Gasoline and Diesel Pricing New Zealand

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A dissertation submitted to
Auckland University of Technology
In partial fulfilment of the requirements for the degree
of
Master of Business (MBus)

2008

School of Business

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Acknowledgements

I would like to express my gratitude to Dr. Ming-hua Liu and Dr. David Parker for their invaluable support with this project.

Abstract

Motorists are interested in knowing what is causing the escalating at-pump petroleum prices and how does gasoline or diesel price respond to changes in international crude oil prices and currency exchange rates. This study investigates both the long-run and short-run relationships between these factors. An Error Correction Model is developed and used to test the actual 210 weekly retail petrol and diesel prices over a four-year period from 2004 to 2008. The results suggest that the world crude oil prices do have an impact on the local retail prices both in the long run and the short term, while in contrast, the currency exchange rate effect is not found in the long term. An asymmetric effect is also observed in retail petrol prices, but not in retail diesel prices. In this study, different tax treatment between the two is found to be the main reason for the differential adjustment speeds of petrol and diesel.

1.0 Introduction

Petrol and diesel, being the “energy drivers” for the majority of machines and vehicles, are the most important and most consumable goods in our daily lives. Their price fluctuation directly affects consumers’, especially motorists’ daily consumption, and indirectly affects the prices of many other products and services. Furthermore, the fluctuation could even influence a country’s economy and political policies. Since it plays such a vital part in our lives, the price increase of petrol and diesel attracts much attention and is of vital concern. The objective of this study is to examine how do gasoline and diesel prices respond to changes in the crude oil price and the exchange rate between New Zealand dollar and the US dollar.

There are many factors affecting domestic petrol and diesel retail prices. International factors include the quantity of oil supplies, changes in international crude oil prices, and movements in the dollar exchange rate; while domestic factors include local price cycles, retail outlet competition, such as barriers to entry into the market and the level of government taxes.

Since retail petrol/diesel prices are constituted by the crude oil price, government taxes, transport and delivery charges, and the crude oil price is expected to be the key determinant among them, how the at-pump retail prices react to changes in the crude oil prices is the area we want to focus on.

Most of the previous studies on the relationship between the crude oil prices and petrol/diesel prices were on large-population countries like United States (US) and Australia. Although findings vary, it is commonly believed that the effect of crude oil price changes on petrol/diesel prices does exist—so does the asymmetry effect. In this study, the asymmetry effect refers to the adjustment speed of gasoline price in response to the increase or decrease of crude oil price or currency exchange rate. On the other hand, do the same phenomena exist in New Zealand—an island nation with a well-educated, relatively small population? That is one of the main objectives of this research.

As crude oil is priced in US dollars, the change in exchange rate on the US dollar against the New Zealand dollar is expected to have an effect on the retail petrol/diesel prices. This is the other area we shall investigate.

An Error Correction Model (ECM) is adopted in the testing of short-run symmetric and asymmetric effects for both petrol and diesel prices. Based on the four-year, 210-week period of price series, it is found that there is a long-run relationship between the world crude oil price and the New Zealand petrol/ diesel retail prices; the New Zealand diesel price is more sensitive to the change in crude oil prices than to petrol prices; short-run asymmetric effects do exist in the petrol prices but not in the diesel prices, in other words, there is no difference in the adjustment speed when the diesel price is above or below its equilibrium. In contrast, petrol prices adjust much faster upwards than downwards. The findings are largely due to the different tax rate treatment on petrol and diesel fuels by the New Zealand government.

This study is structured as follows: Section 2 reviews the general background of the world crude oil market and the New Zealand petroleum market, followed by reviews of some of the previous research and studies done by various scholars; Section 3 develops the models and equations used in the analysis, with the data listed in Section 4; Section 5 details the analysis results together with a discussion on the findings, and Section 6 concludes the study.

2.0 Literature review

2.1 The Crude Oil Market

Along with economic growth, the demand for petroleum has increased throughout the world. Based on the information from the Official Energy Statistics from the US Government in 2006, the world as whole consumes about 84.95 million barrels of crude oil per day, which exceeded the daily crude oil production of 84.52 million barrels per day; the daily oil consumption in the US is about 20.68 million barrels per day, which ranks it at the top of the worldwide consumption table; while New Zealand is ranked at number 66, with a daily consumption of 0.16 million barrels (New Zealand Energy Profile, 16th November 2008).

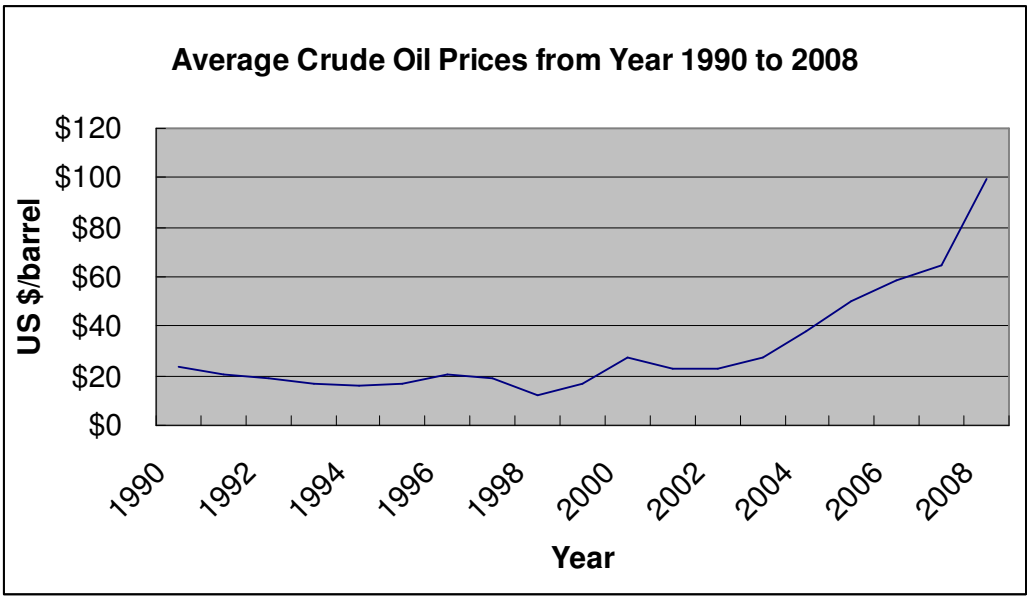
Due to the large demand and consumption, crude oil price has sustained an increased trend since the year 1994 (Figure 1), with the record books rewritten again by Energy traders on April 15, 2008, pushing oil futures past US$114 a barrel as gasoline and diesel prices struck new highs of their own at the pump (Schreck, 2008). The same pattern was found in petrol prices, with the crude oil price climb hiking to US $100 per barrel in April 2008.

