Station-Level Price Elasticities of Demand for Gasoline in a Market with Price Cycles*

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Abstract

Regular gasoline price cycles are prevalent in many Canadian and Australian cities. This paper uses a unique data set to estimate station-level price elasticities of demand for gasoline in a market with regular price cycles. The estimated own, cross and intertemporal elasticities suggest that the drivers in this market are very price sensitive and that gasoline has likely been used a loss leader. These results support the hypothesis that the observed gasoline price cycles are Edgeworth cycles and that if the many individual retail stations are all independent price setters, the cycles would disappear and the resulting equilibrium would be competitive.

JEL: L13, L42

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1. Introduction

Retail gasoline prices in many Australian and Canadian cities exhibit high-frequency price cycles in which prices increase rapidly and substantially and then decline gradually over a period of a week or longer. What is driving these price cycles has been the subject of public debates, government investigations and even price-fixing court proceedings.[1] A growing empirical literature has also emerged to investigate whether the Edgeworth cycle equilibrium in the Maskin and Tirole (1988) dynamic oligopoly model can be used to explain the observed price cycles (see, e.g., Eckert 2002, Eckert 2003, Eckert and West 2004, Noel 2004a and Noel 2005 on Canadian markets; Wang 2005a, b on Australian markets). This literature has presented substantial evidence supporting the Edgeworth cycle theory, and in particular, the hypothesis that the dynamic interaction between the oligopoly firms in those cycling markets is responsible for the price increases. An implication of the theory is that the price cycles would disappear if the large number of individual gasoline stations were left to set their own prices because the tight oligopoly coordination needed to hike price would be absent in such a market structure.

To date, however, this literature has not been able to investigate the demand side of the cycling gasoline markets.[2] Yet such a study will reveal the extent to which the demand conditions of the cycling markets resemble the Maskin and Tirole model. More importantly, such a study will shed light on a counterfactual, but important policy question: if the many retail outlets are all independent price setters, will the resulting equilibrium in the currently cycling retail markets be competitive? Unfortunately, the existing literature has not been able to estimate

[1] The Federal Court of Australia found that a group of local distributors and retailers in an Australian gasoline market coordinated explicitly through extensive phone calls to generate the sudden and substantial price increases. Australian Competition and Consumer Commission v Leahy Petroleum Pty Ltd and Others [2004], Federal Court of Australia 1678, December 17, 2004. A similar price-fixing case in another Australian gasoline market is currently before the Federal Court of Australia.

[2] Slade (1986) estimates price elasticities of demand for 13 gasoline stations in a submarket of Vancouver in the summer of 1983, but the Vancouver market at that time did not have regular price cycles.

the demand for or the market power of the individual gasoline stations in the currently cycling markets because of the lack of appropriate station-level quantity data. The difficulty lies mainly in the price volatility in these markets: it is common for a retail site in such a market to change its price several times within a single day.[3] To estimate the station-level gasoline demand in these highly volatile markets, quantity data that matches the timing of price changes is needed. Quantity and price data averaged over a fixed period (say, a day) is unlikely to yield accurate estimates of price elasticities.[4]

In this paper, I am able to collect price-quantity data that matches in timing by exploring the special timing restriction on price setting in an Australian market with regular price cycles. In Western Australia, a law, called the 24-hour-rule, requires that (1) all the gasoline stations in the Perth area must notify to the government their next day's retail prices by 2:00pm each day so that the notified price can be published on the internet around 3:00pm, and (2) the notified prices must be posted on the price board at the beginning of the next day and must remain unchanged for 24 hours. Because the firms have to set their next day's prices without observing those of their rivals, they effectively have to set prices synchronously once every 24 hours. This timing restriction makes it possible to collect daily sales data that matches the daily prices.

