Are Unleaded Gasoline and Diesel Price Adjustments Symmetric?
A Comparison of the four larger EU Retail Fuel Markets

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ABSTRACT

The purpose of this paper is to examine the nature of price adjustments in the gasoline markets of Germany, France, Italy and Spain. We examine if crude oil prices are transmitted to the retail gasoline prices in the short and long run and we test the symmetry of price adjustments hypothesis. An Error Correction Model, which accounts for possible asymmetric adjustment behaviour, is applied for the estimation of the international crude oil price pass-through and testing of the symmetric/asymmetric nature of the retail fuel price adjustments in these economies. Our results show that rigidities in the transmission process exist but the retail fuel speed of upward/downward price adjustment to equilibrium is considered as symmetric in all four economies analysed. Thus, our findings on the whole do not provide firm evidence to support the "rockets and feathers" hypothesis that crude oil price increases are passed along to the retail customer more fully than the crude oil price decreases.

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1. Introduction

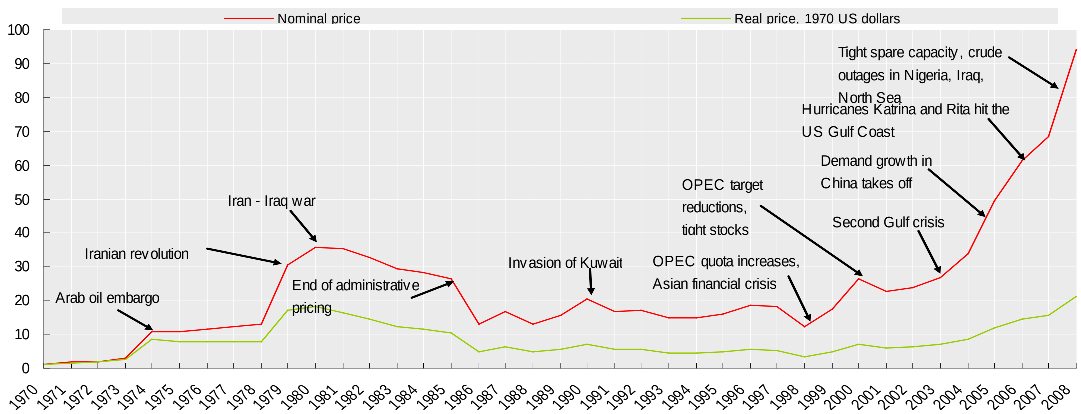
Standard macroeconomic texts ascertain that there are both aggregate demand and aggregate supply transmission effects from oil prices to economic activity. Oil is an important raw material in the production process that directly affects the cost of production and consequently the aggregate supply of goods[1]. A change in oil prices also affects the after-tax income of households since the demand for transport fuels is very inelastic (due to the absence of direct substitutes). Thus, aggregate consumption[2] and aggregate investment are affected too. Fluctuations in international crude oil prices since the early 1970's (see Figure 1), global dependence on oil and OPEC, strong increase in oil demand from fast growing emerging economies like China, permanent oil shocks and their effects on economic growth and terms-of-trade, have triggered a lot of attention internationally and sparked many researchers to observe the behavior of retail gasoline prices and analyze the oil price transmission mechanism (Asche et al., 2003).

For oil importing countries, producer prices are exogenous to retailers located in the domestic economy. The adjustment of retail fuel prices in response to changes in international crude oil price is a fundamental element of the oil price transmission mechanism. To this end, the regular monitoring and assessment of the oil price pass-through is critical for energy authorities and antitrust policy makers in their attempt to monitor the competitiveness of their energy sectors.

[1] The 1973 Arab oil embargo, which led to a surge in the price of oil from $1.84/barrel in 1972 to $10.77 in 1974 (see figure 1), was the major cause of a "supply shock" that hit the world industrialised economies and changed the terms-of-trade in favour of oil exporting countries. The end result was a recession due to the reduction in the aggregate supply of goods and services and consequently high unemployment and high inflation throughout the 1970's in oil importing nations.

[2] In the wake of the Iranian revolution in 1979 and the start of the Iran-Iraq war in 1980, oil prices rose to a high of nearly $40 (see Figure 1). More than a decade now the world crude oil prices, even when adjusted for inflation, have been almost steadily rising on a year-to-year basis and reached a historical peak just under $150/barrel in July 2008. The key causes of this steady increase in oil prices between 1998-2008 were the OPEC decision in 1999 to reduce oil stocks, the expectation of a second war in Iraq in 2003, the hit of the eastern coast of the US Gulf of Mexico by the Hurricane Katrina in late August 2005 and the existence of oil demand shocks (increased demand for oil by the emerging economies) throughout the 2005-2009 (Kilian, 2009 and OECD, 2010) as well as speculative bubbles (Lammerding et al. 2012). These increases have affected significantly the price for gasoline that consumers pay around the world and thus households' after-tax income and aggregate consumption.

Figure 1: Crude oil spot prices (US dollars per barrel)



Source: OECD (2010) “Economic, Environmental and Social Statistics”, OECD, Paris.

There are three interesting questions about the oil price pass-through issue. First, if there is a change (increase or decrease) in international crude oil prices will this change be transmitted to the retail fuel prices? If the oil price transmission mechanism is efficient, any change in crude oil prices will be transmitted to retail fuel prices, ultimately influencing both aggregate domestic demand (through the after-tax income of households and the aggregate consumption) and output produced. An issue, which is closely related to the question above, is how much of the change in crude oil prices will be transmitted to the retail fuel prices in the short-rum and how much in the long run. This issue has to do with the magnitude of the short-run and long-run crude oil price elasticities with respect to retail fuel prices. If there is a complete pass-through in the long run (that is the long-run crude oil price elasticity with respect to retail fuel prices is close or equal to 1), no rigidities in the oil price transmission mechanism will exist and the retail fuel market will adjust fully either to rising or declining crude oil prices. If the oil price pass-through is not complete in the long run (that is the long-run crude oil price elasticity with respect to retail fuel prices is less than 1), price rigidities in the oil price transmission mechanism will be present and the retail fuel prices will adjust partially either to rising or declining crude oil prices.

Second, how much time (in terms of the number of days, weeks or months) will it take for a given change (increase or decrease) in the crude oil price to be fully transmitted to the retail fuel prices? The answer to this question gives us an indication of how fast or show is the oil price transmission.

Third, is the retail fuel price speed of adjustment to crude oil price changes symmetric? This is the so called "symmetry of price adjustments" hypothesis. If the rate of adjustment of retail fuel prices to increases and decreases of the international crude oil prices is the same, then the price adjustment to equilibrium is considered as symmetric. A symmetric/asymmetric speed of adjustment might be explained by the organizational structure of the oil industry. It is expected that the more competitive the retail fuel market is, the more likely will be that that firms in the oil industry will not engage in an unspoken collusion to maintain higher profit margins and thus the more likely will be that the rate of adjustment of retail fuel prices to increases and decreases of the international crude oil prices will be the same. Although a discussion of the market structure for retail fuel products is useful for an assessment of the "symmetry of price adjustments" hypothesis, symmetry itself is not a proof of a competitive market because any market power might be related to other factors such as the cost of product differentiation.

