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Price Cycles and Price Leadership in Gasoline Markets: New Evidence from Canada*

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Abstract

This paper studies the determinants of Edgeworth Cycles, price leadership and coordination in retail gasoline markets using daily station-level price data for 110 markets in Ontario, Canada for 2007-2008. We find an "inverse-U" relationship between markets' propensity to exhibit price cycles and their size. More concentrated markets are less likely to exhibits cycles and we highlight regional clustering among cycling and non-cycling markets. Within cycling markets, we find brands' stations (Esso, Shell, Petro-Canada, Sunoco) lead price jumps and coordinate market prices, while independents (Ultramar, Pioneer, Olco, MacEwen) aggressively undercut prices over the cycle.

Keywords: Retail gasoline prices; Edgeworth Cycles; Price leadership; Coordination
JEL Codes: L11, L9, D22

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1 Introduction

Empirical research on gasoline markets has recently exploited high-frequency, daily station-level price data across many markets to deepen our understanding of retail gasoline price dynamics. Lewis (2009), Doyle et. al (2010) and Lewis (2011) show variation in the presence of retail gasoline price cycles across markets is systematically related to market structure: highly concentrated markets and markets with small shares of non-branded gasoline stations are less likely to exhibit price cycles.[1] Since retail gasoline price cycles resemble Edgeworth Cycles from Maskin and Tirole's (1988) oligopoly model, this framework serves as the competitive benchmark for examining linkages between pricing dynamics and market structure.[2]

Wang (2009) and Lewis (2011) further study the mechanism that generates price cycles empirically, finding that price leadership and coordination amongst branded retailers facilitates both short term price commitments (as in Maskin and Tirole (1988)) and periodic market-wide price jumps ("or restorations") over cycles. Wang (2009) exploits the introduction of a 2001 price regulation in Perth, Australia that increases gas stations' risk in initiating price jumps to identify price leadership amongst brands. BP stations collectively lead almost every price jump pre-regulation, whereas the three major brands' (BP, Caltex and Shell) share the leadership role post-regulation by randomizing whose stations initiate price jumps. Lewis (2011) finds evidence that Speedway is a price leader across cycling cities in the Midwestern U.S. who signals price jumps and coordinates its stations' prices to induce market-wide price coordination within and across cities.[3]

In this paper, we develop new empirical results over the determinants of price cycles, and the role of price leadership and coordination in generating cycles, using a unique dataset of

[1]Respectively, these three papers use data from 85, 115 and 165 U.S. cities. Eckert (2002) and Noel (2007a) obtain similar results based on weekly gasoline price data across a smaller number of cities (19) in Canada. "Brand" retailers are typically classified as large firms with many stations across many markets who are vertically integrated with their own oil refineries.

[2]See Noel (2011) for a comprehensive overview of the empirical literature on Edgeworth Cycles.

[3]Wang (2008) and Houde and Clark (2011) use case studies from Ballarat, Australia and a price-fixing case in Québec, Canada to show gasoline retailers even depart from competition and tacitly or explicitly collude to ensure price commitment and coordinate on prices over price cycles.

daily station-level retail gasoline price observations for 110 local markets in Ontario, Canada from August 1, 2007 to August 12, 2008. These data have been provided to the authors by the owners of the GasBuddy Organization Inc. (GasBuddy), and are the universe of price observations collected by their price reporting websites across these markets over this period.

To the best of our knowledge, this is the first paper to exploit high frequency price data across a large cross section of markets from outside of the U.S. to examine dynamics in retail gasoline prices. Moreover, our data present an opportunity to examine urban/rural differences in pricing dynamics across markets. Whereas previous papers examine cities in the U.S. (Lewis (2009), Doyle et. al (2010) and Lewis (2011)) and Canada (Eckert (2002) and Noel (2007a)), our dataset contains both major urban centres and rural locations.[4] One quarter of the markets in our sample have less than 9,000 people. As such, an examination of pricing dynamics amongst markets in the lower tail of the market size distribution is a key contribution of this paper. Beyond characterizing the roles of market structure and coordination in generating price dynamics, our study, as well as those mentioned, importantly informs anti-trust authorities on how to monitor firms' conduct and identify abuses of market power in retail gasoline markets empirically.

After outlining our data sources and estimation sample in Section 2, we develop our empirical analysis of the determinants of price cycles in Section 3. We find an "inverse-U" relationship between market size and the probability a market exhibits price cycles. Complementing the results of Noel (2007a), we show this is driven by two distinct types of non-cycling cities: small, rural "sticky pricing" markets where retail prices respond sluggishly to daily fluctuations in wholesale prices, and large, urban "cost-based pricing" markets where prices move in lock-step with daily wholesale price movements. Market structure also affects whether price cycles exist, namely more concentrated markets are less likely to exhibit price cycles. We also find evidence that price cycles exist within particular regions of the province: (1) along Lake Ontario around Kingston in Eastern Ontario; (2) the Niagara Region toward

[4] The smallest market we can find referenced in previous studies is Timmins, Ontario from Eckert (2002) and Noel (2007a) which has a population of 42,997 people according to the 2006 Canadian Census.

the New York state border; and (3) in the Southwest toward Windsor and the Michigan border. Cycling cities also exist in the rural Northern parts of the province, but mainly among cities along the Trans-Canada highway. Overall, our findings of urban/rural and regional effects as key determinants of price cycles, that are obtained from high-frequency data from a different country and sampling method than previously used, re-affirm and build upon the results from Lewis (2009), Doyle et. al (2010) and Lewis (2011) for the U.S..

In Section 4, we present findings on price leadership and undercutting intensity across gas stations run by brands (Esso, Shell, Petro-Canada and Sunoco) and independents (all other non-brand firms). We find price dispersion amongst retailers is minimized during price jumps and subsequently rises over the duration of price cycles. Our analysis of stations' participation rates in price restorations shows Esso, Shell, Petro-Canada and Sunoco are active participants while independent stations run by Ultramar, Pioneer, MacEwen and Mac's are less likely to participate. Similar to the findings over price leadership and coordination from Australia and the U.S. of Wang (2009) and Lewis (2011), branded firms in Canada also use their large market presence to initiate price jumps and coordinating market prices.

We further find brand and independent stations exhibit statistically and economically significant differences in their price undercutting intensity between price jumps ("the undercutting phase"). Following restorations, brands' stations maintain their prices at or above market-level averages, simply following average prices as prices decline from their previous restoration price. In contrast, independent stations run by Ultramar, Pioneer, Olco and MacEwen are quite aggressive in undercutting prices following restorations. For example, the day following a restoration, Ultramar and Pioneer undercut the prior restoration price by an additional 0.58 and 0.43 cents per litre (cpl) beyond the market-level average price cut of 1.13 cpl. By day seven of the cycle, these firms undercut the restoration price by 2.83 and 1.43 cpl beyond the market-level average price cut of 3.22 cpl.

2 Data sources

Our primary data source is the universe of daily station-level regular unleaded gasonline price observations for all cities, towns and villages in the Canadian province of Ontario collected by GasBuddy from August 1, 2007 to August 12, 2008. These data are obtained from voluntary, anonymous price spotters who submit prices to GasBuddy's North American website (www.gasbuddy.com), provincial website (www.ontariogasprices.com), or city-specific websites (i.e., www.torontogasprices.com, www.ottawagasprices.com). Users of these advertiser-sponsored websites check or report individual station prices using personal computers and mobile phones. They build user profiles by reporting prices, and potentially win prizes for their efforts. In 2006, the North American GasBuddy website was the most popular website for searching for gasoline stations' prices in the U.S. (Lewis and Marvel (2011)).

While the raw data identifies 403 unique locations, some locations refer to suburbs or subdivisions within a city.[5] We obtain coordinates for each location using name searches in Google Maps (http://maps.google.ca), and aggregate up "close" locations by defining two or more locations as being within the same market if the Great Circle Distance between them is less than 15 kilometres. After aggregating up we obtain 270 local retail gasoline markets.

The estimation sample includes markets with price observations on 250 or more days and at least 0.5 observations per station per day. These restrictions yield a subsample 595,668 station-price-day observations across 110 markets, which encompass 2,138 stations and 185 unique brands. Keeping with previous studies on the Canadian retail gasoline industry (Eckert and West (2005)), we define the large vertically-integrated gas companies, Esso, Shell, Petro-Canada and Sunoco, to be "brands" and all other stations to be "independents."[6] The four brands account for 414 (19.36%), 319 (14.92%), 362 (16.93%) and 240 (11.23%) of the

[5]For example, Amherstview in Kingston, or London North, South, East and West.

[6]Husky Oil is another branded vertically-integrated gasoline retailer in Canada, however mainly competes in Western Canadian retail markets. While we observe a small collection of Husky stations in our sample, Husky's market presence in Ontario is quite small.

stations in the estimation sample.

Atkinson (2008b) highlights three sources of sample selection in the GasBuddy data worth noting from the outset: (1) geographic location (spotters observe more prices for stations in high-traffic areas); (2) station brands (spotters pay more attention to brands' stations and less attention to independents' stations); and (3) relative prices (spotters are more likely to report prices that are above or below the current average gas price within a city). To assess the severity of these selection biases, Atkinson (2008b) compares various statistics from self-collected bi-hourly station-level data and data he recorded from GasBuddy's websites for Guelph, Ontario in 2005. Two of his findings are pertinent for our paper: (1) the daily average retail price from his high frequency data is well-approximated by the daily average retail price from the GasBuddy data; and (2) independents' stations are underreported relative to brands' stations. The prior finding lends credibility to our analysis of the existence of price cycles, market size and structure in Section 3. The latter finding requires us to caveat our results regarding price leadership and undercutting intensity in Section 4.

We also use data on the wholesale (or "rack") price of gasoline from MJ Ervin and Associates in our analysis of the determinants of price cycles. These data correspond to the average rack price amongst non-branded retailers within a market. They are available for five major cities in our sample: Ottawa, Toronto, Hamilton, London and Sarnia. Rack price locations are matched to GasBuddy locations according to the rack price location that is closest to a given GasBuddy location in terms of Great Circle Distance.

To account for differences in demographics across markets, we match our GasBuddy locations to their corresponding 2006 Canadian Census Subdivision and obtain data on average household income, fraction of population that drives to work and fraction of population with post-secondary education. We further retrieve accurate estimates of markets' population and urban density from Statistics Canada's 2006 GeoSuite package.

3 Gasoline price cycles in Ontario

In this section we investigate how market size and structure affects the probability a market exhibits cycles in its average daily after-tax retail gasoline price.[7] The patterns of interest are depicted in Figures, 1-3, which plot the average daily retail and rack prices for Goderich (pop. 7,560), St. Thomas (pop. 36,110), and Ajax (pop. 90,160). Figure 1 highlights rigidities in retail price adjustment over time in Goderich as average retail prices do not move with daily fluctuations in the rack price. Figure 2 shows asymmetric price cycles that resemble Edgeworth Cycles (Maskin and Tirole (1988)) in St. Thomas. Prices exhibit a saw-tooth pattern whereby they periodically experience dramatic price increases ("restorations") followed by a sequence of daily price declines ("undercutting phase"). Figure 3 shows retail prices move in lock-step with daily fluctuations in the rack price in the city of Ajax. In the nomenclature of Noel (2007a), these figures suggest Goderich, St. Thomas and Ajax exhibit "sticky pricing," "asymmetric price cycles" and "cost-based pricing."

Classifying cycling markets

To study the relationship between price cycles, market size and structure, we classify cycling and non-cycling markets using Lewis (2009)'s simple classification rule: if the median daily change in the average retail price is less than -0.025 cents per litre (cpl) Canadian, a market exhibits price cycles.[8] Intuitively, markets with price cycles should experience relatively more negative daily average price changes since there are many undercutting phase days and relatively fewer restoration days. For non-cycling markets, we expect daily price increases and decreases to cancel each other out over time. For example, in Goderich, St. Thomas and Ajax the median daily average price changes are 0, -0.299 and 0.012. Figure

[7] The 2007-2008 excise tax on gasoline in Ontario is 10 cents per litre. The 5% Government Sales Tax is applied to the pre-excise tax price and the excise tax.