According to Bamberger and Pirog (2008), there are four major components which comprise the retail prices of gasoline and diesel fuel: 1) the price of the crude oil; 2) federal and state taxes; 3) the cost of refining, which is referred to as the “refiner margin”; and 4) the costs of distribution (transportation) and

marketing. When the price of crude rises or fluctuates, the relative percentage share of these components of the retail price will shift.

In Bamberger and Pirog's report for the US Congress, during the one-year period from January 2007 to January 2008, the crude oil proportion share of retail gasoline price had increased constantly from 53.9 per cent to 67.9 per cent. The same phenomenon is also found in the retail diesel price: the crude oil proportion share of the retail diesel price had increased from 51.5 per cent to 62.5 per cent. These data reflect a significant change in the retail price for both gasoline and diesel fuel, and thus it is concluded that the crude oil price did play a vital role in determining the gasoline/diesel price (Bamberger & Pirog, 2008).

Figure 1



Source: http://inflationdata.com/inflation/inflation_Rate/Historical_Oil_Prices_Table.asp

Since the petroleum price forms part of the manufacture and transportation costs, the rise of the crude oil price brings to us not only increased commodities' prices, but also a price shock[1] to our economy. The world oil price effect is also transmitted to the New Zealand market.

2.2 The New Zealand Petroleum Market

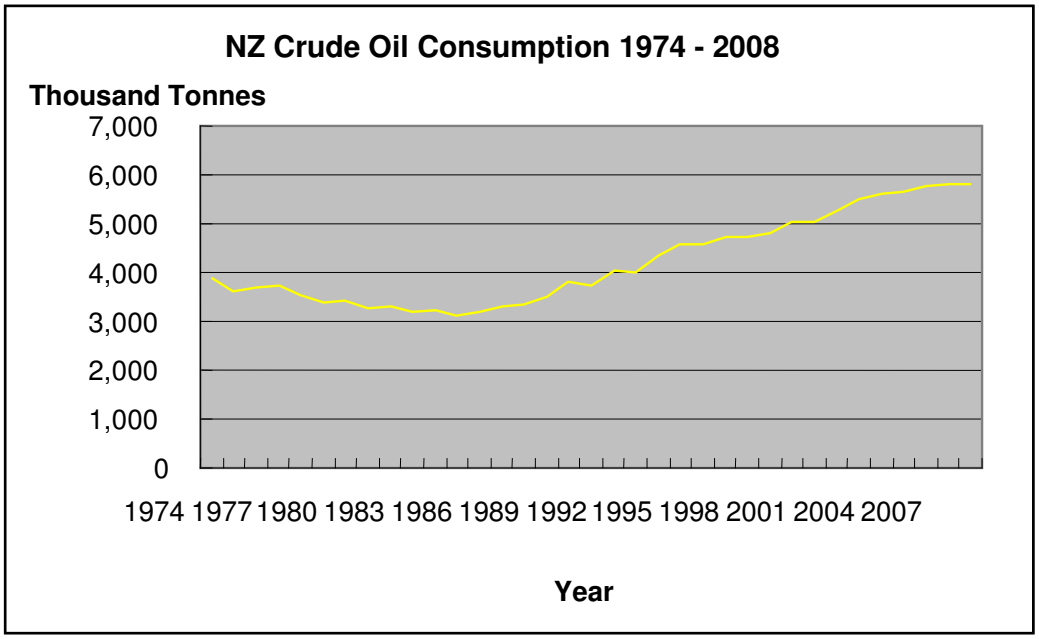
With a population of about 4 million people and 3.8 million registered on–road vehicles as at 30 June 2005, the daily crude oil consumption of 0.152 million indicates New Zealand uses a comparatively large amount of oil as transport fuel than other OECD countries, but lesser amounts of oil products for residential heating and other non-transport purposes (Delbruck, 2005). Domestic demand for petroleum products grew by 4 per cent per annum between 1985 and 1995 (Report to the New Zealand Ministry of Commerce, 1997). In the past 10 years, New Zealand has maintained a steadily increasing consumption of around 3 per cent per annum in its petroleum market (see Figure 2).

According to a report to the New Zealand Ministry of Commerce in July 1997, the New Zealand petroleum market was deregulated in May 1988, and is characterised as a "downstream oil industry."[2] The four privately owned oil

[1] Price shock normally refers to the effects that the price of oil has on an economy, such as the economic recessions caused by the oil crises in 1973 and 1979.
[2] The downstream oil industry refers to the lack of price competition in New Zealand's market for petroleum products.

companies, BP, Caltex, Mobile and Shell, together with the transport companies and service station owners and operators formed the downstream oil industry.

Figure 2



Source: http://www.med.govt.nz/templates/MultipageDocumentTOC____31827.aspx

Though the country has ample reserves of energy in forms of water power, gas and coal, the majority of the demand for crude oil in New Zealand is satisfied through import. In the year 2007, New Zealand produced 0.047 million barrels of crude oil per day—about one-third of its daily consumption. The major import ports are Tauranga, Wellington and Lyttelton.

The local supply of oil comes from a refinery located at Marsden Point in the North Island, to which the 12 seaboard terminals are connected by pipelines.

Then oil and refinery products are distributed from the terminals to around 1,900 retail sites in the country.

Similar to oil industries in other countries, the oil market in New Zealand is regulated and controlled by the government by means of taxes and levies. In order to achieve and maintain a certain percentage of profit, a number of cost-reducing horizontal agreements between oil companies, and contractual vertical agreements between wholesalers (oil companies) and service station dealers exist in the industry.