In this paper, we examine the nature of price adjustments in the gasoline markets of Germany, France, Italy and Spain in relation to the three key questions stated above. We concentrate on these four European Union economies since there are only few recent studies in the relevant literature dealing with the issue of oil price transmission and because these are the four larger retail fuel markets in the EU. More specifically, in this piece of work we test whether the international crude oil prices are transmitted to the retail fuel prices, that is, diesel oil and unleaded gasoline in Germany, France, Italy and Spain. We then estimate the short-run and long run elasticities of crude oil price with respect to both diesel and unleaded gasoline prices. In conjunction with this issue, we calculate how much time (number of weeks) it takes for a given change in the crude oil prices to be fully transmitted to the retail fuel prices in the economies examined. Finally, we test the "symmetry of price adjustments" hypothesis, which is whether retail fuel price speed of adjustment (to upward and downward crude oil price change) is symmetric or asymmetric.

One of the distinctive features of our paper is that we employ a disaggregated Error Correction Model (ECM hereafter), which accounts for possible asymmetric adjustment behaviour and offers a parsimonious modelling approach for separating the price adjustment mechanism into a short term (direct) and a long-term (indirect) component and for distinguishing price asymmetries in retail fuel markets within the same pass-through dynamic model. To the best of our knowledge, this study is the first to assess the impact of crude oil price changes on retail fuel prices by using a disaggregated ECM Model. Second, since evidence of prior research seems to be inconclusive, we provide new evidence on crude oil price transmission to retail fuel price and the issue of price asymmetries by using a recent data set that includes the German, French, Italian and Spanish retail fuel markets. Finally, we give some explanation of how symmetry might arise in these markets by presenting and discussing extensively the organizational structure of the oil industry in the four major European industrialized economies. An assessment of the market structure for retail fuel products in these markets can provide a stronger basis for a critical discussion of our results. Our empirical results show that although rigidities in the transmission process are present and variations across the selected EU member-states exist, the retail gasoline speed of upward/downward price adjustment is considered as symmetric. Thus, our findings on the whole do not provide firm evidence that crude oil price increases are passed along to the retail customer more fully than the crude oil price decreases.

The paper is structured as follows. In Section 2 we review the relevant literature on crude oil price transmission to retail fuel prices. In Section 3 we present the organizational structure of the oil industry in Germany France, Italy and Spain. Section 4 presents data and the disaggregated Error Correction econometric methodology. The empirical results, on the estimates of the speed of adjustment, of the degree of pass-through completeness in the short and long-run as well as results on the symmetric speed of adjustment hypothesis for retail fuel prices are given in Section 5. Section 6 concludes the paper.

2. Literature Review

The issue of crude oil price pass-through to retail fuel prices along with the adjustment process has been examined by a number of scholars by looking at different countries, for different time periods, with different frequency of data, different market stages and different econometric methodologies applied. Bacon (1991), in his seminal paper on “rockets and feathers”, uses biweekly data for the UK gasoline market for the period 1982-1989 and finds evidence of an asymmetric price adjustment process. Galeotti et al. (2003) focus on the issue of presumed asymmetries in the transmission of shocks to crude oil prices onto retail prices of gasoline in selected European countries from 1985 to 2000, by using monthly data. Their results “….strongly confirm the emergence of widespread price asymmetries in the data….” (p.178). Meyler (2009) tests the symmetry hypothesis for the twelve initial Euro member countries from 1994 to 2008, by using weekly data and finds weak evidence of statistical significant asymmetries across the countries examined. Grasso and Manera (2007), estimate three different econometric models (namely asymmetric ECM, autoregressive threshold ECM and ECM with threshold) on price asymmetries by using monthly data for the gasoline markets of France, Germany, Italy, Spain and the UK over the period 1985–2003. Evidence of long term asymmetries exist in the direct changes of retail prices as compared to the change in the international price of oil. Cleredes (2010) tests the response of retail gasoline prices (with and without taxes) to changes on the world oil price by using weekly data for all EU 27 counties and finds significant variation in the adjustment mechanism across countries while evidence of asymmetric adjustment is fairly weak. Finally, Bermingham and O'Brien (2011), in a more recent study of the Irish and the UK liquid fuels market, use threshold autoregressive models, monthly data for the period 1997-2008 and find no evidence to support the asymmetric price hypothesis.

There is no consensus in the empirical literature for European economies on the “rockets and feathers" hypothesis[3]; mixed results exist on whether retail gasoline prices reflect decreases (drop like a "feather") in international producer prices as fully as they do price increases (rise like a "rocket"). In other words, evidence is inconclusive as far as it concerns the symmetric adjustment of retail fuel prices to crude oil prices. Overall, findings of the literature differ from country to country depending mainly on the country/regions examined, the time period considered, the frequency of data used and econometric methods applied. It is difficult though to assess whether the variation in findings across studies is due to the data set used or statistical methodologies employed.

A number of explanations regarding the symmetric/asymmetric adjustment of retail fuel prices to crude oil prices are presented in the relevant literature. Bacon (1991) provides two explanations regarding the slow response of gasoline prices to crude oil price changes, namely the *relative demand* and the *exchange rate* explanation. The former states that asymmetric adjustments occur due to exogenous changes in demand for oil and the latter that gasoline retail prices do not fully adjust to exchange rate changes. Borenstein, Cameron, & Gilbert (1997) argue that *market power* and *oligopolistic coordination*, that is few dominant firms in the industry are engaged in an unspoken collusion to maintain higher profit margins, can explain downward price rigidities in the market for gasoline.

Balke, Brown & Yucel (1998) discuss the *customer reaction* explanation, where customers react strongly to retail fuel price increases if they have the bargaining power to do so. They also argue that asymmetric reaction in the gasoline price changes might occur due to differences in *accounting methods* in estimating the value of the oil stocks that refiners possess. According to the *costly adjustment* hypothesis (Borenstein & Shepard, 2002), levels of production and inventories are costly to alter and thus firms tend to spread the adjustment costs over time. As far as it concerns the *consumer search cost*

[3] Among others include Bacon (1991), Manning (1991), Lanza (1991), Kirchgassner and Kubler (1992), Reilly and Witt (1998), Godby et al. (2000), Asplund et al. (2000), Bettendorf et al. (2003), Galeotti et al. (2003), Meyler (2009) and Bermingham and O'Brien (2011)

hypothesis (Johnson, 2002), price differentiation among gasoline retailers could differ due to their spatial distribution and the different product and services they offer. Finally, Davis & Hamilton (2004) argue that asymmetric adjustment of gasoline prices could be partly attributed to the *menu costs hypothesis*, according to which there are certain costs related to obtain information regarding the optimum price.