[8] This classification strategy been recently used by Doyle et. al (2010), Lewis (2011) and Lewis and Noel (2011). Converting our baseline critical price change to U.S. cents per gallon (ignoring differences in inflation across Canada and the U.S.) yields $\frac{-0.05\ CA\ cents}{litre} \times \frac{3.7854\ litre}{1\ gallon} \times \frac{1.0660\ US\ cents}{1\ CA\ cents} = \frac{-0.2018\ US\ cents}{gallon}$. This compares to a critical price difference of -0.2 cents per gallon in Lewis (2011), who uses U.S. data from 2004-2010. The exchange rate is the average US/CA exchange rate from 2007 reported by the Bank of Canada, available online at http://www.bankofcanada.ca/rates/exchange/exchange-rates-in-pdf/).

C.1 in the appendix shows that the distribution of the median daily change in average prices across markets has a large mass around zero and a non-negligible mass of markets in its left tail.[9] Under our -0.05 cpl cut-off rule, we classify 27 of the 110 markets in our sample as cycling.

3.1 Market size, structure and the presence of price cycles

The top panel of Table 1 contains preliminary evidence of the relationship between market size and the probability a location exhibits price cycles. A tabulation of our cycling indicator across the quartiles of the population distribution suggests an "inverse-U" relationship: two and seven markets in the first and fourth quartiles exhibit price cycles, whereas both the second and third quartiles have ten cycling markets. The bottom panel of Table 1 tabulates our cycling indicator across the quartiles of the HHI distribution, revealing that the probability of observing price cycles is lower in more concentrated markets.[10] The small number of cycling markets in the bottom quartile of the population distribution and top quartile of the HHI distribution largely corresponds to 15 markets that lie in the intersection of these two groups. These are small, rural markets with only a few gas stations in our sample.

Motivated by the differences in retail prices' response to changes in rack prices in Figures 1-3, we calculate the correlation between daily changes in average retail prices and rack prices for each market, and see if these correlations vary with market size, structure and price cycling status. We compute separate correlation coefficients for days with positive changes in rack prices and days with negative changes in rack prices. This allows for differences across negative and positive wholesale cost shocks, possibly due to asymmetric passthrough. While examining such correlation coefficients does not constitute an exhaustive analysis of passthrough, these correlations provide simple summary statistics that illuminate differences

[9] The companion appendix of additional figures and robustness checks for the results in this paper is online at http://sites.google.com/site/dprbyrne/.

[10] Like Doyle et. al (2010) and Lewis (2011), we compute HHI by market in terms of station counts. Hirschberg et. al (2003) highlight the important issue that HHI measures potentially lack comparability across markets of different size and with different players. We have replicated all the findings in this paper using their adjustment factors for HHI (p.140-141) that permit cross-market HHI comparisons, and find virtually no differences our results.

in retail prices' response to changes in rack prices across cycling and non-cycling markets, and across urban and rural markets.[11]

Figures 4 and 5 plot the correlation coefficients for negative and positive rack price changes against the logarithm of markets' population, distinguishing cycling markets (triangles) from non-cycling markets (diamonds). The bottom left and top right corners of both figures highlight two distinct clusters of non-cycling cities: small markets with low correlations between daily changes in retail and rack prices (i.e., sticky pricing markets like Goderich) and large markets with high correlations between daily changes in retail and rack prices (i.e., cost-based pricing markets like Ajax). Cycling cities exhibit correlations that are comparable to small non-cycling markets during negative rack price changes, and are in between small and large non-cycling cities' correlations for positive rack price changes. Table 2 lists corresponding sample averages and standard deviations of the correlation coefficients across the quartiles of the population and HHI distributions. The top panel highlights substantial differences in the average correlation coefficient across markets in the top and bottom quartiles of the population distribution of 0.658 and -0.022 for negative daily rack price changes (similar for positive rack price changes). The bottom panel shows markets in the top quartile of the HHI distribution exhibit substantially lower correlations between daily changes in retail and rack prices. The main takeaway from Figures 4-5 and Table 2 is that collections of both small, highly concentrated sticky pricing markets and large, less concentrated cost-based pricing markets exist in our sample.

A third potential determinant of price cycles is the geographic location and urban density of markets. We highlight spatial patterns in the prevalence of price cycles by plotting the

[11]A full examination of passthrough in our sample is itself an extensive exercise that we leave for future work with these data. As such, we do not make claims regarding the degree of asymmetric passthrough across negative and positive daily changes in rack prices. Rather, we focus on differences in correlations in daily changes in retail and rack prices across large/urban and small/rural non-cycling markets to establish the existence of sticky and cost-based pricing markets in our sample. For formal investigations of wholesale price passthrough in retail gasoline markets see Borenstein et. al (1997), Deltas (2008), Noel (2009) and Lewis and Noel (2011). Borenstein et. al (1997) and Deltas (2008) find gasoline stations passthrough wholesale price increases faster than decreases. Noel (2009) highlights the importance of accounting for price cycles in examining asymmetric passthrough, while Lewis and Noel (2011) further show passthrough is faster in markets with price cycles.

location of cycling (triangles) and non-cycling (diamonds) markets across Statistics Canada's 2006 ten four-digit economic regions for Ontario in Figure 6.[12] The cluster of large diamonds around the "Golden Horseshoe" in Southern Ontario (i.e., from Toronto past Hamilton) highlight a collection of urban non-cycling markets (such as Ajax).[13] Overall, 19 (70.4 %) of the 27 cities in the top quartile of the population distribution lie in the Toronto, Hamilton-Niagara or Kitchener-Waterloo-Barrie economic regions. Among these 19 cities, the average correlation coefficient between daily changes in average retail and rack prices is 0.863 (s.d.=0.209) and 0.744 (s.d.=0.185) during negative and positive price changes. This indicates that cost-based pricing is prevalent in this part of the province.

In contrast, small diamonds (i.e., the less populous non-cycling markets) are located in the far less dense parts of the province along tertiary highways: in the Northeast and Northwest economic regions, on the Bruce Peninsula and the Northern parts of the Kingston-Pembroke economic region. Out of the 28 locations with populations in the bottom quartile of the population distribution, 23 lie within these areas. Amongst these 23 markets relatively sticky pricing exists as the average correlation coefficients between daily changes in the average retail and rack prices is only -0.016 (s.d.=0.120) and 0.038 (s.d.=0.069) during negative and positive rack price changes.

As one moves away from the Toronto-Hamilton region, a larger fraction of cities exhibit price cycles. Price cycling markets are predominant in markets along Lake Ontario around Kingston in Eastern Ontario, in the Niagara Region toward the New York state border, and

[12] The 2006 economic region definitions (numbers) for Ontario are Ottawa (3510), Kingston-Pembroke (3515), Muskoka-Kawarthras (3520) Toronto (3530), Kitchener-Waterloo-Barrie (3540), Hamilton-Niagara (3550), London (3560), Windsor-Sarnia (3570), Stratford-Bruce-Peninsula (3580), Northeast (3590) and Northwest (3595). More information on these definitions can be found at http://www.statcan.gc.ca/subjects-sujets/standard-norme/sgc-cgt/2006/2006-er-re-eng.htm

[13] Two non-cycling markets in these regions contrast findings from previous studies. Atkinson (2008a) finds price cycles exist in Guelph, Ontario and nearby cities like Kitchener-Waterloo in 2005. Noel (2007b) shows 22 stations in Toronto for 131 days in 2001 exhibit weekly price cycles. We classify Guelph, Toronto and their surrounding markets as non-cycling in our sample. We reaffirm our classifications by looking at market level average prices and individual stations' prices at daily frequencies in these cities graphically, finding no evidence of asymmetric price cycles over our sample period like those in St. Thomas. The difference in our findings possibly relates to Noel's (2007a) finding that markets can transit into and out of price cycling regimes over longer time horizons. His results are based on weekly data for 19 Canadian cities for just over 10 years. To date, no empirical results on these transitions based on daily station-level data exist.

to the Southwest around Windsor and the Michigan border. Cycling cities also exist in the northern parts of the province, but mainly in the northern cities along the Trans-Canada highway such as Barrie (pop. 128,436), North Bay (pop. 53,970), Sudbury (pop. 157,855), Sault Ste. Marie (pop. 74,950) and Thunder Bay (pop. 109,140).

Our finding of geographic clustering in pricing dynamics, particularly amongst the non-cycling and cycling markets in the Southern Ontario, is consistent with our discussions with industry experts and an actual gas station owner who both claim companies have regional offices that set pricing strategies across markets within different regions. Houde and Clark (2011) similarly report regional representatives exist for gasoline retailers in Québec. Atkinson (2008a) also finds evidence of regional pricing phenomena in Southern Ontario in 2005 amongst retail gasoline markets in Guelph, Kitchener, Cambridge and Waterloo.

3.2 Formal analysis of the determinants of price cycles

We formally study the relationship between the market size and structure, regional effects and the presence of price cycles by estimating the following linear-in-probability model:

$$1\{\text{PriceCycles}\}_i = \beta_0 + \beta_1 HHI_i + \beta_2 ShareInd_i + \beta_3 Pop_i + \sum_{j=1}^{10} \beta_{4j} 1\{\text{ER}_{ij}\} + X_i \beta_5 + \epsilon_i \quad (1)$$

where $1\{\text{PriceCycles}\}_i$ is an indicator function equalling one if city i is classified as having price cycles. HHI_i is the Herfindahl-Hirschman Index in terms of stations counts and $ShareInd_i$ is the share of stations that are independents in city i.[14] Pop_i is the population of city i (in 100,000's), $1\{\text{ER}_{ij}\}$ is a dummy variable equalling one if market i is in economic region j, and X_i is a vector of market i demographic controls from the 2006 Census including average household income, fraction of population who drive to work, fraction of population

[14]Lewis (2011) and Doyle et. al (2010) also use these market structure variables to investigate their impact on the probability a city exhibits price cycles. Since we identify stations by whether we observe any price reports for a station from one of the GasBuddy websites from 2007 to 2008, an important concern is whether sample selectivity of certain brands or independents biases our market structure measures. Using independently collected data from Kent Marketing Ltd., a primary distributor of data for the Canadian retail gasoline market, on stations' identities and characteristics for 67 markets in Ontario, we have verified for 46 markets that overlap between this sample and the GasBuddy sample that our market structure measures accurately match those from Kent Marketing.

with post-secondary education and urban density.

Estimation results

Regression coefficient estimates for seven specifications of equation (1) are reported in Table 3. Specifications (1)-(3) show a statistically significant negative relationship between HHI and the probability a city has price cycles. Interpreting the magnitude of the column (3) estimates, a one-standard deviation increase in HHI of 0.275 reduces the probability a location exhibits price cycles by 15.5%. This effect is large relative to the 26.4% average probability a market exhibit cycles in the sample. The share of independents has a positive, though statistically insignificant relationship with the probability of cycling. There are mixed and statistically insignificant estimates for the population slope coefficients.

Specification (4) adds the economic region dummy variables and remainder of demographic controls to the set of regressors. Beyond allowing us to investigate regional effects in cycling propensity, the inclusion of these dummies accounts for unobserved regional heterogeneity that likely confounds our market size and structure coefficient estimates. The estimates for the economic region dummies are consistent with the regional patterns discussed above. Markets in the Toronto, Kitchener-Waterloo-Barrie and Hamilton-Niagara Regions have statistically significant lower propensities to exhibit price cycles. Cities and towns in the Kingston-Pembroke, Windsor-Sarina and the Northeast economic regions have a significantly higher propensity of having price cycles. We continue to find a statistically and economically significant negative relationship between concentration and the probability a market exhibits cycles after controlling for demographics and region-specific effects.

