect firms' strategic responses to consumer heterogeneity, with pricing designed to attract uninformed consumers at high prices and informed consumers at low prices—resulting in distinct pricing adjustments depending on the nature of the cost shock.

Other Relevant Studies on Pricing Strategies in Competitive Market

The literature on retailers' price competition strategies extends to other firms, such as grocery stores. Grocery retailers can adopt various approaches: maintaining high margins on some products and low margins on others, offering relatively stable prices across the board, or implementing a hybrid of both. These strategies serve different consumer segments and reflect retailers' efforts to align pricing with shoppers' needs and preferences.

A well-established classification in this context is the spectrum from ***Everyday Low Pricing (EDLP)*** to ***Hi-Lo pricing***, as documented by Hoch, Drèze, and Purk (1994). EDLP involves maintaining consistently low prices with limited promotional activity and targets consumers who face higher travel costs or are less informed about prices. These consumers prefer to complete their shopping in a single trip and seek reliability across product categories (Bliss 1988). In contrast, Hi-Lo pricing relies on frequent and deep discounts to attract more price-sensitive, informed consumers who are willing to shop across multiple stores and time their purchases around promotions (Lal and Rao 1997). Bell and Lattin (1998) find that Hi-Lo formats tend to appeal to shoppers making smaller, more frequent trips. Importantly, retailers use EDLP and Hi-Lo not only as promotional tools but also as broader store positioning strategies. Ellickson and Misra (2008) argue that while pricing strategies are central to store identity, they function more as coordination mechanisms within broader operational and marketing systems rather than as tools of sharp differentiation.

Drawing inspiration from this literature, we show that pricing strategies in gasoline retailing exhibit an analogous spectrum, ranging from high-price consistency to high-frequency price variation. Using a machine learning approach, we identify three distinct pricing paradigms that vary systematically across gas stations and market environments. At one end of the spectrum is a segment we term ***Everyday High Price (EDHP)***—stations that maintain stable but elevated prices. At the other end are ***Volatiles***, which change prices frequently and exhibit substantial variability. Most stations lie along a continuum between these two extremes. These paradigms reflect differences in how firms manage costly price changes to attract different types of consumers.

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Chapter 3 - Retailer Pricing Under External Shocks: Carbon Tax vs. Wholesale Price

Introduction

The impact of tax on retail prices has been a classical academic research topic due to its importance to consumers, firms, and the economy. Taxes increase the prices of goods, change the quantity demanded, and impact buyers and sellers by changing the surplus accruing to each (Bishop 1968). They can be used as mechanisms to reduce the consumption of goods whose production results in negative externalities (Carlton and Loury 1980). The effect of taxes on reducing demand is well established (Claudy et al. 2021; Feldman and Ruffle 2015) , but the literature on taxes' impact on retailers' price competition strategies is sparse.

Implementing Canada's carbon tax on gasoline market has sparked considerable controversy in recent years, leading to public protests, heated parliamentary debates (Wherry 2024), and even threats of a no-confidence vote ("'We've had enough'"). While much of the discourse has centered on the burden imposed on consumers, the tax also presents significant pricing challenges for retailers, who must determine how to incorporate its effects into their pricing strategies. Existing studies indicate the complexity within the tax pass-through process. Retail price increases resulting from the tax can vary, being less, equal, or even more than the actual amount of the tax levied (Besley and Rosen 1999). However, the relevant empirical literature has largely concentrated on the demand-side effects of such taxes, with limited attention to how retailers adapt their pricing in response. Moreover, many studies rely on simplifying assumptions—such as homogeneous consumer sensitivity to price changes (Carlson and McAfee 1983)—that overlook the heterogeneity in consumer behavior and the strategic complexity retailers face. In reality, consumers vary in their responsiveness to price changes, and gas stations must adapt their pricing based not only on evolving consumer attitudes but also on local market competition. Despite this, few studies have examined the actual mechanisms through which retailers adjust prices in response to external cost shocks.

Beyond carbon tax imposition, other external factors—most notably fluctuations in wholesale gasoline prices—routinely affect both the cost structures faced by gas stations and consumer expectations about price changes. A growing body of research has examined how upstream cost shocks influence retail pricing behavior. For example, Borenstein, Cameron, and Gilbert (1997) and Borenstein and Shepard (2002) show that wholesale price changes are often passed through to retail prices in an asymmetric manner, with prices rising more quickly than they fall. Similarly, Johnson (2002) highlights the role of consumer search frictions in shaping the pass-through of cost shocks. While these studies contribute important insights into the effects of production costs on pricing, they tend to focus on pass-through rates rather than contrasting the effects of different cost shocks.

As a result, it remains unclear whether—and how—different types of external shocks, such as carbon taxes and wholesale price fluctuations, elicit distinct strategic responses in retailer pricing. Specifically, the literature offers limited insight into how firms adjust their pricing in response to shocks that differ not only in economic magnitude but also in their informational salience and perceived legitimacy. This gap is particularly salient in the gasoline retail sector, where firms operate in high-frequency pricing environments and must respond to both consumer heterogeneity and evolving market conditions.

To address this gap, the present study examines the mechanisms through which two distinct external shocks — carbon tax imposition and wholesale price variation — affect retail prices in the gasoline market.

We develop a theoretical framework to examine how carbon taxation and wholesale gasoline price fluctuations influence gas stations' pricing decisions. Both types of shocks directly affect retail prices by altering stations' cost structures. However, beyond this direct effect, they also reshape consumers' search behaviors, thereby exerting an indirect influence on retail pricing. We posit that carbon taxes and wholesale price changes impact consumer search behavior in systematically different ways, leading to opposing implications for retailer pricing.

Specifically, while the carbon tax increases gas stations' costs and places upward pressure on retail prices, it also enhances price salience, prompting consumers to engage in more extensive search activity. This increase in search intensity raises the proportion of informed consumers in the market, compelling retailers to price similarly to each other. As consumers become more likely to compare prices across stations, firms face stronger incentives to price competitively to retain demand. As a result, the degree of tax pass-through to final retail prices is reduced relative to a scenario in which consumer search behavior is held constant. In this way, increased consumer search mediates the effect of the carbon tax on retail pricing outcomes.

Furthermore, the effect of external shocks on increased consumer search is moderated by market structure, particularly by the number of competing firms. When more firms are in the market, the marginal benefit of search goes down for each additional search committed by the retailer, reducing the incentive to search in areas with a larger number of competitors. Thus, although the carbon tax stimulates greater consumer search activity, the extent to which this leads to increased consumer search and intensified retail price competition depends on the interaction between consumer behavior and market structure. In markets with many firms, increased search may not fully translate into lower prices if firms adjust their strategies to exploit less-informed segments.

In contrast, increases in wholesale gasoline prices typically do not trigger a comparable rise in consumer search activity. Consumers often perceive wholesale price fluctuations as transitory and routine, and are therefore less inclined to engage in active price comparison in response to such shocks. Moreover, they may expect that retail prices driven by wholesale cost increases will decline once wholesale prices fall, reducing the urgency to search. As a result, the consumer response is generally muted, leading to a lower proportion of informed consumers in the market and, consequently, weaker price competition among retailers. Similar to the carbon tax context, when the number of competing firms is high, the marginal benefit of each additional search is lower, resulting in some firms choosing to price higher to exploit this tendency in consumers.

To address the research question and test our hypotheses, we collected hourly price data for regular-grade gasoline from 79 gas stations in Hamilton, covering an eight-week period before and after the implementation of the federal carbon tax. These data were merged with daily city-level wholesale gasoline prices and local market information obtained from Statistics Canada.