3. Market structure for oil products in Germany, France, Italy and Spain

3.1 The German market for oil products

Germany's oil market is fully liberalized and characterised by a relatively large number of market participants (OECD, 2013). It should also be noted that no government ownership exist in any segment of the supply chain (refineries, distribution network, retailing) of the country's oil market (IEA, 2013). Nine companies are active in the refining market of oil, where three of them hold nearly 65% of the capacity share. These are the Shell Deutschland Oil, the Deutsche BP and the Total Deutschland. Regarding the retail oil market, the German government promotes the use of diesel in private transport. International Energy Agency notes that competition is active in all sectors of the German oil market (IEA, 2013).

3.2 The French market for oil products

The French market for oil products has a number of features. First, with respect to the refinery market, 13 plants operate in metropolitan France plus several overseas. Second, there are significant discrepancies between refining capabilities and demand, when considered on a product-by-product basis; there is a mismatch between refining capacity and the demand for products in the French market for oil products (IEA, 2010). The present discrepancy between refining capacity and domestic consumption results in middle distillate imports and gasoline exports. Third, the French retail market for gasoline oil consists of hypermarkets and retail outlets owned by oil companies. In late 2009, market share for the retail outlets and hypermarkets was around 60%. According to the International Energy Agency the

French motor fuel retail market is highly competitive, as its market structure results in a very low retail margin (IEA, 2010).

3.3 The Italian market for oil products

The Italian oil market is fully liberalized as imports, exports, trade and prices are free and set without restraints (IEA, 2009a). The government intervenes only to protect competition and to avoid abuse of dominant position. Distribution in the market is principally undertaken by integrated oil companies. Former state oil company, Eni, maintains a dominant position in the Italian upstream oil sector, although a number of privately owned Italian and foreign companies have also established a significant presence in the sector. Currently, Eni has the largest share of the market (30%). In addition, there are three foreign companies operating in Italy; the Tamoil, the Kuwait Petroleum and the Lukoil. Their combined market share of the Italian retail distribution and wholesale market is around 18% and approximately 17%, respectively.

Before 2008, competition in the distribution market for oil products was hampered, to some extent, by government intervention in the market. According to the International Energy Agency, there were few government restrictions on the entry market conditions for companies that were not vertically integrated (IEA, 2003 and 2009a). However, the liberalization measures adopted with Law no. 112/2008 eliminated access requirements to the road fuel distribution network in the form of minimum distances and surfaces (OECD, 2013). Also, Law Decree no. 1/2012, eliminated residual obligations in the opening of new stations (such as the obligation to sell different types of oil products), liberalized entry of fully automated retailers and liberalized agreements between owners and plant managers. The Italian Competition Authority (ICA) in its latest report argues that the liberalization process, that started after 2008 has been reinforced by the elimination of some administrative barriers to entry and the increase in the number of active un-branded fuel distribution networks (ICA, 2013). According to the ICA report, the transition from the previous oligopolistic structure in the retail fuel market in Italy to an upcoming competitive one can be attributed to the above mentioned factors.

3.4 The Spanish market for oil products

The Spanish oil retail market is characterized as fully open to competition (IEA, 2009b). This is based on the fact that the number of wholesale operators has increased from 49 in late 2005 to 84 in February 2010. In addition, market concentration, as measured by the Herfindahl-Hirschman index, has been steadily declining in recent years and in 2010 was 16% lower than in 2001. Spanish energy supply is provided by the private sector in all areas of the oil market, where the National Energy Commission (government agency) regulates the natural monopoly aspects of the energy system to ensure, for example, third-party access and transparency by private companies. The Hydrocarbon Logistics Company has a dominant role in the distribution network, as it possesses around 25% of the market. Spain is well served with refineries, with a total capacity that is close to covering the overall Spanish demand for oil products. Around 90% of the refining capacity is in the hands of two companies; RepsolYPF and Cepsa. These were established when the market was liberalized in 1992. The Spanish retailing market for oil product can be divided into direct sales (36% share of the market) and sales through filling stations (64% share of the market). In Spain there are about 9,000 petrol stations, most of which (83%) are owned by wholesale operators through exclusive distribution agreements (OECD, 2013). Overall, transport fuels are considered to be relatively cheap in the Spanish retail market. More specifically, Spain had the fourth-lowest gasoline prices and the third-lowest diesel prices in OECD in the first quarter of 2013 (OECD, 2013). Taking into account the extensive analysis of the organizational structure of the oil industry in Spain, one can reach the safe conclusion that the Spanish oil market is currently fully liberalized and competitive conditions has already been set in motion.

4. Data and Econometric Methodology

Data used for crude oil prices refer to weekly Europe Brent spot prices (FOB) and is collected from the U.S. Energy Information Administration. Our analysis focus on two types of retail products; the unleaded (Euro 95) and diesel fuel prices. Weekly retail fuel prices (net of tax) for Germany, France, Italy and Spain are only available from 2002 onwards and are collected from the Eurostat. Thus, data used cover the period between 7/01/2002 and 12/12/2011. All oil product prices were converted to Euro per 1000 litres, using the appropriate US Dollar/Euro exchange rate provided by the International Financial Statistics. Figures 1-5 (available in Appendix) present the evolution of crude oil prices and the retail fuel prices between 7/01/2002 and 12/12/2011 for France, Italy, Spain and Germany. As is it is evident, international crude oil price was raised by almost 105% between January 2007 and the middle of 2008. Moreover retail fuel prices were characterized by intense fluctuations during the oil market crisis in 2008. In Tables 1A and 1B (available in Appendix), we present the weekly descriptive statistics (average, minimum, maximum and standard deviation) separately for each country and each type of retail fuel between 2002 and 2011. As it is shown in Table 1A, Spain has the highest average diesel oil price while Italy has the highest average unleaded gasoline price.

The pass-through literature is mainly related to the way crude oil price changes are transmitted to diesel and unleaded gasoline prices. A variety of econometric models have been used in the empirical literature on pass-through transmission models. Such models mainly include the ECM (Engle and Granger, 1987), the Threshold Autoregressive model (Enders and Granger, 1998; Enders and Siklos, 2001) and the LSE-Hendry approach (Hendry, Pagan and Sargan, 1984; Hendry, 1987; Hendry and Krolzig, 2005). A more recent discussion of the LSE-Hendry methodology as well as of other econometric approaches on how to estimate short and long-run economic relationships (the co-integrating vector error correction model and the vector autoregression approach) is given by Rao (2007). Cramon-Taubadel and Loy (1997), Cramon-Taubadel (1998), Cramon-Taubadel and Meyer (2000) introduced the symmetric/asymmetric error correction approach through an ex-ante disaggregation of data. Within this framework, Bachmeier and Griffin (2003), Rao and Rao (2008), presented an alternative dynamic approach with an embedded asymmetry, which is known as the *disaggregated ECM model.* This model is intuitively appealing and its main advantage is that two different speed of adjustment, for positive and negative change in the variables included, can simultaneously be estimated. In our case, the disaggregated ECM methodology, with an embedded asymmetry, allows for the speed of adjustment coefficients to be estimated separately for each type of retail fuel, when the producer oil prices are increasing or decreasing.

