18th World IMACS / MODSIM Congress, Cairns, Australia 13-17 July 2009
http://mssanz.org.au/modsim09

Spatial Competition in Metropolitan Petrol Pricing

Beare, S. [1] **and S. Page** [1]

[1] *Concept Economics*
Email: stephenbeare@concepteconomics.com.au

Abstract: As many motorists would be aware, retail petrol prices vary by location on a day to day basis. This suggests that there is a high degree of spatial competition between petrol stations. While prices in capital cities such as Melbourne and Sydney vary throughout the day, the introduction of Fuel Watch in Perth requires that prices be set 24 hours in advance and remain fixed for that period. Lowest prices by area and prices by postcode are publicly available on the internet and both email and phone services by area are available.

The fixing of petrol prices throughout the day under Fuel Watch is likely to change to nature of spatial competition. In particular, the risks of setting prices that are too low or high are potentially higher. These risks are not symmetric as product sold at low prices must be replaced while high prices tend to delay product sales. These risks are enhanced by making price information widely available. Further, these risks are likely to be location specific, depending on the degree of isolation of a particular station.

Daily petrol prices by location in Melbourne, Perth and Sydney were analysed using spatial autoregressive (SAR) models. SAR models allow both spatial and temporal correlations in prices between neighbouring locations to be taken into account. The models were estimated and then used to simulate the impact of Fuel Watch on the distribution of prices within capital cities.

The pricing restrictions under Fuel Watch were not found to have a significant effect on average prices. However, Fuel Watch did alter the distribution of prices. The incidence of prices that were well below the daily average was substantially reduced while the incidence of prices well above the daily average was not. The distribution becoming more right skewed but a greater density of prices below the average and close to the median.

While Fuel Watch may not have reduced average prices it still has the potential benefit of reduced search costs. Given that this search usually involves transport there may be environmental benefits as well. However, Fuel Watch reduces the likelihood of finding a bargain and in fact the need to access price information. Additionally, Fuel Watch may offer large multi-site retailers opportunities for gaming behaviour. A real time monitoring system that eliminated the need to fix price for an extended period may provide one way of overcoming price risks for retailers while continuing to reduce search costs, but raises concerns about potential group gaming behaviour by all petrol retailers.

Keywords: *Geographic Pricing, Risk, Spatial Econometrics, Fuel Watch.*

1. INTRODUCTION

The volatility of retail petrol prices is the subject of intense motorist scrutiny as well as government scrutiny here in Australia. Much of the focus on petrol prices has been on the cycle of high spikes and slow decreases in prices on a weekly basis. Given these large price rises usually occur across an entire city there have been allegations of collusion among retailers.

In 2001, in response to motorists concerns regarding the large and seemingly uniform increases in petrol prices across the price cycle the Government of Western Australia introduced 'Fuel Watch'. Fuel Watch provides, from 2.30pm every afternoon, the prices of petrol for the subsequent day (for a period of 24 hours starting at 6am). Lowest prices by area and prices by postcode are publicly available on the internet and both email and phone services by area are available. Petrol retailers are not allowed to change the price charged for petrol from the one notified for that 24 hour period.

The Fuel Watch scheme claims to offer motorists the potential to save hundreds of dollars as "it [Fuel Watch] puts pressure on retailers to notify the most competitive price they can because if they set their prices too high they will lose sales to their competitors" (Fuel Watch 2009).

The findings of the 2007 Australian Competition and Consumer Commission (the ACCC) price enquiry into the price of unleaded petrol were similar. The ACCC noted in its findings that "the inability for firms to change their intra-day prices implies that the short-term losses from leading the price cycle up are greater. The price leader will lose a significant portion of its more price sensitive sales on the day it leads price up and run the risk of further losing market share if other market participants do not follow suit on the second day of the cycle. Consequently a price leader might be expected to choose to lead the price up by a smaller size to limit lost sales volumes" (ACCC 2007 p247).

