Are Unleaded Gasoline and Diesel Price Adjustments Symmetric?

A Comparison of Eurozone 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 France, Italy, Spain and Germany. 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 adjustment hypothesis. A disaggregated general-to-specific model is applied for the estimation of the international crude oil price pass-through and testing the symmetric/asymmetric behaviour of the retail fuel markets in these economies. Our results show that rigidities in the transmission process are present and variations across the selected Eurozone member-states exist. The retail fuel prices' speed of upward/downward adjustment behaviour is considered as symmetric in all four economies analysed. Thus, our model has not accumulated evidence to support the "rockets and feathers" hypothesis that retail fuel prices rise faster than they fall in response to changes in crude oil prices. We believe that our results can be useful for the EU energy authorities and antitrust policy makers in their attempt to monitor the competitiveness of their energy sectors.

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Keywords: Crude oil prices pass-through, disaggregated general-to-specific model

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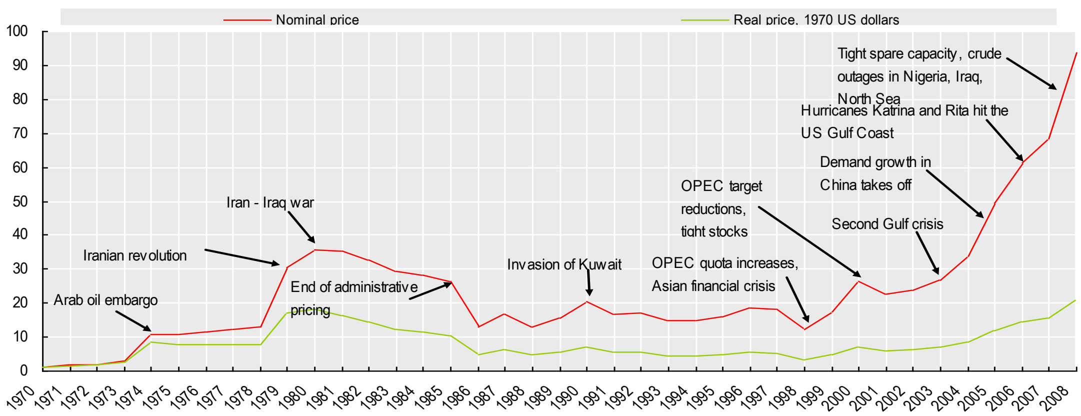
1. Introduction

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.

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



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

The volatility 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

[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 increased demand for oil by the emerging economies throughout the 2005-2009 (OECD, 2010). These increases have affected

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. 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. For example, if there are price rigidities in the unleaded gasoline market, this will imply that the particular retail market adjusts rapidly to rising crude oil prices but slowly to declining crude oil prices (also known as the “rockets and feathers” hypothesis pioneered by Bacon (1991)). 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.

In this paper, we first test whether the international crude oil prices are transmitted to the retail fuel prices, that is, diesel oil and unleaded gasoline. We then examine the short-run and long run rigidities (elasticities) between crude oil prices and diesel as well as crude oil prices and unleaded gasoline, in France, Italy, Spain and Germany. Second, we test the “symmetry of adjustment” hypothesis that is whether retail fuel price speed of adjustment (to upward and downward crude oil price change) is symmetric or asymmetric. Third, 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.

One of the distinctive features of our paper is that we employ the disaggregated general-to-specific model (hereafter GETS), which it offers a parsimonious modelling approach for separating the price adjustment mechanism into a short term (direct) and a long-term (indirect) component and for

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significantly the price for gasoline that consumers pay around the world and thus households’ after-tax income.

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 the disaggregated GETS method. Second, the issue of pass-through has been concentrated on the US retail gasoline market while there are only few studies about the major Eurozone economies. In the light of this, we provide new evidence on crude oil price transmission and the issue of price asymmetries by using a recent data set that includes the French, Italian, Spanish and German 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 are mixed as far as it concerns both the oil price transmission process and pass-through completeness; it is evident that rigidities in the transmission process, variations across the countries analysed and non-completeness at least in some cases, are present. The retail gasoline prices' speed of upward/downward adjustment behaviour is considered as symmetric in the economies analysed. 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 and rapidly than the crude oil price decreases.