The disaggregated ECM methodology, with an embedded asymmetry, is implemented in three steps. First, the equilibrium (long run) relationship is estimated by regressing the retail fuel prices on the international crude oil price (equations 1a and 1b).

$$\text{Log } UNL_t = \phi_0 + \phi_1 \times \text{Log } Oil_t + \varepsilon_t \quad (1a)$$

$$\text{Log } DSL_t = \psi_0 + \psi_1 \times \text{Log } Oil_t + \upsilon_t \quad (1b)$$

UNL stands for the premium unleaded gasoline price, DSL stands for the diesel price, Oil stands for the crude oil price, φ_1 and ψ_1 measure the long-run impact of the retail fuel prices to a 1 cent (per litre) increase in the international crude oil price (long-run pass-through or long run elasticities) and ε_t and υ_t are the two error terms. Residuals from the two regressions (e_t and u_t) represent deviations from the long-run equilibrium.

The second step specifies the change in retail fuel prices as a function of the change in international crude oil price, of past changes in retail prices and of deviations from the long run equilibrium (the residuals e_t and u_t from the first step). Based on a simple error correction model, the regression residuals e_t and u_t from equations 1a and 1b are plugged into equations 2a and 2b and in this way we end up with the following short run dynamic oil adjustment equation.

$$\Delta \text{ Log } UNL_t = \sum_{i=1}^{n} \rho_i \ \Delta \text{ Log } UNL_{t-i} + \sum_{i=0}^{n} \lambda_i \ \Delta \text{ Log } Oil_{t-i} - \theta_1 \times e_{t-1} + \delta T + \xi_t \quad (2a)$$

$$\Delta \text{ Log } DSL_t = \sum_{i=1}^{n} \gamma_i \ \Delta \text{ Log } DSL_{t-i} + \sum_{i=0}^{n} \eta_i \ \Delta \text{ Log } Oil_{t-i} - \theta_2 \times u_{t-1} + \delta T + \nu_t \quad (2b)$$

The Greek letter Δ stands for first difference operator, ρ_i γ_i λ_i and η_i are the short-run elasticities and show the direct effect or short-run impact of changes in crude and retail oil prices, θ_1 and θ_2 are the coefficients of the speed of adjustment to the long run equilibrium, T is the time trend and ξ and ν are the error terms of the two short run dynamic oil adjustment equations. The speed of adjustment coefficients should be negative since it is expected that any departure from the equilibrium position in the immediate past period will be offset in the current period by θ_1 and θ_2 proportion. The model also includes lagged changes in retail fuel prices ΔUNL_{t-i} and ΔDSL_{t-i} in order to allow for the possibility of previous retail price changes affecting current pricing decisions.

The third step involves the determination of a short run dynamic price adjustment equation for each type of retail fuel (unleaded and diesel). This is the so called *disaggregated (*with an embedded asymmetry) *ECM model*, which allows all of the coefficients in equation 2a and 2b to differ depending on whether the change in the international crude oil price is positive or negative. Rao and Rao (2008) provide a complete derivation, formulation and discussion of the specification of the *disaggregated ECM model* with an embedded asymmetry. This is a variant of equations 2a and 2b and can take the following form:

$$\Delta \text{ Log } UNL_t = \sum_{i=1}^{j1} \beta_{R,i}^{-} \ \Delta \text{ Log } UNL_{t-i}^{-} + \sum_{i=0}^{j2} \beta_{W,i}^{-} \ \Delta \text{ Log } Oil_{t-i}^{-} + \theta_1^{-} (\text{ Log } UNL_t - \varphi_0 - \varphi_1 \text{ Log } Oil_t)_{t-1} +$$

$$+ \sum_{i=0}^{j3} \beta_{W,i}^{+} \ \Delta \text{ Log } Oil_{t-i}^{+} + \sum_{i=1}^{j4} \beta_{R,i}^{+} \ \Delta \text{ Log } UNL_{t-i}^{+} + \theta_1^{+} (\text{ Log } UNL_t - \varphi_0 - \varphi_1 \text{ Log } Oil_t)_{t-1} + \delta T + \xi_t$$

(3a)

$$\Delta \text{ Log } DSL_t = \sum_{i=1}^{j1} \beta_{R,i}^{-} \ \Delta \text{ Log } DSL_{t-i}^{-} + \sum_{i=0}^{j2} \beta_{W,i}^{-} \ \Delta \text{ Log } Oil_{t-i}^{-} + \theta_2^{-} (\text{ Log } DSL_t - \psi_0 - \psi_1 \text{ Log } Oil_t)_{t-1} +$$

$$+\sum_{i=0}^{j3}\beta_{W,i}^{+}\ \Delta\,\text{Log}\ \ Oil_{t-i}^{+}\ +\sum_{i=1}^{j4}\beta_{R,i}^{+}\ \Delta\,\text{Log}\ \ DSL_{t-i}^{+}+\theta_2^{+}(\ \text{Log}\ \ DSL_t\ -\ \ \psi_0-\psi_1\ \ \text{Log}\ \ Oil_t\,)_{t-1}\ +\ \ \delta T+\nu_t$$

(3b)

In equations 3a and 3b, θ_1^+, θ_2^+ are the speed of adjustment coefficients when crude oil price increases and θ_1^- and θ_2^- are the speed of adjustment coefficients when crude oil price decreases. These coefficients capture the error correction adjustment speed when the retail fuel prices are away from their equilibrium. In other words, these coefficients show how fast departures from the equilibrium position in the past period will be offset in the current period. They are expected to be negative because if the price of the previous period was above/below its long-run level in the current period it is expected to fall/increase in order to restore the long-run relationship.