To anticipate results, the estimated own price elasticities range from -5.51 to -18.41, indicating that drivers in the Perth area are indeed very sensitive about gasoline price. The results also suggest that some drivers have engaged in intertemporal substitution. The observed Lerner indices range from 1.6% to 6.4%, indicating that the market power of the retail outlets is in fact smaller than that implied by the estimated price elasticities, likely a result of loss leader

[3] For example, in its Consumer Fact Sheet on Gasoline Prices, Competition Bureau of Canada notes that “it is common for a gasoline station to change its prices more than 25 times per week.” (www.competitionbureau.gc.ca.)
[4] The daily average prices for two nearby stations could be identical, yet their prices may be different at a given time within a day.

pricing. These results suggest that the Perth market would be competitive if the gasoline stations are left to be independent decision makers.

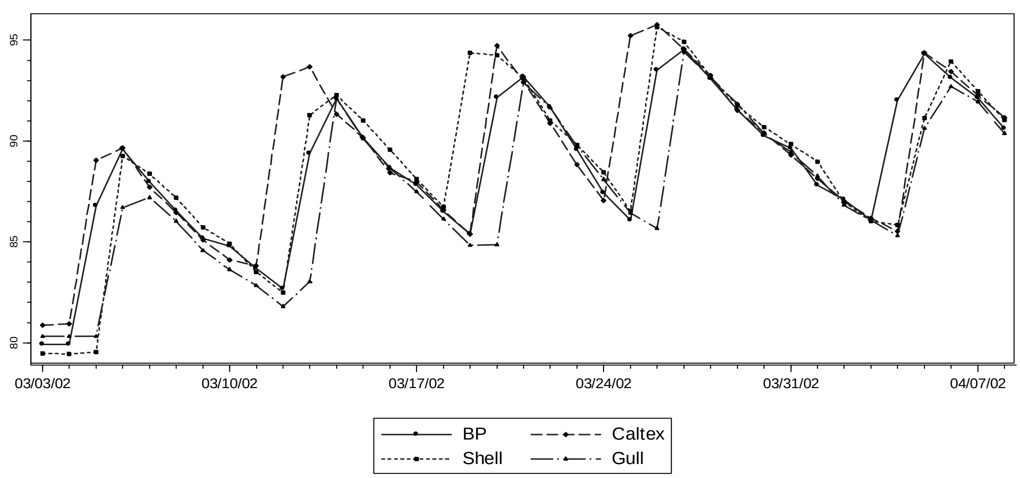
Section 2 summarizes the existing literature to explain why price cycles would disappear if retail outlets were independent price setters, and provides the basic market background. Section 3 describes the data and section 4 presents the elasticity estimates. Section 5 concludes.

2. Existing Literature and Market Background

The Maskin and Tirole duopoly model features a homogenous product such that the competitive equilibrium would prevail in a static setting, but in a dynamic setting, the Edgeworth cycle equilibrium can arise. The assumption of a homogenous product implies that a firm has a strong incentive to undercut its rival to steal the market. For this reason, the market price declines gradually to the competitive level, at which point, in the words of Tirole (1988, p.256), "a firm could raise its price dramatically and lure its rival to charge a high price for at least some time [through the force of strategic complementarity]." However, in a model with three or more players, after one firm has raised its price, none of the remaining firms experience individually the allure of strategic complementarity. When simulating a 3-player model, Noel (2004b, p. 16) confirms the emergence of "'delayed' starts in which following firms do not follow immediately and even 'false' starts in which the relenting firm returns to the bottom when others do not follow soon enough." That is, a coordination problem exists at the cycle bottom. Wang's (2005a) empirical evidence confirms that this coordination problem is hard to resolve if the number of players is large in a market. Wang uses the detailed trial record from a price-fixing case to study the pricing behavior and communication patterns of the colluding gasoline firms (local distributors and retailers) in an Australian market with regular price cycles. Wang finds that, even though the firms in that market made extensive phone calls to coordinate the price-hikes, about half of the attempts to hike price failed because not all firms (especially the independent brands) followed the lead price hikes. Wang also documents that the independent brands, if following the lead price increases, hiked their prices to a level about 0.2 to 0.4 cents per liter lower than that of the major brands.