The paper is structured as follows. Section 2 presents the literature review on crude oil price transmission channel to retail fuel prices. In Section 3 we briefly refer to the market structure for oil products in France, Italy, Spain and Germany. Section 4 presents data and the GETS econometric methodology. The empirical results on estimates of the speed of adjustment and symmetry of adjustment hypothesis are given in Section 5 and 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. Some studies concentrate on US retail gasoline market. A non-exhaustive list of papers include Burbidge and Harrison (1984), Mork (1989), Karrenbrock (1991), Shin (1994), Duffy-Deno (1996), Borenstein et al. (1997), Balke et al. (1998), Peltzman (2000), Borenstein & Shepard (2002), Bachmeier, & Griffin (2003) and Radchenko (2005).

Other studies that focus on non-US economies 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). 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 (Germany, France, UK, Italy and Spain) 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 whether retail gasoline prices reflect decreases (drop like a "feather") in international producer prices as rapidly and 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* 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 France, Italy, Spain and Germany

3.1 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. According to International Energy Agency (IEA, 2004), there are significant discrepancies between refining capabilities and demand, when considered on a product-by-product basis. In other words, there is mismatch in refining capacity versus demands for products in the French market for oil products. The present discrepancy between refining capacity and domestic consumption results in middle distillate imports and gasoline exports. Second, the French retail market for gasoline oil consists of retail outlets (owned by oil companies) and hypermarkets. At the end of 2007, market share for the retail outlets and hypermarkets was around 44% and 56%, respectively. According to the International Energy Agency (IEA, 2009b), competition in the retail market and the resulting decrease in retail price margins have forced the closure of numerous gasoline oil outlets. In general, the retail market for gasoline products is considered to be highly competitive.

3.2 The Italian market for oil products

The Italian oil market is fully liberalized as imports, exports, trade and prices are 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 refining oil sector. Currently the company has the largest share of the market (30%). In addition, there are three foreign companies operating in Italy (Tamoil, Kuwait Petroleum and Lukoil), where their combined market shares of the Italian retail distribution and the wholesale market is around 18% and approximately 17%, respectively. In the distribution market for oil products, competition is hampered to some extent by government intervention in the market. According to the International Energy Agency (IEA, 2003 & 2009a), there are persistent restrictions on the entry conditions into the market for companies that are not vertically integrated. This has led to an unsatisfactory degree of modernization of the distribution network, high retail prices and more generally an insufficient degree of competition in the market at the expense of consumers.

According to Italian competition authority barriers to the opening of new retail outlets exist due to a number of legal definitions that is mandatory minimum distances between pumps and minimum areas designated for commercial activities. According to the latest report of the International Energy Agency (IEA, 2009a), although liberalization and market reform have visibly had an impact on the wholesale markets for oil products, work remains to be done as far as it concerns the necessary reform of the distribution and retail sectors. The International Energy Agency argues that the sale of gasoline and diesel at retail gasoline stations is still governed by outdated legislation, which has a negative impact on retail prices and potentially hampers competition.

3.3 The Spanish market for oil products

The Spanish oil market is in a transition phase from a fully regulated to a fully liberalized system according to the International Energy Agency (IEA, 2005). 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 distribution network of Spain can be characterised as a quasi monopoly. 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 the two companies namely 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 and sales through filling stations (36% and 64% of the market, respectively). According to IEA (2005), the profit margins for the dealers regarding sales of diesel in the filling station market is considered to be high, compared to other European countries. One reason for this could be that Spain has a relatively low density of filling stations compared to some other countries in Europe due to local planning restrictions. The retail market is dominated by RepsolYPF (3,616 stations, 41.6%) and Cepsa (1,550 stations, 17.8%). International Energy Agency (IEA, 2007b) characterizes the Spanish oil sector as heavily concentrated and there is a lack of new entrants despite the fact that there are not considerable entry barriers.

3.4 The German market for oil products

Germany's oil market is fully liberalized and characterised by a relatively large number of market participants. It should also be noted that no government ownership exist in any sector of the country's oil market (refineries, distribution network, retailing). 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 (IEA, 2007a) notes that competition is active in all sectors of the German oil market.

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) are collected from Eurostat and the data cover the period between 7/01/2002 and 12/12/2011 for France, Italy, Spain and Germany. All oil product prices and 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 high volatility 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) for each type of fuel in each country 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 general-to-specific approach, known as GETS model (Hendry, Pagan and Sargan, 1984; Hendry, 1987; Hendry and Krolzig, 2005). A more recent discussion of the GETS 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 (Von) and Loy (1997), Cramon-Taubadel (Von) (1998), Cramon-Taubadel (Von) 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, known as the *disaggregated GETS model*, originating from the LSE-Hendry GETS methodology, which has more intuitive appeal. The main advantage of the model is that two different speeds of adjustments, for positive and negative change in the variables included, can simultaneously be estimated. In our case, it allows for the retail oil prices and the speed of adjustment coefficients to be analysed separately, when the producer oil prices are increasing or decreasing.