Although there are only a relatively small amount of oil companies in the New Zealand petroleum market and the real retail prices of petroleum have risen relative to indicators of import parity prices, there is no persistent long-run barrier to entry in the New Zealand petroleum market (Report to New Zealand Ministry of Commerce, 1997). New Zealand has no barriers in the form of tariffs, quotas or import licensing on importing refined products. A new entrant who complies with the Resource Management Act has easy entry to the market.

Tax and GST rates on petrol and diesel at-pump prices in New Zealand are a little different. As shown in Table 1, New Zealand has a very low tax on diesel – about 11 cents per litre compared with a 17% tax in the US and even higher, 57% in the UK. However, there is a separate road user charge for all diesel-powered vehicles. Therefore, the at-pump diesel price is always lower than the petrol price.

The different component shares of retail petrol and diesel prices are shown in the following two figures (Figures 3 and 4).

Figure 3

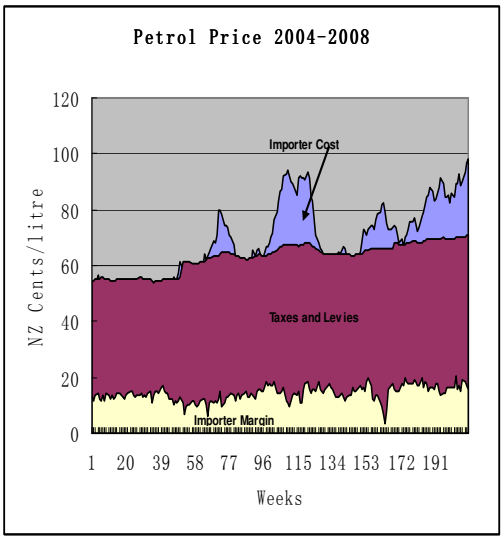
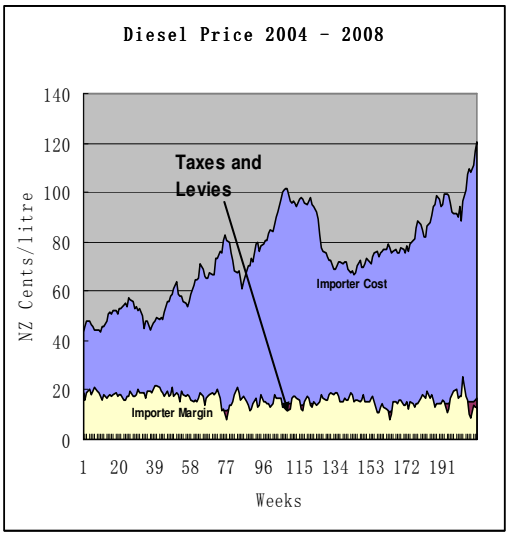


Figure 4



Sources: Ministry of Economics and Development website

Table 1: Proportion of total petrol and diesel price paid as tax (as at September 2005)

Country	Tax % of pump price for a litre of petrol	Tax % of pump price for a litre of diesel
UK	65%	57%
France	62%	45%
New Zealand	42%	11%
Canada	29%	24%
US	14%	17%

Sources: Ministry of Economic Development website

2.3 The relationship between crude oil and gasoline

Several studies have investigated the relationship between the prices of crude oil and gasoline. The asymmetry effect is the key area of interest among most of the studies. According to Eltony (1998), the asymmetric pattern of adjustment which has been termed “rockets and feathers” in the literature, indicates that in the cost-increase case, the adjustment starts instantly and rapidly, while in the cost-decrease case, downward price adjustment started after an initial delay followed by a series of smaller steps.

In Bacon (1991), based on fortnightly data for the period 1982-1989, it is found that changes in exchange rate are fully passed on into retail prices in the long run. There is a significant degree of asymmetry in the adjustment of prices to increases and decreases in costs. For cost changes of the order of 1 per cent per litre, the mean lag of the price rise is 4.38 time-periods (about two months) for a rise in product prices and 4.77 periods for a fall in products’ prices. Changes in exchange rates are felt one period later giving a mean response of 5.38 time-periods to a fall in the dollar/sterling rate. The adjustment of prices to cost rises is more concentrated around the mean lag than that to cost falls, so that price rises appear to be sharper and less gradual than price falls. There is a trend increase in other costs or margins of 0.015 per cent/litre per fortnight.

By investigating the movement in petrol prices and international factors (changes in the crude oil prices and the dollar exchange rate), an asymmetric relationship has been observed. This will be demonstrated in the following paragraphs. Karrenbrock (1991) employs US 1983–1990 monthly data to study the empirical relationship between wholesale and after-tax retail gasoline prices. By adopting a distributed lag model, the author found that the length of time in which a wholesale price increase is fully reflected in the retail gasoline prices is the same as that of a wholesale price decrease for premium and unleaded regular gasoline. The study also found that consumers do benefit from wholesale gasoline price decreases.

Duffy-Deno (1996) developed his study, which was based on the US weekly data for 1989—1993, on the downstream relationship between wholesale and net-of-tax-retail gasoline prices. By using a general unrestricted distributed lag specification, the result shows strong short-run and long-run asymmetries, with a fuller, longer (four weeks) adjustment in the case of price rises and an incomplete, and shorter (two weeks) adjustment for price falls. The same result was found in the Borenstein's (1997) study. Based on the weekly data for 1986—1992, the empirical investigation confirms the common belief that retail gasoline prices react more quickly to increases in crude oil prices than to decreases (four versus eight weeks). An ECM is estimated but, like the previous study, only asymmetry for price changes is permitted in the model.

However, even if all the markets are very competitive, so that the average of the prices for these products follows the crude oil price very closely, the refinery

price of gasoline will not necessarily follow the crude oil price movement (Bacon, 1991).

Balke et al. (1998) extend the work of Borenstein et al. (1997) by using two different model specifications with weekly data from 1987 to 1997. In particular, the authors use a distributed lags model in the levels of prices with asymmetric effects and an ECM representation which allows for both long-run and short-run asymmetries. On the basis of an encompassing test this last specification is preferred. Both models involve three prices, with the wholesale price depending upon oil and spot prices and the retail price upon wholesale and spot prices. The authors do not obtain unambiguous evidence concerning asymmetry, being weak in the specification in levels and moderate and persistent in the ECM**.**

In the Swedish retail market, evidence was found by Asplund et al. (2000) that, in the short run, prices adjust much slower downwards than upwards, and prices respond more rapidly to exchange rate movements than to the spot market prices.

