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Research Technical Paper

Testing for Asymmetric Pricing Behaviour in Irish and UK Petrol and Diesel Markets

Colin Bermingham **Derry O' Brien***

Central Bank and Financial Services Authority of Ireland
P.O. Box 559, Dame Street
Dublin 2
Ireland
http://www.centralbank.ie

*The views expressed in this paper are the personal responsibility of the authors. They are not necessarily held either by the CBFSAI or the ESCB. All errors are our own. The authors would like to thank Kieran McQuinn for helpful comments. Email: colin.bermingham@centralbank.ie, derry.obrien@centralbank.ie

Abstract

This paper empirically tests whether Irish and UK petrol and diesel markets are characterised by asymmetric pricing behaviour. The econometric assessment uses threshold autoregressive models and a dataset of monthly refined oil and retail prices covering the period 1997 to mid-2009. A methodological note is included on the importance of the specification of the number of possible regimes. In particular, the possibility of conflicting price pressures arising from short-run dynamics in retail prices and responses to disequilibrium errors needs to be explicitly modelled. For both the Irish and UK liquid fuel markets at national levels, the paper concludes that there is no evidence to support the "rockets and feathers" hypothesis that retail prices rise faster than they fall in response to changes in oil prices. It is still possible that a lack of competition at a more local level may accommodate asymmetric pricing behaviour.

Non Technical Summary

Although there is evidence to suggest that the profit margins in Irish transport fuel markets are relatively modest, the perception persists that the retail transport fuel market in Ireland is not entirely competitive with consumers not benefitting from falls in crude oil prices with the same rapidity as they are burdened with rises in crude oil prices. This perception is to a large extent based on anecdotal evidence only, as there is a dearth of studies that have empirically tested whether Irish fuel markets are characterised by asymmetric pricing behaviour. The National Consumer Agency (NCA) investigated the movements of refined prices, wholesale prices and retail pump prices in Ireland during 2008. While the NCA concluded that there is little evidence to suggest unwarranted delays in the passing through of refined oil price falls to consumer prices, their study was based on a just one year of data and did not assess the issue using econometric models.

This paper contains a rigorous econometric assessment of the pass-through of oil prices in Irish liquid fuel markets using a long span of data. The UK fuels market is also examined for comparison purposes. The econometric analysis uses threshold autoregressive models to test for asymmetries, which allow for the possibility of response rates changing when passing a non-zero threshold rather than the typical zero threshold in models of asymmetry. The threshold model approach has intuitive appeal and is consistent with a variety of pricing behaviour models presented in the industrial organisation literature. A second methodological improvement is the use of multi-regime models. This type of model takes explicit account of price pressures from different sources in the system of equations.

For both the Irish and UK liquid fuel markets at national levels, the paper concludes that there is no evidence to support the "rockets and feathers" hypothesis that retail prices rise faster than they fall in response to changes in oil prices. The retail fuel markets are quite competitive, particularly for Ireland. The market here is characterised by modest profit margins and a relatively high number of filling stations per head of population. This type of market structure is not consistent with asymmetric pricing. From this viewpoint, despite a common perception of asymmetric pricing behaviour on the part of fuel retailers, the results are consistent with the market structure.

1 Introduction

The heightened volatility in international crude oil prices in recent years has intensified interest in aspects of the pass-through of oil prices to retail prices in the domestic fuel market. In particular, interest has focused on the speed of the pass-through of oil prices and any possible associated asymmetric pricing behaviour that may suggest retailers have some short-run market power. Generally, when a market is perfectly competitive, the price setting behaviour of firms is symmetric in reaction to increases or decreases of the same order of magnitude in input costs. Although there is evidence to suggest that the profit margins in Irish transport fuel wholesale and retail markets are relatively modest, the perception persists that the retail transport fuel market in Ireland is not entirely competitive with consumers not benefitting from falls in crude oil prices with the same rapidity as they are burdened with rises in crude oil prices. Indeed, the Department of Enterprise, Trade and Employment commissioned a study in September 2008 to identify "why pump prices for petrol and diesel have not fallen in line with the drop in the wholesale price of oil".

While the issue of pass-through of oil prices to liquid fuel prices has been treated extensively for the US and larger euro area countries, there is a dearth of studies assessing the oil price pass-through and possible asymmetries in the Irish liquid fuels (petrol, diesel and heating fuel) markets. The National Consumer Agency (NCA) studied the relationship between crude prices and downstream product prices but the main analysis relied on graphical illustrations based on data for 2008 only. The pass-through in Ireland has also been examined by Meyler (2009) using standard asymmetric error correction models as part of study across 12 euro area countries. We adopt a more sophisticated econometric model, the threshold autoregressive model, which we argue has more intuitive appeal. Such a model allows for the possibility of response rates changing when passing a non-zero threshold rather than the typical zero threshold. At the same time, we provide extensive Irish context by, for example, discussing structural indicators for the Irish market. The econometric model is estimated based on a long time series of refined oil and retail (petrol and diesel) prices. Therefore, this paper addresses a significant gap in the literature. An assessment of the structure and pricing behaviour in these markets can also provide a stronger basis for short-term inflation forecasting exercises and a better understanding of the direct effects of oil price shocks.

Various structural indicators of liquid fuel markets in Ireland are examined to shed some preliminary light on the issue of a possible lack of effective competition. The main focus of this paper is to determine the pass-through rates and test for asymmetries in Irish fuel markets but the equivalent pass-through rates in the UK are also examined in order to provide some context. It is important to note that, if there are asymmetries, this analysis does not identify why these pricing asymmetries occur or at what stage of the supply chain (wholesale or retail) they may arise. We propose to use a threshold autoregressive model to ascertain whether significant asymmetries characterise Irish and UK liquid fuel markets. Such a non-linear modelling approach has some intuitive appeal, with the higher pass-through kicking in when a certain threshold is passed. While the analysis uses long time series and sophisticated econometric techniques the results on oil price pass-through rates come with some caveats attached. There are challenges to assessing the pass-through of oil prices in the case of Ireland which may limit the robustness of the results. These include the low frequency of the data, which are only available at a monthly frequency whereas a weekly or higher frequency would be preferable. Cross-subsidisation may also distort the pass-through with retailers supporting revenues by increasing margins in non-fuel items to offset tighter margins in pump prices.

The paper takes the following structure. Section 2 briefly discusses the results from previous studies on the oil pass-through to retail pump prices for the Irish and other euro area countries' markets. The subsequent section describes the structure of the fuel markets in Ireland using on a range of indicators of competition while also providing some further background information on the pricing mechanisms involved. The data used for the study of pass-through and asymmetries is described in Section 4. Sections 5 introduces the various modelling approaches while Section 6 describes the results. Section 7 presents a methodological note on the importance of a multi-regime specification in threshold autoregressive models. Finally, Section 8 summarises the findings and concludes that broadly there is no evidence to support the view that retail prices rise faster in Irish and UK liquid fuel markets at national levels than they fall in response to oil price changes.

2 Oil Price Direct Pass-through Literature

There are numerous studies of oil pricing asymmetries, forming part of the extensive "rockets and feathers" literature that examines whether retail prices rise faster than they fall in response to changes in oil prices. Many of these studies have been undertaken for fuel markets in the US and larger euro area countries and have adopted a wide range of econometric approaches. Borenstein et al. (1997), in a seminal paper, examined price asymmetries in US gasoline markets and found retail prices showed asymmetry to crude oil price changes, possibly reflecting inventory adjustment effects. Geweke (2004) contains an excellent exploration of the econometric issues faced in analyses of pricing asymmetries in fuel markets and provides a useful critique of the important empirical studies on US fuel markets available up to that point. With a broader geographical coverage, Manera and Frey (2007) discusses the results from the various empirical studies undertaken in analysing asymmetries in price transmission generally while also providing a comprehensive overview of the alternative econometric approaches adopted.