The disaggregated GETS 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).

$$UNL_t = \phi_0 + \phi_1 \times Oil_t + \varepsilon_t \tag{1a}$$

$$DSL_t = \psi_0 + \psi_1 \times Oil_t + \upsilon_t \tag{1b}$$

UNL stands for the premium unleaded gasoline price, DSL stands for the diesel price, Oil stands for the crude oil prices, ϕ_1 and ψ_1 measure the long-run impact of the retail fuel prices to a €1 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. The 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.

$$\Delta UNL_t = \sum_{i=1}^{n} \rho_i \times \Delta UNL_{t-i} + \sum_{i=0}^{n} \lambda_i \times \Delta Oil_{t-i} - \theta_1 \times e_{t-1} + \xi_t \tag{2a}$$

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

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 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 adjustment equation for retail unleaded and diesel prices, with an embedded asymmetry (disaggregated GETS 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 an asymmetric adjustment equation. This is a variant of equations 2a and 2b and can take the following form:

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

$$+ \sum_{i=0}^{j3} \beta_{W,i}^{+} \Delta Oil_{t-i}^{+} + \sum_{i=1}^{j4} \beta_{R,i}^{+} \Delta UNL_{t-i}^{+} + \theta_1^{+} (UNL_t - \varphi_0 - \varphi_1 Oil_t)_{t-1} + \delta T + \xi_t \qquad (3a)$$

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

$$+\sum_{i=0}^{j3}\beta_{W,i}^{+}\ \Delta\ Oil_{t-i}^{+}\ +\sum_{i=1}^{j4}\beta_{R,i}^{+}\ \Delta\ DSL_{t-i}^{+}+\theta_2^{+}\,(DSL_t - \psi_0-\psi_1\,Oil_t)_{t-1}+\ \delta\,T+\nu_t \qquad (3b)$$

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 its long-run level (e_{t-1} and u_{t-1} are positive) in the current period it is expected to fall 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 GETS 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 ($\Delta Oil_t > 0$), a corresponding response of all positive coefficients ($\beta_w^{+}, \theta_1^{+}, \theta_2^{+}$) is expected. On the other hand, the corresponding negative coefficients ($\beta_w^{-}, \theta_1^{-}, \theta_2^{-}$) are assumed to respond in any negative change of the independent variable ($\Delta Oil_t < 0$).

Before applying the disaggregated GETS model to our dataset, we discuss whether it is necessary to test for the number of co-integrated vectors between the dependent and the independent variables. Rao et al. (2010) argue that cointegration techniques and GETS are observationally equivalent but "GETS based on the classical methods is simpler to use and well suited for the purpose of testing theories" (p. 697). Moreover, Hendry[3] 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 GETS 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 fuel prices), it does not need to be pre-tested for cointegration.

Nevertheless, we follow Johansen (1995) in order to test for unit root and co-integration in our data series. 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[4]. 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 (Table 2-3). We find that the optimal lag length in all four different countries is three and two, when the dependent variable is the unleaded and diesel retail fuel price, respectively. 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

[3] See Hendry, Pagan, and Sargan (1984), Hendry (1987) and Hendry and Krolzig (2005).
[4] Augmented Dickey and Fuller results for unit root tests are available upon request from the authors.

that all series examined tend to co-integrate pair wise[5]. Finally, The GETS specifications 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 Table 4-5 in the Appendix) and that our econometric results are robust to misspecification.

5. Empirical Results

The disaggregated GETS methodology is applied and equations 3a and 3b are estimated separately for each country and each type of retail fuel by using ordinary least squares (OLS) and the non-linear least squares methods (NLLS)[6]. The OLS and NLLS estimates are compared and giving similar results. We thus present here NLLS estimates and OLSs' are available from the authors upon request. In order to enhance readability and to conserve space we report here only the main parameters of interest from the GETS regression in tables 1-4 below.

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

First, for all four Eurozone 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.

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[5] Eigenvalue and Trace tests for co-integration are available upon request from the authors.

[6] In econometric terms the corresponding "activation" will be triggered in equations 3a and 3b with the help of a dummy variable. More specifically, all positive coefficients will take the value of 1, when a positive change in the dependent variable occurs, and will be zero otherwise.