In the Galeotti, Lanza and Mineral (2003)'s study, by representing and examining the complex chain of crude oil into the refined gasoline product as a two-stage process, asymmetries were found in the transmission chain of price shocks to final gasoline prices: first-stage adjustment speeds are generally smaller in absolute value than second-stage speeds, and adjustment is faster in the second stage of the chain than in the first stage. Evidence on exchange rate asymmetries were also found and the result suggested that gasoline prices are

more responsive to increases in the exchange rate than decreases, and this fact again emerges clearly in the first-stage results. However, the asymmetry effect is not found in the above studies.

Shin (1994) relates the average wholesale price of oil products to the prices of oil in his investigation of the US market. He uses monthly data for the period 1986—1992. His dynamic model quite simply regresses average wholesale price changes on positive and negative oil price changes and shows no evidence of short-run asymmetric effects.

Godby et al. (2000) studied the Canadian market for both premium and regular gasoline. The analysis was based on weekly data for 13 cities between 1990 and 1996. By noting that the asymmetric ECM specifications used in previous studies are mis-specified if price asymmetries are triggered by a minimum absolute increase in crude cost, a Threshold Auto Regressive model within an ECM was implemented in the paper. On this basis the authors failed to find evidence of asymmetric pricing behaviour.

While most of the previous researches focused on markets of western countries, a few studies were also conducted on petroleum markets in the pacific region.

In the Motor Association of Australia (MTAA)'s report to the Senate Economics Legislation Committee (2006), it was found that there is strong correlation between the crude oil price and petrol price; and the retail price of petrol is mainly determined by the wholesale price of petrol, the level of government

taxation and government subsidies. Since the Wholesale prices in Australia are determined by a theoretical import price parity calculation by adjusting an international benchmark price – Singapore Unleaded, the influence of Australian/US dollar exchange rate on wholesale prices also had impact on the retail petrol price.

The findings of MTAA are supported by Hale and Twomey (2008) in their report to New Zealand Ministry of Economic Development. The analysis of Twomey and West has extended the findings: in the New Zealand petroleum market, the petrol/diesel retail prices go down as quickly as they go up, which is different from the Australia market; the main reasons for the difference are different levels of price transparency and retail price cycles between New Zealand and Australia markets.

Furthermore, a similar view of the relationship between the petrol price and the crude oil prices was suggested in the study of Delpachitra (2002). By adopting the multivariate error correction models and using the actual weekly wholesale and retail prices of diesel and unleaded petrol, it was concluded that, in the New Zealand petroleum market, the price adjustments in domestic markets in response to price changes in world crude oil markets and refined product markets are very weak. Domestic wholesale prices appear to be the key variable in determining retail prices. Lack of competition in the wholesale sector is found to be the main reason for weak price adjustments.

In summary, the above literature has shown us that an asymmetry effect does exist in some markets—with varied adjustment speeds of petroleum prices in response to the change in crude oil prices and currency exchange rates. The following sections detail the methods and models used in the analysis and the results found in the New Zealand market.

3.0 Methodology

In this study, both the short-run and long-run relationships between petrol/diesel prices, crude oil prices and currency exchange rates are tested. A linear regression model was used in the testing of short-run relationships, while a multivariate model (using co-integration tests) was adopted in the test of long-run relationships.

3.1 Assumptions

Since New Zealand is a small country in comparison to the world market, it is commonly believed that the trading of crude oil in New Zealand is affected by the world crude oil market, but the opposite is not true. Therefore, prior to the establishment of models, it is assumed that the New Zealand petrol/diesel prices are determined by the crude oil price in the world market and the causality relationship between them is only in one direction, that is, from the world market to the New Zealand domestic market.

Some basic assumptions for the Linear Regression Model are also applied in the following model establishment (Kennedy, 2003):

1. There is a linear relationship between the dependent variable and independent variables plus a disturbance term; and there is no exact linear relationship between the independent variables — in New Zealand, it is in our common belief and observation that two independent variables, crude oil prices

and exchange rate, are not correlated, that is, the change in exchange rate will not affect the crude oil price, and vice versa. Therefore, this assumption is automatically fulfilled.

2. The expected value of the disturbance term is zero, and all disturbance terms have the same variance and are not correlated with each other. In other words, all disturbance terms in the model analysis must have an expected value of zero and same variances, in violation of this assumption, the calculated intercept value would be biased.

3.2 Empirical Models

Firstly, the long-run relationship between the petrol/diesel price, crude oil price and exchange rate is as follows:

$$y_t = \alpha_0 + \alpha_1 x_t + \alpha_2 z_t + \varepsilon_t \quad (1)$$

Where y_t denotes the price of petrol/diesel at week t; x_t represents the price of crude oil and z_t is the corresponding US dollar/NZ dollar exchange rate; ε_t is the disturbance term; α_0 , α_1 and α_2 are the model parameters: α_0 is the constant mark-up; α_1 measures the degree of pass-through of crude oil price change in the long run, while α_2 measures the degree of pass-through of exchange rate in the long run.

Secondly, to examine the short-run petrol/diesel price change in response to the changes in price of crude oil and exchange rate, an error-correction model is used to test for difference in the petrol/diesel price adjustment when they are above or below their equilibrium level.

$$\Delta y_t = \beta_1 \Delta x_t + \beta_2 \Delta z_t + \beta_3 (y_{t-1} - \alpha_0 - \alpha_1 x_{t-1} - \alpha_2 z_{t-1}) + V_t \quad (2)$$

Where Δ denotes first difference and V_t is the error term. $\hat{\varepsilon}_{t-1} = (y_{t-1} - \alpha_0 - \alpha_1 x_{t-1} - \alpha_2 z_{t-1})$ is the residual of the long-run relationship given by Equation (1). β_1 represents the immediate or short-run pass-through rate for crude oil, that is, it measures how much of the change in the underlying benchmark crude oil price gets reflected in the petrol/diesel price in the same period. β_2 measures the immediate or short-run pass-through rate for exchange rate, and β_3 captures the error correction adjustment speed when the rates are away from their equilibrium level (which is expected to be negative).