Figure 1 shows the daily average regular unleaded gasoline prices of the four largest gasoline brands in the Perth market over the period March 2 through April 14, 2002. The unit of price is Australian cent per liter. BP, Caltex and Shell are the three largest oil brands and Gull is the largest independent brand in this market. It is apparent that one or more major oil brands lift up their prices in big jumps and then the other brands follow on the second or third day. In Australia, the oil firms by law are vertically separated, but Wang (2005b) documents that they synchronize and homogenize intrabrand retail price increases through vertical restraints. Wang (2005b) shows that the independent brands in the Perth market almost always follow the price increases initiated by the major brands, but with an average discount of about 2-cent per liter.

Figure 1: Daily Average Regular Unleaded Gasoline Prices of the Four Brands in the Perth Market



Note that intrabrand synchronization through vertical restraints dramatically reduces the number of competitors, thus facilitating the coordination to hike price. Synchronized intrabrand price hikes by one or more major brands are also a quick and effective way to provide smaller gasoline brands with the allure of strategic complementarity. The major oil firms in Canada are vertically integrated so that intrabrand coordination can be easily achieved. How the oil firms in Canada use central computer systems to control retail prices is described by Conference Board of Canada (2001, p. 26). This report (p. 28) states that price restorations are "almost always led by majors or regional refiners," and a price restoration attempt "will be abandoned or adjusted" if it is not followed by all firms. Eckert and West (2004) indeed find that price restorations are led by major oil brands in the Vancouver market. Noel (2005) also finds that retail outlets of major brands in the Toronto market are more likely to lead price up, but outlets of independent brands are more likely to lead price down.

The existing evidence suggests that if the many gasoline stations are left to set their own prices, the coordination problem will prevent price cycles from occurring. Indeed, regular gasoline price cycles have only been observed in markets where either vertical integration or vertical restraint is present. But would the resulting equilibrium in the currently cycling gasoline markets be competitive if the retail stations are left to set their own prices? The answer depends on the station-level gasoline demand. It is claimed by industry studies that Canadian and Australian drivers are very price sensitive,[5] but no empirical evidence has been offered. The Maskin and Tirole model assumes a homogenous product, but Noel's (2004b) simulation of the model shows that the Edgeworth cycle equilibrium can arise as long as the product is not too

[5] For example, Conference Board of Canada (2001, p. 25) writes that "Canadian motorists are perceived as being very sensitive to gasoline prices, and this is borne out by their behavior in the marketplace. Canadians will change stations for price differences of fractions of a penny, even though the impact of the price differences may only amount to five or ten cents on an average fill-up." Similarly, the Federal Court of Australia asserts that "retail market in Ballarat [, an Australian city]… was so highly price sensitive that even a difference in price of less than one cent per liter ("cpl") could significantly influence the volume of petrol [gasoline]." ¶47, Australian Competition and Consumer Commission v Leahy Petroleum Pty Ltd and Others [2004], Federal Court of Australia 1678, December 17, 2004.

differentiated. Therefore, even if it is certain that the observed gasoline price cycles are Edgeworth cycles, it cannot be inferred that the station-level demand is highly elastic.

According to many industry participants, many drivers in Perth engage in spatial substitution by searching for a lower price on the day when they have to fill their car. Price search may take place in a neighborhood or along the way of commute, but, according to the station owners, a typical station in Perth competes most intensely with two or three sites in the neighborhood. Given that the gasoline price cycles are regular and somewhat predictable, drivers may also engage in intertemporal substitution by changing the timing of filling their car. Note, however, that the timing of going to gasoline station is largely determined by an individual's driving behavior, and the cost of filling too early or too late is very high. Therefore, the time span (in days) within which a driver has the flexibility to substitute over time is limited.