Table 1: The GETS pass-through estimates: Unleaded

unleaded	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 (-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)	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)

Note: t-statistics in parentheses

For example, estimates for Germany indicate that if the unleaded fuel price is above its long-run level, it will return to that level by making up 17% of the difference each week. If the unleaded fuel price is below its long-run level, it will return to that level by making up 9% of the difference each week.

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

Diesel	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 in parentheses

Second, we next examine the degree of pass-through completeness between crude oil prices and retail unleaded and diesel in the short-term (within one week). The immediate short-term pass-through coefficients, $\beta_{w,0}^+$ (captures the response to a positive shock) and $\beta w,0^-$ (captures the response to a negative shock) are positive (as expected) and statistically significant for both unleaded gasoline (see Table 1, column 3 and 4) and diesel (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. 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.

Third, we calculate the mean adjustment lag of a complete pass-through for each country and each type of retail fuel separately (for unleaded fuel see Table 1, column 5 and 6 and for diesel see Table 2, column 5 and 6). 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 suggest that when the international crude oil price increases by 1 cent (per litre), this change will be transmitted fully to the unleaded fuel price within 1.41 weeks and to the diesel price within 1.88 weeks. Also, our calculations suggest that when the international crude oil price decreases by 1 cent (per litre), this change will be transmitted fully to the unleaded fuel price within 1.66 weeks and to the diesel price within 2.93 weeks.

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 equations 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 φ_1 =1 and ψ_1=1, which implies that changes in crude oil prices will be transmitted fully to retail fuel prices in the long run. 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. This indicates that the long run 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 separately. 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 is tested by using the Wald ($\chi 2$) – test[7]. 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: Unleaded retail 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).

[7] The critical value of χ^2 statistic with one degree of freedom is 5.02 (5% confidence interval).

Table 4: Testing for symmetric/asymmetric speed of adjustment to equilibrium: Diesel retail 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 in line with Bachmeier & Griffin (2003) and 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 Eurozone 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 test the symmetry of adjustment hypothesis separately for each country and each type of retail fuel. Lastly, 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.

The empirical results are mixed regarding the price transmission process and the pass-through completeness. We show that rigidities in the long run transmission process are present; variations across the four countries exist as well as non-completeness, at least in some cases. 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 diesel and unleaded gasoline markets in France, Italy, Spain and Germany, 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. Next in our research agenda is to identify at what stage of the supply chain (producer, wholesale and retail) price asymmetries might arise and analyse them in both stages of the transmission chain separately; as oil is moving from the oil field to the retail gasoline outlet.

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Appendix

Table 1A: Descriptive statistics for Diesel prices, 7/2/2002 – 12/12/2011 (in Euros)

	mean	st. dev.	min	max
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
Germany	0.462	0.139	0.232	0.803

Table 1B: Descriptive statistics for Unleaded prices, 7/2/2002 – 12/12/2011 (in Euros)

	mean	st. dev.	min	max
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
Germany	0.428	0.118	0.194	0.748