According to Hendry (1995), the mean adjustment lag (MAL) could be calculated by the following equations:

$MAL_1 = (1 - \beta_1) / \beta_3$ — Crude Oil

$MAL_2 = (1 - \beta_2) / \beta_3$ — Exchange Rate (3)

In order to test for the short-run asymmetric effect in the petrol/diesel prices when they are above or below their equilibrium prices, the equation below is adopted:

$$\Delta y_t = \delta_1 \Delta x_t + \delta_2 \Delta z_t + \delta_3 \lambda \hat{\varepsilon}_{t-1} + \delta_4 (1-\lambda) \hat{\varepsilon}_{t-1} + \eta_t \quad (4)$$

with an indicator variable λ. If the residual error [$\hat{\varepsilon}_{t-1} = (y_{t-1} - \alpha_0 - \alpha_1 x_{t-1} - \alpha_2 z_{t-1})$] is positive, λ is positive or otherwise zero. δ_3 Captures the error correction adjustment speed when the rates are above their equilibrium values and δ_4 captures the error correction adjustment speed when the rates are below their equilibrium values.

In addition, the following equations are used to define the asymmetric mean adjustment lags through the use of the standard Wald-test to determine if δ_3 is significantly different from δ_4:

$$MAL_1^+ = (1-\delta_1)/\delta_3 \quad \text{— Crude Oil}$$

$$MAL_2^+ = (1-\delta_2)/\delta_3 \quad \text{— Exchange Rate} \quad (5)$$

$$MAL_1^- = (1-\delta_1)/\delta_4 \quad \text{— Crude Oil}$$

$$MAL_2^- = (1-\delta_2)/\delta_4 \quad \text{— Exchange Rate} \quad (6)$$

MAL^+ represents the mean adjustment lag when the petrol/diesel prices are above their equilibrium value and MAL^- represents the mean adjustment lag when the petrol/diesel prices are below their equilibrium value.

4.0 Data Set

A weekly series of data, covering a period of 210 weeks from 23rd April 2004 to 25th April 2008, are used in this study. All data were taken from the official website of New Zealand Ministry of Economics and Development. The 210-week sample shows a fair degree of variation in gasoline markets.

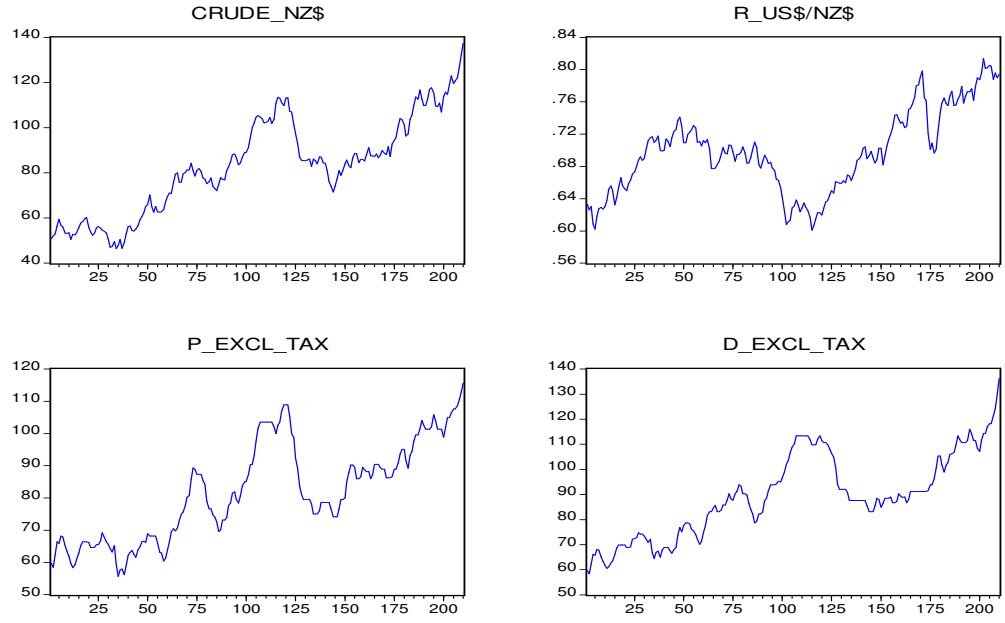
There are three types of oil—Brent, West Texas intermediate and Dubai—which serve as a price benchmark for the other types of crude oil. Based on their different varieties and qualities, West Texas intermediate is primarily used in the U.S. market; while Brent is commonly accepted in Europe. Dubai crude, produced in the Unite Arab Emirates, is served as the benchmark price for sales into Asian countries like Singapore (Oil Market Explained, October 18th, 2007). Since the oil consumption in New Zealand is depends on imports that comprise of crude oils produced in Unite Arab Emirates (Delpachitra, 2002), in this analysis, Dubai crude is chosen to represent the price of the crude oil market. The weekly average price of Dubai crude is reported as US$ per barrel, which is converted into NZ$ per barrel based on the corresponding weekly average exchange rate (US $/NZ $).

As mentioned in an earlier section—section 2.2 The New Zealand Petroleum Market—the New Zealand Regular gasoline price is made up of taxes and direct levies, imported costs and importer margins. The importer cost is based on the Singapore benchmark petrol price plus an estimated importation cost including freight, insurance, losses, and wharfage.

For research purposes, in this study we focus only on the unleaded price excluding tax for both petrol and diesel. The following graphs (Figure 5) show the changes of weekly average Dubai crude, US$/NZ$ exchange rate, Petrol_excl_tax price and Diesel_excl_tax price for the 210-week period from April 2004 to April 2008. The descriptive statistics for the four variables are listed in Table 2.[3] The data series of the four variables are transformed into natural logs for the purpose of analysis.

Figure 5

Price Movements of Dubai crude, US$/NZ$ exchange rate, Petrol_excl_tax price and Diesel_excl_tax price for the 210-week period



Note: The horizontal axial represents the number of weeks, while the vertical axial represents the New Zealand dollar amounts of crude oil price, petrol/diesel price and the dollar amount of exchange rate accordingly (Anti-clockwise).

[3] Note: Diesel vehicle users in New Zealand must also pay road user charges on a per km basis, which is not included in the data and graphs.