Specifications (5)-(7) replace HHI, share independent and population with dummy variables that equal one if a market lies within a particular quartile of the HHI/ share independent/population distributions. For each specification, the baseline group is the first quartile of the HHI/share independent/population distribution. The column (5) estimates show markets in the top quartile of the HHI distribution have a significantly lower probability of exhibiting price cycles. All else equal, locations in the top quartile are 43% less likely to exhibit price cycles, whereas markets in the remaining three quartiles have stastically indistinguishable differences in cycling propensity. The highly concentrated markets in the top quartile include the 15 sticky pricing small rural markets discussed above. The column (6) estimates do not indicate statistically significant differences in the prevalence of price cycling across markets in the share independent distribution.

Reflecting our findings from Table 1, the column (7) estimates show that markets in the top three quartiles of the population distribution have a statistically significantly higher probability of price cycling relative to cities in the bottom quartile. Moreover, the "inverse-U" relationship between city size and the probability of observing price cycles persists. Intermediate-size cities in the third quartile of the population distribution are the most likely to exhibit price cycles. The magnitude of the differences in cycling probability are large compared to the 26.4% average cycling probability across cities: markets in the third quartile are 14.8% and 9.7% more likely to exhibit price cycles than those in the second and fourth quartiles. Only the prior difference is statistically significant at the 10% level, which partly reflects the fact that we only have 90 degrees of freedom under specification (7).

Two final results from our column (5)-(7) estimates are worth noting. Market concentration continues to have statistically significant negative relationship with the probability of price cycles. Even within the quartiles of the market size distribution we find more concentrated markets are less likely to exhibit price cycles. The marginal effect of a one-standard deviation increase in HHI falls to 10.1% under specification (7), however is still large at 38.3% of the average cycling probability across cities. Finally, markets located in the Toronto, Kitchener-Waterloo-Barrie and Hamilton-Niagara economic regions continue to have a significantly lower probability of exhibiting price cycles.

Benchmarking findings to U.S. results

Previous studies of retail gasoline price cycles and their determinants across U.S. cities by Doyle et. al (2010) and Lewis (2011) are important benchmarks for our analysis. Both papers use daily station-level retail price data collected via consumers' credit card transactions and other survey methods by Oil Price Information Service (OPIS). After controlling for state fixed effects and market shares of various stations within markets in terms of station counts, Lewis (2011), finds, as we do, a negative and positive relationship between HHI and the share of independents, and the prevalence of price cycles across cities. However, only the share of independents coefficient is statistically significant in his regression, the opposite of our finding. This suggests that market concentration effects and share of independent effects are difficult to separately identify once one accounts for region/state fixed effects. Doyle et. al (2010) also find cities with a larger share of independents are more likely to exhibit price cycles. Similar to our results, they find markets in the top quartile of their HHI distribution are the least likely to exhibit price cycles, and that only cities in the third quartile have a statistically higher probability of exhibiting price cycles (regression coefficients relating the level of HHI to the existence of price cycles are not reported). Our findings related to market size, urban/rural differences and regional effects in cycling propensity, which are obtained from a completely different data collection method and country, re-affirm and build upon these established findings from the U.S..

Robustness checks

Tables C.1 and C.2 of the appendix contain two additional sets of estimates that check the robustness of our results to our classification scheme for cycling cities. These robustness checks replace the dependent variable with an indicator function equalling one if city i's median daily change in its average gasoline price is -0.025 and -0.075 cpl. The magnitude and statistical significance of the estimates in both sets of robustness results are similar to our benchmark estimates. The results are more similar under the -0.075 cpl cut-off rule.

4 Price coordination and leadership in cycling cities

In this section we use our station-level data to characterize price cycles in cycling markets and investigate the extent to which different firms participate in price restorations and undercut prices following a restoration. We restrict our empirical analysis to conservative daily frequencies as sample selection issues from GasBuddy spotters likely undermines any "real-time" analysis of identifying exactly which stations are the first to initiate price jumps during restorations and undercut restoration prices.[15] To facilitate comparisons across studies, we follow the approach of Lewis (2011) throughout our analysis.

Identifying restorations

To study firms' roles in the restoration and undercutting phases of price cycles, we must first identify restoration events. We use a cut-off rule to do so: a restoration day occurs if a market's median gasoline price increases by 1.5 cpl over consecutive days or over two days. Under this definition, a single restoration period is either one or two days, allowing for the possibility that some retailers restore their prices on day t while others restore their prices when they open their stations on day $t+1$. In either event, the median price will reflect these price changes on days t or $t + 1$ during a restoration. We use the inter-day changes in the median rather than the average gasoline price within markets to avoid the impact of extreme price observations in identifying restoration events. A station is classified as participating in a restoration if its price is greater than or equal to the market's median price on either day one or two within a restoration period.[16] Restoration days are set as "day zero" within cycles. The length of a cycle is the number of days between the last restoration day of the previous restoration period and the first restoration day of the next restoration period. The restoration price is computed as the maximum daily median price within a one or two day restoration period.

Figure C.2 in the appendix illustrates how daily changes in median prices and our 1.5 cpl cut-off rule identifies price restorations for St. Thomas. Restorations correspond to

[15] Atkinson (2008a)'s highlights the ineffectiveness of GasBuddy data in identifying the within-day timing or price restorations and undercutting by stations.

[16] Lewis (2011) p.17 uses a somewhat different restoration definition that also permits restorations to occur over one or two days. He requires a minimum share of stations in a market to increase their prices by either 5 US cents per gallon (or 8 US cents in a robustness check) over a one or two day period for a restoration to be established. In terms of CA cents per litre, these cut-off price changes are 1.41 cpl and 2.25 cpl (similar conversions as above). We do not use a minimum participation rate in identifying price restorations since we are concerned with potential measurement error due to sample selection issues with our internet-collected GasBuddy data. Rather, we elect to use a conservative restoration identification rule based on daily changes in the median gasoline price with a market over time.

the positive spikes in the daily median price that are sufficiently large to pass the 1.5 cpl horizontal cut-off line. A key concern in identifying restorations with changes in the median price is that large daily changes in rack prices may generate large changes in retail prices and hence the median retail price. An alternative metric to account for this is the change in the daily median "margin" between stations prices and the rack price.[17] We plot this series for St. Thomas in Figure C.2 as well. Of course, large changes in the median price and margin occur on the same day. However, there are many instances where large negative changes in the rack price generate large margin differences that do not correspond to large, restoration-driven daily changes in the median price. We have exhaustively investigated changes in the median price and margin along these lines for our cycling locations and find changes in the less volatile median price is generally better at identifying restorations.

4.1 Characterizing price cycles

Table 4 contains various summary statistics that characterize price cycles across our cycling markets. In total, our 1.5 cpl cut-off rule identifies 910 cycles/restorations across our cycling markets. The average price jump during restorations ranges from 3.45 (s.d.=1.69) cpl in St. Catharines to 8.07 cpl in Brockville. The average cycle duration ranges from 5.06 days in Sault Ste. Marie to 10.17 days in Chatham. We find locations' HHI (logarithm of population) is positively (negatively) correlated with their average price jump and cycle duration, though all correlations are statistically insignificant. Restorations systematically occur during the middle part of the week: across all restorations and markets, 260 (28.6%) and 220 (24.2%) occur on Wednesday and Thursday. Restorations most frequently occur on either Wednesday or Thursday in 25 of our 29 cycling markets.

We characterize the level and dispersion of prices amongst brand and independent stations over the price cycle in Figures 7 and 8. Following Lewis (2011), these figures are constructed by (1) computing the difference between stations' daily prices and the last restoration price

[17] Denoting this difference as a "margin" is a slight abuse of language since we do not observe individual stations' rack price, only the average rack price of independents, implying we cannot compute the true median margin.

within their market; (2) computing box-and-whisker plots of this price difference by days since the last restoration within each market; and (3) taking the average of the five components of the box-and-whisker by days since last restoration across the cycling markets. The figures therefore depict the average level and dispersion of prices amongst brand and independent stations by days since last restoration across the 29 cycling markets, normalized by the last restoration price within markets. Both figures show price dispersion amongst brand and independent stations is minimized during restorations and gradually increases as price cycles progress. Thus, restorations periods involve stations coordinating their prices, with price dispersion subsequently rising as brands and independents undercut restoration prices.

Though the level and growth in price dispersion is comparable over price cycles amongst brands and independents in Figures 7 and 8, the price levels are noticeably different. On average across cycling markets, brands' median price differential from restoration prices is zero during restoration periods while independents have a median price differential of about -0.75 cpl.[18] Thus, brands tend to set the restoration price and independents immediately undercut it. Comparing the rate at which stations' prices fall relative to the last restoration price over the cycle, we see independent stations' prices fall at a faster rate than brands stations' prices. By day seven of a cycle, brand and independent stations' median price is around -2.5 cpl and -3.4 cpl below the last restoration price. By day 14 of the cycle, these brand and independent median price cuts are approximately -3.1 cpl and -4.1 cpl. Overall, these figures provide preliminary evidence that independent stations are relatively more aggressive in undercutting prices between restorations.

4.2 Firm participation in restorations

We estimate a linear-in-probability model to quantify firm-specific participation rates in restorations. Specifically, we predict that gas station i participates in restoration τ according

[18]The use of "median" in this and the following three sentences is a slight abuse of language. The "median" is technically the average across markets' median price differential from the last restoration price by day of the cycle.

to the following regression equation:

$$1\{\text{Stn}_i \text{ participates in Rest}_\tau\}_i = \beta_{0j} + \sum_{j=1}^{J} \beta_{1j} 1\{\text{Firm}_{ij}\} + \epsilon_{i\tau} \tag{2}$$

where $1\{\text{Stn}_i \text{ participates in Rest}_\tau\}_i$ is an indicator function equalling one if station i participates in restoration τ, $\beta_{0\tau}$ is a restoration fixed effect and $1\{\text{Firm}_{ij}\}$ is an indicator function equalling one if station i is run by gasoline company j. We include firm-specific dummy variables for each of the four brands and for seven independents/non-branded firms that have sufficiently many stations across markets to estimate a firm-specific effect (Canadian Tire, Ultramar, Pioneer, Olco, 7-11, MacEwen, Mac's). The remaining stations correspond to other independent firms in the sample, which we treat as a single homogenous group, and which serve as our baseline group for the remainder of the paper. The inclusion of restoration-specific intercepts implies we use within-restoration variation in firms' participation rates to estimate $\beta_{1j} \ldots \beta_{iJ}$, allowing us to recover firm-specific effects that are robust to time and market-specific heterogeneity. To check the robustness of our estimates with respect to the cut-off daily median price change that identifies restorations we estimate (2) using dependent variables that correspond to our baseline 1.5 cpl cut-off price, as well as 2 cpl and 2.5 cpl cut-off values.

Table 5 presents our coefficient estimates under the three different cut-off rules. All three columns yield similar results both in terms the statistical significance and magnitude of the estimates, indicating that our results are robust to our restoration event cut-off rule. We therefore focus on the estimates based on the 1.5 cpl cut-off rule. Consistent with the day 0 city-average box-and-whisker plots from Figures 7 and 8, we find the four major brands are more likely to be involved in restorations, whereas independents are less likely to restore their prices. These differences are statistically and economically significant: Esso, Shell, Petro-Canada and Sunoco exhibit marginally higher restoration participation rates of 27.9%, 23.4% 30.9% and 21.3% relative to the baseline average participation rate of 31.3%. Conversely, Ultramar, Pioneer, MacEwen and Mac's have significantly lower participation rates that are 12.4%, 18.4%, 17.0% and 21.4% below the baseline participation rate. The remaining non-branded stations do not exhibit significantly higher or lower participation rates in restorations with the exception of Canadian Tire stations. These stations are 11.3% more likely than the baseline group to restore their prices during restorations. Given Canadian Tire is a large distributor of hardware and automotive goods in Canada, it potentially uses its branding advantage as a retailer to maintain market share while actively matching restoration prices.