Figure 1: France

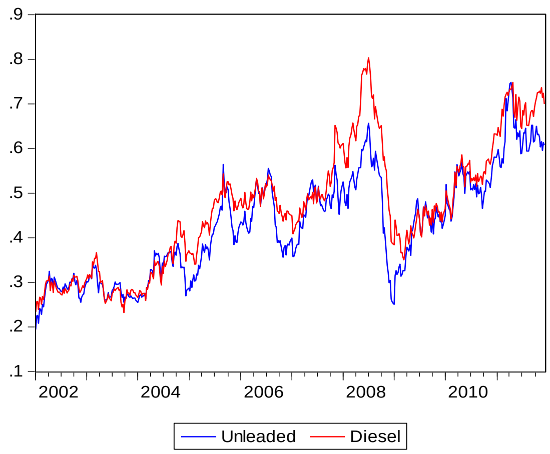


Figure 2: Italy

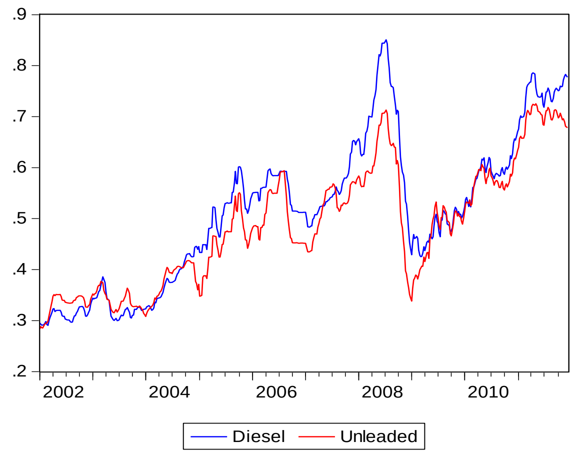


Figure 3: Spain

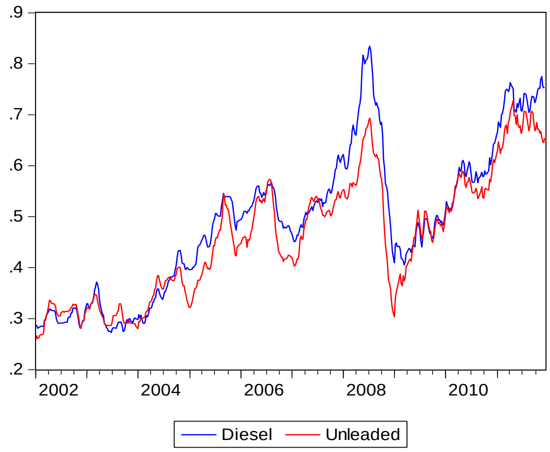


Figure 4: Germany

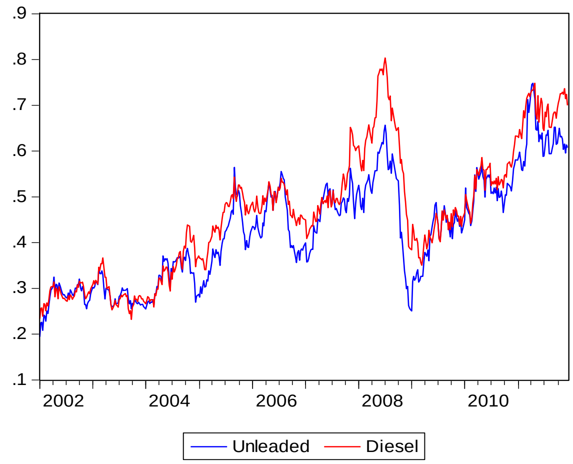
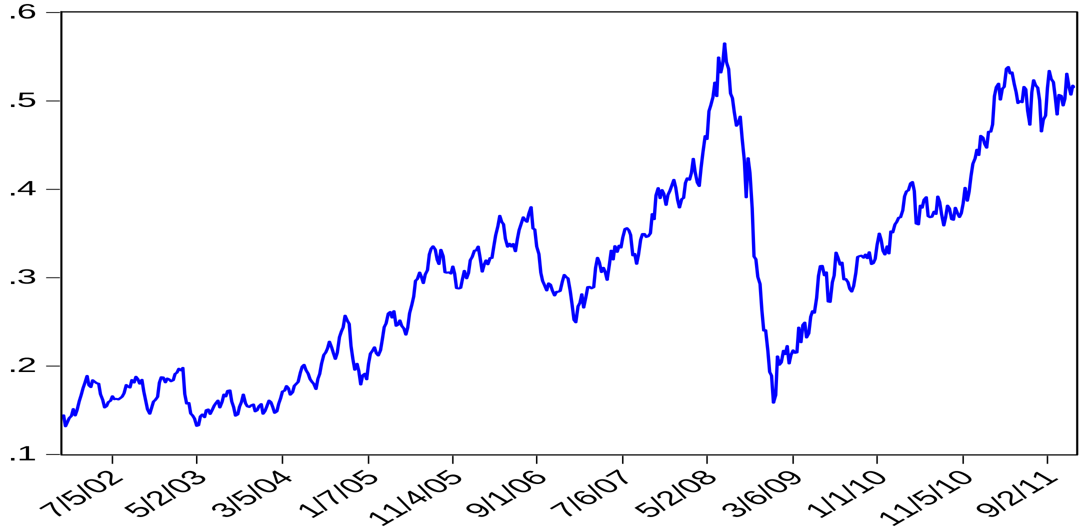


Figure 5: Monthly Crude Oil Prices* in Euros/Liter (2002-2011)



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

Table 2: Lag selection criteria when Unleaded is the Dependent Variable[1]

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 3: Lag selection criteria when Diesel is the Dependent Variable[1]

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

[1] 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 4: LM test for Serial correlation: Diesel retail fuel price[2]

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 5: LM test for Serial correlation: Unleaded retail fuel price[2]

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

[2] 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).