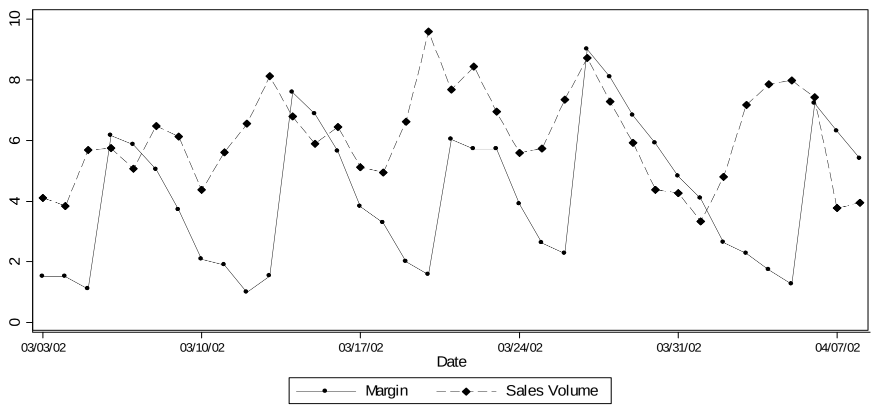
3. Data and Summary Statistics

I collected the daily retail price and sales quantity of regular unleaded gasoline at eight retail stations and the wholesale prices these stations paid to the oil firms. The retail prices for the competing sites of these eight stations were downloaded from the internet website used by the government to post daily retail prices (http://www.fuelwatch.wa.gov.au). Even though four of the eight stations carry a major oil brand, they are all independent in that they set their own retail prices and pay contract prices to the oil firms. These eight sites are located in eight different suburbs of the Perth area so they are not direct competitors to each other. The sample period for the quantity data differs across the stations. Table 1 shows the sample periods and the summary statistics for each site. According to the station owners, two of the three brand B stations (B2 and B3 in table 1) face well above average competition, and the other six stations face average or below average competition.

Table 1: Summary Statistics for the Eight Individual Gasoline Stations

Station code	Sample period for quantity data	Retail price mean (cents)	Retail margin mean (cents)	Std. Dev. of retail margin (cents)	Lerner index mean (%)	Daily quantity mean (liters)	Std. Dev. of daily quantity (liters)	Distance of closest sites (kilometers) First	Second
A1	07/01/03 to 10/31/03	91.25	5.16	2.34	6.2	6528	1548	1.4	1.7
A2	07/01/03 to 10/31/03	92.17	6.05	2.29	7.2	7761	1515	0.4	1.5
A3	07/01/03 to 10/31/03	91.46	5.17	2.34	6.2	7076	1561	0.6	2.2
A4	07/01/03 to 10/31/03	89.79	3.68	1.83	4.4	5338	1291	4.2	5.6
B1	07/01/02 to 10/31/03	90.21	4.41	1.79	5.3	3307	1250	0.9	1.7
B2	08/25/01 to 06/26/02	85.94	2.94	2.28	3.7	2005	885	1.0	2.2
B3	01/03/01 to 11/23/01	88.02	1.30	2.19	1.6	1655	1364	0.0	0.4
C1	02/12/02 to 06/30/02	86.62	4.03	1.90	5.1	6257	1475	0.9	1.3

Figure 2: Daily Retail Margin (cents per liter) and Sale Volume (thousand liters) for one Site



Define retail margin as the difference between the after-tax retail price and the wholesale buying price. The defined margin is the upper bound of a gasoline station's profit margin since the wholesale price is the lower bound of a station's marginal cost. Figure 2 shows one station's daily retail margin. It is clear that this station's margin is characterized by cycles similar to the price cycles. The margin cycles result directly from the retail price cycles, for the wholesale prices paid by the independent stations are much more rigid. Define the daily Lerner index as the daily retail margin divided by the daily after-tax retail price. Although not reported here, the daily Lerner indices for these independent stations are also characterized by cycles. Note that the retail gasoline stations controlled by the oil firms may not experience profit margin cycles as the independent stations do. The daily sales quantity for this site is also shown in figure 2. It is clear that the sales volume for this site is volatile. Table 1 contains the average retail margin, the average Lerner index, the average daily sales volume and their standard deviations for each of the eight stations over their respective sample periods. The standard deviations of daily sale volume are large, especially for the brand B stations. The last two columns of table 1 report the distances of the sample stations' two closest competing stations. The median distances of the first and second closest stations are, respectively, 0.9 and 1.7 kilometers.