Table 2

Descriptive statistics of crude oil, US$/NZ$ exchange rate, petrol price and diesel price

	Mean	Medium	Maximum	Minimum	Standard Deviation
Crude Oil	82.818	84.103	137.433	46.351	21.200
US$/NZ$ exchange rate	0.698	0.697	0.814	0.601	0.051
Petrol_excl_tax	81.834	79.829	115.658	55.724	15.159
Diesel_excl_tax	89.297	88.318	136.255	58.349	16.489

From Figure 5, we can observe that there has been an increasing trend for the crude oil price in the last four years, with its first peak in April 2006 (week 117) at US$113.42 per barrel, and its second peak in April 2008 (week 210) at US$137.43 per barrel. The increasing trend is also observed in both the petrol and the diesel price series. There is a positive relationship between the crude oil price and the petrol/diesel prices: the petrol and diesel prices tend to move toward the same direction as the crude oil price. In contrast, a negative relationship is found between the US$/NZ$ exchange rate and the petrol/diesel prices: the two series tend to move in an opposite direction. The correlation coefficient among the four variables are shown in Table 3 below, the result

indicates that both the New Zealand petrol and diesel prices are highly correlated to the crude oil price rather than the US/NZ dollar exchange rate.

Table 3

Summary of Correlation Coefficient

	CRUDE_NZ$	R_US$_NZ$	P_EXCL_TAX	D_EXCL_TAX
CRUDE_NZ$	1.000	0.319	0.961	0.970
R_US$_NZ$	0.319	1.000	0.270	0.266
P_EXCL_TAX	0.961	0.270	1.000	0.966
D_EXCL_TAX	0.970	0.266	0.966	1.000

However, what is the long-term relationship and short-term dynamics between the crude oil, exchange rate and the petrol/diesel prices? In the following section, we are going to test the relationships by using the models we developed in Section 3.

5.0 Analysis of Results and Discussion

5.1 Long-run relationship

5.1.1 Co-integration test

To start our analysis, a co-integration test is used to test whether the four price series are co-integrated in the long term. The Johansen Multivariate Co-integration Test is employed to determine the long-run relationship of crude oil, the US $/NZ $ exchange rate and petrol/diesel prices as a system of equations.

A unit-root test is performed for all price series before running the co-integration tests. It is found that all four price series are non-stationary (has a unit root) at level, but stationary (no unit root) at their first difference. Results are summarised in Table 4 below:

Table 4

Results of Unit Root Test (Levels & First Difference)

	Levels		First Difference	
Variables	**t- stats**	**p-value**	**t- stats**	**p-value**
Crude_NZ $	-0.06059	0.9517	-11.6025	0
P_excl_tax	-1.08329	0.2800	-9.1640	0
D_excl_tax	-0.31464	0.7534	-9.2984	0
US$/NZ$ exchange rate	-1.49414	0.1367	-11.8585	0

Critical Value (5%) = -2.87526

Johansen developed two likelihood ratio tests for testing the number of co-integration vectors (r): the Trace Test and the Maximum Eigenvalue Test. The trace statistic tests the null hypothesis of $r = 0$ (i.e. no co-integration) against the alternative that $r >$ o (i.e. there is one or more co-integration vector). The maximum Eigenvalue statistics tests the null hypothesis that the number of co-integrating vectors is r against the specific alternative of r+1 co-integration vectors (Johansen, 1988). Table 5 below summarises the co-integration test results.

All the Maximum Eigenvalue and Trace statistics above are significant at the 5% level, which indicates the petrol/diesel prices are co-integrated with both the crude oil price and exchange rates, in other words, in terms of long–term relationships, there is a positive relationship between the petrol/diesel prices and the crude oil price, and a negative relationship between the petrol/diesel prices and the exchange rate.

Furthermore, the long-run relationship between the petrol/diesel prices, crude oil price and the exchange rate are examined by Equation 1.

Table 5

*** Co-integration between Crude Oil, US$/NZ$ Exchange Rate and Petrol Price**

	Maximum Eigenvalue Statistic	Trace Statistic
R=0	58.00100 (21.13162)	140.8080 (29.79707)
R<=1	49.16760 (14.26460)	82.80697 (15.49471)
R<=2	33.63937 (3.841466)	33.63937 (3.841466)

(Note: The values in brackets show the 5% critical value.)

*** Co-integration between Crude Oil, US$/NZ$ Exchange Rate and Diesel Price**

	Maximum Eigenvalue Statistic	Trace Statistic
R=0	56.01735 (21.13162)	139.5817 (29.79707)
R<=1	49.61673 (14.26460)	83.56432 (15.49471)
R<=2	33.94760 (3.841466)	33.94760 (3.841466)

(Note: The values in brackets show the 5% critical value.)

5.1.2 Long-run relationship by Equation 1

As mentioned in Section 3, in Equation 1: $y_t = \alpha_0 + \alpha_1 x_t + \alpha_2 z_t + \varepsilon_t$, α_0 measures the mark-up; while α_1 and α_2 measure the pass-through rates for the crude oil price and exchange rate accordingly.

From the summarised results in Table 6 below, it is found that the mark-up (α_0) is higher for the Diesel_excl_tax price than the Petrol_excl_tax price. As the New Zealand government has different rates of tax on petrol and diesel prices, the higher mark-up on the diesel retail prices is due to the lower taxes and levies on the diesel.

Table 6

	α_0	p-value	α_1	p-value	α_2	p-value
Diesel_excl_tax	0.0026	0.0968**	0.241976	0.0000*	0.15843	0.1743
Petrol_excl_tax	0.0016	0.3520	0.286743	0.0000*	0.15294	0.2348

Note: ** Indicates the p-value is significant at 10% level
* Indicates the p-value is significant at 5% level

The coefficient α_1 (Crude Oil effect), with p-values significant at the 5% level for both petrol and diesel, indicates a positive relationship between the diesel and petrol prices and the crude oil prices does exist in long run. For every dollar increase in the crude oil price, the diesel and petrol prices will increase 24 cents and 29 cents respectively.

However, with p-values insignificant at neither 5% or 10% level for petrol and diesel prices, coefficient α_2 (Exchange rate effect) suggests that in the long run,

the relationship between the petrol/diesel prices does not hold. In other words, in the long run, the US $/NZ $ exchange rate will not have any effect on the petrol and diesel retail prices in New Zealand.