While both the carbon tax and wholesale price increases exert upward pressure on retail prices, we find that they produce contrasting effects on consumer search intensity and, consequently, on the retail prices. For the carbon tax, overall, 3.90 cents per liter is passed on to consumers from the 4.40 cents originally levied, equivalent to a pass-through rate of over 88%. The overall impact is composed of the direct and indirect effects of the tax on price. The direct tax effect on retail price is 3.93 cents per liter. Besides, the tax indirectly influences pricing via its impact on consumer behavior: by increasing price salience, the carbon tax leads to greater consumer search activity, which in turn intensifies price competition. This effect is captured by a decline in market-level price dispersion of 0.48 cents per liter. The reduction in dispersion yields a secondary effect on pricing: retail prices are approximately 0.03 cents per liter lower than they would be in the absence of increased search, resulting in the overall tax pass-through of 3.90 cents per liter. This reflects the mediating role of price competition in the pass-through process.

In contrast, increases in wholesale prices are associated with a decline in consumer search intensity. Consumers tend to perceive these shocks as transitory, weakening their incentive to compare prices across stations. This reduction in search activity is reflected in a modest increase in price dispersion of 0.02 cents per liter, suggesting a softening of price competition. As a result, the indirect effect of wholesale price increases on retail pricing is minimal, with only 0.001 cents added to the retail price for each 1-cent rise in wholesale cost. The primary driver of retail price adjustment is the direct pass-through: on average, 0.94 cents of each 1-cent increase in wholesale price is passed on to consumers.

Moreover, we find that the relationship between cost shocks and price dispersion is moderated by local market structure. In markets with a larger number of competing stations, the carbon tax's effect on consumer search intensity is amplified. This is because the consumers expect a more complicated variation in retail prices and are more willing to engage in price search activities. The amplified consumer search intensity causes more price competition among the gas stations and further reduces price dispersion. We find price dispersion due to carbon tax declines by 0.09 cents per litre for each additional competitor in the area.

In contrast, wholesale price fluctuations are a regular occurrence and are generally perceived by consumers as transitory. Retail price variation stemming from these fluctuations reduces consumers' price sensitivity and dampens their incentive to engage in active price search. A higher number of gas stations in a local market adds to price complexity. When wholesale prices rise, consumers in such markets are more inclined to treat the price variation as temporary, creating an opportunity for retailers to raise prices. Our empirical results show that for every 1-cent increase in wholesale gasoline prices, price dispersion increases by 0.01 cents per liter for each additional competitor in the local market.

This study develops a comprehensive understanding of how different external shocks influence pricing dynamics in the retail gasoline market. We identify and test the mechanisms through which specific shocks—namely, carbon taxation and wholesale price fluctuations—reshape the intensity of consumer search, which in turn affects retailer pricing decisions. The carbon tax raises firms' costs and retail prices, but also increases price salience, prompting greater consumer search activity. This intensification of search enhances competition among retailers and moderates the degree of pass-through to final consumers. In contrast, wholesale price increases, though economically similar in terms of cost impact, reduce consumer search intensity and reshape retailer pricing.

While standard economic theory treats tax imposition and wholesale cost increases as similar shocks—both raising marginal cost and thus retail prices—we demonstrate that they can have divergent competitive effects. Our findings show that similar upstream cost increases do not necessarily elicit similar strategic responses. Specifically, the carbon tax leads to tighter price competition, while wholesale price increases result in looser competition, due to differences in how each shock shapes consumer behavior and firm incentives.

The remainder of the paper is structured as follows: In the next section, we review the relevant literature and subsequently discuss the context of the carbon tax in Canada. The following section is devoted to developing a theoretical framework and the hypotheses we want to test. The succeeding section details the data and the methodology used to test our framework. The study's results are then discussed, and their implications are explained in the discussion section. The final section concludes the paper.

Relevant Literature

Two streams of literature in Marketing and Economics are pertinent to this research. The first examines the relationship between tax policy and market competition. The second assesses the connection between consumer search behavior and price dispersion. We will examine each in turn.

The first stream of relevant literature comes from public economics and focuses on the relationship between tax policy and market competition. Sumner (1981) and Sullivan (1985) examine differences in excise taxes among states in the U.S. and find firm pricing consistent with that in highly competitive markets. In the U.S. brewing industry, Rojas (2008) studies firm pricing in the period before and after the doubling of excise taxes in the beer market and finds firm pricing consistent with predictions from Bertrand competition. Hamilton (2009) shows that under certain conditions, tax imposition can result in increased price competition among firms. In the empirical literature on gasoline markets, Doyle and Samphantharak (2008) observe stations in two Midwestern states before a tax holiday and after its subsequent reinstatement. They find that the change in tax policy increases competition for gas stations situated at the borders with States where tax policy is unchanged. Alm, Sennoga, and Skidmore (2009) compare taxes on gasoline in different states in the U.S. and note differences among them in terms of the amounts passed through to consumers. They suggest that a higher degree of competition in urban states likely results in different tax pass-through rates observed between rural and urban states. Our study adds to this body of work by providing evidence that carbon tax implementation intensifies price competition and by articulating the consumer search mechanism through which this effect operates.

The second relevant stream of literature examines the relationship between consumer search behavior and price dispersion in retail gasoline markets, a topic that has been widely studied in both Economics and Marketing. Since Stigler's (1961) seminal paper observing price dispersion in homogeneous good markets and his suggestion of incomplete information as its rationale, a vast literature in economics and marketing has developed around testing theories of price dispersion to that observed in the market (Marvel 1976; Baye, Morgan, and Scholten 2006; Pennerstorfer et al. 2020). The theoretical literature proposes product differentiation and consumer search as the two main explanations for observing price dispersion in the market. In product differentiation models, price dispersion results from consumers' preferences for a particular product (Perloff and Salop 1985; Barron, Taylor, and Umbeck 2004). In contrast, those of consumer search predict price dispersion due to heterogeneity in consumer information sets regarding prices in the market (Salop and Stiglitz 1977; Burdett and Judd 1983). The empirical literature on price dispersion and consumer search in gasoline markets relevant to our research explores the relationship between price dispersion and the density of competitors in a local market where consumers have heterogeneous search costs. The findings in the literature regarding the role of the number of competitors in the local market affecting price dispersion are mixed. Considering the effect of local competitors, Lewis (2008) finds that gas stations frequently change prices and that the density of competitors is negatively related to price dispersion. Iyer and Seetharaman (2008) find that gas stations in densely clustered markets, i.e., those which face more rival firms in their market, display a greater range of prices compared to stations in less clustered markets. Regarding the impact of wholesale price changes on price dispersion Chandra and Tappata (2011), and Lewis and Marvel (2011) find lower price dispersion in markets when wholesale prices increase. Lewis (2011) observes an increasing effect of wholesale price on price dispersion in the market. Our study adds to this literature by examining the impact of carbon taxation. We find that carbon tax implementation reduces price dispersion across markets, though this effect is attenuated in markets with more competitors. Conversely, wholesale price increases are associated with greater price dispersion, highlighting a contrasting consumer response to different cost shocks.

Context around carbon tax in Canada

Finland was the first country to introduce a carbon tax in 1990, paving the way for similar policies across Europe. Sweden, Denmark, the Netherlands, and Norway soon followed with their own versions of carbon pricing. In North America, early adopters included Boulder, Colorado, and the province of Quebec, both of which implemented carbon taxes in 2007, followed by British Columbia in 2008 and Montgomery County, Maryland in 2010 (Xiang and Lawley 2019). Globally, the 2015 Paris Agreement—signed by 194 countries—reinforced the commitment to pricing carbon emissions, either through tradable emission permits or direct carbon taxes (Andersson 2019).

In Canada, the federal government mandated a carbon tax in provinces that had not enacted their own emissions pricing mechanisms. Effective April 1, 2019, the federal backstop applied to Manitoba, New Brunswick, Saskatchewan, and Ontario, introducing a levy on gasoline and other fossil fuels to penalize carbon emissions. In Ontario, the initial surcharge was 4.4 cents per liter in 2019. The tax had been designed to increase annually each April, reaching 17.71 cents per liter in April 2024, with scheduled increments continuing until it reaches 37.43 cents per liter by 2030 ("Doug Ford slams April carbon tax hike | CP24.com" 2024). In April of 2024, the federal government scrapped the highly unpopular carbon tax.