There are a limited number of studies that examine the pricing behaviour in Irish fuel markets. The NCA Report investigated the movements of refined prices, wholesale prices and retail pump prices in Ireland during 2008. While the NCA Report concluded that there is little evidence to suggest unwarranted delays in the passing through of wholesale price changes consumer prices, their study was based on a just one year of data and did not assess the issue using econometric models. The study presented valuable information on the working of the liquid fuels industry in Ireland. Meyler (2009) examines the oil pass-through across all euro area countries using a standard asymmetry model and uses levels data rather than the standard approach in the literature of modelling the series in logs. The broad conclusion arrived at in the study is that the pass-through in euro area countries generally is full and quick and there are no significant pricing asymmetries.

The standard asymmetry model may be mis-specified as there is likely to be a fixed cost associated with price changes such that firms make adjustments to prices only when the input cost change is sufficiently large to justify incurring the cost of implementing the price change. A threshold autoregressive model (TAR) may be used to allow for such a non-zero threshold effect i.e. asymmetric pricing is only triggered by a minimum absolute change in crude (or refined) oil costs. The TAR model is a more general form of the standard asymmetry model with the threshold arbitrarily set to zero in the case of the latter. The threshold variable is typically based on the current price change or on the average price change over a number of time periods. These models tend to focus more on the short-run asymmetries - lag to initial response and the duration of the response - rather than the long-run response - whether the cost change is fully passed through. The Hansen (1998) bootstrap approach is commonly used to test the null hypothesis of a linear model against the TAR alternative.

While the TAR approach has much intuitive appeal, the added value from adopting a threshold pricing approach depends on the accuracy of the estimate of the true threshold and on whether the threshold is economically and statistically significantly different from zero. Al-Gudhea et al. (2007) found evidence in support of threshold pricing for the US gasoline market while Asplund et al. (2000) also identified some threshold pricing in Swedish gasoline markets although the fixed costs appeared to be relatively small. Finally, Godby et al. (2000) applied TAR models to the Canadian gasoline markets but did not find any evidence to support pricing asymmetries. The threshold autoregressive model is explained in greater detail in Section 5.

3 Structure of the Irish Oil Market

The recent report by the National Consumer Agency provides a detailed examination of the various stages of the oil market. This oil market is currently entirely downstream in nature i.e. activities in the industry are restricted to refining, storage, distribution and sales of refined products. Crude oil is imported to Whitegate, Ireland's only oil refinery, while refined oil is imported to wholesalers' storage depots located around the country. The wholesalers in turn sell to distributors or directly to retailers while the distributors sell to a range of industrial and service station retailers. There are no oil pipelines in Ireland so the product is transported entirely by road or by sea, which can add significantly to costs relative to the UK where there are oil pipelines.

The price of interest in this paper is the price charged to consumers and there is some tentative evidence to suggest that the retail market is relatively competitive. Over 75 per cent of service stations are independently owned but many operate under Solas agreements whereby the retailer is tied to a certain supplier for typically a period of five years. However, these retailers along with service stations licensed by oil companies can set their own prices. In terms of concentration, there are no restrictions on the number of stations. There are up to 2,034 service stations in Ireland and the number of stations per capita in Ireland is one station for every 2,020 inhabitants. This compares with one station per 9,539 inhabitants in the UK and one station per 3,113 people in Northern Ireland. In 2005, the market share of three largest firms in Irish retail transport fuel sector was about 53 per cent while the corresponding share for the euro area was 49 per cent.[1] Turning to the profits of Irish subsidiaries of oil firms, an analysis of profits by the NCA, which looked at the financial accounts of large oil firms, suggests that net profits after tax as a proportion of the cost of sales (including from non-fuel sales) are quite modest at between 0.6 per cent and 2.3 per cent. Altogether, this suggests that the market structure at national level is comparatively competitive although fuel markets are essentially local in nature and the degree of competition may vary significantly across regions, cities and towns.

While the frequency of price changes in the wholesale market can be quite high, the prices often tend to be based on monthly averages of refined oil prices. About 30 per cent of the oil imported into Ireland is destined for the Whitegate oil refinery, with the majority of customers (about 60 per cent) of Whitegate paying monthly averages for refined oil while the remaining customers pay based on twice weekly rates. Wholesalers that purchase imported refined oil mainly pay at a price based on the average of the month and tend to change their selling prices twice a week based on the average of refined prices over the previous two or three days. Currency and other hedging may also dampen fluctuations in the wholesale price. As a result, any slow speed of pass-through of refined prices to wholesale prices may partly reflect a degree of smoothness in prices due to trading on futures markets although it would not explain any persistent asymmetries in pricing. The frequency of price changes at the retail stage is also quite high. The pricing mechanism for fuel products may be distorted somewhat as retailers may avail of opportunities for cross-selling with higher margins in non-fuel items, such as food and beverages, compensating for tighter margins in petrol and diesel. Moreover, the entry of large supermarket chain such as Tesco into the petrol and diesel retail markets may have accelerated this trend, although the impact is likely limited to a relatively small number of localities for now, particularly given that retail size restrictions remain in place.

4 Data for Price Pass-through and Asymmetries Analysis

There are a number of choices to make in terms of the data for a study of this nature. For the international oil price, one can use the price of either crude or refined oil. The prices

[1] The corresponding figure for the UK is not available.

of refined gas and diesel are used in this study, as refined prices reflect the cost to the wholesaler or retailer more closely than crude prices. The refining margins have fluctuated significantly in recent years, particularly for diesel, and therefore using crude prices are not an appropriate proxy for the prices ultimately paid by the wholesaler or retailer. The refined oil prices are Rotterdam gasoline and diesel prices in dollars per barrel converted to euro per litre. Regarding the retail price, again there are two options - including the pre-tax or final tax-inclusive retail price in the study. The choice of retail price depends on the research question. The emphasis in this paper will be on the pass-through to the pre-tax price, as this price is controlled by retailers. The monthly pre-tax petrol and diesel price level data are taken from the European Commission Weekly Oil Bulletin and unpublished monthly price indices for petrol and diesel are kindly provided by the CSO.

All data are at a monthly frequency and at national level. Ideally, the data would be at a weekly or higher frequency and available at local level rather than national. There are higher frequency data available on user websites such www.pumps.ie but they are of questionable reliability. There are also wholesale price data available from www.fuelsonlineprices.com. Any finding of asymmetry between refined oil price changes and retail price changes could be further investigated in a follow-up study on the wholesale and retail stages separately to identify at which stage it may be more of an issue. In this respect, it is interesting to note that the margins seem to be of a similar order at both stages - around 2.5 cents per litre. The monthly prices data for the UK have also been taken from the EC Weekly Oil Bulletin. The data collection methodologies for Irish and UK data may differ somewhat so comparisons may not be strictly comparable. Prices in the fuel supply chain in Ireland are often based on monthly averages, which suggests that the pass-through in the case of Ireland may be relatively sluggish and any significant asymmetries may still be picked up using data of a monthly frequency.

5 Estimating Asymmetry

5.1 Basic Cointegration Model

The price of liquid fuels at retail level closely follows developments in refined prices. Figure 1 shows the price of refined gasoline together with the retail price of petrol. The strong observed comovement between retail and refined prices is suggestive of a cointegrating relationship between the two. Figure 2 shows the logs of these prices, with separate scales this time. Again, there is strong comovement with the log series.[2] This implies a long-run relationship of the form

$$PC_t = \alpha + \phi PR_t + \epsilon_t \tag{1}$$

where PC_t is the consumer or retail price at time t and PR_t is the refined price. Augmented Dickey-Fuller tests find that all the price series contain a unit root regardless of whether we use logs or levels. Using the Engle-Granger two-step approach, the residual of the long-run equation is checked for a unit root and the null of no cointegration between refined and retail prices is very strongly rejected in each case[3] and so our initial statistical tests confirm the commonly found cointegrating relationship between retail and refined prices. This relationship allows us to embed the long-run residual, which is the ECM term $\epsilon_t = ecm_t = PC_t - \phi PR_t - \alpha$ in an error correction model (ECM) of the form:

$$\Delta PC_t = \gamma + \theta ecm_{t-1} + \sum_{i=1}^{q} \eta_i \Delta PC_{t-i} + \sum_{j=0}^{p} \beta_i \Delta PR_{t-i} \tag{2}$$

The existence of a cointegrating relationship between refined and retail prices for both logs and levels means we have a choice in terms of how to specify the model. Although specification in terms of logs is standard in most econometric models, we choose the levels specification for both statistical and conceptual reasons. Statistically, the long-run equation shows much stronger cointegration properties when specified in levels rather than logs. Furthermore, in a study of European fuel prices, Meyler (2009) finds that there can be instability in the long-run relationship if specified in logs but this problem does not arise in the levels specification. The final statistical benefit of the levels specification is in terms of the fit of the short-run equations. We find there is considerable improvement in the R^2 of the short-run equation when the specification is in levels.