4.3 Undercutting intensity by firms over price cycles

Recall from Figures 7 and 8 that brands set the level of restoration prices and are less aggressive in undercutting than independents over the price cycle. We now formally measure the extent to which stations operated by different firms undercut restoration prices using a regression model that allows for firm-specific effects in undercutting intensity. We normalize prices with the last restoration price and compute $\text{PriceDiff}_{it\tau} = \text{Price}_{it} - \text{RestPrice}_{\tau}$, the difference between station i's price on date t and the last restoration price observed on date $\tau < t$. Using these price differentials we estimate the following regression model:

$$\text{PriceDiff}_{it\tau} = \beta_0^{t-\tau} + \sum_{j=1}^{J} \beta_{1j}^{t-\tau} 1\{\text{Firm}_{ij}\} + \epsilon_{it}; \quad \tau < t < \tau + 1 \tag{3}$$

where the coefficients have time superscripts as we allow for a different coefficient for each day since the last restoration. Recall $1\{\text{Firm}_{ij}\}$ is an indicator function equalling one if station i is operated by firm j. Thus, $\beta_{1j}^{t-\tau}$ measures how much firm j–run stations undercut the last restoration price on average across cycling cities $t - \tau$ days following a restoration.

We present our parameter estimates for days one through seven since last restoration in Table 6. One day following a restoration, Esso, Shell, Petro-Canada and Sunoco stations have 0.63, 0.30, 0.60 and 0.43 cpl higher gasoline prices than the average price cut of 1.13 cpl, though Shell's price difference is not statistically significant different from zero. As price leaders in initiating price jumps, stations run by these brands shade up their prices relative to other stations in an attempt to maintain restoration price levels. As price cycles progress on days two through seven after a restoration, the constant estimates in Table 6 show prices fall to 1.44 to 3.22 cpl below the last restoration price on average. Over these days, brands' coefficients are statistically insignificant, suggesting that brand-run stations undercut the restoration price in a similar fashion to all other firms in a market. That is, these leading firms simply following the cycle and are not aggressive in undercutting others during the undercutting phase of price cycles.

The findings for independents' stations starkly contrasts those of the brands. The day after a restoration, on average stations run by Ultramar, Pioneer and Mac's immediately undercut the restoration price by an additional 0.58, 0.43 and 1.11 cpl beyond the market-wide average price cut. These are statistically significant and large average discounts of 51.5%, 37.9% and 98.2% relative to the day one average price cut of 1.13 cpl. For days two through seven of a cycle, the estimates indicate that Ultramar, Pioneer, Olco and MacEwen stations charge price differentials that are significantly below the market-level average price cut from the last restoration price in terms of both economic and statistical significance (at least at the 10% level). Two days following a restoration, Ultramar, Pioneer, Olco and MacEwen undercut the restoration price 1.58, 1.10, 0.49, 0.76 cpl beyond the 1.44 cpl average price cut. By day seven after a restoration, their prices are an additional 2.83, 1.43, 1.02 and 1.10 cpl below 3.22 cpl market-level average price cut. Ultramar is the most aggressive of these three firms in undercutting prices: on average across our day one through seven estimates its estimated price differential is 91.0% below the average restoration price cut. For Pioneer, Olco and MacEwen these figures are 58.3%, 34.4% and 33.1%, indicating that Pioneer-run stations are the second most aggressive undercutting stations followed by Olco and then MacEwen. We jointly test the equality of the seven coefficients across firms and reject the null at the 5% level when comparing Ultramar to Olco or MacEwen, or when comparing Pioneer to Olco or MacEwen. Statistically, Ultramar and Pioneer are the aggressive defectors from restoration prices and Olco and MacEwen are the less aggressive.[19]

A final point of note from the results in Table 6 is that non-branded stations run by the major hardware and automotive retailer, Canadian Tire, and the large convenience store chain, 7-11, are are non-aggressive in undercutting prices over the cycle. In general, their price cuts from the last restoration price do not significantly differ from the baseline market-level average price cut. In fact, on days two, three and five of the cycle 7-11 stations have statistically significantly smaller price cuts relative to the baseline level. This suggests that these retailers leverage their branding advantage from their core competencies to maintain market share while charging higher retail gasoline prices over the cycle.

Robustness checks

The appendix contains robustness checks for the undercutting results, where we re-estimate the regression model in (3) except we use cut-off rules based on 2 cpl and 2.5 cpl one or two day changes in markets' median price to identify restorations. The corresponding robustness checks are listed in Tables C.3 and C.4 of the appendix. The estimates are very similar in terms of magnitude and statistical significance to those in Table 6, implying our main conclusions regarding undercutting intensity are unchanged. We have estimated equations (2) and (3) under alternative definitions of cycling markets where we classify markets as having cycles if their median daily change in average prices is less than -0.025 and -0.075 cpl. We also find our results are also to how we classify cycling versus non-cycling markets.

Caveats

Given the potential selection biases in our the GasBuddy data, we raise some caution over the interpretation of our findings. Returning to the sources of selection bias from Atkinson (2008b), to the extent that independent stations are under-sampled relative to brands by GasBuddy price spotters, and to the extent independent stations' prices truly

[19]These findings are generally consistent with previous research that focus on the role of independents in specific cities in Canada. Atkinson (2008a) finds Pioneer is the most aggressive undercutting firm in Guelph Ontario using self-collected high frequency data from 2005. Eckert and West (2004) find Pioneer plays a key role in undercutting and generating price volatility in Ottawa, Ontario relative to Gatineau, Québec using daily price data from www.gastips.com from 2000.

differ from market-level average prices, our measures of price dispersion in Figures 7 and 8 likely underestimates the degree of price dispersion over price cycles.

To the extent that price spotters are more likely to report brands' stations' prices during a restoration over independents' prices (either due to the geographic location of brands' vs. independents' stations or pure branding effects), our estimates of participation rates for brands during restorations will likely be biased upward. Under this sample selectivity, stations run by brands will have "too large" an influence in determining the daily median price for a market relative to a random sample of stations' prices within a day and market. As a result, we will be more likely to observe instances where brands' stations prices are set at or above the median during restoration periods, implying they will be classified as restoration participants "too-often."

It is less clear how sample selection bias affects the magnitude of our price undercutting findings. It is unclear the extent to which GasBuddy spotters over- or under-sample stations' prices that are above or below the city-wide average price; one could make a case for either. To the extent that brands (independents) truly undercut market level average retail prices, over sampling of higher prices set by brand-run stations would tend to push up (down) the magnitude of brands' (independents') undercutting estimates in equation 3. Over-sampling independents' lower prices would tend to push down (up) independents' (brands') undercutting estimates.

5 Concluding remarks

The findings in this paper constitute a comprehensive analysis of price cycles, price coordination and leadership in retail gasoline markets. We find evidence of an inverse-U relationship between market size and the presence of price cycles that is driven by the existence of small, rural sticky pricing and large, urban cost-based pricing markets in the lower and upper tail of the market size distribution. More concentrated markets are less likely to exhibit price cycles, and cycling markets exist within one of three clusters in Eastern

Ontario, the Niagara region and the Southwest toward Windsor, or amongst cities on the Trans-Canada highway in the rural Northern part of the province. Within cycling cities, we find stations run by the major brands, Esso, Shell, Petro-Canada and Sunoco, tend to coordinate their prices to initiate market-wide price jumps, and non-aggressively follow market-level average prices over the undercutting phase of the cycle. In contrast, independent stations tend not to participate in restorations and aggressively undercut prices during the undercutting phase. To our knowledge, this is the first non-U.S. analysis of price cycles, price leadership and coordination using high-frequency retail gasoline prices for a large cross section of markets. Another key point of difference is our access to data for small rural markets that permits a novel examination of retail gasoline price dynamics in the lower tail of the market size distribution.

Taken together, our findings from Sections 3 and 4 motivate future research on how market structure and inventory behaviour affect retail gasoline price dynamics. Within Southern Ontario, our findings of price leadership and coordination within the intermediate-sized markets around Kingston, Niagara Falls and Windsor show that brands can exploit their relatively large networks of stations to periodically induce market-wide price jumps and coordination in gasoline prices.[20] However, our finding that price cycles cease to exist in the large urban markets around Toronto and Hamilton suggests that beyond some point, brands' network size relative to the number of independent retailers is insufficient to allow them to influence market prices via price cycles. Competition in these markets leads to retail prices that are tied to daily movements in wholesale prices (i.e., cost-based pricing).[21]

Within Northern Ontario, cities along the Trans-Canada highway exhibit price cycles, however as markets shrink and become more concentrated, price cycles disappear and sticky pricing equilibria prevail. Market structure and price coordination can also potentially explain these differences. Since brands' stations are essentially the entire network within small

[20]We broadly define Northern Ontario to consist of the Northeast and Northwest economic regions, and Southern Ontario to consist of all other economic regions.

[21]Houde and Clark (2011), p.8, similarly argue that brands' network size relative to the number of heterogeneous independents is a key constraint that governs brands' ability to lead market prices in Québec.

rural markets, price coordination amongst brands is easier to facilitate than within the Northern cities where independent stations exist. The resulting lack of retail gasoline price response to wholesale price changes in our rural markets, in the extreme, could be seen as consistent with tacit collusion, as suggested by previous researchers (Borenstein and Shepard (1996), Borenstein et. al (1997), Eckert and West (2005), among others).

A key difference in the comparison of cycling and non-cycling markets in Southern and Northern Ontario is that the disparity in shipping route density around cycling and non-cycling markets is much larger in the North. Northern cycling cities sit on a main shipping route along the Trans-Canada highway through to Toronto whereas small non-cycling cities are remote and lie on secondary highways. This contrasts the cycling and non-cycling markets in the South which generally lie within the Montreal-Windsor corridor along the dense 400-series Ontario provincial highways.[22] This "difference in the difference" between cycling and non-cycling cities in Southern and Northern Ontario suggests infrequent gasoline inventory shipments may also contribute to nominal price rigidity in rural markets. Aguirregabiria (1999) shows theoretically and empirically that the prevalence of large sunk inventory shipping costs, like those incurred for sending fuel to remote markets, and a non-zero probability of stock-outs can generate (S,s) pricing patterns similar to those in Figure 1 for Goderich and among the Northern rural markets.[23]

Future research in applied theory that explains firms' use of network size to influence and coordinate market prices, and its interaction with market structure, is invaluable for further explaining the differences in pricing dynamics across rural and urban markets found in this paper. Empirical research that formally investigates the link between inventories and the dynamics of retail gasoline prices along the lines of Aguirregabiria (1999) also represents an important research frontier.

[22] A map of the 400-series provincial highways is provided in Figure C.3 in the online appendix.

[23] Another possibility is that station owners in rural markets primarily receive information on current wholesale prices from their infrequent gasoline shipments with which they base their retail prices upon. Reis (2006) shows this sort of costly and imperfect information acquisition over costs is also a micro-foundation for nominal price rigidities amongst firms.