The daily sales quantities are measured for each calendar day. For the period since August 24, 2002, retail prices are fixed for the 24 hours from 6:00am to 6:00am. To match the price and quantity data, it is important to verify each station's operating hour. Stations B1 and B3 operate Monday through Saturday and the other five stations operate seven days per week. Six of the eight stations operate within the hours between 6:00am and midnight, so there is no price-quantity mismatch. One station operates 24 hours per calendar day, so a six-hour (from midnight to 6:00am) price-quantity mismatch exists. Another station opens at 5:00am, so a one-hour discrepancy exists. For both stations, the calendar day average prices recorded by the stations are used to match quantity. For the other six stations, the prices downloaded from the website are identical to the prices recorded by the stations.

4. Model Specification and Elasticities

Let q_{it} be the log quantity of regular unleaded gasoline sold by gasoline station i on date t, and p_{it} be the log (before-tax) price for this site. Consider the following simple demand model for gasoline station i on date t:

$$q_t = c + \alpha\, p_t + \hat{\mathbf{p}}_t \boldsymbol{\beta} + \gamma_1 p_{t-1} + \gamma_2 p_{t-2} + \gamma_3 p_{t+1} + \gamma_4 \hat{p}^1_{t-1} + \mathbf{w}\boldsymbol{\theta} + \varepsilon_t\,,$$

where the subscript i is omitted. The parameter α is the contemporary own price elasticity. The vector $\hat{\mathbf{p}}_t \equiv (\hat{p}_t^1, \hat{p}_t^2, ..., \hat{p}_t^k)$ denote the log prices of station i's k competing stations on date t. In particular, $\hat{p}_t^1$ is the price of station i's closest competing station, $\hat{p}_t^2$ is the price of its second closest competitor, and $\hat{p}_t^3$ is the price of its most likely competitor other than its two closest competitors. This third station is usually, but not always, the third closest. Also taken into account are factors such as whether the station is connected to station i by major roads or the station is of a different brand. The vector $\boldsymbol{\beta}$ collects the cross-price elasticities. If the price of the third station is found to have a significant effect on q_{it}, the fourth most likely competing site is also considered.

The γ's are the intertemporal elasticities of substitution. It is assumed that a driver can substitute over a period of four days: the past two days, the current day and the next day. Note that drivers in Perth are able to know for sure the following day's price by searching for the website. To capture the possibility that drivers may substitute over time between station i and its competing sites, the price of its nearest competing site's price in the previous day $\hat{p}_{t-1}^1$ is considered in the demand equation. Intertemporal effects are not included in the equations for the two brand B sites that operate only six days since the lag or forward values of p_{it} do not have well-defined timing for these two stations. The row vector $\mathbf{w}$ collects the day of week dummies, and the column vector $\boldsymbol{\theta}$ contains the corresponding coefficients. For those stations that operate 7 days per week, dummies for Monday through Saturday are included. For those stations that operate 6 days per week, dummies for Monday through Friday are included.

It is assumed that the price variables are not correlated with the regression error term. Note that the Edgeworth price cycle equilibrium arises from the strategic tensions among the oligopoly players, and the underlying market demand and marginal cost are constant over time. While the market demand for gasoline in the Perth market changes slightly on a daily basis, the daily variations in demand or marginal cost certainly account for little of the pricing dynamics shown in figure 1. It is therefore reasonable to assume that demand or cost shocks, if exist, play little role in the dynamics of the daily retail prices.