It also makes more sense theoretically to specify the model in terms of absolute price levels because a one cent increase in refined prices will lead to a one cent increase in pre-tax prices if there is full pass-through. However, the impact of a one per cent increase in refined prices on post-tax prices will depend on the actual level of refined and retail prices. There is

[2] The graphs for diesel show similar properties.

[3] The results of unit root tests and cointegration tests are not presented in the interests of brevity but are available from the authors upon request.

a large tax element to retail prices. This mainly consists of excise duty, which is a fixed tax, and VAT, which is an ad valorem tax. The tax element accounts for a larger percentage of the retail price when prices are low and a smaller percentage when prices are higher. Therefore, if we model in logs, pass-through will depend on the price level. This can be avoided by using a model in levels. For this reason, together with the superior statistical properties, the log specification is dropped in favour of the levels specification for the rest of the analysis. The levels specification could result in a problem with heteroscedasticity so all results presented later are based on Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors.

From the equations above, it is implied that the cointegration relationship is estimated using the Engle-Granger two-step procedure. In the interests of robustness, we also use the ARDL approach suggested by Peseran, Shin and Smith (2001). This approach uses a one-step non-linear estimator, in which the long-run cointegrating relationship is embeded in the short-run equation. In Table 1, we present the estimates of the intercept, α and the slope coefficient, ϕ, from the long-run equation for both the ARDL non-linear estimator and the OLS estimator of the Engle-Granger two-step procedure. The ARDL method and the OLS method yield very similar results for both petrol and diesel in both the UK and Irish markets. Although not formally tested, it is clear that the differences in the parameter estimates are well within the bounds of statistical variation. This suggests that the results of the study are not sensitive to the choice of estimator. For this reason, we conduct our tests of asymmetry with the standard OLS estimator, as outlined in the equations above.

5.2 Simple Models of Asymmetry

The standard cointegration model is not sufficiently rich to capture the underlying dynamics if there is asymmetry in the transmission of changes in the price of refined oil[4] to retail prices. The model presented in equation 2 implicitly assumes symmetric adjustment around $\Delta PR_t = 0$, so that all coefficients are the same regardless of whether changes in refined prices are positive or negative. To allow a different response to positive and negative refined price changes, define the following indicator variable, I_t:

$$I_t = \begin{cases} 1 & \text{if } TR_t > \tau \\ 0 & \text{if } TR_t \leq \tau \end{cases}$$

[4]We use the general term “refined oil” instead of referring to both refined gasoline and refined diesel.

where TR_t is the value of the threshold variable at time t and τ is the estimate of the threshold. In the zero threshold model, the threshold variable is the change in the refined price, ΔPR_t, and τ is zero. The model can then be expressed as:

$$\Delta PC_t = \gamma + \theta_1 ecm_{t-1} + \sum_{i=1}^{q} \eta_i \Delta PC_{t-i} + \sum_{j=0}^{p} \beta_{1,i} \Delta PR_{t-i}, \quad I_t = 1 \tag{3}$$

$$\Delta PC_t = \gamma + \theta_2 ecm_{t-1} + \sum_{i=1}^{q} \eta_i \Delta PC_{t-i} + \sum_{j=0}^{p} \beta_{2,i} \Delta PR_{t-i}, \quad I_t = 0 \tag{4}$$

One set of parameters apply when the change in the refined price is positive and another set when that change is negative. Although the model is presented as two separate equations to clarify the concept, estimation proceeds in a single equation manner. The equations above can give rise to a number of different types of asymmetry and we consider three alternatives. We first estimate a model in which the only source of asymmetry is through different parameters for the ECM term. The speed of adjustment towards equilibrium varies depending on the value of the threshold variable.[5] In terms of the coefficients, this model means that $\theta_1 \neq \theta_2$ but the other coefficients in the model are restricted to be the same in both regimes. In the second type of model, we only allow asymmetry in the lags coefficients on the refined price. In this scenario, the ECM coefficient is the same in both regimes. Thus the $\beta_{1,i}$ and $\beta_{2,i}$ coefficients vary but the other coefficients are constant. Finally, we allow both the ECM and lag parameters to vary. This is the most flexible model but the lags on the autoregressive terms and the constant are still invariant across regimes. We do not allow the autoregressive parameters to change because the price pressures in the system should come through the equilibrium error and the change in the upstream price.

In the preceeding discussion, the threshold was defined to be the change in the refined price. We also allow for alternative threshold variables. In particular, we allow the lagged change in the refined price and a moving average of recent price changes as two alternative threshold variables. The moving average is based on the current change and the lagged changes from the past two months. For each of the three threshold variables, we estimate the three models of asymmetry described above to give a total of nine models of the zero threshold variety. We present and discuss results in a later section once all asymmetric models have been explained.

[5] Although asymmetric responses in the ECM are permitted, the long-run cointegrating relationship between the refined price and the retail price represented in equation (1) must still be identical for price increases and decreases. This restriction is required to prevent the possibility of ever widening margins.

Figure 3 presents a graphical representation of a zero threshold model. The graph shows the change in retail prices on the Y axis for a given change in the refined price on the X axis. This is for illustration purposes so it only represents the short-run response. The black line represents the symmetric case. In this hypothetical economy, half the change in the crude price is reflected in the retail price in the symmetric case. The dashed line represents the asymmetric case. When the change in the crude price is negative, one quarter of the change is reflected in the retail price. The diminished responsiveness relative to the symmetric case is evident from the fact that the black line is closer to the X axis when below zero. If the change in the refined price is positive, the change in the retail price is more responsive for the asymmetric model with three quarters of the crude change passed through to refined prices. Although simplistic by design, this example highlights the nature of a model with a zero threshold.

5.3 Interpreting the Model

The specification presented through equations 3 and 4 is the basic approach to specifying asymmetry in a cointegration framework. Parameter change models based on indicator variables are quite standard tools in econometrics. However, one needs to be very careful in terms of the interpretation of this model. In this section, we present the results for the long run equations for the pre-tax petrol and diesel models. This gives us an insight into the behaviour of the equilibrium error, which then allows us to describe the model more intuitively.

Returning to Table 1, which presents the estimates of the coefficients of the long-run equations, consider the OLS results for the Irish models. The coefficient on the refined price, ϕ, is close to one in both cases. This shows that movements in the refined price are matched almost one for one with movements in the retail price. The intercept, *lambda*, in these equations is an estimate of the equilibrium margin between retail and refined prices. This is approximately 17 cent for petrol and 19 cent for diesel in the sample. The equilibrium error has already been expressed as $ecm_t = PC_t - \phi PR_t - \alpha$. Given that $\phi \approx 1$, this equilibrium error is the current margin between retail and refined prices less the equilibrium margin.

The intuition becomes more obvious when we examine Figure 5, which depicts both the margin between retail and refined prices and the equilibrium error. The graph shows that when the equilibrium error is positive, the margin between retail and refined prices is above its long-run average with the corollary true when the equilibrium error is negative. Given the coefficient of close to one in the long-run equation, changes in the equilibrium error largely reflect changes in the retailer's margin. Retail prices lag refined prices under the assumed pass-through relationship. It follows that the equilibrium error will be positive, and so the margin above its long-run average, when there has previously been a fall in the refined price. This is borne out by the data, which show a large negative correlation between the value of the equilibrium residuals and the change in the refined price.