Despite its significant public visibility, the carbon tax in Ontario was not applied at the point of sale. Instead, the transfer of the carbon tax to the government occurs through gasoline distributors, who are taxed based on the quantity sold and are tasked with remitting the tax to the government. The price at which distributors sell gasoline to gas stations already includes the carbon tax, and retailers then determine the extent to which this increased cost is passed on to consumers (www.mnp.ca). Thus, retailers play a crucial role in this transmission process.

The carbon tax became a contentious issue during the 2019 Canadian election and resurfaced in political debates in 2024. The primary opposition party advocated for the abolition of the carbon tax to alleviate the burden of rising gasoline and heating fuel prices on the public, already contending with escalating living costs. Our study looks at the carbon tax's impact on retailer pricing, which has a direct impact on consumer welfare. While gasoline taxes do reduce consumer welfare (Bento et al. 2005) price competition can mitigate its effects by tempering the amount of tax passed through to consumers.

Theoretical Framework and Hypotheses Development

Theoretical Framework

We now develop a framework to evaluate the impact of two external cost shocks on retailer pricing: a carbon tax and wholesale price fluctuations. The impact of these two shocks can be understood in terms of a direct and an indirect effect. The direct effect of both the wholesale price increase and tax imposition is to raise the cost for retailers, which is then passed on to consumers in terms of higher prices.

The indirect effect of the cost shocks on retailer pricing occurs by changing consumers' search behavior. According to search theory, a market is split between consumers with price information known as “informed” consumers and those who do not possess this information, i.e., “uninformed” consumers (Varian 1980). Informed consumers incur a search cost to acquire pricing information and make purchases at the lowest available price; uninformed consumers opt for convenience, purchasing from a firm of their convenience. The intensity of consumer search is the proportion of consumers who choose to become informed about prices.

The search intensity in the market affects retailers' pricing since retailers can either price low to attract informed consumers or charge a monopoly price to uninformed consumers. A higher proportion of informed consumers, i.e., higher search intensity, makes it unattractive to charge a monopoly price since there is a smaller set of uninformed consumers to exploit. Furthermore, the number of firms in the market affects consumers' search intensity because a larger number of firms in the market means that consumers expect higher competition. So the marginal gains from search are lower. Based on this framework, we develop our hypotheses next.

Hypotheses Development

The first two hypotheses concern the direct effects of the carbon tax and wholesale prices, while subsequent hypotheses (H3-H7) concern the indirect effects. Both the carbon tax and wholesale price increases raise gas stations' gasoline costs. Therefore, they are expected to push up the retail prices in the market.

H1: Carbon tax imposition increases the retail price in the market.

H2: Wholesale price increases raise the retail price in the market

The introduction of a carbon tax represents a rare, exogenous shock to the gasoline market that alters consumers' expectations on market prices and incentivizes more low-price search activity. Anticipating the increase of retail prices, the marginal consumer —who were previously indifferent between searching and purchasing immediately—are now more likely to engage in active price search. This shift increases the proportion of informed consumers in the market—those who are aware of which stations offer lower prices. As search intensity rises, retailers face a reduced share of uninformed consumers and, consequently, greater pressure to price competitively. In response, prices converge, resulting in reduced price dispersion following the carbon tax implementation.

H3: Consumer search intensity in the market increases after the imposition of the carbon tax.

In contrast, wholesale price fluctuations are a routine feature of the gasoline market and are typically perceived as part of normal supply-side dynamics. Retailers regularly adjust prices in response to daily or periodic changes in wholesale costs. However, because such adjustments are expected and frequent, they are less likely to attract consumer attention or prompt active search behavior. As a result, the proportion of informed consumers—those who monitor price movements and compare across stations—remains relatively low. Furthermore, when retail prices rise in the context of wholesale volatility, consumers often interpret these changes as temporary and may delay purchases in anticipation of future price declines. This dampens the incentive for consumers to search actively and, in turn, reduces competitive pressure on retailers. Consequently, firms face less pressure to converge on a uniform price, increasing price dispersion.

H4: Consumer search intensity in the market decreases with increases in wholesale price

As the proportion of informed consumers increases in the market, retailers find it increasingly harder to price differently from other stations. The proportion of uninformed consumers who can be charged a high price shrinks, and the market becomes more competitive, driving down the retail price (Brown and Goolsbee 2002; Cachon, Terwiesch, and Xu 2008).

H5: Retail price in the market decreases with increased consumer search

As the carbon tax is imposed and more consumers choose to become informed, the search intensity increases, but this increase is not uniform across markets. The search intensity is affected by the number of firms in a market. In a market characterized by a greater density of competitors, consumers typically anticipate more vigorous competition, resulting in diminished marginal gains from search activities. Nevertheless, the imposition of a carbon tax is a prominent event that generates uncertainty regarding changes in price distributions. Consumers anticipate that the tax will be passed, but they are uncertain of the amount each retailer will pass. The greater the number of competitors, the higher the uncertainty about changes in pricing, consequently promoting more extensive search behaviors due to carbon tax imposition in areas with a higher concentration of competitors.

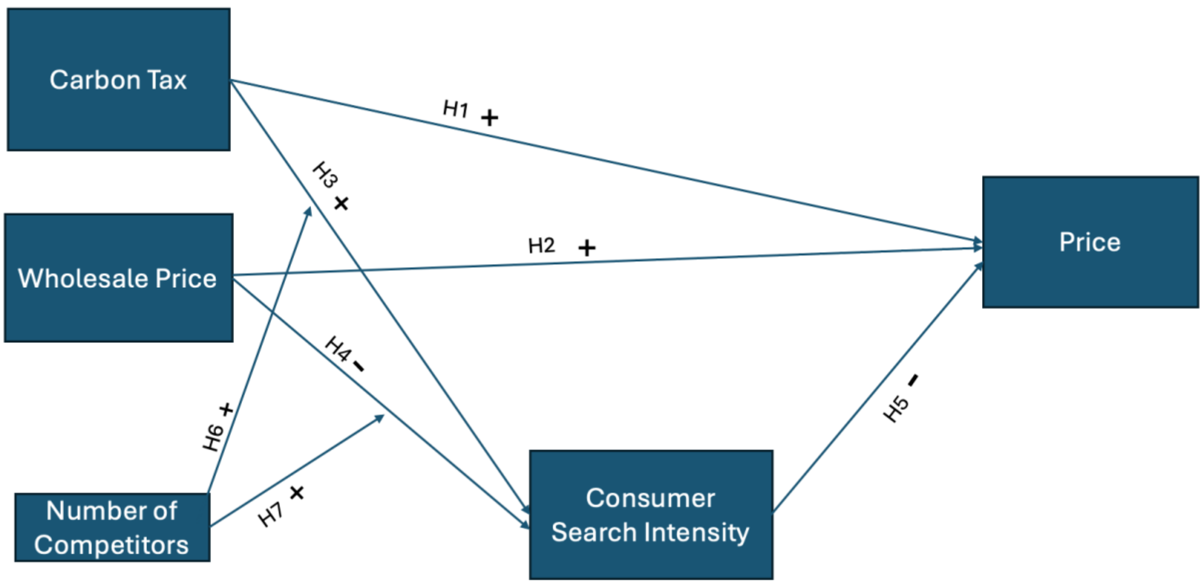
H6: The effect of the carbon tax to increase consumer search intensity becomes stronger in areas with a larger number of competitors

The effect of wholesale price increases on consumers' search intensity is also moderated by the number of competitors in the market. For consumers, increases in wholesale prices may be seen as part of regular wholesale volatility, and they may anticipate future wholesale prices to decline. This makes it more attractive for consumers to delay their search and reduce current search intensity (Tappata 2009). Consumers in the markets with a higher number of rival firms expect lower marginal gains from search. Given that we expect wholesale price increases to depress consumer search, a higher number of competitors in the area will lead to further decreasing consumer search intensity in the market.

H7: The effect of wholesale price increases to reduce consumer search intensity becomes stronger in areas with a larger number of competitors

Figure 3.1 summarizes the theoretical framework used to analyze the effect of two different external shocks on retailer pricing.