However, perhaps of greater risk to the petrol retailer of losing sales to a competitor is the risk that the price charged is too low. These risks are not symmetric as product sold at low prices must be replaced, while high prices tend to delay product sales. These risks are enhanced by price being fixed for 24 hours and making price information widely available. Further, these risks are likely to be location specific, depending on the degree of isolation of a particular station.

The objective of this paper to investigate whether a scheme such as Fuel Watch may increase the risk to petrol retailers. If this is the case, it should be possible to observe these risks – either the risk that the price will be set too low (increasing sales but decreasing profit and requiring replacement stock), or the risk that the price will be set too high (decreasing sales but not requiring replacement stock) – through observing any changes in the distribution of prices.

2. ANALYSIS OF DAILY PRICE DATA FROM PERTH AND SYDNEY

Unleaded petrol prices were obtained from Fuel Watch for Perth and Sydney for the period January 1 1998 to 30 May 2008. The data consisted of simple daily average prices by postcode. The averages were not volume weighted. The data was collected on a Monday through Friday basis in 1998 and 1999 and on a 7 day basis thereafter.

Two separate analyses were conducted.

- The first was an examination of median prices in the Perth and Sydney markets over the full period of 10 years and 5 months. The purpose of this analysis was to determine if there have been any significant breaks or trends in the relative price of unleaded petrol in the two markets.
- The second was a detailed look at the geographic structure of the Perth and Sydney markets for selected years. The purpose of this analysis was to examine whether Fuel Watch has affected the distribution of prices.

2.1. Median price analysis

Daily median prices were calculated from the postcode level price data for Perth and Sydney. Medians were used because volume data was not available to construct a weighted average and medians are a more robust measure of central tendency than a simple average.

A daily price ratio was then calculated; the Perth price divided by the Sydney price. There appeared to be two phases in the data. The first was an increase in relative prices in Perth immediately after the introduction of Fuel Watch. This was followed by a sustained reduction in relative prices and lower price variability that started in early 2004. The latter appears to be the most likely structural beak in the data. However, in the long term the data may in fact be mean reverting. That is, the data moves about a constant value in the longer term.

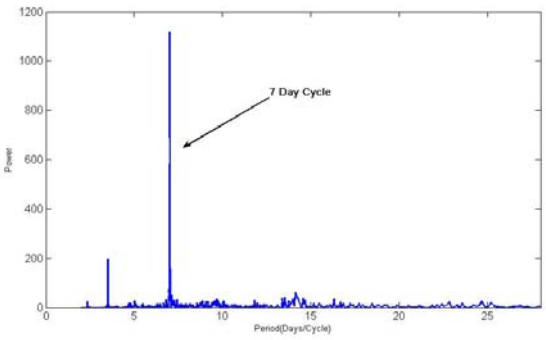

Figure 1. Power spectrum of the price ratio versus cycle length

On closer visual examination the data appeared to exhibit stable price cycles. A Fourier analysis was then conducted to determine if there were stable cycles within the data. The power spectrum plot for the series indicates a strong 7 day cycle in the price series, as seen in **Figure 1** .

Next, the data was differenced on a weekly or 7 day basis. That is, price changes between successive Mondays, Tuesdays and so forth were calculated. The differenced prices appeared to be stationary over the full history of the data set. The only clear indication of a structural break in the data was a reduction in the variability of the weekly change in price starting in 2004 and ending in early 2006 – a long time after the introduction of Fuel Watch.

As the level and differenced data is cyclical it is difficult to determine if the data is stationary using autoregressive techniques. A simple time trend regression was fitted to the difference data to test the hypotheses that:

- The mean difference is zero, implying that there is no long term trend in the level data; and
- There is no time trend in the difference data, implying that there is no long term pattern in relative price increases or falls in the two markets.

Table 1. Time trend regression

Variable	Coefficient	Significance Level
Constant	-0.0000	0.0001
Trend	-0.0000	0.0139

The regression results (**Table 1**) indicate that there is no significant trend in the price ratios or the difference in the price ratios.

In summary, there does not appear to be any significant affect of Fuel Watch on the ratio of median prices in the Perth and Sydney markets. The price ratio were stable over the 10 year period but varied cyclically in the short to medium term The only countervailing argument would be that wholesale price margins have increased in Perth relative to Sydney after the introduction of Fuel Watch.