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A Figures

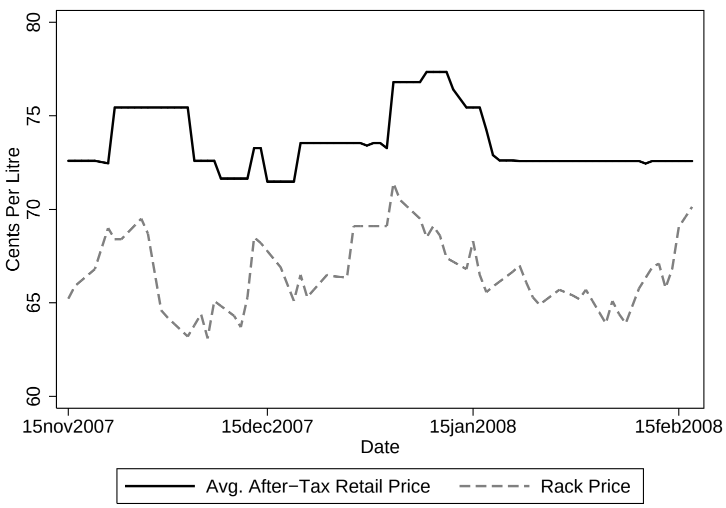

Figure 1: Median Retail and Rack Prices: Goderich, Ontario

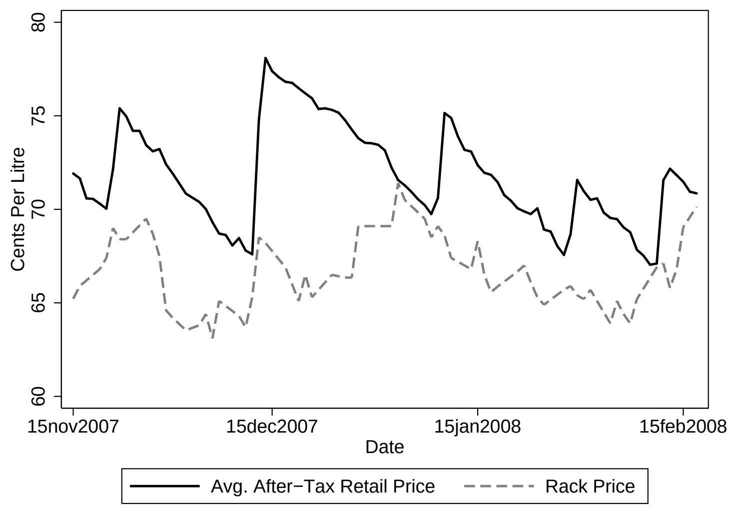

Figure 2: Median Retail and Rack Prices: St. Thomas, Ontario

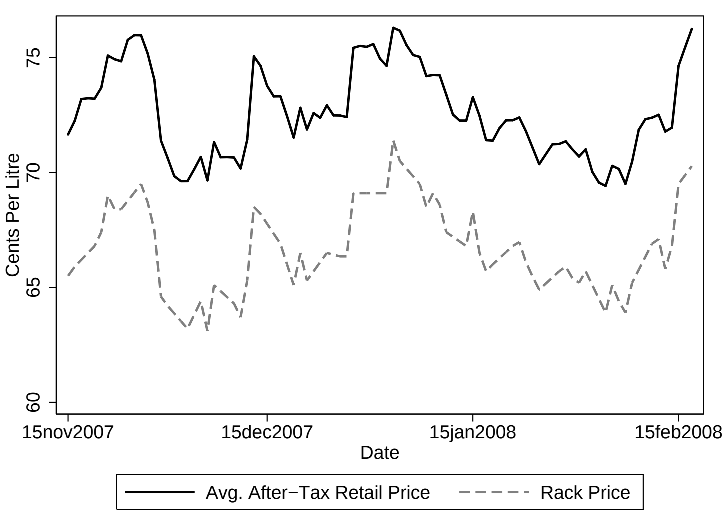

Figure 3: Median Retail and Rack Prices: Ajax, Ontario

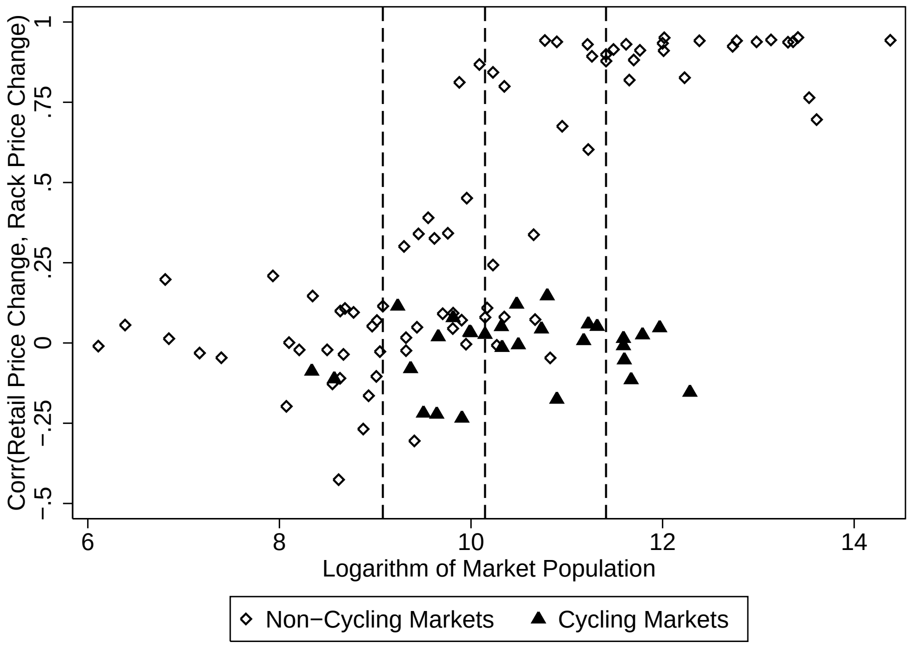

Figure 4: Market Corr(Retail Price Change, Rack Price Change) vs. Market Size
Correlation During Negative Daily Rack Price Changes
Quartiles of Log(Population) Distribution Indicated by Dashed Lines

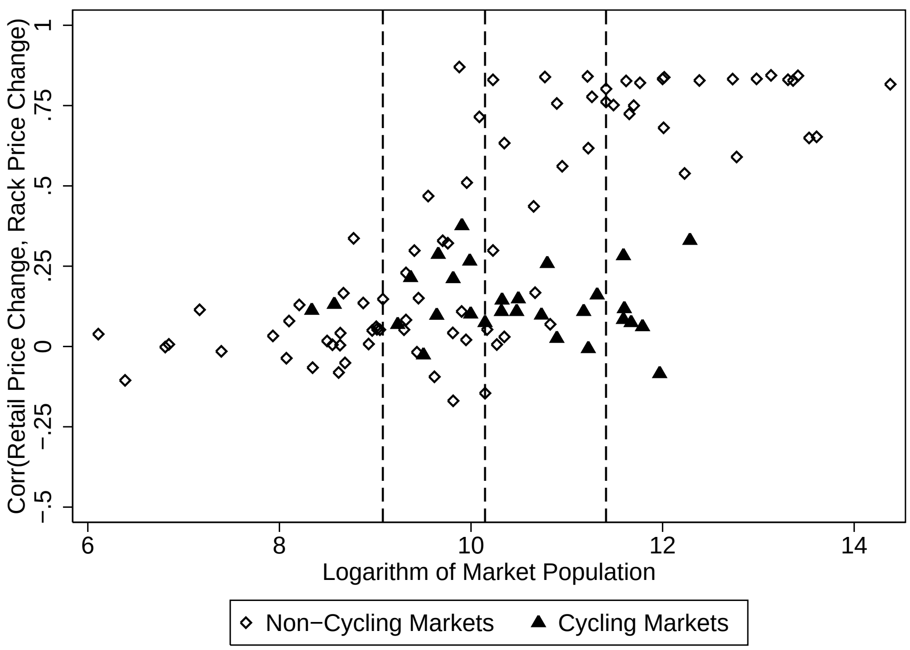

Figure 5: Market Corr(Retail Price Change, Rack Price Change) vs. Market Size
Correlation During Positive Daily Rack Price Changes
Quartiles of Log(Population) Distribution Indicated by Dashed Lines

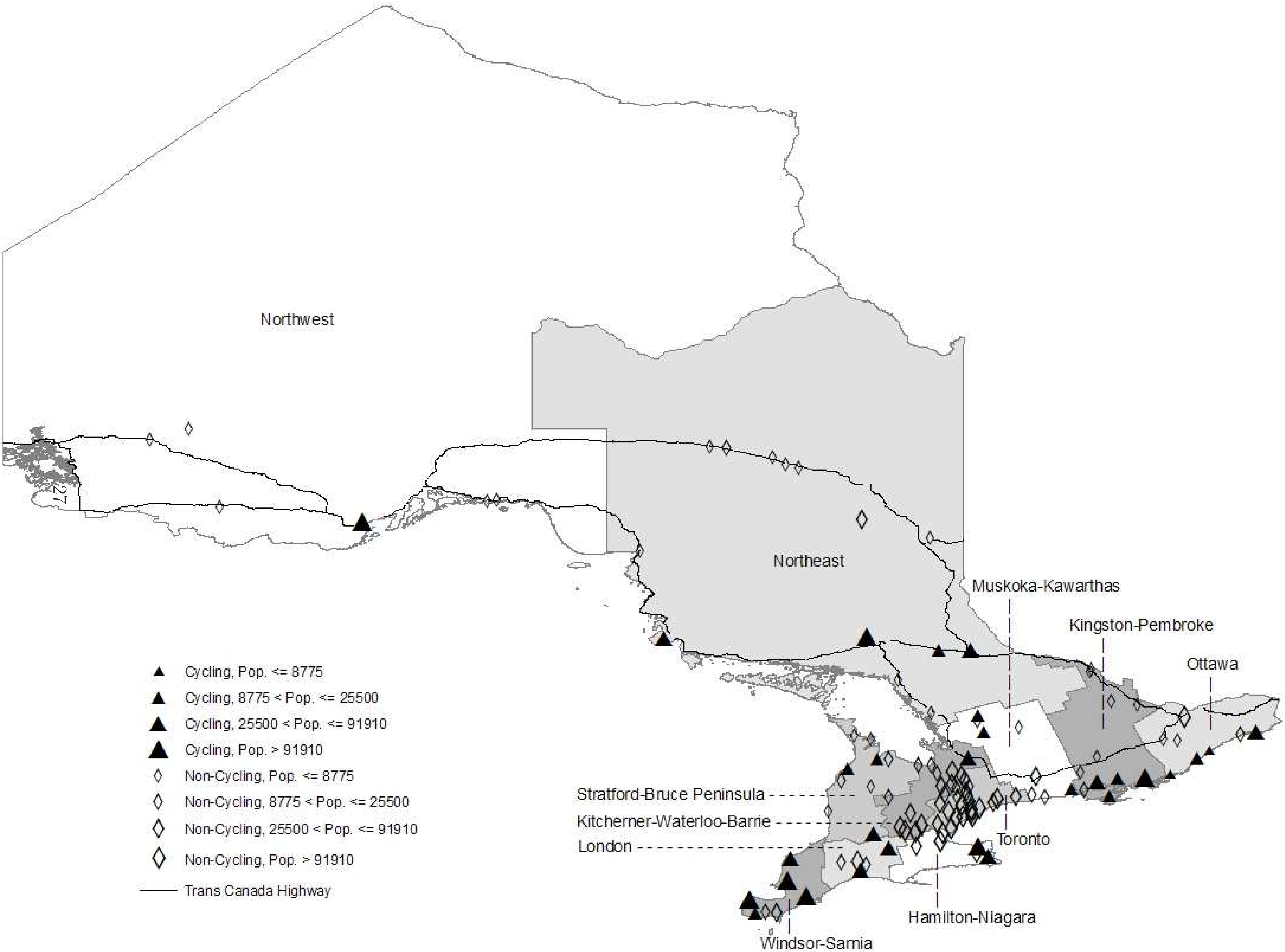

Figure 6: Cycling and Non-Cycling Cities in Ontario, Canada (Economic Regions Shaded)

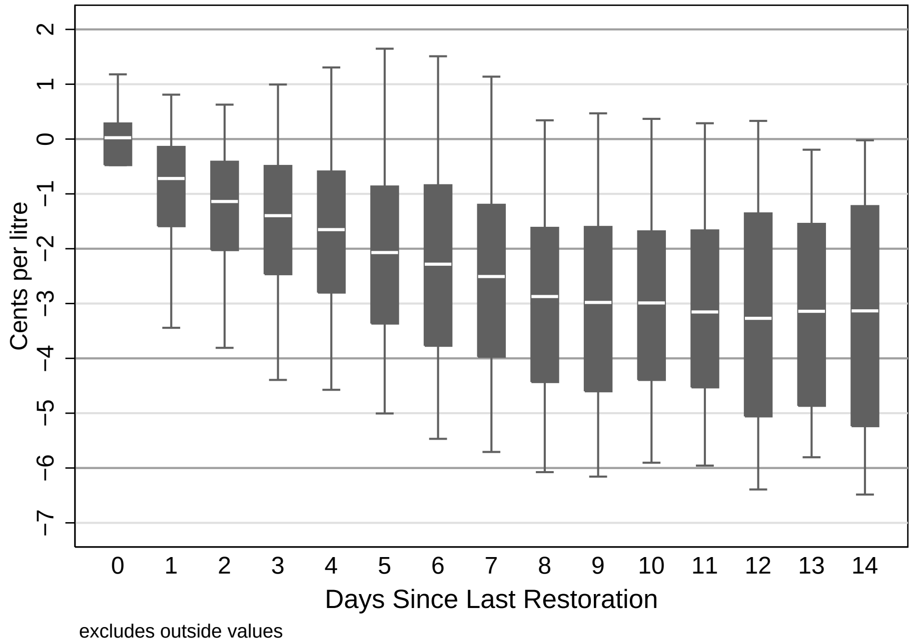

Figure 7: Level and Variability of Brands' Gas Prices over the Price Cycle
Box and Whisker Plots of Stations' Prices Averaged Across Cycling Markets