Figure 3.1 Theoretical Framework for Direct and Indirect Effects of Carbon Tax and Wholesale Price on Retail Price



Data and Methodology

Data and Variables

In this study, we collected hourly gas price data from 79 gas stations in Hamilton, Ontario, Canada in 2019. The dataset covers all gas stations in the city. The real-time gas price data for each station was sourced from Google, which obtains its information from the Oil Price Information Service (OPIS). OPIS is a widely used data source in Marketing and Economics studies on gasoline prices (Nishida and Remer 2018). A carbon tax was imposed on the gasoline market on April 1st, 2019. We utilized 16 weeks of gas price data: eight weeks before the tax imposition and eight weeks after it. We obtained the latitude and longitude coordinates for each station from Google Maps to calculate the distance between gas stations and assess the level of local competition. Furthermore, we collected daily wholesale gasoline prices for the city of Hamilton provided by Suncor Energy. Table 3.1 presents the key variables in our data that will be used in our empirical analysis.

Table 3.1 Descriptive Statistics – Retail Gasoline Market Hamilton

	Mean	Std Dev
Retail Price – Regular Grade Gasoline (cents/liter)	112.59	11.58
Wholesale Price ((cents/liter))	69.61	9.93
Carbon Tax Dummy	0.5	0.5
Number of competitors within 1.5 km	3.00	2.61
Price Dispersion in Local Markets – (cents/liter)	3.25	2.10
Total Number of Gas Stations	79	-
Total Number of Local Markets	79	-

Across local markets in Hamilton over the 16-week observation period, the average price dispersion—measured as the standard deviation of retail prices—was 3.25 cents per liter. During the same period, the average retail price of regular-grade gasoline across all gas stations was 112.71 cents per liter, while the average wholesale price was 69.61 cents per liter. On average, each local market contained approximately three competing gas stations, reflecting the localized nature of retail competition in this setting.

Given that competition in the gasoline sector is highly localized, we define each gas station's market as the area within a 1.5-kilometer radius, following the approach used in prior research (Chandra and Tappata 2011). We use the standard deviation of retail prices within a local market to measure consumer search intensity. The smaller this number, the higher the search intensity.

Model Specification

We have a panel of 79 gas stations that will be used to test our hypotheses. The Hausman test results suggest that we use the fixed effects estimator, which will allow us to control for observed and unobserved time invariant variables that may affect the impact price. Equation (1) assesses the overall effect of the carbon tax and wholesale price on expected retail price in market j, accounting for time and station fixed effects. α_j is the time-invariant station fixed effect for station j, which controls for station-specific features at individual gas stations. Our data is collected each hour so we control for shocks to retailers based on time of the day along with controlling for the effect on price due to day of the week represented by γ_t and θ_t respectively. The Tax_t variable is an indicator which is 0 during the period the tax was not implemented and 1 otherwise. ϵ_{jt} represents the idiosyncratic error term for individual gas stations each hour. The standard errors are clustered at individual gas station levels to provide heteroskedasticity and autocorrelation robust errors across all regressions.

$$RetailPrice_{jt} = \beta_0 + \mathrm{B}_1\mathrm{WholesalePrice}_t + \mathrm{B}_2 Tax_t + \alpha_j + \gamma_t + \theta_t + \epsilon_{jt} \text{ ----- (1)}$$

To calculate the indirect effect of the carbon tax on retailer pricing, we follow the process to test the mediation effect of consumer search intensity on retail prices and the moderating effect of wholesale price and carbon tax on consumer search intensity (Muller, Judd, and Yzerbyt 2005; Kalaignanam, Kushwaha, and Rajavi 2018). To test the mediation effect, we first regress the retail price in a market on wholesale price and the carbon tax as in Equation 1. We then regress our measure of consumer search intensity i.e. we regress price dispersion on wholesale price and carbon tax along with the relevant controls (Equation 2). As the final step in assessing the mediation effect of consumer search intensity on retail price we regress the retail price on carbon tax and wholesale price and control for the search intensity in the last period (Equation 3). The indirect effect of the carbon tax on retail price is the product $\beta_5 * \beta_9$. The indirect effect of the wholesale price is obtained by the product $\beta_4 * \beta_9$.

$$PriceDispersion_{jt} = \beta_3 + \beta_4 \mathrm{WholesalePrice_t} + \mathrm{B}_5 Tax_t + \alpha_\mathrm{j} + \gamma_t + \theta_\mathrm{t} + \epsilon_{jt} \text{ -- (2)}$$

$$RetailPrice_{jt} = \beta_6 + \beta_7 \mathrm{WholesalePrice_t} + \mathrm{B}_8 Tax_t + \beta_9 \mathrm{PriceDispersion_{t-1}} + \alpha_\mathrm{j} + \gamma_t + \theta_\mathrm{t} + \epsilon_{jt} \text{ ----------- (3)}$$

To gauge the moderating impact of the number of competitors on the effect of wholesale price and carbon tax on consumer search intensity we use Equation 4.

$$PriceDispersion_{jt} = \beta_{10} + \mathrm{B}_{11} \mathrm{WholesalePrice_t} * \mathrm{Competitors_t} + \mathrm{B}_{12} Tax_t + \alpha_\mathrm{j} + \gamma_t + \theta_\mathrm{t} + \epsilon_{jt} \text{ ------------------- (4)}$$

Results

Table 3.2 Results

Dependent Variable	Retail Price	Price Dispersion	Retail Price	Price Dispersion
	IV -> DV	IV -> Me	IV + Me -> DV	Mo -> Me
	(1)	(2)	(3)	(4)
Day of Week Effect	✓	✓	✓	✓
Hourly Effect	✓	✓	✓	✓
Wholesale Price	0.94**	0.02**	0.94**	-0.02**
Tax	3.90**	-0.48**	3.93**	-0.16
Wholesale*Competitors	-	-	-	0.01**
Tax*Competitors	-	-	-	-0.09**
Price Dispersion	-	-	0.07*	-
Intercept	43.69**	1.81**	43.70**	1.82**
N	171,584	171,584	171,584	171,584
R sq	93.85%	6.14%	93.86%	7.10%

IV – Independent Variable, Me – Mediator, Mo – Moderator, DV – Dependent Variable

*Significant at 10%, **Significant at 5%

Each column in Table 2 represents a separate regression. Columns (2) and (4) employ price dispersion as the dependent variable (DV), which is the measure of consumer search intensity and is calculated as the standard deviation of the prices in the local markets at each hour. Columns (1), and (3) test for independent variable (IV) effects on average retail price. Column (1) shows the regression outcomes of Equation 1 (the overall impacts of the carbon tax and wholesale price on gas station retail prices). The results support both H1 and H2. For the overall effect of the carbon tax on retail price, we see that out of a 4.4 cents per liter levy, more than 88% is passed through to consumers (3.90 cents per liter). It also shows that for every one-cent increase in the wholesale price, the retail price rises by 0.94 cents. Column (2) shows the outcome of Equation 2 (The carbon tax's and wholesale price's impact on price dispersion in local markets). The carbon tax significantly reduces price dispersion by 0.48 cents per liter. This supports the hypothesis H3, indicating that consumer search intensity in the market has increased due to the tax, which is reflected in lower price dispersion. Column (2) also supports H4, which states that consumer search intensity declines slightly with increasing wholesale prices. Although the magnitude of the effect of the wholesale price on price dispersion is small (0.02), it is highly statistically significant, implying that gas stations can exploit daily wholesale price changes to reduce consumer search, which would help to soften price competition among gas stations.

Column (3) shows the outcomes of Equation 3, supporting the hypothesis H5 that increasing search intensity decreases retail price. If the increased consumer search intensity reduces price dispersion by 1 cent, the effect on retail price is to lower it by 0.07 cents.