2.2. Market Structure Analysis

Market structures were analysed using daily prices by postcode in Perth and Sydney for the calendar year 2007 and a pre Fuel Watch year in Perth. The calendar year 2000 was selected for the pre Fuel Watch year as this was the only year for which prices were available on a 7 day basis.

Prices were converted into daily mean price deviations for each market. That is, the price in each postcode was divided by the mean price of the respective capital city for each day.

A descriptive statistical analysis was conducted using a number of plots, including:

- A box and whisker plot, showing the interruptible range and outlying deviation in daily prices by post code (**Figure 2**); and
- A cumulative rank distribution plot, that provides an indication of the geographic or locational stability of relative prices over time (**Figure 3**).

The inter-quartile range, indicated by the box, contains 75 per cent of all observations. The plots show that the majority of data falls within narrow bounds in both Perth and Sydney and in Perth before and after the introduction of Fuel Watch. However, the 2007 plot for Perth indicates that the distribution of prices is right

skewed in Perth compared to Sydney and compared to Perth prior to the introduction of Fuel Watch. The fact that there was a reduction in the overall variability in Perth between 2000 and 2007 may have been due to any number of factors. The point here is the change in the symmetry of the distribution. There are a greater percentage of high priced postcodes in Perth as opposed to Sydney. When comparing the pre and post Fuel Watch periods in Perth, Fuel Watch appears to have the effect of eliminating the lower end of the price range in Perth.

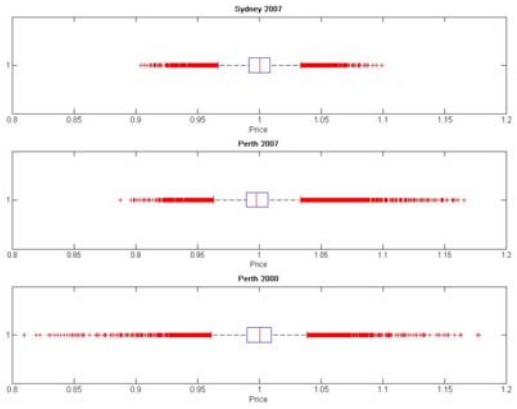

Figure 2. Mean daily price deviations

Further the distributional effects are evident in the box and whisker plots. The tails of the distribution are generally much wider than would be expected for a normal distribution as indicated by the large number of outlying points. That is, the highest and lowest deviations appear to be greater than one would expect from a normal distribution. In Perth post Fuel Watch prices are skewed to the right.

It might be argued that these differences between markets and over time are due to structural change in the cost of providing retail services. For example, because there are now fewer lower cost locations in Perth due to rapid growth in the economy of Western Australia. However, this does not appear to be the case, as can be seen by the cumulative distribution of postcode ranks. The ranks in the graphs are constructed by assigning each postcode a daily rank from lowest to highest. These are then averaged across days and the postcodes are ordered from the lowest average rank to the highest and then plotted. If the price deviations were structural then we would expect the ranks to be reasonably stable. That is, they would range from a reasonable low average rank to a reasonably high average rank. If the deviations were simply random with respect to location we would expect most postcodes to have an average range that was in the middle.

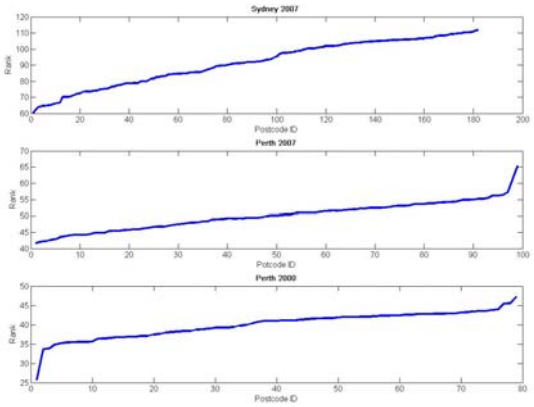

Figure 3. Cumulative distribution of postcode ranks

The data for all the cities fits the latter hypothesis with the great majority of ranks fall in the middle. In Perth the ranks fall with about plus or minus 10 ranks of the middle. The ranks are a little bit more stable in Sydney.