If retailers allow prices to rise more quickly than they fall, as posited in the rockets and feathers literature, this will be represented by a larger coefficient on the positive ECM term. Positive equilibrium errors typically correspond to a period of falling refined prices. The speed of adjustment coefficient is always negative as it is working to bring the system back to equilibrium. In an asymmetric model, a smaller coefficient on the positive ECM term relative to the negative means that there is less downward pressure on retail prices to restore the equilibrium margin after a period of falling refined prices compared to the upward pressure on retail prices following a period of increasing refined prices. This is the type of asymmetry we search for in the ECM coefficients.

We have mentioned three possible threshold variables for the paper - the current, lagged and moving average change in the refined price. The approach described in equations (3) and (4) allows certain coefficients in the model to vary depending on the value of the change in the refined price and this approach is often adopted in the literature. The value of the equilibrium error is another source of price pressure in the system. A model which divides the sample according to positive or negative values of the threshold variable does not result in a corresponding division of the equilibrium error into positive and negative values. There may be conflicting price pressures from the change in the refined price and the value of the equilibrium error. It is readily apparent that four possible cases arise.

Interactions between ECM and short-run dynamics

	ECM(+)	ECM(-)
$\Delta PR(+)$	(1) $+ -$	(2) $+ +$
$\Delta PR(-)$	(3) - $-$	(4) - $+$

In the first regime, both the equilibrium error and the change in the upstream price are positive. A positive equilibrium error means that retail prices are above their equilibrium level so there will be downward pressure on the retail price. The change in the retail price and the error correction mechanism will work against each other in this situation. In regime 2, both the positive change in the refined price and the negative equilibrium error exert upward pressure on retail prices and in regime 3 they both exert downward pressure. Regime 4 again represents a scenario where there are opposing price pressures.

We believe that the comparison between regimes 2 and 3 is the most valid, as there are no conflicting price pressures. The model as presented in equations (3) and (4) partitions the sample according to positive and negative changes in the refined price. However, when the change in the refined price is positive, the equilibrium error can still take on positive values, putting opposing pressure on price. If we wish to distinguish between the behaviour of retailers when price pressures are unequivocally positive or negative, we must compare regime 2 with regime 3. For this reason, we estimate threshold models with four different regimes and the ECM and lag coefficients can vary in each regime.

5.4 Threshold Models of Asymmetry

It may not be the case the threshold is actually zero in practice. Retailers may change their behaviour when the change in the refined price, be it positive or negative, passes some threshold value other than zero. A non-zero threshold could arise for cost and competitiveness reasons or simply as a result of strategic pricing. In this section, we consider non-zero threshold models of asymmetry. It is possible to test for non-zero thresholds using a procedure developed by Hansen (1998).

The threshold model extends the model presented above in a natural way. Instead of defining the indicator variable according to values of the threshold variable above and below zero, a non-zero value of τ is now permitted as the threshold estimate. Figure 4 provides a graphical representation. In the example shown, the behaviour of the dashed line, which is indicated by its slope, is the same for negative and small positive changes in the threshold. However, for larger positive changes in the refined price, the responsiveness of the retail price increases dramatically, as represented by the large jump in the graph.

In terms of implementing this approach, the candidate threshold variable TR_t is ordered by size and 15% of the tails are trimmed. For each possible remaining value of the threshold, a model like that in equation (3) is estimated. The residual sum of squares and threshold value is recorded for each model. The model with the lowest residual sum of squares is taken as the estimate of the threshold. Hansen (1998) provides a bootstrap procedure to test for the statistical significance of the threshold estimate and we use 5000 replications in our test.[6] As with the zero threshold models, we consider three threshold variables and three types of asymmetric model meaning that a total of nine models are estimated. Standard model selection criteria are used to choose between them. For each model, we calculate the Akaike Information Criteria (AIC) and the Schwarz Bayesian Criteria (SBC) and the appropriate model is chosen based on consideration of these two statistics in conjunction with the adjusted R^2.

It is equally appropriate to consider the four different regimes when implementing the non-zero threshold. The threshold procedure trims 15% of the tails. If the threshold value chosen by the procedure is close to the trimmed portion, there is a relatively small number of observations above the threshold value. As the values lying above the threshold also need to be divided according to positive and negative values of the equilibrium error, there may not be enough observations in one or both regimes to get accurate parameter estimates. We consider two methods to deal with this problem depending on the data. Generally, most observations that are above threshold are associated with a negative equilibrium error, which represents the unequivocally positive case (Regime 2). As there are so few observations for the regime with positive equilibrium errors and above threshold, this regime is merged with the regime corresponding to negative equilibrium errors and below threshold. In other words, the two regimes with conflicting price pressures are collapsed to one regime with comparison still valid between the wholly positive and negative regimes. In other cases, for observations above the threshold, there may be a more even split between positive and negative equilibrium error. If this leads to estimation problems, the 15% trim is expanded to a 20% trim. In practice, we favour the three regime approach, which collapses the two regimes with conflicting price pressures to one regime, as it allows a more comprehensive threshold search.

[6]For further details of the testing procedure, see Hansen (1998).

6 Results

6.1 Asymmetry in the Irish Market

In Table 2, we present the model selection criteria for both pre-tax petrol and diesel models. The AIC and SBC are calculated such that a smaller value indicates a better fit. Results are presented for a standard ECM model with no asymmetry, an asymmetric ECM model, a zero threshold model and a non-zero threshold model in the cases where a non-zero threshold exists. These terms are explained in the previous section but a glossary of model descriptions is provided at the back of the paper for convenience. The table shows the model, the type of asymmetry allowed, the threshold variable and the model selection statistics. The specification column is mainly for use with the threshold models and indicates if asymmetry is permitted in the ECM term, the lags or both the ECM and the lags. For each type of model, results are presented for the model with the best diagnostics out of the nine possible combinations of threshold variable and asymmetry type.

The first row in each section presents the results for the basic model with no asymmetry. These models tend to perform quite well on an individual basis in the sense that the R^2 of the basic models is quite high. In the case of petrol, there is a marginal deterioration in model fit according to the AIC and SBC when asymmetry is permitted in the ECM term. This type of asymmetry is based on a positive or negative equilibrium error and so the choice of threshold is not relevant in this case. When we consider a zero threshold for the current change in refined prices, there is an improvement in the fit of the model according to all statistics. This is a three regime model. When the threshold on the change in the refined price is allowed a non-zero value, there is some evidence of a threshold at -0.4c for the moving average change. While this model improves on the symmetric model according to some statistics, it fails to outperform the zero threshold model based on the current change in refined prices, which is the preferred model for petrol.

In the case of diesel, the basic model fits the data quite well although the R^2 is smaller than that of the symmetric petrol model. For the zero threshold ECM model, there is a slight improvement in fit according to the AIC and R^2. When we also allow for asymmetry based on a zero threshold for the moving average of the refined price, the resulting model again improves the fit according to all the model selection statistics. Once again, the conflicting price regimes are collapsed so the chosen model has three regimes. For diesel, there is no evidence of a non-zero threshold for any of the candidate threshold variables so the model selected is the three regime model.

Table 3 presents the coefficients for the chosen petrol and diesel model. In both cases, a three regime model which allows asymmetric behaviour in the lag response is selected. The "2" superscript on the lag coefficients denotes the coefficients for the regime with positive price pressures, the "3" superscript applies to the regime with negative price pressure and the lags without a superscript refer to the regime with conflicting price pressure. For petrol, the ECM coefficient indicates that 43% of any equilibrium error is eliminated in the following period, implying quite a fast speed of adjustment. If we sum the coefficients on the lag terms for each regime, we get a total of 0.614, 0.473 and 0.662 for the positive, conflicting and negative regimes respectively. The coefficient sums are larger for the outer regimes so that adjustment is quicker when the price pressures are persistently in either the positive or negative direction. However, the summed coefficients are very similar for the positive and negative regimes. We test the null hypothesis that these coefficient sums are not equal. As the residuals are non-normal, we use a bootstrap procedure with 5000 replications to construct the test statistic and reject the null hypothesis that the coefficient sums are not equal. There is no evidence that pass-through is greater for positive changes in the refined price. In the case of negative price pressures, the effect is contemporaneous in the sense that adjustment takes place in period t. For the positive regime, the bulk of the adjustment takes place in $t-1$. Thus, although the magnitude of adjustment is the same for the positive and negative regimes, adjustment is marginally quicker for the negative regime.