Moreover, $\beta_{w,0}^+$ and $\beta_{w,0}^-$ are the coefficients of the immediate short-term pass-through and are expected to be positive as they capture the response of the retail fuel prices to a change in the international crude oil price. These coefficients measure the short-run impact of changes in crude oil prices or how much of the change in crude oil prices gets reflected in the retail fuel prices in the same period. T is the time trend. The e_{t-1} and u_{t-1} parameters in equation 2a and 2b are replaced with their equivalent (UNL_t - φ_0 - $\varphi_1 Oil_t)_{t-1}$ in equation 3a and $(DSL_t - \psi_0 - \psi_1\ Oil_t)_{t-1}$ in equation 3b. The former and the latter are the error correction terms of the ECM model and can be thought as the measure of past period departure from the equilibrium. Rao and Rao (2008) point out that the coefficients and variables in equation 3a and 3b with the superscript (+) are relevant when international crude oil prices increase and with the superscript (–) are relevant when international crude oil prices fall. In other words, for any positive change in the independent variable (ΔOil_t>0), a corresponding response of all positive coefficients (β_w^+, θ_1^+ and θ_2^+) is expected. On the other hand, the corresponding negative coefficients (β_w^-, θ_1^- and θ_2^-) are assumed to respond in any negative change of the independent variable (ΔOil_t<0).

Before applying the disaggregated ECM model to our dataset, we test for the number of co-integrated vectors between the dependent and the independent variables. We follow Johansen (1995) in order to test for unit root and co-integration in our data series[4]. Prior expectation that crude oil prices and retail fuel prices, should be I(1) in their levels, as most macroeconomic variables are, is confirmed for all series examined by using Augmented Dickey and Fuller test. Results for unit root tests are presented in Tables 2A and 2B in the Appendix.

The number of the existing co-integrating vectors from the Johansen's methodology, is sensitive to the number of lagged variables (n) of the initial vector (Johansen, 1995). Due to this sensitivity the following lag selection criteria are implemented; the modified Likelihood Ratio test statistic, the Final Prediction Error test, the Akaike, the Schwarz and finally the Hannan-Quinn information criteria. Results for the optimal lag structure of equations 3a and 3b in the four different countries are presented in the Appendix (Tables 3A and 3B in the Appendix). We find that the optimal lag length in all four different countries is three, when the dependent variable is the unleaded retail fuel price, and two, when the diesel retail fuel price is the dependent variable. These results demonstrate that the optimal lag length is robust to the use of different lag selection criteria. According to the Eigenvalue and Trace tests from the Johansen's methodology, in all bi-variate cases there is a unique co-integrated vector of order 1 (r=1), which supports the hypothesis that all series examined tend to co-integrate pair wise. Eigenvalue and Trace tests for co-integration are presented in Tables 4A and 4B in the Appendix.

Finally, the disaggregated ECM specification in equation 3a and 3b allow for the presence of autoregressive lags. Therefore, we provide evidence that the error structure of the estimated equations does not present serial correlation (see Tables 5A and 5B in the Appendix) and that our econometric

[4] Having said that, Rao et al. (2010) argue that cointegration techniques and ECM are observationally equivalent but "based on the classical methods is simpler to use and well suited for the purpose of testing theories" (p. 697). Moreover, Hendry repeatedly stated that if the underlying economic theory is correct, then the variables in the levels must be co-integrated and, therefore, a linear combination of the I(1) levels of the variables must be I(0). As this approach holds for the ECM model (that is the model is based on the assumption of a stable long-run relationship between the international crude oil price and the retail

results are robust to misspecification.

5. Empirical Results

The disaggregated ECM methodology is applied and equations 3a and 3b are estimated separately for each country and each type of retail fuel by using the non-linear least squares method. In order to enhance readability and to conserve space we report below, in tables 1-4, only the main parameters of interest from the disaggregated ECM Model.

5.1. Speed of Adjustment Estimates and the Degree of Pass-Through Completeness in the short and long-term

For all four EU economies, the coefficients of the error correction term θ^{+} (when prices increase) and θ^{-} (when prices fall) are negative (as expected) and statistically significant when both retail unleaded (see Table 1, column 1 and 2) and diesel (see Table 2, column 1 and 2) are used as the dependent variables. This means that crude oil price increases and decreases are transmitted to the retail unleaded and diesel prices in the long term. Estimates for Germany indicate that if the unleaded fuel and diesel prices are above their long-run level, they will return to that level by making up 17% of the difference each week. If the unleaded fuel and diesel prices are below their long-run level, they will return to that level by making up 9% and 15%, respectively, of the difference each week. Also, results for France show that if the unleaded fuel and diesel prices are above their long-run level, they will return to that level by making up 11% and 7%, respectively, of the difference each week. If the unleaded fuel and diesel prices are below their long-run level, they will return to that level by making up 10% and 7%, respectively, of the difference each week. Likewise, for Italy, if the unleaded fuel and diesel prices are above their long-run level, they will return to that level by making up 10% and 5%, respectively, of the difference each week. Again, when the unleaded fuel and diesel prices are below their long-run level, they will return to

fuel prices), it does not really need to be pre-tested for cointegration.

Table 1: The disaggregated ECM pass-through estimates for retail Unleaded fuel price

Country	Positive Speed of Adjustment (θ^+)	Negative Speed of Adjustment (θ^-)	Immediate (Short run) Positive pass-through (β^+)	Immediate (Short run) Negative pass-through (β^-)	Positive Mean adjustment lag of a complete pass-through $(\varphi_1 - \beta^+)/\theta^+$	Negative Mean adjustment lag of a complete pass-through $(\varphi_1 - \beta^-)/\theta^-$	Long run pass-through (φ_1)
Germany	-0.17 (-4.92)	-0.09 (-2.24)	0.50 (5.55)	0.59 (7.24)	1.41	1.66	0.74 (18.1)*
France	-0.11 (-4.71)	-0.10 (-3.79)	0.45 (10.23)	0.30 (7.46)	2.54	4.30	0.73 (20.2)*
Italy	-0.10 (-4.49)	-0.12 (-4.82)	0.25 (7.83)	0.26 (7.84)	3.20	2.58	0.57 (19.6)*
Spain	-0.10 (-4.70)	-0.07 (-3.59)	0.33 (10.5)	0.25 (7.57)	2.80	5.14	0.61 (19.8)*

that level by making up

Note: t-statistics are presented in parentheses. *The computed (χ^2) test statistic is presented for testing whether the estimated coefficient for long-run interest rate elasticity is equal to 1.

12% and 4%, respectively, of the difference each week. Finally, for Spain, results demonstrate that if the unleaded fuel and diesel prices are above their long-run level, they will return to that level by making up 10% and 6%, respectively, of the difference each week. If the unleaded fuel and diesel prices are below their long-run level, they will return to that level by making up 7% and 6%, respectively, of the difference each week.