Given the estimated parameters in Columns (2) and (3), we can calculate the indirect effect of the carbon tax and wholesale price on retailer pricing. Specifically, the indirect effect of the carbon tax via consumer search intensity is -0.48 * 0.07 = -0.03 (the Sobel test statistic is marginally significant at $p < 0.10$). Therefore, the indirect impact of the tax is -0.03 cents per liter. The indirect effect is the reduction in tax pass-through because the carbon tax induces consumers to search more, making the market more competitive. The effect is small, around 1% of the total carbon tax levied on gasoline, but it is statistically significant. Column (3) shows that the direct effect of the carbon tax is 3.93 cents per liter. Hence, its overall effect 3.90 cents shown in Column (1) equals the sum of its direct effect (3.93 cents) and indirect effects (-0.03 cents). Similarly, the indirect impact of the wholesale price is also quite small but statistically significant (0.02 * 0.07 = 0.0014, the Sobel test statistic is marginally significant $p < 0.10$).

Lastly, Column (4) illustrates the moderating effect of the number of competing stations in the market on consumer search. As the number of competitors increases in the market, the carbon tax's effect on consumer search intensity is amplified. For each additional competitor in the market, consumer search intensity increases, which reduces price dispersion by 0.09 cents per liter (H6). For wholesale prices, the moderating effect is also significant (H7). A higher number of competitors in the market reduces consumer search intensity and raises price dispersion by 0.01 cents per liter for each additional competitor in the local market.

Discussion

The findings reported in the previous section have implications for our understanding of the effects of external shocks on retailers' pricing strategies. The main finding from the last section shows that similar shocks may have different reactions from consumers and firms. From a firm's point of view, both a tax increase and a wholesale price increase are increases in production costs. Still, retailers adapt to react differently to each of these changes due to consumers' search reactions being different. Introducing a carbon tax increases consumer search, while increases in wholesale price are likely to reduce incentives for consumer search, resulting in different subsequent pricing reactions from retailers. Wholesale prices are volatile, and frequent changes in them result in retailers making frequent adjustments to their own prices. The volatility makes consumers' information sets regarding prices in the market obsolete much faster, thereby deterring search.

Contrasting the effect of wholesale price changes on consumer search to that of the carbon tax has another important implication: One-time shocks to the market are effective at disrupting equilibrium search behavior in the market. Given that this particular shock is in the form of a tax, it is much more likely to impact behavior because research shows that consumers are far more averse to price changes from taxes than those due to equivalent changes from other factors (Sussman and Olivola 2011). Furthermore, although our study only considers a period of 16 weeks, such shocks can have long-lasting impacts on the competitive changes in the market. Findings from the Australian retail gasoline market suggest that a one-time shock to the gasoline market (gas station chain acquisition by a rival chain) permanently changes consumers' search behavior (Byrne and Nicolas de Roos 2022).

It is interesting to note from the previous section that while the results are statistically significant, the effect sizes are small. However, this masks an important facet of gasoline sales. The market is competitive, and margins are small. According to Statistics Canada, gasoline sales in Ontario in 2023 amounted to nearly 16 billion litres. This means that while effect sizes for price will be small for consumers and barely noticeable in some cases, the large volumes sold could result in substantial revenue effects for firms.

Conclusion and Future Research

This research examines how carbon taxation and wholesale price fluctuations distinctly impact retail gasoline pricing through their effects on consumer search behavior and competitive dynamics. While both the carbon tax and wholesale price increases raise retail prices, they operate through different mechanisms. The carbon tax not only raises firms' costs directly but also indirectly increases consumer search intensity by making prices more salient, which in turn intensifies price competition and reduces tax pass-through. In contrast, wholesale price increases are perceived by consumers as routine and temporary, thereby reducing search intensity and softening competition. The study uses detailed price data from Hamilton, Ontario, around the carbon tax's implementation, showing that more than 88% of the tax is passed through to retail prices. However, increased consumer search lowers price dispersion by 0.48 cents/liter, mediating the final retail price by 0.03 cents/liter. Conversely, wholesale price hikes increase price dispersion by 0.02 cents/liter. The findings challenge the conventional view that all supply-side cost increases yield similar market outcomes, highlighting how consumer behavioral responses fundamentally shape competitive dynamics.

This study introduces avenues for further research. For instance, while our analysis focuses on the short-term effects of the carbon tax on price competition, it is essential to recognize that policies can wield differing impacts over the short and long term. Future investigations could explore how taxes influence retailer pricing and competition dynamics over the long term. Moreover, although we find the effect of a specific type of tax on consumer search and hence on price competition, it would be helpful to understand the impact of different kinds of taxes on price competition. Subsequent research could elucidate how taxes influence non-price competition among retailers, providing valuable insights into broader market dynamics.

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Chapter 4 - Pricing Paradigms in Retail Gasoline: A Machine Learning Approach

Introduction

Pricing has been investigated extensively in economics and marketing. While most extant research has focused on optimal price level and price dispersion (Barron, Taylor, and Umbeck 2004, Lewis 2008, Noel 2018), price adjustment —such as the frequency and timing of price changes — has received comparatively limited attention. Firms routinely adjust prices following discernible patterns in many retail sectors, such as supermarkets, big-box retailers, and gas stations. For example, retailers strategically design price alterations to match peak hours, undercut rivals, fuzz customer purchase behaviors, or discriminate between price-sensitive and price-insensitive customers. While retailers clearly integrate concerns about price levels, variability, and timing in their pricing strategies, the academic literature has yet to fully explore such integration and background rationales, especially in highly competitive environments.

The majority of the pricing literature focuses on optimal pricing decisions under static market conditions, including various forms of price discrimination based on consumer heterogeneity (Mussa and Rosen 1978; Stokey 1979; Varian 1985; Varian, Hal R. 1989; Shaffer and Zhang 2000; Armstrong and Vickers 2001) and price competition models based on differing market structures, such as Cournot competition driven by output decisions (Cournot, A. 1838), Bertrand competition with homogeneous goods (Bertrand J.L.F. 1883), and frameworks incorporating horizontal and vertical product differentiation (Hotelling, H. 1929; Perloff and Salop 1985; Moorthy 1988; Shepard 1991). However, retail markets are rarely static. In practice, firms operate in dynamic environments where demand conditions and competitor prices fluctuate frequently. Under such conditions, pricing decisions must be adaptive and forward-looking. Moreover, rather than determining a single, fixed optimal price, firms must formulate broader pricing strategies that evolve over time in response to changing market conditions and strategic interactions with rivals.

This paper defines the routine that a retailer follows in dynamically adjusting prices over time as a ***pricing paradigm***. We seek to identify the pricing paradigms employed by retailers in the gasoline market as part of their broader dynamic pricing strategies. More specifically, we ask: What constitutes a pricing paradigm — what features or dimensions are critical for retailers' dynamic pricing routines? What are the typical pricing paradigms observed in the retail gasoline sector? And what market conditions influence a retailer's choice of paradigm?

To address the above research questions, we investigate gas stations' pricing paradigms in the retail gasoline market. The retail gasoline market is an ideal context for investigating retailers' pricing paradigms because the market is highly dynamic. Retailers have to make pricing decisions repeatedly and frequently, and the market situation fluctuates with intensive competition. We begin by examining retail gasoline price data to uncover the composition of gas stations' pricing paradigms. Our data consists of hourly prices for regular-grade gasoline from all stations in Hamilton, Ontario, collected from February to December 2019. Based on insights from prior research, we extract nine relevant pricing features from each gas station's price series. We then conduct a factor analysis to identify underlying pricing dimensions, revealing three central components: ***price level***, ***price variance***, and ***price adjustment frequency***. These dimensions serve as the foundation for defining each station's pricing paradigm.

To classify gas stations into distinct pricing types, we perform cluster analysis on the extracted factor scores. The analysis yields three robust and interpretable pricing paradigms. The first, which we term ***Volatiles***, features a low average price, but high variance and frequent adjustments. The second group, ***EDHP*** (Everyday High Price), exhibits high prices but minimal variability and rare price changes. The third group, ***Centrals***, falls between the two on all dimensions. These clusters suggest a systematic relationship: gas stations with lower average prices tend to adjust prices more frequently, while those with higher average prices follow more stable pricing routines.