A similar pattern emerges in the diesel market. The ECM coefficient is almost -0.7, indicating that a lot of the adjustment in the model is taking place through the error correction mechanism and the coefficients on refined prices changes are correspondingly smaller. The summed coefficients are 0.404, 0.159 and 0.532 for the positive, conflicting and negative regimes respectively. Once again, the conflicting regime has a more sluggish response. The reaction to negative price changes is again contemporaneous. For positive price changes, half of the pass-through takes place in period $t-2$. The negative pass-though coefficient is a bit stronger than the sum of the positive but the null hypothesis that they are not equal is rejected at the 5% level. Again, there is no evidence in favour of the perception that prices increase faster than they fall. The results of these models indicate that there is asymmetry in the market, as asymmetric models outperform symmetric models. The retail price response is faster when price pressures are either wholly positive or negative. In addition, the negative response appears to be marginally quicker than the positive response. The retail of petrol and diesel is a very competitive industry in Ireland and is characterised by tight margins. The asymmetry found in the models is consistent with this type of market.

6.2 Asymmetry in the UK Market

Table 4 provides an overview of the model selection criteria for the UK. The results for the UK refer to pre-tax prices again. The R^2 for the basic symmetric petrol model is 86%, which is higher than the corresponding figure of 79% for the Irish petrol market. When we allow asymmetry based on the ECM term, there is virtually no change in the fit of the model. For the zero threshold in the refined price, the AIC again remains unchanged. There is a minor improvement in the R^2 but the SBC indicates a slightly poorer fit. Finally, a non-zero threshold model is considered. The threshold is estimated at 0.5c based on the moving average change in the refined price. The four regime model was again collapsed to three regimes by merging the regimes with conflicting price pressures. The resulting model is a multi-regime non-zero threshold model but asymmetry is only permitted through the ECM terms. This model has the best performance according to all statistics but the improvement in the fit is very small. The R^2 for the symmetric model is 86% and this only increases to 86.2% for the chosen asymmetric model. The fractional improvements in the AIC and SBC are of a similar magnitude. Thus, although the statistics prefer the non-zero threshold model, the evidence in favour of this model relative to the symmetric model is weak. Nonetheless, we estimate this model and examine its properties.

The R^2 for the symmetric diesel model is 77%, compared to 71% in the Irish market. The asymmetric ECM model again fails to change the fit of the model to any significant degree. When the zero threshold for the refined price is considered, there is an improvement in all statistics. The model is based on the current change in the refined price and asymmetry is allowed in both the ECM and lag coefficients. This is an example of the three regime model in which all relevant coefficients vary. Non-zero threshold models fail to improve on the fit of the zero threshold model. The improvement in fit relative to the symmetric model are more meaningful here compared to the petrol case.

Table 5 presents the coefficients for the selected petrol and diesel models for the UK market. In the case of petrol, the asymmetry in the model comes from different coefficients on the ECM terms in the three different regimes. The coefficients on the ECM terms are -0.493, -0.434 and -0.233 for regime 3, the neutral regime and regime 2 respectively. Regime 2, the positive regime, has a change in the refined price which is above threshold and a negative equilibrium error. For this negative equilibrium error, the speed of adjustment coefficient of -0.233 means that upward pressure on prices eliminates nearly 23% of any equilibrium error in the following period. Regime 3, which is the negative regime, has a change in the refined price which is below threshold and a positive equilibrium error. In this regime, the speed of adjustment coefficient means that the downward pressure on prices eliminates approximately 49% of any equilibrium error in the following period. In the case of conflicting price pressures, the speed of adjustment parameter is about 43%. The error correction in the system is weakest when there is upward pressure on prices.

For the diesel model, asymmetry is permitted in both the ECM term and the lags. We see that the coefficient on the ECM in regime 3 is again greater than in regime 2, again suggesting weaker error correction in the upward direction. However, the difference between the two is not statistically significant according to the bootstrap test. The ECM term for the regime with conflicting price pressure is not statistically significant. The summed coefficients on the refined price terms are 0.763, 0.437 and 0.917 for the positive, conflicting and negative regimes respectively. As with the Irish results, the parameter sums are greater when price pressures are unambiguously positive or negative. Although the response is slightly stronger for the negative regime, the positive and negative parameter sums are not statistically different. For the positive regime, the impact is quite evenly spread between periods t and $t-1$. For the negative regime, the impact is more immediate with a stronger response in period t relative to $t-1$. The UK results are consistent with the Irish results in that they provide no support for the theory that retailers respond more quickly to price increases.

The asymmetry in the UK markets for petrol and diesel differs to the extent that the asymmetry comes through the error correction mechanism for petrol but through the direct response to changes in refined prices for diesel. When we consider the UK and Irish results in tandem, the asymmetry and its specification is similar. For both Irish markets and the UK diesel market, the asymmetry is manifested through the coefficients on the lagged changes in refined prices. The improvement in fit for these models relative to the symmetric model may be modest but it is clear that asymmetry exists. The price response is stronger for the regimes with reinforcing price pressures. Furthermore, when we compare the positive and negative regimes, there is evidence of modest asymmetry in favour of the negative direction. These results show no support for the contention that retailers respond more quickly to increases in the international price of oil.

7 Importance of Multi-Regime Specification

While some papers in the literature acknowledge that there may be conflicting price pressures from refined price changes and the equilibrium error, the models are still restricted to two regimes based on the behaviour of some threshold variable or occasionally in terms of the equilibrium error. There are some instances of three regime models but the three regimes are defined according to the behaviour of one threshold variable. We believe that that it is important to consider the price pressures from both the ECM term and a threshold variable through a multi-regime model of the sort used in this paper.

As a counterfactual exercise, we take the models chosen earlier with the best model selection statistics and compare these models to the best performing two regime models. The two regime models are chosen according to the same methods used for the three regime model. The regimes are defined according to whether the refined price threshold variable is above or below its threshold value and so no account is taken of whether the equilibrium error is positive or negative. Table 6 presents the model selection statistics for these two regime models. For convenience, it also contains the statistics for the symmetric models and the corresponding three regime models reported in earlier tables.

With the exception of the UK petrol market, the two regime model is generally outperformed by the three regime model. Thus, in most cases in this paper, the division of samples into periods of wholly positive or negative price pressures helps to improve the fit of the model. The two regime models outperform the symmetric models on the balance of evidence but the improvement in fit is generally small. Ostensibly, it appears that both the two and three regime models find the same asymmetry but that the more refined three regime model picks it up more clearly. Closer examination of the two regime models shows that this is not always the case. For Irish petrol prices, the two regime model is virtually identical to the three regime model.[7] For diesel, the asymmetry in the two regime model comes from a larger coefficient for one of the ECM terms. However, the bootstrap procedure shows the ECM coefficients are not significantly different so the model collapses to the symmetric case. Thus, for the Irish diesel market, we would conclude there is no asymmetry if using two regime threshold models.

In the case of the UK petrol market, asymmetry in the three regime model is found in the ECM terms, with upward pressure weaker than downward pressure. The selected two regime model also finds some evidence of asymmetry in the ECM coefficients and the bootstrap procedure confirms that the difference in the ECM coefficients is statistically different at the 5% level. In contrast to the three regime case, it is the negative ECM term which is greater for the two regime model and so the results are completely different. As the ECM terms are now defined according to the threshold variable, this means that there is stronger error correction when the change in the refined price is negative. This case highlights most clearly the problem with allowing different ECM responses based only on another threshold variable - it is very difficult to interpret the meaning of the ECM coefficients because the equilibrium error could be positive or negative when the refined price change is below threshold.