Due to the insignificance of the exchange rate effect, in the following tests for short-run symmetric and asymmetric effects, the coefficient for the exchange rate is neglected from the calculation.

5.2 Short-run symmetric effect

As mentioned in Section 3, in order to examine how the petrol/diesel price changes in response to the changes in price of crude oil in the short run, an error-correction model is formed as below, with the statistics results summarised in Table 7: $\Delta y_t = \beta_1 \Delta x_t + \beta_2 \Delta z_t + \beta_3 (y_{t-1} - \alpha_0 - \alpha_1 x_{t-1} - \alpha_2 z_{t-1}) + V_t$. (As the exchange rate is found to be insignificant on changes in petrol/diesel prices in Section 5.2, the corresponding coefficient β2 is replaced with zero in the calculation.)

The results of Equation 2 (short-run symmetric ECM) are reported in Table 8. As expected, β3 for both the Diesel_excl_tax price and Petrol_excl_tax are negative and statistically significant at the 5% level. The result suggested the petrol/diesel prices are mean-reverting to long-run equilibrium, that is, the petrol/diesel prices will adjust upwards when they are below their equilibrium levels and adjust downwards when they are above equilibrium levels.

The adjustment speed for both the diesel and petrol prices is quite close, with the diesel price adjustment speed being a little faster than that of petrol prices (1.252 weeks for diesel versus 1.340 week for petrol). Compared with the MAL_1 value, the comparative higher value in MAL_2 indicates the following: both the petrol and diesel prices have a shorter adjustment time period in response to the crude oil price effect (1.252 weeks and 1.340 weeks) than the exchange rate effect (1.410 weeks and 1.496 weeks). That is, when there is a change in the US$/NZ$ exchange rate, it takes a longer period of time for both the petrol and diesel prices to adjust back to their equilibrium price level.

Although from the result of the short-run symmetric ECM, it is found that petrol and diesel prices will adjust back to their equilibrium, the speed that they will adjust upwards when they are below the equilibrium price level and the speed that they will adjust downwards when they are above the equilibrium level are not necessarily the same.

The short-run asymmetric effect is tested by Equation 4 in the next section.

Table 7

Results of Short-run Symmetric Effect

	β1	T-value	β2	T- value	β3	T-value	MAL_1	MAL_2
Diesel_excl_tax	0.112	2.901*	0.000	0.000	-0.709	-10.250*	1.252	1.410
Petrol_excl_tax	0.105	2.759*	0.000	0.000	-0.668	-10.116*	1.340	1.496

Note: 1. * indicates the T-value is significant at the 5% level. β3 captures the error correction adjustment speed.
2. MAL_1 measures the mean adjustment lag for the petrol/diesel prices in response to the crude oil price change.
3. MAL_2 measures the mean adjustment lag for the petrol/diesel prices in response to the US$/NZ$ exchange rate change.

5.3 Short-run asymmetric effect

Equation 4: $\Delta y_t = \delta_1 \Delta x_t + \delta_2 \Delta z_t + \delta_3 \lambda \hat{\varepsilon}_{t-1} + \delta_4 (1-\lambda) \hat{\varepsilon}_{t-1} + \eta_t$ is used to test the short-run asymmetric effect, and the results are summarised in Tables 8 and 9, while Table 10 compares the results of the Symmetric model and Asymmetric model.

From the results reported in Table 8, it is found that all the t-values are significant at the 5% level, except the p-value of the Wald test for diesel price. Due to the insignificant p-value of 0.652, we cannot accept the null hypothesis of Ho: δ3= δ4 in analysing the asymmetric effect for diesel prices. That is, there is no significant difference in the adjustment speed when the diesel prices are above or below their equilibrium prices. The fact is also reflected the Mean Adjustment Lags. In response to a crude oil price change, it takes about 1.3 weeks for diesel prices to adjust downward, compared to 1.2 weeks for it to adjust upwards. In the case of changes in the currency exchange rate, the adjustment speed is comparative longer: it takes about 1.5 weeks for the diesel price to adjust downwards while it takes 1.3 weeks to adjust upwards. Thus, there is no short-run asymmetric effect for the diesel prices regardless whether the cause is a change in crude oil prices or the US$/NZ$ exchange rate.

Table 8

Results of Short-run Asymmetric Effect

	δ1	t-value	δ2	t-value	δ3	t-value	δ4	t-value	Adjusted R^2	Wald	p-Value
Diesel_excl_tax	0.116	2.928*	0.000	0.000	-0.67	-6.15*	-0.76	-5.62*	0.461	0.205	0.652
Petrol_excl_tax	0.139	3.398*	0.000	0.000	-0.11	-5.05*	-0.81	-0.87*	0.316	24.293	0.000*

Note: 1. The null hypothesis for the Wald test is Ho: δ3= δ4, that is, there is a significant difference in the adjustment speeds when the prices are above or below their equilibrium level.
2. * Indicates the p-value is significant at the 5% level.

Table 9

Results of Short-run Asymmetric Effect

	MAL^{+}_{1}	MAL^{+}_{2}	MAL^{-}_{1}	MAL^{-}_{2}
Diesel_excl_tax	1.329	1.502	1.172	1.325
Petrol_excl_tax	7.609	8.842	1.069	1.242

Note: 1. MAL^{+}_{1} and MAL^{+}_{2} represent the mean adjustment lag when the petrol/diesel prices are above their equilibrium level in respond to a crude oil effect.

2. MAL^{-}_{1} and MAL^{-}_{2} represents the mean adjustment lag when the petrol/diesel prices are below their equilibrium level in respond to an exchange rate effect.

Table 10

Mean Adjustment lags in weeks:

	Symmetric Model		**Asymmetric Model**			
	MAL_1	MAL_2	MAL^{+}_{1}	MAL^{+}_{2}	MAL^{-}_{1}	MAL^{-}_{2}
Diesel_excl_tax	1.252	1.410	1.329	1.502	1.172	1.325
Petrol_excl_tax	1.340	1.496	7.609	8.842	1.069	1.242

The p-value of Wald test for the petrol price, on the other hand, indicates that there is a significant difference in the adjustment speed when the petrol price is above or below its equilibrium price. In other words, the short-run asymmetric effect does exist in the petrol price in response to both the crude oil effect and exchange rate effect. The upward adjustment speed for petrol price is much faster than the downward adjustment speed: in the case of the crude oil price change, it takes around 1.07 weeks to adjust upward, but 7.6 weeks to adjust downward. Similar adjustment speed for petrol prices is found in the case of exchange rate changes: it takes about 1.24 weeks to adjust upwards and 8.84 weeks to adjust downwards.