Having established three distinct pricing paradigms, we conceptualize them as lying along a continuum from more variable and operationally complex strategies (e.g., the Volatiles paradigm) to simpler, more stable ones (e.g., the EDHP paradigm). Implementing a highly variable pricing strategy imposes greater managerial and operational costs; thus, firms that are better equipped to manage these complexities are more likely to adopt such strategies. We empirically test this proposition by modeling the likelihood that a gas station adopts one pricing paradigm over another as a function of station- and market-level characteristics. Our results show that gas stations in higher-income neighborhoods, those affiliated with chain brands, and those located in more competitive local markets are more likely to adopt the Volatiles pricing paradigm, characterized by low average prices but high variance and frequent adjustments. In addition, gas stations situated near highways also tend to prefer Volatile pricing over more stable alternatives.

This study identifies three distinct pricing paradigms in the retail gasoline market, offering a ***more structured*** view of retail long-term pricing behavior than previously available. Existing research has largely focused on detecting cyclical patterns in certain regional markets or concluded that retail pricing appears random, with no discernible structure. In contrast, we apply a machine learning approach to extract three core dimensions of pricing behavior: price level, price variance, and price adjustment frequency. These dimensions allow us to position gas stations along a spectrum of pricing paradigms—from "simpler" and more stable strategies to more dynamic and volatile ones. Moreover, we explore gas stations' choice of pricing paradigm based on market conditions and station-level characteristics.

The remainder of the paper is structured as follows: The next section covers the relevant literature, after which we summarize the data and identify the pricing paradigms. The following sections develop a theory to explain these pricing paradigms and develop hypotheses to test the theory based on gas station and market characteristics. The subsequent section discusses the results of the hypothesis testing and ends with a conclusion.

Literature Review

This study contributes to and extends two primary streams of literature. The first stream investigates the existence and nature of pricing patterns in the retail gasoline industry. Given the central role that price competition plays in shaping market outcomes, a considerable body of research has been devoted to analyzing gasoline markets to determine whether gas stations exhibit systematic pricing behaviors that could reveal insights into their competitive strategies. The broader literature on gasoline pricing largely concludes that, in many markets, gasoline prices do not adhere to easily identifiable or consistent patterns (Lewis 2008; Hosken, McMillan, and Taylor 2008; Taylor, Kreisle, and Zimmerman 2010). Instead, gas station prices tend to fluctuate in a seemingly erratic manner, shifting unpredictably between low and high levels without clear regularity or predictable cyclicality (Lach and Moraga-González 2017). Nevertheless, researchers have identified a subset of markets that deviate from this general finding by exhibiting a particular form of cyclical pricing behavior (Noel 2008). These patterns, referred to as "Edgeworth Cycles," have been documented across various metropolitan and regional gasoline markets in Canada (Eckert and West 2005) and the United States (Lewis and Noel 2011). A distinctive sequence characterizes Edgeworth Cycles: prices escalate sharply over a short period, followed by a gradual and prolonged decline. Once prices reach a trough, they increase rapidly, initiating a new cycle (Maskin and Tirole 1988). This cyclical behavior suggests a form of dynamic competition where firms engage in repeated undercutting followed by sudden upward price adjustments. Outside of these particular instances of Edgeworth Cycles, gasoline pricing does not exhibit discernible or predictable patterns (Chandra and Tappata 2011). Building on this, our study proposes that the characterization of gas station pricing behavior can be further refined. Specifically, we demonstrate that it is possible to identify pricing patterns along multiple dimensions beyond the traditional scope considered in earlier studies. Moreover, we provide evidence that within a given market, gas stations may adopt heterogeneous pricing strategies, manifesting distinct and systematic patterns along these different dimensions. This expanded perspective contributes to a more nuanced understanding of competitive dynamics in retail gasoline markets.

The second stream of literature pertinent to our research examines the complexity and variability of retailers' pricing strategies. Within this body of work, scholars have sought to understand the extent to which retailers vary their prices and the underlying motivations for choosing either complex, variable pricing or more straightforward, more uniform pricing strategies. Researchers have documented instances across various industries where retailers opt for uniform pricing, exhibiting minimal variation across products, locations, or time periods (Cho and Rust 2010; Shiller and Waldfogel 2011). These findings suggest that despite the theoretical advantages of tailoring prices to local market conditions or consumer demand, many retailers maintain stable pricing structures, possibly due to operational simplicity, brand consistency, or consumer expectations. Chu, Leslie, and Sorensen (2011) argue that many stable pricing strategies are chosen because the incremental profit gains achievable through variable pricing are often not substantial enough to outweigh the costs and complexities associated with implementing and managing differentiated pricing across numerous outlets. Thus, uniform pricing emerges as a rational strategy offering a "close enough" profit level relative to the theoretically optimal but more complex variable pricing. DellaVigna and Gentzkow (2019) extend this discussion by demonstrating that retail chains persist in using uniform pricing even when significant heterogeneity exists across stores regarding local price elasticities of demand. Their findings indicate that firms knowingly forgo additional profits that could be captured through tailored pricing in favor of the simplicity and potential non-price benefits associated with uniformity, such as easier advertising, reduced managerial burden, and maintaining a consistent brand image across different markets. Within the gasoline retail market context, Remer (2019) provides related insights by analyzing the frequency of price changes across gas stations. His study finds that independent stations and those operated by smaller firms exhibit lower responsiveness to cost fluctuations or external economic shocks than larger, possibly more sophisticated competitors. Building on and contributing to this literature, our study demonstrates that gas stations can indeed be systematically classified based on the magnitude and variability of their price changes. We show that some stations consistently engage in highly stable, uniform pricing, while others exhibit significant variability and frequent price adjustments. Moreover, we provide evidence that these differences in pricing patterns are linked to specific station-level and market-level characteristics. In doing so, we offer a more detailed understanding of the strategic choices gas stations make in their pricing behavior and the structural factors that may drive the adoption of simpler versus more complex pricing strategies.

Data

This study draws on data from all gas stations operating in Hamilton, Ontario, Canada. Between February and December 2019, we collected hourly retail price data for regular-grade gasoline at each station, resulting in a dataset covering 79 stations with complete pricing histories. We use the hourly price of regular-grade gasoline and develop daily measures for each gas station over 11 months of 2019, from February to December.. These data were obtained from Google, which provides real-time pricing information, as well as details on each station's brand affiliation and physical location. Latitude and longitude coordinates from Google Maps were used to compute distances between stations and to measure the density of nearby competitors. To account for variation in local market environments, we obtained postal code–level demographic data from Statistics Canada. In particular, we aggregated median household income data to reflect socioeconomic conditions across neighborhoods. These station- and market-level variables will be used to estimate the probability of a gas station adopting one pricing paradigm versus another.

Dimensions of Gas Station Pricing Paradigms

To identify gas stations' pricing paradigms, we first determine the critical dimensions of retailers' pricing routines. We first need to extract key features from each gas station's pricing data to determine these dimensions. In this regard, we follow Shankar and Bolton (2004), who identify essential features of retailers' pricing strategy that should be extracted from the data. Their context is the grocery market, and we adopt these features for the gasoline market. They suggest that key features of retailers' pricing include pricing consistency, i.e., the price variance over a given period. Price movement intensity, i.e., by how much and how often prices change. Their third criterion is relative price, which is how far above and below the average the price for a particular unit is. Based on these criteria, we arrive at the following list of features extracted from the data to classify the pricing paradigms. Table 4.1 gives the definitions for each of the extracted features.

Table 4.1 List of Pricing Features

Pricing Strategy Features	Interpretation and implication
Daily.max.p	Maximum price charged by a gas station in a day
Daily.min.p	Minimum price charged by a gas station in a day
Daily.mean.p	Average price charged by a gas station in a day
Daily.var.p	Variance of prices charged by a gas station in a day
Daily.up.depth	Average depth of daily upward adjustment
Daily.down.depth	Average depth of daily downward adjustment
Daily.up.freq	Total number of upward price adjustments in a day
Daily.down.freq	Total number of downward price adjustments in a day
Daily.NA.duration	Total number of hours without price adjustment in a day

To determine the number of factors based on the features in Table 1, we use a parallel analysis scree plot in Figure 4.1 (Williams, Onsman, and Brown 2010). The points above the red dotted line in the plot indicate that the 3-factor solution would be optimal given our features.