The results are presented in table 2. The estimated own price elasticities are highly significant and very large (in absolute value), ranging from 5.51 to 18.41. Two brand B stations have the largest elasticities (13.6 and 18.41), a result consistent with the fact that they have extremely volatile daily sales volumes. The average own-price elasticity for the other six gasoline stations is 6.65. As mentioned before, the two brand B stations with very large elasticities face well above average competition, and the other six stations face average or below average competition. It is thus reasonable to expect that the average own price elasticity for the individual stations in the Perth market is above 6 in absolute value. These own price elasticity estimates are considerably larger than those found by Slade (1986) for 13 gasoline stations in a submarket of the Vancouver area. Slade's estimates range from 0.4 to 7.7 and the mean is 4.5.

The estimated own-price elasticities are large, confirming that many drivers in Perth are indeed very sensitive about gasoline price. Note, however, that the estimated elasticities, according to the familiar equation, $(p - MC)/p = 1/\varepsilon$, imply Lerner indices much larger than those reported in table 1. Note that this equation applies to situations where the firms engage in standard one-shot price competition. Dynamic effect, due to tacit coordination, should make the observed Lerner index larger than that implied by a model of static competition. However, the observed Lerner indices are actually much smaller than what is implied by the formula. The likely explanation is that gasoline may have been used as a loss-leader: gasoline price is set intentionally low to attract customers for the non-fuel products, most of which have much higher

Table 2: Estimated Demand Equations for the Eight Gasoline Stations

Variable	A1	A2	A3	A4	B1	B2	B3	C1
	Gasoline Stations							
Constant	8.32 (3.17)	4.81 (3.83)	13.75 (11.72)	6.30 (3.18)	4.30 (2.15)	10.80 (6.39)	0.21 (0.09)	8.05 (5.33)
Own price	-6.18 (-4.36)	-6.29 (-9.73)	-5.51 (-7.66)	-8.14 (-7.22)	-6.38 (-5.24)	-13.60 (-12.5)	-18.41 (-11.86)	-7.40 (-5.42)
Competing site 1	0.21 (0.27)	1.22 (3.96)	1.36 (4.00)	2.97 (2.35)	2.99 (2.82)	5.98 (7.9)	11.39 (8.94)	1.59 (2.04)
Competing site 2	1.89 (2.28)	0.62 (1.75)	2.09 (4.25)	1.84 (2.19)	0.81 (1.02)	3.52 (5.66)	7.07 (5.15)	1.32 (2.48)
Competing site 3	0.22 (0.36)	1.53 (2.95)	0.37 (0.66)	0.95 (1.14)	2.06 (2.79)	0.72 (1.23)	1.40 (1.15)	0.40 (0.94)
Competing site 4		0.52 (1.4)			1.19 (1.57)			
Own price lag 1	-2.40 (-1.70)	1.42 (2.25)	1.73 (3.53)	-0.87 (0.82)		-0.31 (-0.25)		0.03 (0.02)
Own price lag 2	2.65 (2.96)	1.79 (3.94)		2.17 (2.80)		2.22 (2.13)		2.75 (3.86)
Own price forward 1	1.65 (1.27)	-0.06 (-0.1)	-0.86 (-1.67)	0.42 (0.52)		1.30 (1.31)		-0.56 (-0.43)
Competing site 1's price lag 1	2.02 (2.65)	0.11 (0.33)	-0.32 (-0.75)	1.10 (1.12)		-0.58 (-0.74)		1.96 (2.80)
Monday	0.17 (2.61)	0.30 (8.43)	0.37 (10.23)	0.35 (7.01)	0.72 (9.20)	0.22 (1.79)	0.13 (1.08)	-0.05 (-1.24)
Tuesday	0.26 (3.77)	0.36 (9.93)	0.41 (11.61)	0.34 (6.86)	0.71 (9.45)	0.48 (3.93)	0.14 (1.19)	0.19 (4.29)
Wednesday	0.34 (4.87)	0.32 (8.58)	0.44 (12.55)	0.42 (8.31)	0.63 (8.18)	0.21 (2.38)	0.31 (2.70)	0.32 (7.3)
Thursday	0.38 (5.48)	0.37 (10.21)	0.43 (12.02)	0.37 (7.35)	0.78 (10.37)	0.29 (3.35)	0.41 (3.55)	0.37 (8.39)
Friday	0.38 (5.45)	0.43 (11.94)	0.52 (14.36)	0.42 (8.4)	0.79 (10.43)	0.25 (2.92)	0.35 (3.02)	0.40 (9.15)
Saturday	0.24 (3.68)	0.18 (5.29)	0.10 (2.94)	0.20 (4.12)				0.36 (8.26)
Observation number	120	120	120	120	385	137	277	136
Adjusted R-square	0.37	0.76	0.82	0.60	0.38	0.67	0.44	0.67