For the UK diesel market, the best performing two regime model is identical to the three regime model. However, the model selection statistics do not provide strong evidence in favour of the two regime model over the symmetric model. As a result, the symmetric model is likely to be chosen when in fact an asymmetric model is required. This exercise demonstrates that two regime models based on a threshold variable can lead to significantly different results to those from three regime models (or four regimes where the data permit). In two of the four markets, we may have concluded there is no asymmetry using conventional models and in third market, we would have found asymmetry of the opposite direction. As the model selections statistics show that multi-regime models have the best performance, it is critical to divide observations into periods of wholly positive or negative price pressures when assessing asymmetry. Given that the literature is almost entirely dependent on two regime models, it raises serious questions regarding existing findings of asymmetry in other markets.

[7] Tables outlining the ceofficients of the four 2 regime models are not provided in the interests of brevity.

8 Summary and Conclusion

A range of structural indicators suggest that Irish retail fuel markets at national level are comparatively competitive, with the markets characterised by relatively tight margins. Still, the perception persists that the retail transport fuel market in Ireland may not be entirely competitive with consumers not benefitting from falls in crude oil prices with the same rapidity as they are burdened with rises in crude oil prices. This perception is to a large extent based on anecdotal evidence only, as there is a dearth of studies that have empirically tested whether Irish fuel markets are characterised by asymmetric pricing behaviour. The NCA investigated the movements of refined prices, wholesale prices and retail pump prices in Ireland during 2008. While the NCA concluded that there is little evidence to suggest unwarranted delays in the passing through of refined oil price falls to consumer prices, their study was based on a just one year of data and did not assess the issue using econometric models. In contrast, this paper contains a rigorous econometric assessment of the pass-through of oil prices in Irish liquid fuel markets using a long span of data. The UK fuels market is also examined for comparison purposes.

The econometric analysis uses threshold autoregressive models to test for asymmetries in the Irish fuel markets. The paper contains a methodological note on the importance of allowing for 3 or 4 regimes in the threshold model specification rather than the two regimes that is standard in the literature. The extension to more than two regimes recognises the conflicting price pressures that may arise from short change dynamics and disequilibrium errors. This paper demonstrates that two regime models for a given threshold variable can lead to significantly different results to those for three regime models (or four regimes where the data permit). In two of the four markets, it may have been concluded there is no asymmetry using conventional models and in third market, asymmetry of the opposite direction would have been found. As the model selection statistics show that multi-regime models (i.e. more than two regimes) have the best performance, it is important to divide observations into periods of wholly positive or negative price pressures when assessing asymmetry. Given that the literature typically relies on two regime models, it raises questions regarding existing findings of asymmetry in other markets.

For the Irish petrol and diesel markets, the pass-through of refined oil price falls appears to be more immediate when price pressures are unambiguously negative. This is in contrast to the popular perception that retailers respond more quickly when prices are positive. The asymmetry in the UK markets for petrol and diesel differs to the extent that the asymmetry comes through the error correction mechanism for petrol and through the direct response to changes in refined prices for diesel. When we consider the UK and Irish results in tandem, the model specifications and the findings of asymmetry are broadly similar. For both Irish petrol and diesel markets and also the UK diesel market, there is a faster response to declines in refined prices when price pressures are unambiguously negative. This is a somewhat unexpected result but similar findings can be been found in the literature on asymmetries for the UK fuel market. Also, while such asymmetry may be statistically significant, it is unlikely to be economically significant. More to the point, there is clearly no evidence in either the Irish or UK liquid fuel markets to support the "rockets and feathers" hypothesis that retail prices rise faster than they fall in response to changes in oil prices at a national level. This does not exclude the possibiity that at a more local level a lack of competition may accommodate asymmetric pricing behaviour.

References

[1] Al-Gudhea, S., T. Kenc and S. Dibooglu (2007), "Do retail gasoline prices rise more readily then they fall? A threshold cointegration approach“, *Journal of Economics and Business*, Vol. 59, pp. 560-574.

[2] Asplund, M., R. Eriksson and R. Friberg (2000), "Price adjustments by a gasoline retail chain", *Scandinavian Journal of Economics*, Vol. 102, pp. 101-121.

[3] Borenstein, S., A. C. Cameron and R. Gilbert (1997), "Do gasoline prices respond asymmetrically to crude oil price changes?", *Quarterly Journal of Economics*, Vol. 112, pp. 305-339.

[4] Manera, G. and M. Manera (2007), "Econometric models of asymmetric price transmission", *Journal of Economic Surveys*, Vol. 21, No. 2.

[5] Geweke, J. (2004), "Issues in "rockets and feathers" gasoline price literature", Report to Federal Trade Commission.

[6] Godby, R., A.M. Lintner, T. Stengos and B. Wandschneider (2000), "Testing for asymmetric pricing in the Canadian retail gasoline market", *Energy Economics*, Vol. 22, pp. 349-368.

[7] Meyler, A. (2010), "The pass-through of oil prices into consumer liquid fuel prices in an environment of high and volatile oil prices", *Energy Economics*, forthcoming.

[8] National Consumer Agency (2008), "Investigation into Petrol and Diesel Price Movements", Report.

[9] Peseran, M. H., Y. Shin, and R.J. Smith (2001), "Bounds Testing Approaches to the Analysis of Level Relationships", *Journal of Applied Econometrics*, Vol. 18, pp. 281-295.