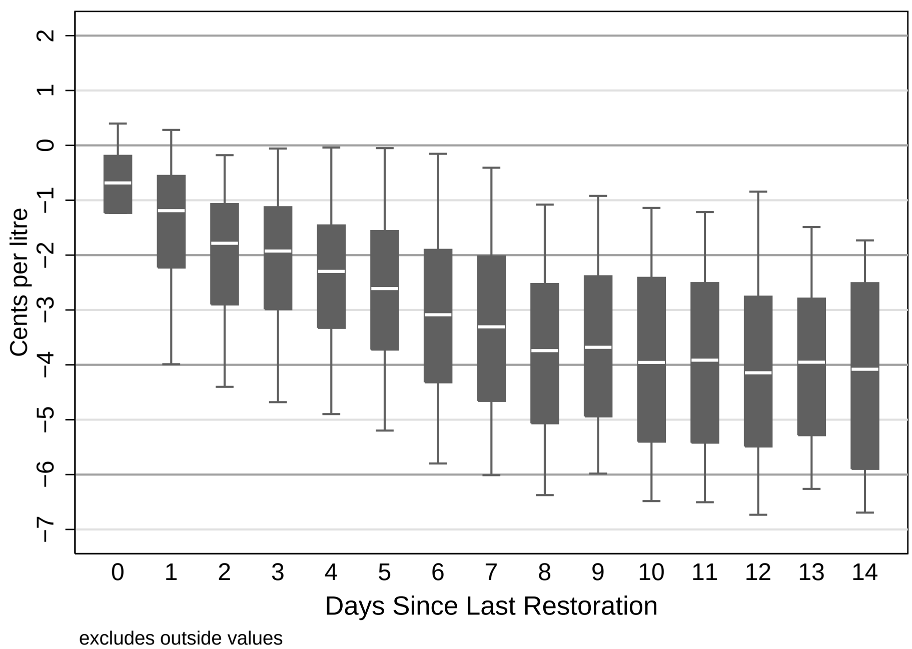

Figure 8: Level and Variability of Independents' Gas Prices over the Price Cycle
Box and Whisker Plots of Stations' Prices Averaged Across Cycling Markets

B Tables

Table 1: Cross Tabulation of Price Cycling Indicator, Market Size and Concentration

	Pop. ≤ 8775	Pop. > 8775 Pop. ≤ 25500	Pop. > 25500 Pop. ≤ 90190	Pop. > 90190	Total
Non-Cycling City	26	18	17	20	81
Cycling City	2	10	10	7	29
Total	28	28	27	27	110
	HHI ≤ 0.134	HHI > 0.134 HHI ≤ 0.187	HHI > 0.187 HHI ≤ 0.280	HHI > 0.280	Total
Non-Cycling City	16	19	22	24	81
Cycling City	12	8	8	1	29
Total	28	27	30	25	110

Notes: A market is classified as having price cycles if its median daily average price change is less than -0.05 cents per litre. The threshold population values of 8,775, 25,500 and 90,190 correspond to the quartiles of the population distribution across the 110 locations in the sample. HHI is computed in terms of station counts within a location. The threshold HHI values of 0.134, 0.187 and 0.280 correspond to the quartiles of the HHI distribution across the 110 locations in the sample.

Table 2: Correlation Between Daily Retail and Rack Price Changes
(By Quartile of the Population and HHI Distributions)

	Avg. Corr(Retail, Rack) Negative Rack Changes		Avg. Corr(Retail, Rack) Positive Rack Changes	
Pop. Distribution				
Q1	-0.022	(0.140)	0.049	(0.091)
Q2	0.125	(0.277)	0.194	(0.241)
Q3	0.351	(0.398)	0.357	(0.320)
Q4	0.658	(0.423)	0.599	(0.305)
HHI Distribution				
Q1	0.286	(0.410)	0.313	(0.291)
Q2	0.438	(0.449)	0.451	(0.328)
Q3	0.282	(0.444)	0.318	(0.359)
Q4	0.072	(0.237)	0.085	(0.185)

Notes: Standard deviations are reported in parentheses. Q# refers to the subset of markets within the $\#^{th}$ quartile of the population distribution in the top panel and the HHI (in terms of station counts) distribution in the bottom panel.

Table 3: Relationship Between Existence of Price Cycles, Market Structure and Size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HHI	-0.618***	-0.631***	-0.621***	-0.563***		-0.411*	-0.367**
	(0.137)	(0.130)	(0.139)	(0.120)		(0.192)	(0.139)
Share Independent		0.109	0.092	0.012	-0.043		-0.011
		(0.164)	(0.156)	(0.279)	(0.305)		(0.242)
Population			-0.015	0.004	0.007	-0.008	
			(0.014)	(0.013)	(0.010)	(0.014)	
HHI [Q2]					-0.026		
					(0.084)		
HHI [Q3]					-0.081		
					(0.119)		
HHI [Q4]					-0.430**		
					(0.176)		
Share Independent [Q2]						-0.024	
						(0.090)	
Share Independent [Q3]						0.091	
						(0.194)	
Share Independent [Q4]						-0.035	
						(0.138)	
Population [Q2]							0.346***
							(0.075)
Population [Q3]							0.494***
							(0.091)
Population [Q4]							0.397***
							(0.113)
ER: Ottawa				-0.146	-0.174*	-0.127	-0.187
				(0.096)	(0.092)	(0.101)	(0.107)
ER: Kingston-Pembroke				0.245*	0.206*	0.220*	0.132
				(0.114)	(0.107)	(0.099)	(0.085)
ER: Muskoka-Kawarthas				-0.081	-0.160	-0.121	-0.231**
				(0.116)	(0.120)	(0.105)	(0.091)
ER: Toronto				-0.491***	-0.584***	-0.541***	-0.672***
				(0.130)	(0.120)	(0.106)	(0.089)
ER: Kitchener-Waterloo-Barrie				-0.483***	-0.567***	-0.521***	-0.704***
				(0.119)	(0.110)	(0.109)	(0.103)
ER: Hamilton-Niagara				-0.308*	-0.411**	-0.422**	-0.536***
				(0.140)	(0.133)	(0.144)	(0.121)
ER: London				-0.048	-0.155	-0.088	-0.276**
				(0.104)	(0.104)	(0.106)	(0.121)
ER: Windsor-Sarnia				0.296	0.189	0.211	0.101
				(0.163)	(0.132)	(0.142)	(0.109)
ER: Bruce Peninsula				-0.036	-0.068	-0.048	-0.188**
				(0.075)	(0.083)	(0.079)	(0.076)
ER: Northeast				0.253**	0.115	0.159*	0.047
				(0.080)	(0.073)	(0.087)	(0.059)
Demographic Controls	N	N	N	Y	Y	Y	Y
R^2	0.155	0.150	0.154	0.356	0.357	0.359	0.448

Notes: The dependent variable is an indicator function equalling one if a market's median daily average price change is less than -0.05 cents per litre. Number of observations is N =110. Standard errors, reported in parentheses, are clustered at the Statistic Canada 4-digit economic region level. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels. "Variable" [Qn] is a dummy variable that equals one if a city's value for "Variable" lies in the n^{th} quartile of the "Variable" distribution across cities. ER: "Region Name" is a dummy variable that equals one if a city lies within the economic region "Region Name." Coefficient estimates for additional controls including average household income, urban density, the fraction of the population who drive to work and the fraction of the population with post-secondary education are not reported.

Table 4: Price Cycle Summary Statistics for Cycling Markets

Economic Region	City/Town	Pop.	Avg. Restoration Price Jump		Avg. Cycle Duration	
Hamilton-Niagara	St Catharines	131990	3.452	(1.688)	7.429	(5.946)
	Niagara Falls	82185	3.880	(1.406)	7.000	(5.944)
Kingston-Pembroke	Kingston	117205	6.872	(1.903)	6.420	(1.907)
	Belleville	48825	5.540	(2.599)	7.732	(4.074)
	Picton	25500	5.084	(2.843)	10.103	(5.453)
	Brockville	21955	8.064	(3.245)	8.914	(4.985)
	Napanee	15405	6.902	(2.299)	7.400	(4.643)
	Brighton	10250	3.794	(1.843)	8.212	(4.917)
	Gananoque	5285	5.609	(2.627)	8.000	(7.274)
London	St Thomas	36110	6.044	(2.142)	9.120	(5.732)
	Woodstock	35480	3.468	(1.555)	5.298	(3.094)
Muskoka-Kawarthas	Orillia	30255	3.913	(2.013)	6.156	(4.557)
	Huntsville	18280	4.819	(2.545)	8.852	(5.934)
	Bracebridge	15650	5.982	(2.942)	8.625	(5.353)
Northeast	Sudbury	157855	6.042	(2.405)	9.960	(5.870)
	North Bay	53970	5.565	(2.047)	8.865	(4.523)
	Sturgeon Falls	13410	5.261	(2.524)	9.720	(4.306)
Northwest	Thunder Bay	109140	3.970	(2.643)	5.352	(4.153)
	Sault Ste Marie	74950	4.022	(2.697)	5.056	(4.529)
Ottawa	Cornwall	45965	4.247	(1.518)	8.735	(4.857)
	Prescott	4180	6.910	(2.221)	8.868	(4.199)
Stratford-Bruce-Peninsula	Stratford	30460	5.353	(2.255)	9.421	(6.336)
	Owen Sound	21745	5.805	(2.278)	7.649	(5.224)
	Port Elgin	11725	4.837	(1.849)	8.286	(4.567)
Windsor-Sarnia	Windsor	216470	5.286	(1.316)	7.043	(3.148)
	Chatham	108175	5.671	(2.185)	10.167	(6.644)
	Wallaceburg	108175	4.391	(1.825)	8.056	(5.641)
	Sarnia	71420	7.709	(3.009)	8.875	(6.354)
	Essex	20030	4.155	(1.909)	9.400	(7.327)

Notes: Standard deviations are reported in parentheses. These statistics are based on 910 cycles identified by a cut-off rule thats defines restorations as one or two day periods where a market's median daily price increases by more than 1.5 cpl.

Table 5: Firm Participation in Restorations

	1.5 cents/litre	2 cents/litre	2.5 cents/litre
Esso	0.279***	0.282***	0.278***
	(0.041)	(0.040)	(0.042)
Shell	0.234***	0.229***	0.212***
	(0.051)	(0.049)	(0.051)
Petro-Canada	0.309***	0.331***	0.315***
	(0.043)	(0.043)	(0.045)
Sunoco	0.213***	0.237***	0.199***
	(0.047)	(0.045)	(0.045)
Canadian Tire	0.113*	0.107**	0.110*
	(0.060)	(0.051)	(0.057)
Ultramar	-0.124***	-0.117***	-0.134***
	(0.045)	(0.039)	(0.042)
Pioneer	-0.184***	-0.179***	-0.192***
	(0.042)	(0.042)	(0.042)
Olco	-0.053	0.017	-0.003
	(0.080)	(0.075)	(0.091)
7-11	0.132	0.159	0.182
	(0.124)	(0.142)	(0.123)
MacEwen	-0.170***	-0.165**	-0.163**
	(0.060)	(0.073)	(0.071)
Mac's	-0.214***	-0.180***	-0.195**
	(0.078)	(0.067)	(0.085)
Constant	0.313	0.250	-0.131
	(0.236)	(0.250)	(0.091)
R^2	0.157	0.170	0.169
N	8698	8155	7831

Notes: The dependent variable is an indicator equalling one if a station sets its price at or above the median price during a restoration period. Standard errors, reported in parentheses, are clustered at the city-brand level. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels. The column headers of #.# cents/litre refer to a cut-off rule thats defines restorations as one or two day periods where a market's median daily price increases by more than #.# cpl.