Notes: The dependent variable in each column is the daily log price for each gasoline station. T-statistics are in parentheses. If the second lagged value of own price is added to equation A3, the coefficient and the t-statistic for the first lagged value of own price becomes 1.15 and 1.73, respectively.

profit margins. The average Lerner index for the Brand C station is about 5%, but, according to its owner, the price-cost margin for this station's non-fuel products is about 30%.[6] Indeed, gasoline possesses the properties of a loss-leader discussed by Lal and Matutes (1994). Drivers have to purchase gasoline frequently, and more importantly, gasoline prices are posted on large boards that are easily observable to drivers. It is interesting to note that drivers in Australia almost always have to go inside the shop to pay for gasoline over the counter even if they use credit cards. It is thus even reasonable to consider non-fuel products as the "impulse" products in the model of Hess and Gerstner (1984). Using gasoline as a loss-leader to compete for customers is the widely reported rationale for the entry of supermarket chains and discount stores to gasoline retailing.

All the cross price elasticities have the expected positive sign and almost all those elasticities associated with the first and second closest competing stations are statistically significant at the 5 percent-level or above. Most of the cross-price elasticities associated with the third most likely competitors are not statistically significant. These results confirm the station owners' observation that a station competes primarily with those stations in the neighborhood, but it should be emphasized that stations near one's work or along the commute road may also be competitors to the station near one's home.

The results in table 2 also confirm that intertemporal substitution does exist. For the six sites for which intertemporal effects are considered, either the first or the second or both lagged values of own prices are found to be significantly positive, but none of the next-day prices are found to be significant. For two sites, the nearest competing sites' prices in the previous day are also significantly positive. These results further suggest that drivers in Perth are sensitive about

[6] The report by the U.K. Office of Fair Trading (1998, p. 43) also notes that non-fuel sales for gasoline stations in the UK are much more profitable than fuel sales.

gasoline price. The coefficients on the weekly dummies clearly indicate that the sales volumes are much lower during the weekend than during the week days for all the eight gasoline stations.

5. Conclusion

The special timing restriction in the Perth gasoline market provides the unique opportunity to collect daily sales quantity that matches the daily prices and to estimate station-level price elasticities of demand in a market with regular price cycles. The estimated own, cross and intertemporal elasticities suggest that the drivers in this market are indeed very price sensitive. The finding that the observed Lerner indices are smaller than those implied by the estimated elasticities also provides indirect evidence that gasoline has been used as a loss leader.

These results suggest that the individual gasoline stations in the currently cycling markets have little market power, thus lending further support to the hypothesis that the observed gasoline price cycles are Edgeworth cycles. This implies that industry studies are correct to interpret the frequent price decreases as reflecting retail stations' fast reaction to each other in the battle of market shares, but those studies miss the critical point that the same market forces would keep the price at a competitive level in the absence of oligopoly coordination. Coordinated price hikes are very unlikely to take place in a market with a large number of independent firms competing for price-sensitive consumers.

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