Figure 1: Consumer Price and Refined Pices

Euro Cents per Litre

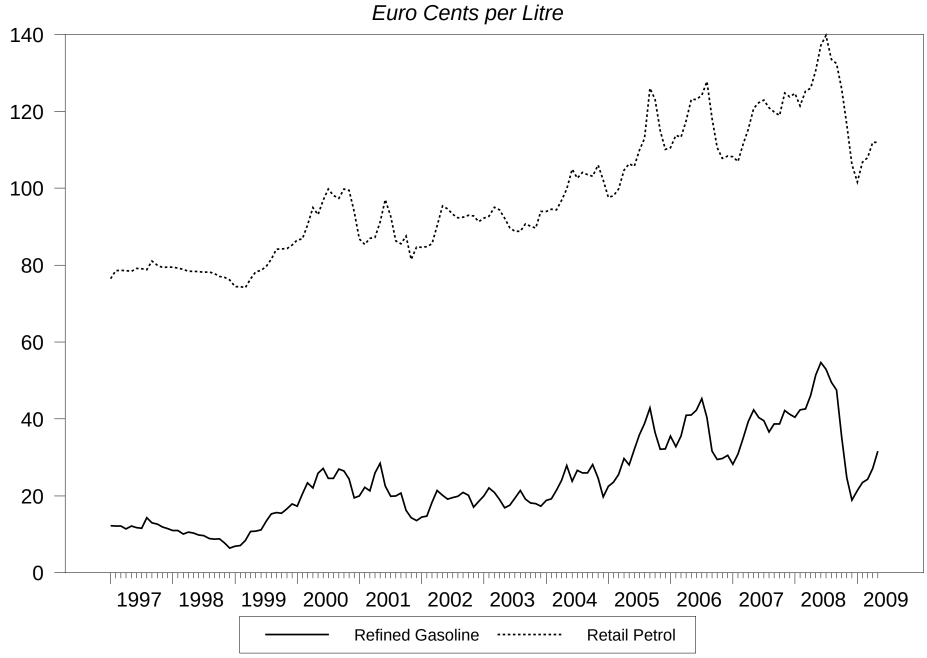

Figure 2: Consumer Price and Refined Pices

Logs

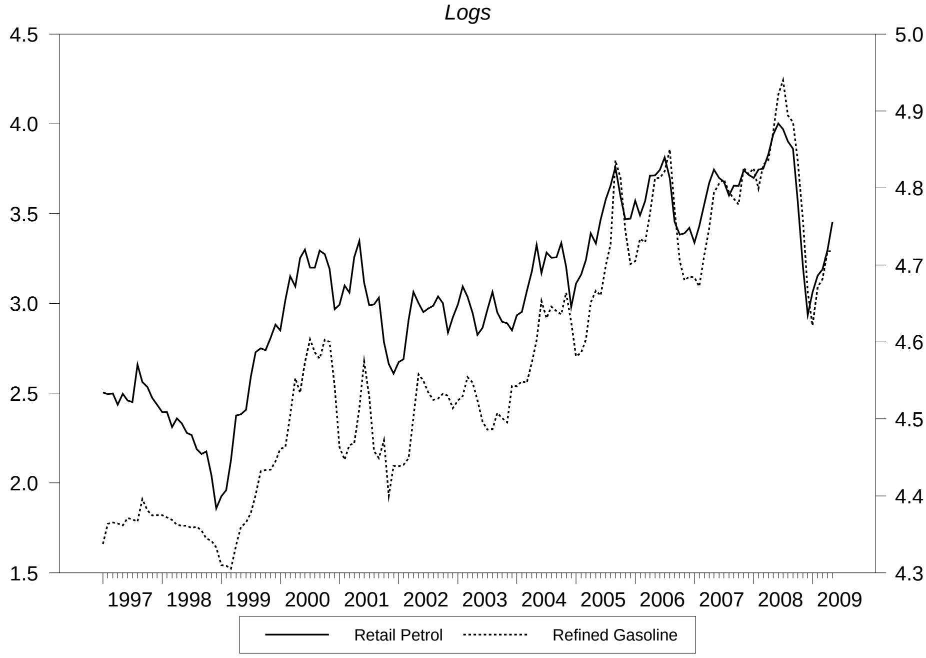

Figure 3: Model with Threshold at Zero

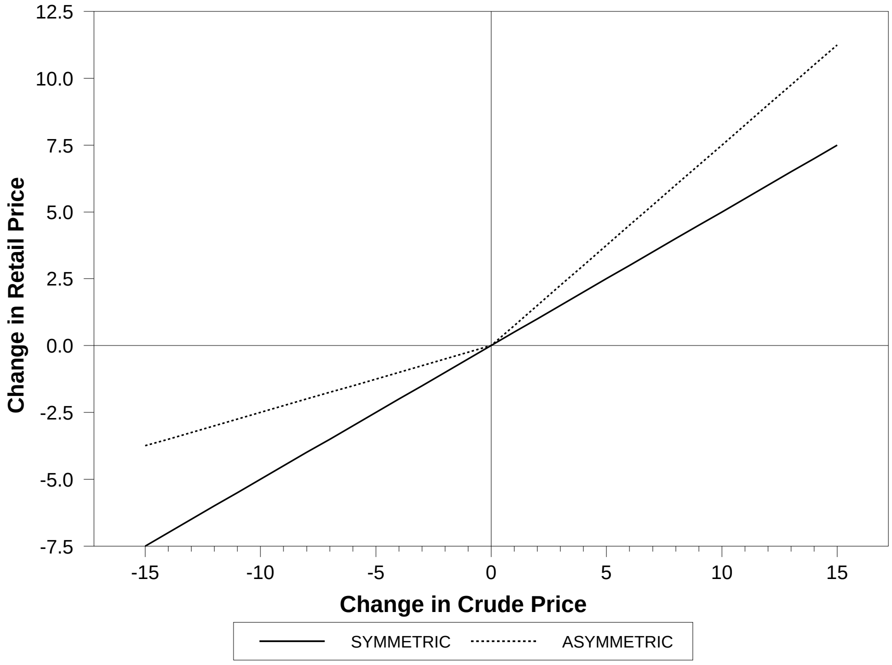

Figure 4: Model with Non-Zero Threshold

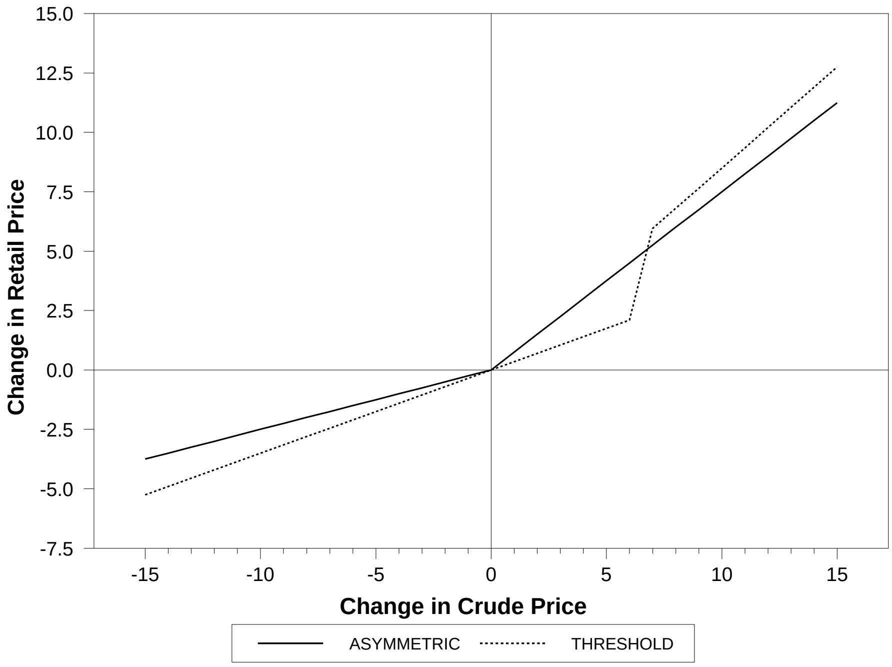

Figure 5: Retail-Refined Spread and Equilibrium Error for Petrol

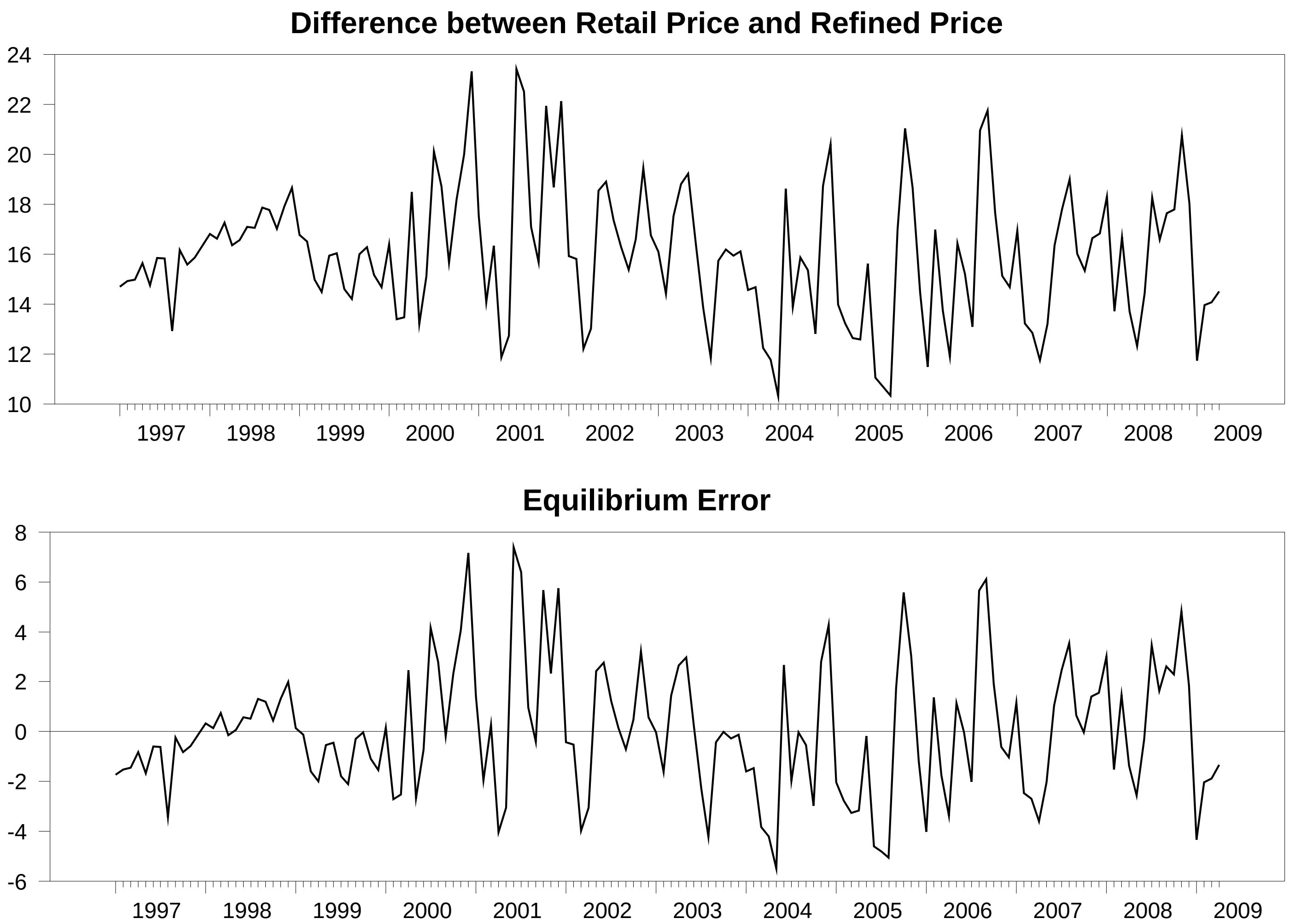

Table 1: Coefficients of Long Run Cointegration Equations

	Petrol Ireland		Diesel Ireland	
Regressor	ARDL	OLS	ARDL	OLS
α	16.856	16.920	18.753	19.175
Std. Error	0.610	0.511	0.377	0.441
ϕ	0.967	0.960	1.012	0.993
Std. Error	0.023	0.019	0.013	0.015
	Petrol UK		**Diesel UK**	
Regressor	ARDL	OLS	ARDL	OLS
α	7.864	7.927	9.831	9.705
Std. Error	0.505	0.394	0.982	0.402
ϕ	1.009	1.004	1.019	0.993
Std. Error	0.019	0.015	0.035	0.015

Note: The dependent variable is the retail price and the independent is the refined price. All coefficients are significant at the 5% level. The ARDL columns refers to coefficients estimated using the Peseran et al (2001) one-step non-linear approach while the coefficients in the OLS columns are estimated using the two-stage Engle-Granger OLS method.

Table 2: Overview of Model Performance

PETROL

Model	**Type of Asymm**	**Thresh. Var**	**AIC**	**SBC**	R^2
Symmetric	N/A	N/A	3.479	3.603	0.787
Asymmetric ECM	ECM Only	N/A	3.488	3.631	0.787
Zero Threshold	Lags Only	Current	3.364	3.508	0.811
Threshold = -0.4c	ECM and Lags	Moving	3.421	3.606	0.803

DIESEL

Model	**Type of Asymm**	**Thresh. Var**	**AIC**	**SBC**	R^2
Symmetric	N/A	N/A	3.644	3.748	0.714
Asymmetric ECM	ECM Only	N/A	3.632	3.757	0.719
Zero Threshold	Lags Only	Moving	3.532	3.655	0.741

Note: Please refer to the first paragraph of section 3.5 for description of this table. In addition, a glossary of model descriptions is provided at the back of the paper.

Table 3: **Coefficients for Selected Model Specification**

	Petrol		Diesel	
Regressor	Coeff.	Std. Error	Coeff.	Std. Error
Constant	0.146	0.088	0.100	0.109
ecm_{t-1}	-0.434	0.087	-0.699	0.070
ΔPR_t^2	0.212	0.127	0.198	0.115
ΔPR_{t-1}^2	0.402	0.113		
ΔPR_{t-2}^2			0.206	0.107
ΔPR_{t-1}	0.316	0.082		
ΔPR_{t-2}	0.163	0.030	0.159	0.068
ΔPR_t^3	0.662	0.106	0.532	0.082

Note: The dependent variable is the change in the retail price. ΔPR_t is the change in the refined price. The superscript "2" refers to regime 2, the superscript "3" refers to regime 3 and no superscript for the other regime. All coefficients significant at 10% level except for constant in diesel equation.

Table 4: **Overview of Model Performance for the UK**

PETROL

Model	**Type of Asymm**	**Thresh. Var**	**AIC**	**SBC**	R^2
Symmetric	N/A	N/A	-6.377	-6.275	0.860
Asymmetric ECM	ECM only	N/A	-6.377	-6.255	0.860
Zero Threshold	ECM only	Moving	-6.377	-6.235	0.861
Threshold = 0.5c	ECM Only	Moivng	-6.382	-6.239	0.862

DIESEL

Model	**Type of Asymm**	**Thresh. Var**	**AIC**	**SBC**	R^2
Symmetric	N/A	N/A	-6.014	-5.912	0.768
Asymmetric ECM	ECM only	N/A	-6.008	-5.886	0.768