The question that remains is: are these structural changes due to changes in the nature of competition in the Perth market? This is addressed in the following section.

2.3. Spatial Analysis

The spatial analysis was used to examine how current and past prices of nearby competitors influenced prices at a particular location. Nearby competitors are defined as the set of nearest neighbours in terms of physical distance.

There are several hypotheses to consider:

- That the Fuel Watch scheme simply delays price competition by a day and has no impact on the distribution of prices;

- The elimination of within day competitions under Fuel Watch alters the process of price competition and changes the distribution of prices.
- That notification of prices under Fuel Watch has an impact on price competition.

Spatial statistics and econometrics have been advanced by a number of researchers including Cressie (1993) and La Sage and Pace (2009). The pricing structure in the Perth and Sydney markets was examined using a Spatial/Temporal Auto-regressive modelling methods developed by Pace (2000). Conceptually, spatial auto-regression is analogous to the more familiar time series or temporal process. In a temporal autoregressive model past prices would be used to predict future prices. In the spatial model, nearby neighbouring values are used to predict what is happening at a location of interest. Postcode locations were obtained through concordance data from the ABS. Postcodes were matched with Statistical Local Areas (SLA) and the centroid of the SLA was used as the reference latitude and longitude. Postcodes that were common to a single SLA were given random locations in the immediate vicinity of the centroid of the SLA.

The starting point of the spatial component of the analysis is to identify a specified number of nearest neighbours and to construct a weighted average of their current or past price. Here, 5 and 10 nearest neighbours were used. For each choice of the number of nearest neighbours and optimal weighting parameter, Rho, was estimated. A Rho value of 1 gives all the nearest neighbours equal weight. A Rho value of 0 gives weight to only the absolutely closest neighbour.

For Perth 2007, the mean price deviation for a given postcode was modelled as a function of:

- The price deviation at that location on the previous day;
- The price deviation at that location two days previous;
- The average neighbouring price deviation on the previous day;
- The average neighbouring price deviation two days previous;
- The minimum price deviation on the previous day.

For Sunday 2007 and Perth 20007, the mean price deviation for a given postcode was modelled as a function of:

- The price deviation at that location on the previous day;
- The price deviation at that location two days previous day;
- The average neighbouring price deviation on the current day;
- The average neighbouring price deviation on the precious day;

The variables, with the exception of the minimum price deviation, were introduced as pairs to allow for an asymmetric price response to above and below average prices. The formula is given as (1):

$$Above = \begin{cases} \hat{p} & if \quad \hat{p} > 0 \\ 0 & otherwise \end{cases}$$
$$Below = \begin{cases} \hat{p} & if \quad \hat{p} < 0 \\ 0 & otherwise \end{cases} \qquad (1)$$

Where phat is the daily mean price deviation.

The use of concurrent prices for neighbouring competitors does introduce a degree of endogeniety. That is, the price at the current location also influences the prices of the neighbours. However, this influence reduces as the number of neighbours is increased, hence the 5 and 10 nearest neighbours are used to test the sensitivity of the estimates to this problem. The optimal Rho value was calculated using a grid search over the log-likelihood. The grid selected was crude as the differences to the coefficient estimates were small.

The Sydney specification was also used for Perth 2007 to ensure that within days affects were not significant. The results were not reported but the contemporaneous effects were low and their inclusion did not substantially alter the estimates of the other coefficients. The results were similar for the 5 nearest competitors and for the 10 nearest competitors. The difference between the spatial models is small and subsequent discussion is focused on the 10 neighbour model – the results are presented in **Table 2**.

In comparing the effects of own lagged prices in Perth 2007 with Sydney 2007 and Perth 2007, there is a much stronger asymmetric price lag effect in Perth post Fuel Watch. The above average lag effect is much

greater than the below average lag in Perth 2007 and reasonably well balanced in Sydney 2007 and Perth 2000. This implies that there is a greater likelihood that an above average site will remain an above average site in Perth post Fuel Watch. Second order lag effects are significant in all the markets but the magnitudes are small.