Figure 4.1 Optimal Number of Factors

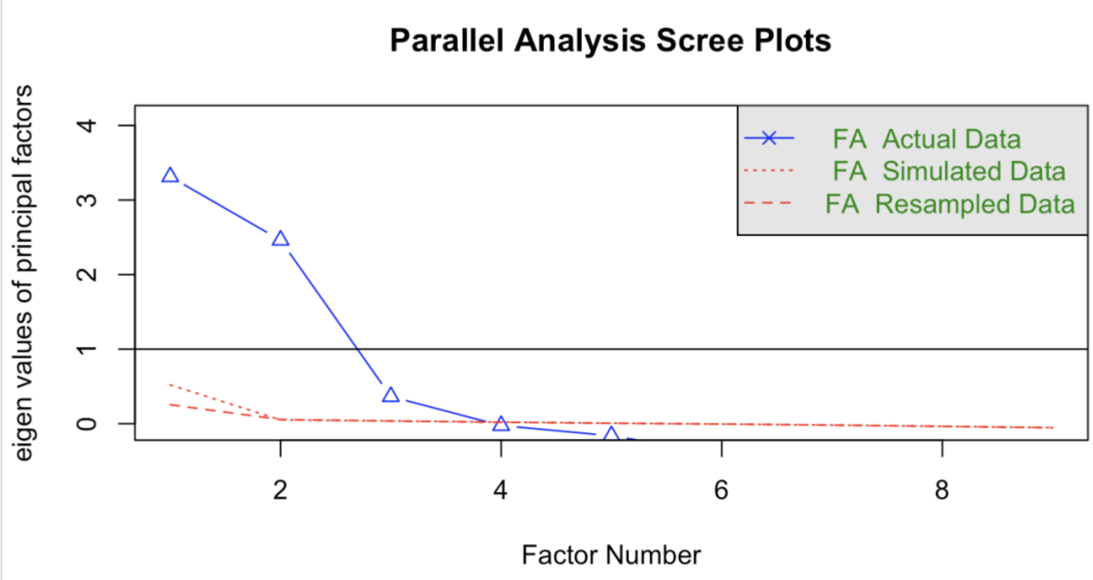

Table 4.2 Standardized Factor Loadings

	Factor 1	Factor 2	Factor 3
Daily.max.p	0.93*	0.32	0.18
Daily.min.p	0.97*	-0.22	-0.04
Daily.mean.p	0.99*	0.02	0.02
Daily.var.p	0.09	0.92*	0.26
Daily.up.depth	0.00	0.08	0.03
Daily.down.depth	0.00	0.06	0.24
Daily.up.freq	-0.02	0.44	0.33
Daily.down.freq	0.00	0.35	0.78*
Daily.NA.duration	-0.14	-0.25	-0.74*

* indicates the factor loading exceeds the minimum requirement.

We generate a 3-factor solution, and the results in Table 4.2 show how each pricing feature loads onto the three factors. High factor loadings of features on a factor indicate that those features correlate highly with the factor. Based on the generally recommended factor loadings cutoff used in Marketing, we use a score of 0.7 to determine the features constituting a factor (Steenkamp and Maydeu-Olivares 2023). From Table 2 we see Factor 1 having high factor loadings for daily max price, daily min price, and daily mean price. These pricing features load onto Factor 1 and can be understood as the price levels that retailers set each day. Similarly, the daily price cuts (as measured by Daily.down.freq) and daily no change (as measured by Daily.NA.duration) have high loadings on Factor 3 and can be interpreted as the frequency of price changes by retailers during a day. Lastly, Factor 2 has a high loading from daily price variance, which can be understood as the magnitude of price change by gas stations daily. Therefore, the three factors uncovered provide us with three dimensions of pricing, which we interpret as the price level, price dispersion, and price adjustment frequency. It is these three dimensions that define retailers' pricing paradigms. Managers make pricing decisions along these dimensions which reveals their pricing paradigms. In the next section, we identify the typical pricing paradigms found in the Hamilton gasoline retail market.

Gas Station Pricing Paradigms

Having identified the three dimensions of pricing in the previous section we would now like to identify whether cohorts of gas stations follow significantly different pricing paradigms. We use the K-medoids algorithm to cluster the gas stations along the three dimensions of price level, price variance, and price adjustment frequency. This unsupervised machine learning algorithm is used ahead of the more commonly used K-means algorithm because it is more robust to outliers in the data (Park and Jun 2009). The analysis indicates that a three-cluster solution is optimal. Therefore, we can classify the 79 gas stations into three groups, each representing a pricing paradigm. Based on the three-cluster classification, we compute average values of the price pattern features for each cluster, which are reported in Table 4.3.

***Table 4.3** Comparison of Pricing Pattern Features Across Clusters*

ID	Size	Daily.max.p	Daily.min.p	Daily.mean.p	Daily.var.p	Daily.up.freq	Daily.down.freq	Daily.NA.duration
1	24	106.15	103.31	104.70	1.20	0.53	0.51	22.28
2	40	107.11	99.62	102.63	2.92	0.90	1.51	20.89
3	15	108.18	97.26	101.52	4.20	1.10	2.70	19.46

Based on the results reported in Table 3, we identify three distinctive price paradigms in Table 4.

***Table 4.4** Description of Three Pricing Paradigms*

Cluster	Size	Price Level	Price Variance	Adjustment Frequency
1	24	High	Low	Low
2	40	Medium	Medium	Medium
3	15	Low	High	High

The results show the market is divided into three cohorts along the identified three dimensions. We call each of these cohorts a pricing paradigm. Retailers with high prices on average (Cluster 1) tend to have stable pricing, as evidenced by significantly lower price variance and low adjustment frequency, and we call them “EDHP” or Everyday High Pricing. Cluster 3 shows the opposite cohort, i.e., these gas stations show lower prices on average but have high price variance, and they adjust their prices a higher number of times per day compared to other groups. This type of pricing is the most volatile, with frequent price changes occurring throughout the day. This cluster represents the Volatile pricing paradigm. Cluster 2 is in the middle along all three dimensions and is termed “Centrals.” In the next section, we develop our theory and hypotheses to identify factors related to a gas station’s selection of one pricing paradigm over another.

Economic Rationales behind Pricing Paradigm: Theory and Hypotheses

The three typical pricing paradigms identified in the previous section indicate the variability of gas station pricing. Research on uniform and variable pricing suggests that changing prices frequently can be costly for firms. This cost arises because firms need to invest in their pricing capabilities, such as information gathering and managerial capabilities, to make frequent price changes profitable (Remer 2019). Pricing managers at many firms do not have access to teams or intelligence for sophisticated decision making, so they find it easier to stick with straightforward pricing (DellaVigna and Gentzkow 2019). We use this idea of price changes being costly to firms to test whether firms with a better ability to bear these costs or more incentive to bear these costs are more likely to adopt a more frequently changing pricing paradigm.

There are several gas station and market characteristics, such as gas station brand, income levels of the area where they operate, the location of gas stations, and the market competition, defined as the number of competitors in the local area, that have been identified as essential determinants of retailers' pricing strategies. We use these characteristics to test how retailer differences among them are associated with the pricing paradigms adopted by retailers in the gasoline market in Hamilton.

Regarding gas station location being on a highway exit or away from it, retailer demand is more sensitive to retail prices when gas stations are located on highway exits (Rossi and Chintagunta 2016) than when they are not (Rossi 2018). As far as brands are concerned, there have been mixed findings in the literature. Hastings (2004) finds that independent gas stations keep competitive pressure on branded stations. Independent stations charge lower prices than branded gas stations, but branded gas stations lower their prices when markets have independent gas stations. The departure of independent gas stations induces prices to move upwards for branded stations. Remer (2019) finds independent gas stations less responsive to cost changes in the gasoline market and offer more stable pricing than branded stations.