Table 2: The disaggregated ECM pass-through estimates for retail Diesel fuel price

Country	Positive Speed of Adjustment (θ^+)	Negative Speed of Adjustment (θ^-)	Immediate (Short run) Positive pass-through (β^+)	Immediate (Short run) Negative pass-through (β^-)	Positive Mean adjustment lag of a complete pass-through $(\psi_1 - \beta^+)/\theta^+$	Negative Mean adjustment lag of a complete pass-through $(\psi_1 - \beta^-)/\theta^-$	Long run pass-through (ψ_1)
Germany	-0.17 (-6.07)	-0.15 (-5.56)	0.51 (6.21)	0.39 (4.77)	1.88	2.93	0.83 (18.8)*
France	-0.07 (-5.87)	-0.07 (-5.44)	0.51 (12.11)	0.27 (6.46)	6.14	9.57	0.94 (17.5)*
Italy	-0.05 (-5.62)	-0.04 (-4.60)	0.32 (9.87)	0.23 (7.40)	10.0	14.7	0.82 (15.1)*
Spain	-0.06 (-5.51)	-0.06 (-5.20)	0.36 (11.0)	0.20 (6.27)	7.66	10.33	0.82 (17.9)*

Note: t-statistics are presented in parentheses. *The computed (χ^2) test statistic is presented for testing whether the estimated coefficient for long-run interest rate elasticity is equal to 1.

We next examine the degree of pass-through completeness of crude oil price with respect to retail unleaded and diesel prices in the short-term (within one week). The immediate short-term pass-through coefficients, $\beta_{w,0}^{+}$, which captures the response to a positive shock, and $\beta w,_{0}^{-}$, which captures the response to a negative shock, are as expected positive and statistically significant for both unleaded gasoline (see Table 1, column 3 and 4) and diesel fuel price (see Table 2, column 3 and 4) in all four economies. Taking Germany as an example, the estimates suggest that when the international crude oil price increases by 1 cent (per litre), the unleaded fuel price will increase within one week by 0.50 cents and diesel oil by 0.51 cents. Also, the estimates suggest that when the international crude oil price decreases by 1 cent (per litre), the unleaded fuel price will decrease within one week by 0.59 cents and diesel oil by 0.39 cents. Moreover, estimates for France, Italy and Spain indicate that when the international crude oil price increases by 1 cent (per liter), the unleaded fuel price will increase within one week by 0.50 cents, 0.45, 0.25 and 0.33, respectively and diesel oil by 0.51 cents, 0.51, 0.32 and 0.36, respectively. Also, our empirical results show that when the international crude oil price decreases by 1 cent (per liter), the unleaded fuel price will decrease within one week by 0.59 cents 0.30, 0.26 and 0.25, respectively and diesel oil by 0.39 cents, 0.27, 0.23 and 0.20, respectively. Finally, $\beta_{w,0}^{+}$ is higher than $\beta_{w,0}^{-}$ in all countries regarding the diesel oil price. This implies that the immediate short-term impact of an increase in crude oil prices is stronger than the short-run impact of a decrease in crude oil prices in the same period.

We then calculate the mean adjustment lag of a complete pass-through for each country and each type of retail fuel separately. The mean adjustment lag of a complete pass-through tells us how much time (number of weeks) it takes for a given change in the crude oil prices to be fully transmitted to the retail fuel prices. Taking Germany as an example, our calculations for unleaded fuel suggest that when the international crude oil price **increases** by 1 cent (per liter), this change will be transmitted fully to the unleaded fuel price within 1.41 weeks (see Table 1, column 5 and 6) and to the diesel price within 1.88 weeks (see Table 2, column 5 and 6). When the international crude oil price **decreases** by 1 cent (per liter), this change will be transmitted fully to the unleaded fuel price within 1.66 weeks and to the diesel price within 2.93 weeks. These numbers indicate a rather fast transmission. Moreover, estimates for France, Italy and Spain indicate that when international crude oil price **increases** by 1 cent (per liter), this change will be transmitted fully to the unleaded fuel price within 2.54, 3.20 and 2.80 weeks, respectively (see Table 1, column 5 and 6) and to the diesel price within 6.14, 10 and 7.66 weeks, respectively (see Table 2, column 5 and 6). Along the same line of reasoning, when international crude oil price **decreases** by 1 cent (per liter), this change will be transmitted fully to the unleaded fuel price within 4.30, 2.58 and 5.14 weeks, respectively (see Table 1, column 5 and 6) and to the diesel price within 9.57, 14.7 and 10.33 weeks, respectively (see Table 2, column 5 and 6). These numbers indicate a rather slow transmission.

Lastly, we examine the degree of pass-through completeness between crude oil prices and retail unleaded and diesel in the long term. The coefficients φ_1 (in equation 3a) and ψ_1 (in equation 3b) measure the degree of pass-through completeness in the long-run. It shows the amount by which the retail fuel price will increase in the long-run in response to an increase of one unit (for example 1 cent per litre) in the international crude oil price. The long-run adjustment is complete when $\varphi_1 = 1$ and $\psi_1 = 1$, which implies that changes in crude oil prices will be transmitted fully to retail fuel prices in the long run. For $\varphi_{1,}$ it makes more sense to test whether it is statistically significantly different from 1, given that this value has a special meaning for a complete oil price pass-through. We test whether estimates for the long run adjustment coefficient are statistically significantly different from 1 by using Wald (χ^2). The computed test statistic (χ^2) is presented in parentheses in Tables 1-2. The critical value of χ^2 statistic, with one degree of freedom, is 3.84 at 5% significance level. In all four cases, the null hypothesis, that φ_1 is equal to 1, is rejected.

The long run crude oil pass-through, when unleaded retail fuel price is used (see Table 1, column 7), is nearly complete for France and Germany (0.73 and 0.74, respectively) and rather incomplete for Spain and Italy (0.61 and 0.57, respectively). Furthermore, when diesel is the retail fuel price (see Table 2, column 7), the long run elasticity is 0.94, 0.83, in France and Germany, respectively and 0.82 for both Spain and Italy. In this case, it seems that the long run price adjustment for all four countries is almost complete in the long run.

5.2. Testing for symmetric speed of adjustment to equilibrium for retail fuel prices

We now consider whether the rate of adjustment of retail fuel prices to increases and decreases of the international crude oil prices is the same for each country and each type of retail fuel. More specifically, we test the symmetry of adjustment hypothesis, that is $\theta^{+} = \theta^{-}$ (Rao and Rao, 2008, Karagiannis et al., 2010 and 2011). The existence of a symmetric speed of adjustment to equilibrium is tested by using the Wald (χ^2) – test. When either unleaded gasoline or diesel are the retail fuel prices, the Wald test indicates that the null hypothesis that the two speed of adjustment coefficients θ^{+} and θ^{-} are equal, could not be rejected at the 5% significance level. The computed test statistic χ^2 for all four countries regarding the unleaded gasoline and diesel fuel prices are presented in Tables 3 and 4, respectively.