Table 6: Firm Undercutting Aggressiveness by Day of Cycle

	Days Since Last Restoration						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Esso	0.632***	0.215	0.008	-0.063	-0.060	0.037	0.247
	(0.160)	(0.427)	(0.528)	(0.603)	(0.678)	(0.681)	(0.630)
Shell	0.302	-0.174	-0.199	-0.317	-0.290	-0.219	-0.107
	(0.203)	(0.359)	(0.481)	(0.525)	(0.602)	(0.622)	(0.651)
Petro-Canada	0.604***	-0.001	-0.122	-0.431	-0.371	-0.277	0.182
	(0.166)	(0.252)	(0.324)	(0.359)	(0.390)	(0.501)	(0.521)
Sunoco	0.431***	-0.155	-0.226	-0.276	-0.320	-0.278	-0.217
	(0.163)	(0.355)	(0.447)	(0.530)	(0.623)	(0.730)	(0.621)
Canadian Tire	0.121	-0.180	-0.236	-0.350	-0.534	-0.372	-0.320
	(0.200)	(0.378)	(0.447)	(0.459)	(0.536)	(0.629)	(0.605)
Ultramar	-0.583**	-1.577***	-1.981***	-2.107***	-2.370***	-2.737***	-2.834***
	(0.228)	(0.569)	(0.567)	(0.617)	(0.668)	(0.673)	(0.995)
Pioneer	-0.429**	-1.098*	-1.252*	-1.498**	-1.637**	-1.466*	-1.428*
	(0.174)	(0.609)	(0.670)	(0.668)	(0.790)	(0.857)	(0.809)
Olco	-0.185	-0.492**	-0.811**	-0.801*	-1.081**	-1.074*	-1.021*
	(0.257)	(0.235)	(0.393)	(0.411)	(0.512)	(0.562)	(0.581)
7-11	0.127	0.588**	0.471**	0.362	0.599*	0.577	0.483
	(0.163)	(0.260)	(0.221)	(0.375)	(0.353)	(0.559)	(0.457)
MacEwen	-0.090	-0.756**	-0.677**	-0.560*	-0.801**	-1.294**	-1.097*
	(0.143)	(0.338)	(0.325)	(0.320)	(0.380)	(0.527)	(0.655)
Mac's	-1.111***	-0.782	-0.646	-0.341	-0.193	0.152	-0.012
	(0.313)	(0.513)	(0.420)	(0.431)	(0.534)	(0.451)	(0.693)
Constant	-1.131***	-1.438***	-1.900***	-2.133***	-2.577***	-2.968***	-3.216***
	(0.127)	(0.130)	(0.154)	(0.151)	(0.202)	(0.242)	(0.214)
R^2	0.037	0.064	0.073	0.076	0.085	0.078	0.067
N	21622	10572	9355	8895	9208	7950	6066

Notes: The dependent variable is the difference between a station's price and the last restoration price where restorations are identified as days where a market's one or two day price difference is more than 2.5 cents per litre. Standard errors, reported in parentheses, are clustered at the city-brand level. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.

C Supplemental Appendix (Not for Publication)

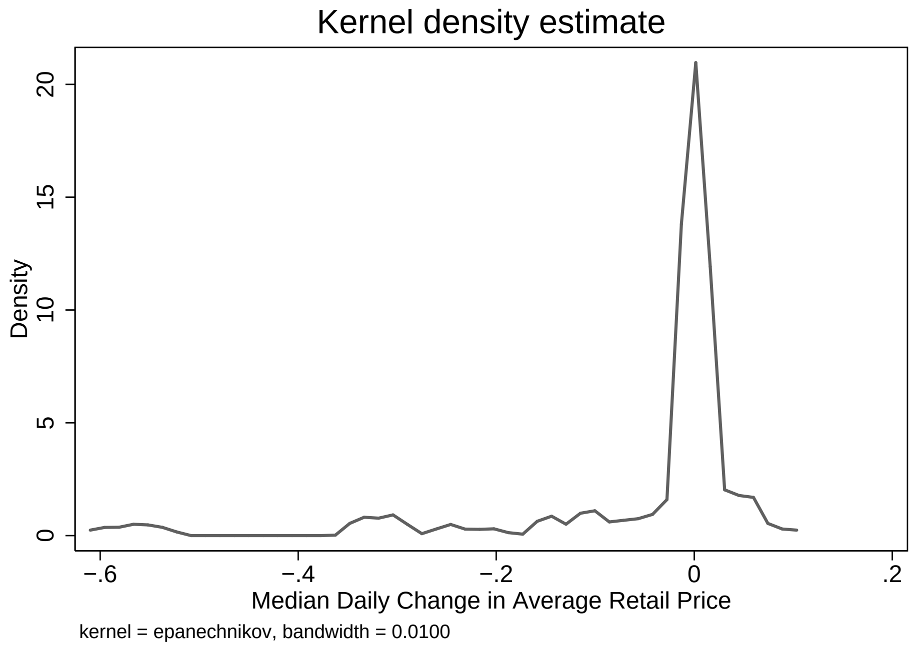

Figure C.1: Kernel Density of Median Daily Change in Average Retail Price

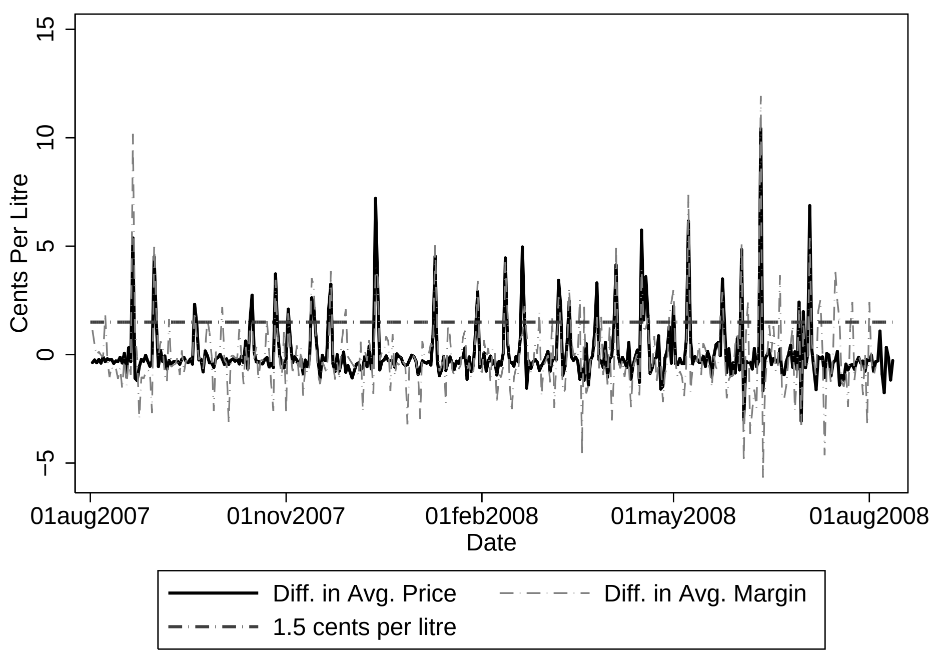

Figure C.2: Daily Difference in Median Retail Price and Median Margin in St. Thomas

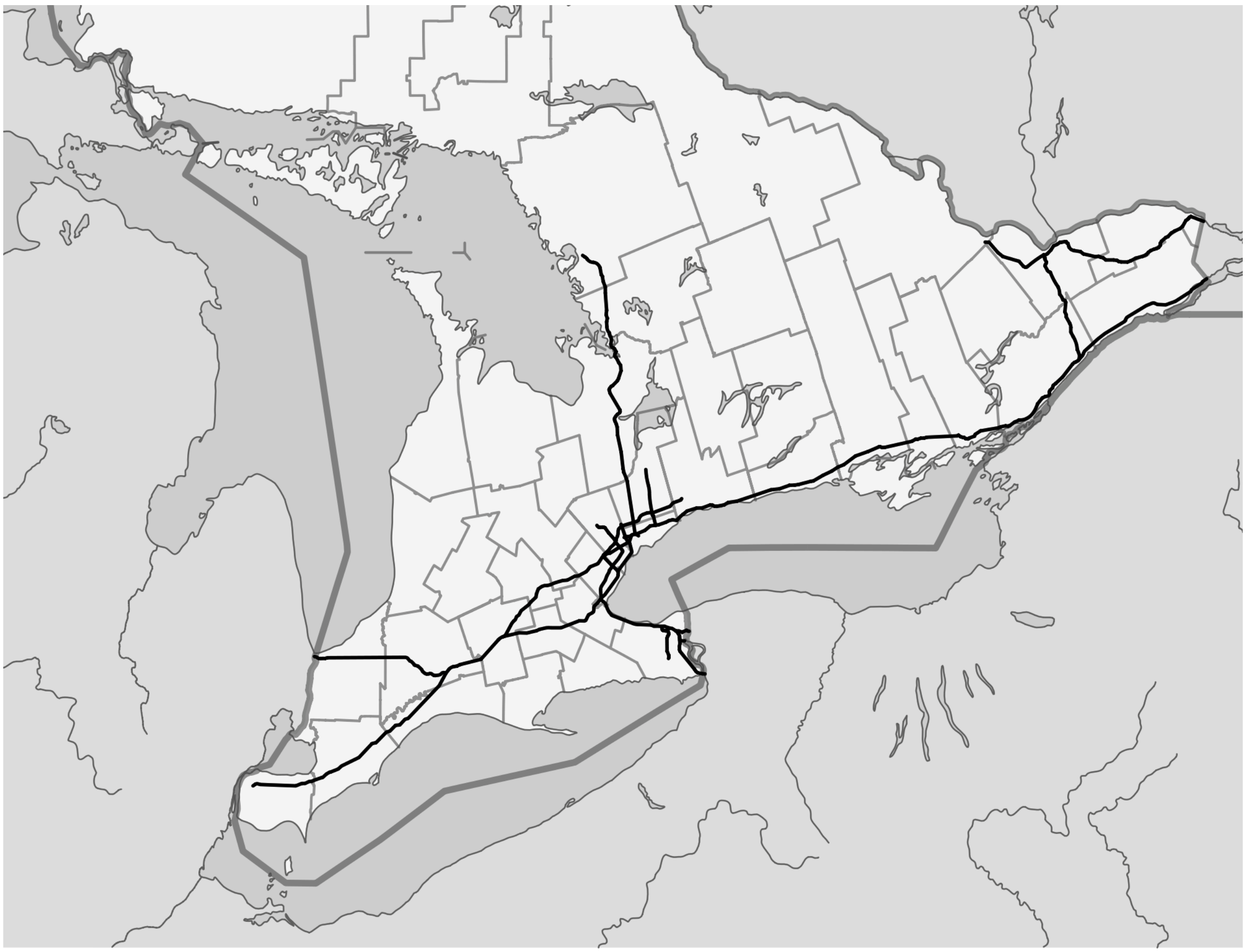

Figure C.3: 400 Series Highways in Southern Ontario
Highways Indicated by Solid Black Lines