Zero Threshold	ECM and Lags	Current	-6.076	-5.914	0.786
Threshold = -1.1c	Lags only	Moving	-6.051	-5.868	0.782

Note: Table 4 has same structure as Table 2.

Table 5: Coefficients for Selected UK Models

	Petrol		Diesel	
Regressor	Coeff.	Std. Error	Coeff.	Std. Error
Constant	0.002	0.001	0.002	0.001
ecm^2_{t-1}	-0.233	0.090	-0.226	0.173
ecm_{t-1}	-0.434	0.120		
ecm^3_{t-1}	-0.493	0.117	-0.387	0.119
ΔPR^2_t			0.405	0.128
ΔPR^2_{t-1}			0.358	0.112
ΔPR_t	0.482	0.034	0.437	0.048
ΔPR_{t-1}	0.253	0.069		
ΔPR^3_t			0.630	0.089
ΔPR^3_{t-1}			0.287	0.103
ΔPC_{t-1}	0.135	0.062		

Note: The structure of Table 5 is similar to Table 3. For the petrol model, there is no asymmetry in the lags of the refined price so the superscripts do not apply.

Table 6: Comparison of Symmetric, 2 Regime and 3 Regime Models

PETROL IRELAND

Model	**AIC**	**SBC**	R^2
Symmetric	3.479	3.603	0.787
3 Regime Model	3.364	3.508	0.811
2 Regime Model	3.452	3.658	0.798

DIESEL IRELAND

Model	**AIC**	**SBC**	R^2
Symmetric	3.644	3.748	0.714
3 Regime Model	3.532	3.655	0.741
2 Regime Model	3.638	3.763	0.718

PETROL UK

Model	**AIC**	**SBC**	R^2
Symmetric	-6.377	-6.275	0.860
3 Regime Model	-6.382	-6.239	0.862
2 Regime Model	-6.403	-6.281	0.864

DIESEL UK

Model	**AIC**	**SBC**	R^2
Symmetric	-6.014	-5.912	0.768
3 Regime Model	-6.076	-5.914	0.786
2 Regime Model	-6.005	-5.863	0.769

Note: The 3 Regime Model is the model with the best performance statistics found in the earlier part of the paper. The 2 Regime model is chosen using the same criteria as the 3 regime model but regimes are defined according to the treshold variable.

Glossary of Terms used to Describe Models

There are a wide variety of models used in the paper. This glossary explains the terminology used and provides a brief description of the models. The terms used here appear in Tables 2, 4 and 6.

Symmetric: This is the standard short-run equation from a cointegration model.

Asymmetric ECM: In this type of model, the speed of adjustment parameters in the short-run equation are allowed to vary depending on whether the equilibrium error is positive or negative.

Zero Threshold Model: In this type of model, parameters in the short-run equation are allowed to vary depending on whether the threshold variable is above or below zero. Tables 2 and 4 outline the parameters which are permitted to vary and the threshold variable. The zero threshold models also divide the sample according to positive and negative equilibrium errors. This results in four different regimes but the two regimes with conflicting price pressures are merged to give a three regime model.

Non-Zero Threshold Model: This type of model allows the threshold variable to have a non-zero threshold value. In all other respects, it is identical to the zero threshold model.

2 Regime Model: This type of model allows parameters in the short-run equation to vary depending on whether the threshold variable is above or below its threshold value. The threshold value may be zero or non-zero. The value of the equilibrium error is irrelevant.