Table 3: Testing for symmetric/asymmetric speed of adjustment to equilibrium: retail Unleaded fuel price

Country	Symmetry Hypothesis $H_0 : \theta^{+} = \theta^{-}$ Wald (χ^2) empirical values	Result
Germany	2.45	symmetry
France	0.31	symmetry
Italy	0.44	symmetry
Spain	1.56	symmetry

Note: We test the symmetry hypothesis by applying the Wald (χ^2) test. The critical value of χ^2 statistic with one degree of freedom is 3.84 (at 5% confidence level) and 5.02 (at 2.5% confidence level).

Table 4: Testing for symmetric/asymmetric speed of adjustment to equilibrium: retail Diesel fuel price

Country	Symmetry Hypothesis H_0 : $\theta^+ = \theta^-$ Wald (χ^2) empirical values	Result
Germany	0.60	symmetry
France	0.51	symmetry
Italy	4.13	Symmetry (at 5% confidence level)/ positive asymmetry (at 2.5% confidence level
Spain	0.28	symmetry

Note: We test the symmetry hypothesis by applying the Wald (χ^2) test. The critical value of χ^2 statistic with one degree of freedom is 3.84 (at 5% confidence level) and 5.02 (at 2.5% confidence level).

It is evident that we could not reject the null hypothesis that $\theta^+ = \theta^-$ when tested separately for each country and each type of retail fuel. Our results are consistent with our analysis in Section 3 regarding the increased levels of competition in the retail oil markets for the economies considered. In addition, this symmetric behavior presented in the selected EU retail fuel markets is theoretically consistent with the *customer reaction hypothesis* (Balke, Brown & Yucel, 1998), where customers are expected to react strongly to retail fuel price increases if they have the bargaining power to do so. Nevertheless, as Peltzamn (2000) argues, symmetry itself is not a proof of a competitive market because any market power that might exist at the retail level might be related to the cost of product differentiation – most in the form of location differences.

6. Conclusions

The issue of crude oil price pass-through to retail gasoline prices along with the adjustment process has been examined by a number of scholars, who look at different countries for different time periods, use different frequency of data and apply different econometric methods. Overall, there is no consensus in the empirical literature whether retail gasoline prices reflect decreases in international oil prices as rapidly and fully as they do price increases. Our study investigates a number of interesting issues. First, we test whether the short and long run oil price transmission process works between crude oil and retail fuel prices. Second, we calculate how much time (number of weeks) it takes for a given change in the international oil prices to be fully transmitted to the retail fuel prices in the economies examined. Lastly, we test the symmetry of adjustment hypothesis, separately for each country and each type of retail fuel.

The empirical results show that rigidities in the transmission process are present and variations across the selected EU member-states exist. Symmetry seems to prevail in all countries analysed regarding the retail fuel markets. Therefore, we do not find evidence in support of the "rockets and feathers" phenomenon reflecting the notion that retail fuel prices rise like a "rocket" and drop like a "feather" in response to international oil price changes. Symmetry findings might be perceived as the end result of an effective regulatory policy of the energy sector in these economies. This is not surprising since the regulatory authorities of the developed countries of our dataset do not face any serious difficulties in implementing and enforcing regulation in their retail oil markets.

We believe that our findings about the nature of price adjustments in the retail unleaded gasoline and diesel markets in Germany, France, Italy and Spain, can be useful for the regulatory energy authorities and antitrust policy makers in their attempt to monitor the competitiveness of oil markets and enforce regulation policy. In this paper we only relate in a single stage the price of crude oil to the pump price. Price asymmetries might arise though at a different stage of the supply chain (producer, wholesale and retail). Next in our research agenda is to identify and analyse the likely price asymmetries in the various stages of the transmission chain as oil is moving from the oil field to the retail gasoline outlet.

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Appendix

Table 1A. Descriptive statistics for Diesel retail fuel price 7/2/2002 – 12/12/2011 (in Euros)

	mean	st. dev.	min	max
Germany	0.462	0.139	0.232	0.803
France	0.450	0.141	0.237	0.787
Italy	0.481	0.145	0.290	0.850
Spain	0.493	0.144	0.272	0.834

Table 1B. Descriptive statistics for Unleaded retail fuel price 7/2/2002 – 12/12/2011 (in Euros)

	mean	st. dev.	min	max
Germany	0.428	0.118	0.194	0.748
France	0.421	0.1266	0.222	0.682
Italy	0.481	0.119	0.282	0.723
Spain	0.458	0.122	0.258	0.728