Table C.1: Relationship Between Existence of Price Cycles, Market Structure and Size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HHI	-0.554***	-0.558***	-0.545***	-0.388**		-0.174	-0.225
	(0.126)	(0.126)	(0.133)	(0.128)		(0.164)	(0.164)
Share Independent		0.032	0.011	-0.117	-0.157		-0.077
		(0.106)	(0.112)	(0.203)	(0.203)		(0.186)
Population			-0.018	-0.004	-0.003	-0.020	
			(0.014)	(0.014)	(0.011)	(0.016)	
HHI [Q2]					-0.047		
					(0.103)		
HHI [Q3]					-0.200		
					(0.119)		
HHI [Q4]					-0.359*		
					(0.170)		
Share Independent [Q2]						-0.061	
						(0.114)	
Share Independent [Q3]						0.118	
						(0.194)	
Share Independent [Q4]						-0.132	
						(0.117)	
Population [Q2]							0.237*
							(0.107)
Population [Q3]							0.492***
							(0.110)
Population [Q4]							0.404**
							(0.167)
ER: Ottawa				-0.192*	-0.178*	-0.147	-0.208*
				(0.090)	(0.088)	(0.102)	(0.094)
ER: Kingston-Pembroke				0.054	0.050	0.039	-0.016
				(0.105)	(0.102)	(0.111)	(0.089)
ER: Muskoka-Kawarthas				-0.223*	-0.280**	-0.274**	-0.311**
				(0.110)	(0.115)	(0.103)	(0.104)
ER: Toronto				-0.498***	-0.501***	-0.548***	-0.694***
				(0.133)	(0.117)	(0.131)	(0.112)
ER: Kitchener-Waterloo-Barrie				-0.496***	-0.536***	-0.538***	-0.702***
				(0.123)	(0.114)	(0.115)	(0.113)
ER: Hamilton-Niagara				-0.328**	-0.388**	-0.488**	-0.569***
				(0.144)	(0.142)	(0.157)	(0.130)
ER: London				-0.054	-0.142	-0.105	-0.265**
				(0.105)	(0.109)	(0.112)	(0.119)
ER: Windsor-Sarnia				0.141	0.095	0.032	-0.047
				(0.151)	(0.131)	(0.139)	(0.113)
ER: Bruce Peninsula				-0.089	-0.091	-0.104	-0.163
				(0.081)	(0.090)	(0.083)	(0.095)
ER: Northeast				0.233**	0.111	0.100	0.037
				(0.080)	(0.079)	(0.089)	(0.074)
Demographic Controls	N	N	N	Y	Y	Y	Y
R^2	0.135	0.127	0.140	0.285	0.292	0.323	0.379

Notes: The dependent variable is an indicator function equalling one if a market's median daily average price change is less than -0.05 cents per litre. Number of observations is N =110. Standard errors, reported in parentheses, are clustered at the Statistic Canada 4-digit economic region level. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels. "Variable" [Qn] is a dummy variable that equals one if a city's value for "Variable" lies in the n^{th} quartile of the "Variable" distribution across cities. ER: "Region Name" is a dummy variable that equals one if a city lies within the economic region "Region Name." Coefficient estimates for additional controls including average household income, urban density, the fraction of the population who drive to work and the fraction of the population with post-secondary education are not reported.

Table C.2: Relationship Between Existence of Price Cycles, Market Structure and Size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HHI	-0.568***	-0.583***	-0.573***	-0.550***		-0.455**	-0.399***
	(0.130)	(0.123)	(0.129)	(0.124)		(0.188)	(0.116)
Share Independent		0.124	0.108	0.055	-0.003		-0.007
		(0.194)	(0.186)	(0.295)	(0.316)		(0.260)
Population			-0.014	-0.001	0.002	-0.006	
			(0.013)	(0.013)	(0.011)	(0.012)	
HHI [Q2]					-0.050		
					(0.094)		
HHI [Q3]					-0.043		
					(0.116)		
HHI [Q4]					-0.376*		
					(0.178)		
Share Independent [Q2]						0.027	
						(0.115)	
Share Independent [Q3]						0.094	
						(0.216)	
Share Independent [Q4]						0.036	
						(0.178)	
Population [Q2]							0.294***
							(0.063)
Population [Q3]							0.372***
							(0.098)
Population [Q4]							0.247*
							(0.113)
ER: Ottawa				0.018	-0.024	0.022	-0.028
				(0.083)	(0.090)	(0.095)	(0.101)
ER: Kingston-Pembroke				0.318***	0.279**	0.306***	0.204**
				(0.098)	(0.100)	(0.088)	(0.082)
ER: Muskoka-Kawarthas				0.088	0.024	0.071	-0.066
				(0.103)	(0.123)	(0.097)	(0.092)
ER: Toronto				-0.295**	-0.387***	-0.311***	-0.463***
				(0.107)	(0.120)	(0.096)	(0.072)
ER: Kitchener-Waterloo-Barrie				-0.287**	-0.367***	-0.307***	-0.479***
				(0.098)	(0.106)	(0.093)	(0.090)
ER: Hamilton-Niagara				-0.093	-0.177	-0.148	-0.281**
				(0.116)	(0.134)	(0.131)	(0.115)
ER: London				0.140	0.050	0.115	-0.057
				(0.088)	(0.099)	(0.092)	(0.102)
ER: Windsor-Sarnia				0.497***	0.395**	0.456***	0.333**
				(0.146)	(0.137)	(0.136)	(0.111)
ER: Bruce Peninsula				0.118*	0.091	0.111	-0.031
				(0.065)	(0.083)	(0.068)	(0.074)
ER: Northeast				0.359***	0.247**	0.315***	0.204**
				(0.072)	(0.080)	(0.085)	(0.066)
Demographic Controls	N	N	N	Y	Y	Y	Y
R^2	0.137	0.132	0.136	0.308	0.293	0.292	0.363

Notes: The dependent variable is an indicator function equalling one if a market's median daily average price change is less than -0.05 cents per litre. Number of observations is N =110. Standard errors, reported in parentheses, are clustered at the Statistic Canada 4-digit economic region level. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels. "Variable" [Qn] is a dummy variable that equals one if a city's value for "Variable" lies in the n^{th} quartile of the "Variable" distribution across cities. ER: "Region Name" is a dummy variable that equals one if a city lies within the economic region "Region Name." Coefficient estimates for additional controls including average household income, urban density, the fraction of the population who drive to work and the fraction of the population with post-secondary education are not reported.

Table C.3: Firm Undercutting Aggressiveness by Day of Cycle

	Days Since Last Restoration						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Esso	0.647***	0.218	-0.040	-0.040	-0.056	0.024	0.300
	(0.162)	(0.383)	(0.528)	(0.623)	(0.674)	(0.687)	(0.691)
Shell	0.318	-0.079	-0.251	-0.292	-0.342	-0.276	-0.158
	(0.215)	(0.340)	(0.483)	(0.530)	(0.590)	(0.585)	(0.680)
Petro-Canada	0.655***	0.079	-0.124	-0.440	-0.366	-0.317	0.111
	(0.173)	(0.243)	(0.320)	(0.358)	(0.380)	(0.497)	(0.546)
Sunoco	0.488***	-0.120	-0.260	-0.283	-0.314	-0.372	-0.152
	(0.163)	(0.350)	(0.466)	(0.502)	(0.602)	(0.764)	(0.668)
Canadian Tire	0.135	-0.228	-0.251	-0.373	-0.541	-0.402	-0.292
	(0.188)	(0.395)	(0.441)	(0.472)	(0.535)	(0.610)	(0.638)
Ultramar	-0.495**	-1.583***	-2.056***	-2.074***	-2.338***	-2.729***	-2.862***
	(0.222)	(0.519)	(0.549)	(0.617)	(0.646)	(0.629)	(1.018)
Pioneer	-0.377**	-1.055*	-1.224*	-1.489**	-1.649**	-1.553*	-1.406
	(0.166)	(0.602)	(0.661)	(0.673)	(0.776)	(0.830)	(0.871)
Olco	-0.069	-0.388**	-0.823*	-0.845*	-0.958*	-1.046*	-0.993
	(0.244)	(0.156)	(0.430)	(0.459)	(0.543)	(0.561)	(0.607)
7-11	0.077	0.749**	0.477**	0.359	0.604*	0.575	0.543
	(0.179)	(0.310)	(0.221)	(0.385)	(0.351)	(0.548)	(0.465)
MacEwen	-0.067	-0.699**	-0.679*	-0.529	-0.786*	-1.305**	-0.970
	(0.149)	(0.334)	(0.364)	(0.333)	(0.401)	(0.513)	(0.747)
Mac's	-1.063***	-0.721	-0.676	-0.451	-0.295	0.045	-0.043
	(0.326)	(0.505)	(0.465)	(0.486)	(0.492)	(0.471)	(0.632)
Constant	-1.147***	-1.474***	-1.879***	-2.135***	-2.555***	-2.957***	-3.292***
	(0.135)	(0.128)	(0.160)	(0.160)	(0.198)	(0.242)	(0.241)
R^2	0.035	0.068	0.073	0.075	0.083	0.076	0.067
N	20382	10033	9036	8691	9058	8100	6093

Notes: The dependent variable is the difference between a station's price and the last restoration price where restorations are identified as days where a market's one or two day price difference is more than 2 cents per litre. Standard errors, reported parentheses, are clustered at the city-brand-restoration level. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.

Table C.4: Firm Undercutting Aggressiveness by Day of Cycle

	Days Since Last Restoration						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Esso	0.627***	0.249	-0.028	-0.084	0.028	0.044	0.338
	(0.166)	(0.371)	(0.539)	(0.621)	(0.665)	(0.706)	(0.691)
Shell	0.332	-0.009	-0.261	-0.292	-0.281	-0.302	-0.161
	(0.207)	(0.321)	(0.489)	(0.526)	(0.592)	(0.585)	(0.665)
Petro-Canada	0.642***	0.113	-0.119	-0.457	-0.329	-0.280	0.033
	(0.178)	(0.227)	(0.331)	(0.345)	(0.365)	(0.492)	(0.534)
Sunoco	0.495***	-0.105	-0.272	-0.262	-0.282	-0.261	-0.170
	(0.167)	(0.328)	(0.492)	(0.491)	(0.582)	(0.724)	(0.726)
Canadian Tire	0.128	-0.224	-0.322	-0.388	-0.512	-0.430	-0.219
	(0.190)	(0.373)	(0.477)	(0.456)	(0.514)	(0.624)	(0.621)
Ultramar	-0.483**	-1.609***	-2.062***	-2.058***	-2.309***	-2.698***	-2.874***
	(0.214)	(0.495)	(0.544)	(0.585)	(0.604)	(0.636)	(0.966)
Pioneer	-0.360**	-1.040*	-1.235*	-1.490**	-1.608**	-1.590*	-1.467*
	(0.163)	(0.584)	(0.670)	(0.652)	(0.763)	(0.814)	(0.857)
Olco	-0.004	-0.367**	-0.773*	-0.898**	-0.796	-1.049*	-0.943
	(0.215)	(0.169)	(0.456)	(0.448)	(0.514)	(0.594)	(0.608)
7-11	0.051	0.829**	0.601***	0.350	0.607*	0.545	0.746
	(0.186)	(0.332)	(0.208)	(0.415)	(0.345)	(0.476)	(0.465)
MacEwen	-0.087	-0.726**	-0.728**	-0.537*	-0.751*	-1.322***	-0.957
	(0.151)	(0.313)	(0.344)	(0.318)	(0.396)	(0.503)	(0.712)
Mac's	-1.053***	-0.494	-0.419	-0.377	0.008	0.317	0.228
	(0.327)	(0.520)	(0.428)	(0.522)	(0.454)	(0.446)	(0.551)
Constant	-1.115***	-1.478***	-1.899***	-2.136***	-2.597***	-2.959***	-3.327***
	(0.138)	(0.132)	(0.162)	(0.158)	(0.199)	(0.243)	(0.242)
R^2	0.034	0.075	0.074	0.075	0.085	0.078	0.068
N	19536	9652	8721	8490	8801	7983	6027

Notes: The dependent variable is the difference between a station's price and the last restoration price where restorations are identified as days where a market's one or two day price difference is more than 2.5 cents per litre. Standard errors, reported parentheses, are clustered at the city-brand-restoration level. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.