The contemporaneous and lagged effects of nearest competitor prices are significant in both Sydney 2007 and Perth 2000. Overall the impact of local competitor prices appears to greater in Sydney than in Perth. This suggests there may be a greater degree of geographic isolation in Perth. The estimates indicate that there was a correction process working. If prices are set too high, relative to surrounding prices, at the start of the day they are adjusted downwards. The converse is also indicated, if prices are set too low at the start of the day they are adjusted upwards.

Table 2. Spatial regression results, nearest neighbours = 10

Variable	Perth 2007		Sydney 2007		Perth 2000	
	Beta	Sign L %	Beta	Sign L %	Beta	Sign L %
Constant	-0.01	100	0.00	52	0.00	36
Own Price A Lag=1	0.85	100	0.44	100	0.71	100
Own Price B Lag=1	0.37	100	0.56	100	0.69	100
Own Price A Lag= 2	0.02	98	-0.12	100	0.02	98
Own Price B Lag= 2	0.15	100	-0.09	100	0.01	88
NN Price A Lag =0	-	-	-0.33	100	-0.19	100
NN Price B Lag =0	-	-	-0.40	100	-0.13	100
NN Price A Lag=1	0.20	100	0.97	100	0.45	100
NN Price B Lag=1	0.20	100	0.90	100	0.42	100
NN Price A Lag =2	0.00	0	-	-	-	-
NN Price A Lag =2	0.11	100	-	-	-	-
Minimum Price Lag =1	+0.00	100	-	-	-	-
Rho	0.75		0.80		0.60	
R-Square	61%		54%		62%	

There are first order lagged competitor pricing effects in Perth 2007 but these are small compared to Sydney and there does not appear to be any lagged correction process. The minimum price deviation has a significant effect on price in Perth 2007. However, the effect is less than one per cent of the average daily price.

Form the coefficient estimates it is difficult to see how Fuel Watch impacts on the overall distribution of prices. To examine this, the Perth 2007 model coefficients were used to simulate the price in Sydney. Overall there is a significant but trivial increase in Sydney prices when the Perth 2007 market structure is imposed on the Sydney market. The more substantive effects are on the price distribution. The predicted impact of Fuel Watch on the Sydney market is to truncate the lower end of the price distribution and skew the upper end to the right. This is largely compensated for by an increase in the number of locations that have prices that are lower under Fuel Watch in the middle of the distribution. The can been seen in the cumulative distribution plot (**Figure 4**). It could easily be argued that there are structural aspects of the Perth and Sydney markets that would leave this hypothetical imposition of Fuel Watch in Sydney open to question. For example, there could be a greater degree of geographic isolation of petrol stations in either other two markets.

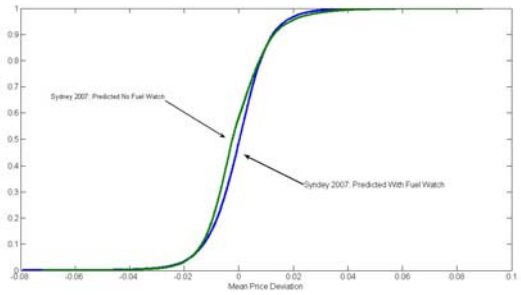

Figure 4. Cumulative distribution plots - Sydney

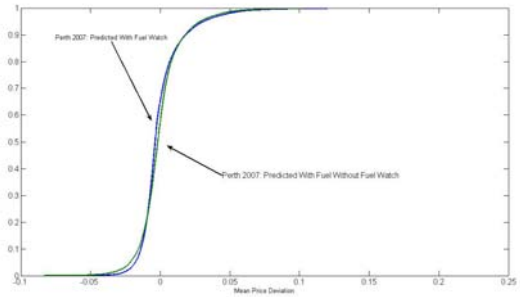

Figure 5. Cumulative distribution plots - Perth

To reduce this potential bias, the estimated market structure in Perth 2000 was imposed on Perth 2007 market. That is, the estimated coefficients from Perth 2000 were used to predict what would have occurred in Perth 2007 if Fuel Watch had not been in place. While Fuel Watch did not have a significant impact on the average market price, the distribution of prices has been skewed to the right under Fuel Watch. Again, there are fewer lower priced locations and there

are a greater number of higher priced locations (**Figure 5**). This is compensated by the fact that there a large number of locations that have slightly lower prices in the centre of the distribution.