Regarding the impact of local competition in retail gasoline, Barron, Taylor and Umbeck (2004), Clemenz and Gugler (2006), Lach and Moraga-Gonzalez (2017), and Pennerstorfer (2020) find a negative relationship between the number of competitors in a market and the average price, while Hosken, McMillan, and Taylor (2008) find no relationship between average price and local station density. There is mixed evidence regarding the impact of the area's median income on retailer pricing. Hosken, McMillan, and Taylor (2008) find that retailers in higher median-income areas have higher margins than retailers in lower median-income areas, while Iyer and Seetharaman (2008) find that retailers price more competitively in areas where they face consumers with lower variation in income than in areas where the variation in consumers' income is higher.

Location Concerns

Location is essential when establishing stations since convenient locations attract higher traffic. Gas station traffic inflows differ in whether they are located along or near highway exits. Highways also have higher traffic flows, and the traffic patterns that determine demand for each of the stations are also more variable compared to those in non-highway locations. Given that highways should have higher but more variable traffic flows, we would expect gas stations on highway exits to have more incentive to offer prices that are more volatile compared to gas stations in other locations.

H1: Gas stations located on highways are more likely to choose a Volatile Pricing Paradigm compared to a Centrals or EDHP Paradigm, i.e., more likely to choose a paradigm with high price adjustment frequency and a lower price level.

Chain Station Concerns

Volatile pricing is more complex and incurs more costs for firms regarding gathering information and managerial input. Chain stores in retail gasoline operate under the brand name of a well-known refiner (such as Shell, Petro Canada, etc.). They are far more recognizable for having an established market presence for an extended period. Branded chain stations dominate the gasoline market in Hamilton and are more numerous than independent retailers. Furthermore, branded stations generally have more resources compared to independent stations and can more easily incur the cost associated with frequent prices. This should result in chain stations changing prices more frequently and better aligning their pricing with market needs. Therefore, branded chain stations are more likely to adopt a low price, high price adjustment frequency paradigm than independent gas stations.

H2: Gas stations belonging to branded chains are more likely to choose a Volatile Pricing Paradigm compared to a Centrals or EDHP Paradigm compared to independent gas stations, i.e., the branded chains are more likely to choose a paradigm with high price adjustment frequency and a lower price level than independent stations.

Competitor Concerns

Turning to the number of competitors in an area, gas stations located in an area with a higher number of competing stations in the market would generate more pressure on retailers' pricing than those operating in a less competitive environment. This is because retailers would need to expend more resources in an area with a higher gas station density to keep their pricing competitive. Retailers would be willing to adopt a more complex pricing strategy that requires more managerial effort and frequent changes to avoid being outcompeted by their competitors. Therefore, in areas with more competitors, gas stations are more likely to adopt a volatile pricing paradigm.

H3: Retailers in areas with more competing gas stations are more likely to choose a Volatile Pricing Paradigm compared to a Central or EDHP Paradigm, i.e., more likely to choose a paradigm with high price adjustment frequency and a lower price level.

Income in Local Area

The incomes of the consumers facing a gas station have competing effects on its pricing. The first is the direct income effect, whereby consumers with higher incomes are less price sensitive. Gas stations located in areas with higher income households should be able to keep higher prices because of price-insensitive consumers, and they can use simple, stable pricing to cater to this population (H4a). On the other hand, retailers might invest more managerial resources to extract the maximum revenue from consumers who are willing to pay more. This would mean that they would offer more variable pricing in areas with higher income households to better align with changing demand over time (H4b). In this case of two competing effects, gas stations would be likely to adopt the pricing paradigm of the effect that is stronger.

H4a: Gas stations in areas with higher median household income are less likely to choose a Volatile Pricing Paradigm compared to a Central or EDHP Paradigm, i.e., less likely to choose a paradigm with higher price adjustment frequency and a lower price level than those in lower median household income areas.

H4b: Gas stations in areas with higher median household income are more likely to choose a Volatile Pricing Paradigm compared to a Central or EDHP Paradigm, i.e., less likely to choose a paradigm with higher price adjustment frequency and a lower price level than those in lower median household income areas.

Regression and Results

We use multinomial logistic regression to investigate whether gas station characteristics are associated with their choices on pricing paradigms, as shown in Equation 1 below. We estimate the probability that gas stations are more likely to select one pricing paradigm over another based on market characteristics.

$$\log\left(\frac{p_{itj}}{p_{it1}}\right) = \alpha_0 + \theta_t + \beta_1 * Highway + \beta_2 * Chains + \beta_3 * Competitors + \beta_4 * Income + \epsilon_0 \text{---------------------------- } 1$$

The dependent variable gives the log odds of firm i, in month t, choosing pricing paradigm j, where j is either pricing paradigm 2 or 3, compared to the base pricing paradigm 1. The pricing paradigms are Volatiles, Centrals, and EDHP. We control for the seasonality faced by the gas stations by using monthly fixed effects which is represented by θ_t.

Table 4.5 Results of Multinomial Regression

Coefficient Estimates	**Centrals**	**Volatiles**
Constant	-1.46**	-2.25**
Highway (H1)	0 .64	2.06**
Chain (H2)	0.54**	1.28**
No. of Competitors (H3)	0.18**	0 .28**
Neighborhood Median Income (H4)	0.01**	0.095**
Monthly Fixed Effects	✓	✓
N	869	869

** Indicates significance at the 5% level.

Table 4.5 shows the results of our multinomial logistic regression with the choice of the pricing paradigm as the dependent variable, where the base level is the EDHP paradigm, and the results in columns Centrals and Volatiles are in comparison to the base level. The results are consistent with our hypotheses. For H1, gas stations around highway exits are more likely to belong to the "Volatiles" pricing paradigm than EDHP, i.e., they are more likely to adopt a low-price, high-frequency price adjustment strategy than non-highway locations. We find support for H2, where we observe that chain stations are more likely to prefer a Centrals or Volatiles paradigm than EDHP. This implies that independent gas stations are more likely to offer stable pricing compared to branded chain stations, and in this regard, our results support Remer's findings (2019). As the number of competitors in a given area increases, gas stations in an area find it harder to price high and are more likely to belong to the Volatiles paradigm as opposed to EDHP, as hypothesized in H3. In this regard, our findings concur with most of the literature exploring the relationship between the number of competitors and average price. Regarding the relationship of median income to the adoption of pricing paradigms, we find support for H4a ahead of H4b. The gas stations in areas with higher median income are likelier to adopt a volatiles paradigm with higher price adjustment frequency and lower average prices.

Conclusion

This study advances the understanding of dynamic pricing strategies in retail gasoline markets by examining the core pricing decisions retailers use as part of their dynamic pricing strategies. While prior research has predominantly focused on price levels and price dispersion, we demonstrate that the magnitude and frequency of price changes are equally critical components of a retailer's pricing strategy, particularly in highly competitive and low-differentiation markets such as gasoline retail. Using detailed hourly price data from Hamilton, Ontario, we extract multiple price features to identify three core dimensions of dynamic pricing strategies: price level, price variance, and price adjustment frequency. Through clustering analysis, we uncover three distinct pricing paradigms— "Volatiles," "Everyday High Price (EDHP)," and "Centrals"—each representing a unique strategic approach to pricing along these dimensions. Our findings reveal an inverse relationship between price level and price adjustment frequency, which we explain through a monopolistic competition framework, emphasizing heterogeneity in demand elasticity across stations. Further, we show that station and market characteristics—such as local income levels, brand affiliation, competitive intensity, and proximity to highways—are related to a station's adoption of a particular pricing paradigm.

The pricing paradigms reveal that gas stations dynamically change their prices over time. In a market with little product differentiation, such as retail gasoline, pricing strategy can be an effective tool to differentiate gas stations from their competitors. Managers can also use this template to determine where they stand in the market regarding their pricing strategy compared to rival firms. They can use this understanding to move closer or further away from the competition.

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