Figure 1: Germany

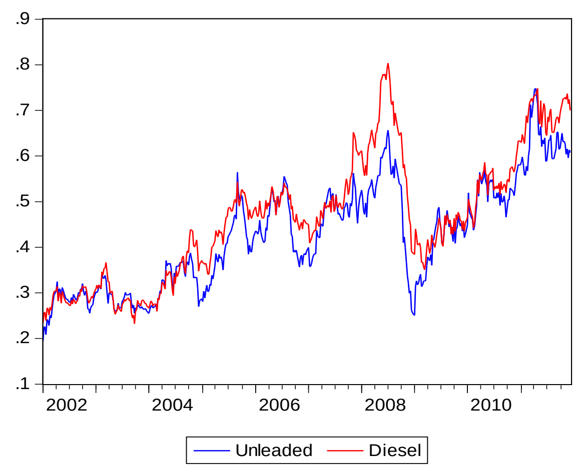


Figure 2: France

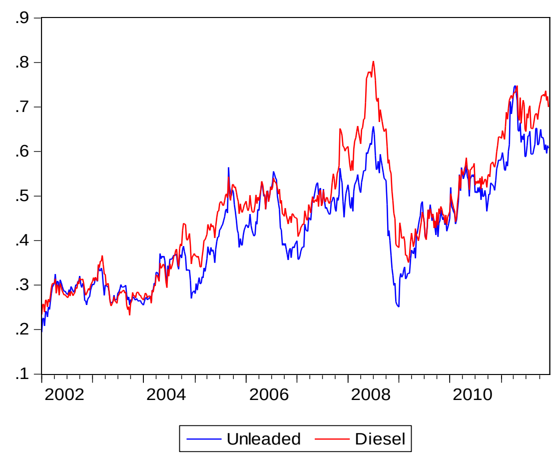


Figure 3: Italy

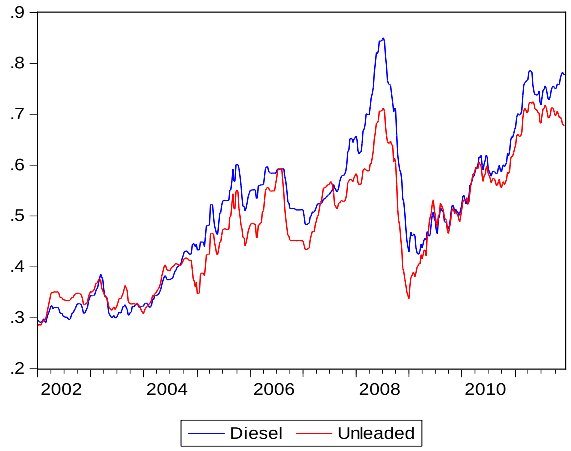


Figure 4: Spain

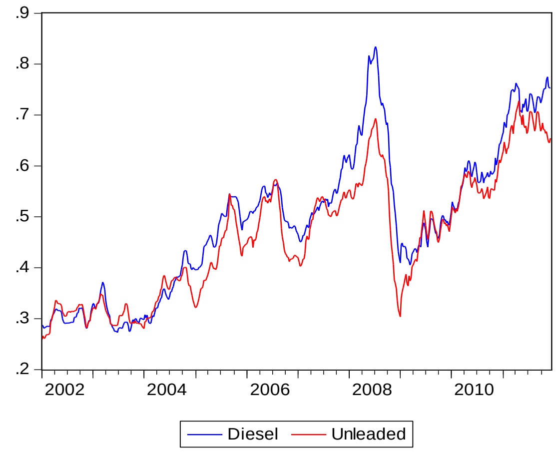
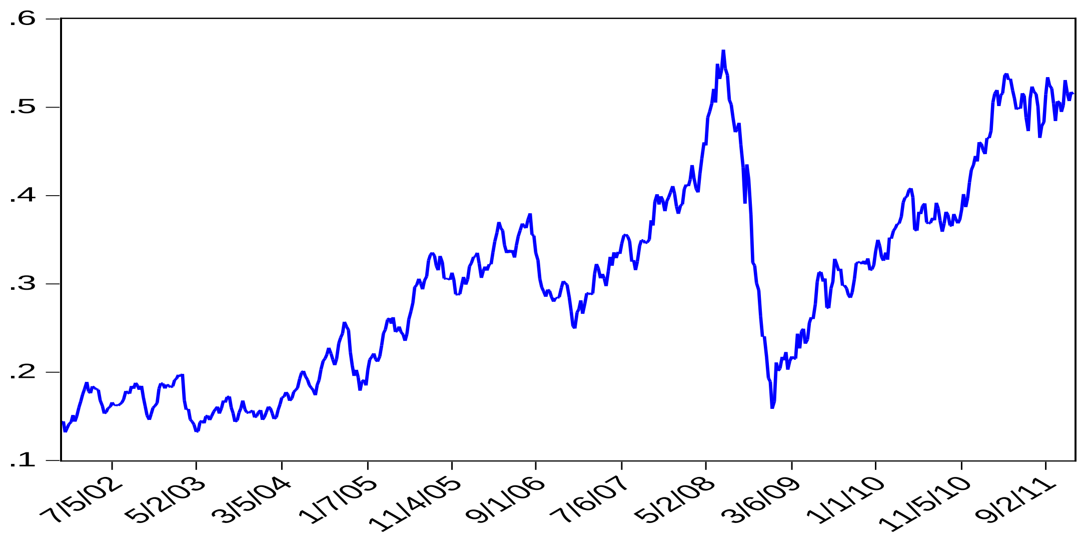


Figure 5: Weekly Crude Oil Prices* in Euros/Liter (2002-2011)



* Crude oil prices refer to Europe Brent Spot Price (FOB).
Source: U.S. Energy Information Administration (EIA)

Table 2A. Unit root tests for Diesel retail fuel price

Variable	ADF I(0)	ADF I(1)
Germany	-2.82	-25.60
France	-2.39	-15.47
Italy	-2.07	-14.68
Spain	-2.21	-14.35

Table 2B. Unit root tests for Unleaded retail fuel price

Variable	ADF I(0)	ADF I(1)
Germany	-3.62	-24.70
France	-2.92	-16.04
Italy	-3.26	-10.99
Spain	-3.36	-13.92

The critical value is -3.41 at 5% significance level and -3.97 at 1% significance level.

Table 3A. Lag selection criteria when Unleaded retail fuel price is the dependent variable*

Country	Number of lags selected	Criteria
Germany	3	LR, FRE, AIC
France	3	LR, FRE, AIC, HQ
Italy	3	FRE, AIC, HQ
Spain	3	FRE, AIC, HQ

Table 3B. Lag selection criteria when Diesel retail fuel price is the dependent variable*

Country	Number of lags selected	Criteria
Germany	2	LR, SC, HQ
France	2	LR, FRE, AIC, SC, HQ
Italy	2	LR, FRE, AIC, SC, HQ
Spain	2	LR, FRE, AIC, SC, HQ

* Equation 3a is tested for optimal lag structure by implementing the modified Likelihood Ratio test (LR), the Final Prediction Error test (FRE), the Akaike Information Criterion (AIC), the Schwarz Information Criterion (SC) and the Hannan-Quinn information criterion (HQ).

Table 4A. The Johansen Pair wise Co-integration Tests for Diesel retail fuel price *

Country	No. of Lags	Rank	Max. Eigenvalue	Trace	No. of Co-integrating Vectors (r)
Germany	(2)	r=0	37.9	41.45	r=1
		r≤1	3.47	3.47	
France	(2)	r=0	25.9	29.7	r=1
		r≤1	3.33	3.33	
Italy	(2)	r=0	28.0	30.73	r=1
		r≤1	2.66	2.66	
Spain	(2)	r=0	28.8	31.99	r=1
		r≤1	3.13	3.13	

Table 4B. The Johansen Pair wise Co-integration Tests for Unleaded retail fuel price *

Country	No. of Lags	Rank	Max. Eigenvalue	Trace	No. of Co-integrating Vectors (r)
Germany		r=0	28.8	31.47	r=1
		r≤1	2.59	2.59	
France		r=0	31.4	34.6	r=1
		r≤1	3.24	3.24	
Italy	(3)	r=0	38.1	41.49	r=1
		r≤1	3.32	3.32	
Spain	(3)	r=0	28.1	31.51	r=1
		r≤1	3.34	3.34	

* The critical value for accepting the hypothesis that r=1 at the 5% significance level for both the Maximum Eigenvalue test and the Trace test, is 3.84.

Table 5A. LM test for Serial correlation: Diesel retail fuel price*

Country	H_0: No serial correlation hypothesis χ^2 empirical values	Result
Germany	2.35	Accept
France	6.58	Accept
Italy	1.73	Accept
Spain	5.90	Accept

Table 5B. LM test for Serial correlation: Unleaded retail fuel price*

Country	H_0: No serial correlation hypothesis χ^2 empirical values	Result
Germany	5.32	Accept
France	14.5	Reject
Italy	11.49	Accept (at 2.5% confidence level)
Spain	6.60	Accept

*LM(5) = x^2(5) and the critical value of x^2 statistic with five degrees of freedom is 11.07 (at 5% confidence level) and 12.83 (at 2.5% confidence level).