As summarised in Table 10, the adjustment speed for diesel prices is overall faster than that of petrol prices, and both the diesel and petrol prices adjusted faster in the case of crude oil price changes than the exchange rate changes. As expected, petrol prices adjust upwards considerably faster when they are below their equilibrium level, in contrast with a much slower speed when they adjust downwards.

5.4 Summary of Findings and Discussion

The findings above could be summarised as follows: (1) There is a long-term relationship between the New Zealand petrol/diesel prices and the world crude oil price. The effect of the US $/NZ $ exchange rate on the change of petrol and diesel prices does not hold in the long run. (2) The result of the symmetric ECM suggested that the petrol/diesel prices are mean-reverting to their equilibrium level in case of changes in either crude oil prices or exchange rates. (3) The asymmetric effect does not exist in the diesel price in response to both crude oil effects and exchange rate effects. In contrast, there is a significant difference between the upward and downward adjustment speed for petrol. (4) Results of both the symmetric model and asymmetric model indicate that the adjustment speed of diesel price is generally faster than the petrol price, that is, the diesel price is more sensitive to the world crude oil price changes and exchange rate changes.

Based on observation, the at-pump petrol price is generally around 50% higher than the at-pump diesel price across New Zealand (when the at-pump petrol

price is $1.539 per litre, the at-pump diesel price is $0.989 per litre). The main determinant of the difference is the different tax treatment between petrol and diesel by New Zealand government.

The finding on diesel prices in New Zealand being more sensitive to international factor changes is supported by the country's consumption and tax treatment of diesel. As mentioned in Section 2.2, diesel is more widely used in commercial areas, while petrol is more commonly used by individual households. The New Zealand government has a considerably low tax rate on diesel prices. Although there is still a separate on-road charge for all diesel users, the additional charge is not directly linked to the amount of fuel used, but the actual kilometres run. The cost of diesel still appears as "cheaper fuel" for most consumers, especially commercial users. In addition, as we have found out in Section 5.1.2, the mark-up for diesel is higher than for petrol. From the retailer's point of view, due to the lower tax rate on diesel, there is more profit selling diesel fuel than selling petrol. When the world crude oil price decreases, it tends to be much easier for them to adjust the diesel price downward—on the basis that even when they decrease the diesel price, the profit they have is still more than for selling the petrol. Therefore, the diesel price is more sensitive to the changes in world crude oil prices, that is, the adjustment speed of diesel is faster compared to that of petrol.

The dominant place of petrol fuel in terms of the energy consumption structure in individual households is another likely reason for the differential adjustment speeds between diesel and petrol prices in New Zealand. Due to the

comparative high demand for petrol, when the world crude oil price increases, in order to maintain the same mark-up, the retailer would adjust the petrol price accordingly and instantly; however, when the world crude oil price decreases, driven by the profit-maximising goal and the fear that the crude oil price might increase sharply in a short time, retailers are not willing to adjust the petrol prices downward immediately. This has caused delays in downward adjustment speeds for petrol prices, and which has also explained the longer mean adjustment lag of 7.6 weeks in response to a decrease in the crude oil price.

Deregulation of New Zealand petroleum market tends to be the third likely reason. Since the market deregulation in 1988, as mentioned in Section 2.2, the barrier to entry is found to be low. Competitions brought by the deregulation has increased the price adjustment speed in case of an increase in crude oil prices; on the other hand, deregulation also led to increased market concentration (Delpachitra, 2002). Due to the limited oil terminals in New Zealand, there is a high possibility that new entrants will engage in tacit collusion and control of the wholesale market – which contributes to the explanation for the long mean adjustment lag of petrol prices as well.

The adjustment speeds of New Zealand gasoline and diesel prices are also different across decades. As it is found in this study, the New Zealand petrol/diesel prices are determined by the world crude oil prices, and there is a long-term relationship between them. In other words, the price movement of petrol/diesel will follow the price movement of crude oil, which could be observed from both Figure 1 and Figure 5. By referring to Figure 1, it is obviously that the adjustment speed of crude oil price is much faster in year

2000s than in 1990s. In the period from 2004 to 2008, the increase of crude oil price is about 77 dollar per barrel, in contrast to the increase of about 17 dollar per barrel from Year 1996 to Year 2000. The four-fold (77 Vs 17) difference in adjustment speeds of crude oil price and petrol/diesel prices could be explained by the substantial growth of demand for crude oil in recent years. Along with the economic and population growth, petrol/diesel are highly demanded and consumed by both households and industries, which has contributed to the sharp price increase over the last 4 years. Fear of run-out of oil reserve and political tension in countries like Iran and Iraq are some other reasons for the sharp increase in both crude oil prices and petrol/diesel prices.

6.0 Conclusion

This study has examined the relationships between retail petrol/diesel prices, crude oil prices and US$/NZ$ exchange rate in the New Zealand petroleum market. The analysis was based on a time series representation of actual weekly retail prices of petrol and diesel. The Error Correction Model was established and used to examine the price adjustment speed of both petrol and diesel.

The results suggest that the world crude oil price does have an effect on the petrol and diesel price movements in both the long run and the short run; in contrast, the effect of the US $/NZ $ exchange rate is not found significant in the long run. The asymmetric effect is found in petrol prices in the short run but not the diesel prices. The adjustment speed of petrol price in response to an increase in world crude oil prices is much faster than the decrease of oil prices. Different tax treatments employed by the government appears to be the key factor in causing the adjustment speed differential between petrol and diesel prices.

However, results might vary due to the assumption of the Error Correction Model used and the limited time-frame of the data. In addition, the price movement in the New Zealand petroleum market could be influenced by other factors like government political issues (such as War in Iraq), crude oil productions and consumptions of other countries; future study of these factors could be employed to extend this study.

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