With respect to the hypotheses set out at the beginning of this section, the results suggest:

- That Fuel Watch reduces the incentive to set very low prices; and
- That Fuel Watch can create incentives for some locations to charge high prices, perhaps those who are located a distance from where the announced lowest prices tend to occur.

3. POLICY IMPLICATIONS

Overall, the average effect on prices under Fuel Watch appears to be negligible. That there are fewer lower priced locations and a greater number of higher priced locations under Fuel Watch is compensated for by the prices in the middle of the geographic distribution of petrol prices tending to be lower.

However, although the retail petrol market appears to be quite competitive with or without Fuel Watch, the operation of Fuel Watch has important implications for the retail petrol market.

The truncation of lower prices in the price distribution means that the incentive to discount petrol has been reduced. This means that although the search costs for petrol prices has been reduced under Fuel Watch the chance of finding a bargain (very low priced fuel) has been decreased.

Given that the main benefit of Fuel Watch appears to be the decrease in search costs for motorists, suggestions to improve Fuel Watch have centered on real time monitoring systems – perhaps price updates every 10 or 15 minutes. This would allow intra-day price changes by retailers whilst reducing motorists search costs. However, aside from the costs of such a system, it also raises concerns over potential gaming behaviour by retailers. In this case, retailers would also have real time access to other retailers' prices and may increase the risk of parallel pricing – a form of non-collusive, but uncompetitive, pricing. For example, a petrol retailer may increase the price of petrol (the price leader) and then monitor the price other retailers are charging. If other retailers increase their price also, the price leader will continue charging the higher price (or perhaps increase the price further to see if the other retailers will again follow), or if other retailers do not increase their price the price leader decreases the price. Although the retailers would not be overtly fixing prices the real time information allows retailers to signal to each other without cost – potentially increasing the average price of petrol.

Fuel Watch may have the potential to increase gaming behaviour in other ways also. First, it may advantage large multi-site petrol retailers who are better able to manage the risk of setting price too low. Single-site retailers, who are less able to manage the risk of setting price too low, may be gamed by the larger multi-site retailers into setting prices low (setting a low price results in little or no profits, while setting higher price may result in no sales). If this were to happen over a sustained period the viability of the single-site retailer may be threatened – with their exit from the market potentially decreasing competition. Second, it may allow multi-site retailers to strategically price petrol based on the proximity of the sites it owns in relation to sites owned by other retailers. For example, sites that are in close proximity to sites owned by another retailer may be nominated to be a low price site, while sites that are isolated from sites owned by other retailers may be nominated to be a high price site. The ability to set a higher price will be determined by the cost of motorists being able to drive to cheaper sites – if the cost of driving to a cheaper retailer is greater than the saving they will buy the petrol from the closer but higher priced site.

These two gaming possibilities are an area for further research – however, analysis will be dependent on the availability of price and location data that also contains owner information.

REFERENCES

ACCC (2007) 'Petrol prices and Australian consumers', Report of the ACCC inquiry into the price of unleaded petrol, December.

Cressie N. (1993) *Statistics for Spatial Data*, John Wiley, New York.

Fuel Watch (2009) 'B. Fuel Prices (FAQ)', http://www.fuelwatch.wa.gov.au/misc/dsp_faq_fuel_prices.cfm.

La Sage J. and Pace K. (2009) *Introduction to Spatial Econometrics*, Taylor and Francis, London.

Pace, K (2000) A Method for Spatial-Temporal Forecasting with an Application to Real Estate Prices, *International Journal of Forecasting*, vol. 16., iss. 2, p229-246