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DO RETAIL GASOLINE PRICES ADJUST SYMMETRICALLY TO CRUDE OIL PRICE CHANGES? THE CASE OF THE GREEK OIL MARKET*

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1 INTRODUCTION

A question that has attracted and continues to attract public attention in many countries, including Greece, is whether domestic retail gasoline prices respond symmetrically to changes in world oil prices or not. In other words, whether retail gasoline prices adjust to both rises and decreases of crude oil prices at the same speed. The issue is particularly interesting, as asymmetry could indicate distortions and non-competitive conditions in the domestic oil market.

According to economic theory, in a perfectly competitive —and hence efficient— market, any change in the marginal cost of a commodity is fully transmitted to its price. If not, this may probably be due to market distortions. The structure of the oil market is particularly important for any economy, given that oil is a commodity that affects both the demand and the supply sides of any economy. From the supply side, oil is an important input of production and thus affects production costs; from the demand side, changes in the prices of oil, given its relatively inelastic demand, have a direct impact on consumers' disposable income. Thus, systematic asymmetry in price adjustments could imply negative consequences for the economy as a whole and a continuing deterioration of consumers' purchasing power to the benefit of producers/suppliers. Asymmetries are often interpreted as the result of speculation by suppliers that take advantage of their market power in the fuel market. In such cases, it is crucial that competition authorities monitor the market, in order to ensure competitive conditions in the market to the greatest possible extent.

This issue has been extensively addressed in the economic literature over the last twenty years. Asymmetry has been tested with respect to the speed of adjustment of prices, i.e. the time required for a crude oil price change to be reflected in domestic oil prices. A number of studies analyse the oil market in several economies. Most of the studies detect asymmetry in domestic retail price adjustments. However, not all studies provide the same results. Their findings vary depending on the period analysed, the size, and the frequency of the sample of observations, and the econometric methodology used.

The evidence on the Greek oil market, reported in studies covering country groups (Meyler, 2009; Cleridis, 2010), is also inconclusive: Meyler (2009) detects some asymmetry in the adjustment of retail fuel prices, whereas Cleridis (2010) does not find any indications of asymmetric pricing. Three recent articles analyse exclusively the Greek oil market. The study by the Foundation for Economic and Industrial Research (IOBE, 2009) offers a comprehensive overview of the domestic oil market and tests for asymmetries by applying the asymmetric error correction model (AECM) to monthly observations for the period January 2005-December 2008. Although the description of the market indicates lack of competition, the econometric analysis concludes that there is no asymmetric pricing. Angelopoulou and Gibson (2010) examine pricing in the domestic fuel market, using weekly observations for the period November 2004-February 2009. They show

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that prices adjust symmetrically to world oil prices, but asymmetrically to tax changes and/or across various regions in Greece. These findings probably reflect a lack of competitive conditions in the Greek market. Polemis (2011) analyses the period January 1988-June 2006 using the asymmetric ECM framework. He provides evidence of asymmetry in the retail gasoline price adjustments in both the long and the short term, which indicates poor competition in the oil market in Greece.

The purpose of the present paper is to test for asymmetry in the Greek retail gasoline price adjustments to crude oil price changes for the period January 2005-July 2012. The value added of the present paper stands on: **(i)** The data sample: the paper uses all available observations for the variables under consideration. The Greek oil market is analysed using weekly observations of a larger statistical sample, which comprises observations from the period of the crisis in the Greek economy. The fact that the paper applies a large number of observations which covers also the crisis period, ensures the reliability of results in terms of economic significance and statistical inference. **(ii)** The econometric methodology: the paper applies the TAR ECM cointegration technique, which has been proved by the relevant literature to be the most robust econometric method for identifying such kind of asymmetries. Nevertheless, and for indicative purposes alone, the study also presents results based on the AECM econometric methodology which has been used in previous studies.

The rest of the paper is organised as follows: Section 2 presents in brief the main theoretical issues and an overview of the literature. Section 3 offers a brief description of the oil market in Greece. It analyses the importance of crude oil for the Greek economy and outlines the market's structure. Section 4 presents the econometric methodology. The data and the empirical results are presented in Section 5. The final section summarises and concludes.

2 THEORETICAL ISSUES – A REVIEW OF THE LITERATURE

Theoretical issues

According to the literature, testing starts with the estimation of the degree to which retail oil prices adjust to changes in crude oil prices. The degree of price adjustment reflects the part of the marginal cost change which is caused by changes in the price of crude oil. In a competitive market, in which price equals marginal cost, the adjustment should be 100%: any change in cost should be passed through to prices.

Adjustment asymmetries are measured by the speed of adjustment of retail prices to world oil price changes. The study examines whether the prices adjust faster upwards (following an increase in crude oil prices), or downwards (following a crude oil price decrease). The speed of adjustment is affected by factors such as adjustment costs and stock levels. Adjustment cost – i.e. the cost of re-pricing – is low for oil companies, as it is associated with adjusting the retail prices of their local vendors. The level of stocks affects pricing as follows: high stocks act as a buffer for retail price increases when oil prices rise, since the increases can be delayed until the delivery of a new load.

The literature provides several interpretations of this asymmetric behaviour (for a comprehensive overview of the theoretical arguments see Balke *et al.,* 1998). The phenomenon can be mainly explained by: (a) the market structure; (b) consumer search costs; (c) consumer behaviour in response to price changes; (d) the oil stock management and pricing practices; and (e) the adjustment cost for refineries.

(a) The market structure which reflects the market power of individual companies can explain the phenomenon. When there are only a small number of producers in a market, they have an incentive to collude and form a cartel in order to maximise their profits. In such a case, a price reduction by a producer (during a period of decreasing prices) may be perceived by competitors as an aggressive move signalling a breach of their agreement. As a result, companies tend to keep prices rigid. In contrast, during periods of increasing prices, as a price increase cannot be misunderstood as breaching the cartel agreement, companies tend to increase their prices immediately.

(b) Search costs associated with the comparison of retail prices stem from the non-competitive structure of the market of gasoline stations. Such costs are particularly high, since prices vary on a daily basis. In addition, consumers tend to regard some stations as cheap, without verifying their belief prior to every purchase. Service stations exploit this consumer loyalty by reacting asymmetrically to changes in oil prices.

Asymmetries can arise even in competitive markets, as shown by arguments (c) to (e) below:

(c) During periods of increasing prices, consumers tend to buy more gasoline, for precautionary reasons, assuming that this upward trend will continue. However, during periods of decreasing prices, demand does not fall at the same speed, causing asymmetries on the demand side. **(d)** In turn, the suppliers' pricing practice is influenced by the future level of oil stocks. If, for instance, new natural oil reserves are discovered, suppliers will not reduce their prices immediately, because pricing depends both on stock levels and production capacity. However, if natural oil reserves are reduced, suppliers will immediately raise their prices in order to lower demand and delay supply shortages in the market. Moreover, if the fall in prices leads to high increase in demand, companies will be reluctant to reduce prices further, unless they have sufficiently high levels of stocks to meet the rise in demand. **(e)** Refineries are also constrained by production costs and production capacity in the short run, which may be another barrier to fast adjustment of gasoline prices.

Review of the literature

The asymmetric adjustment of retail fuel prices to the crude oil price changes has been analysed in a large number of papers. Studies for the UK oil market provide mixed empirical results. Bacon (1991) analyses the UK oil market and detects asymmetric adjustment of retail prices to changes in world oil prices for the period 1982-1989. Wlazlowski (2001) draws the same conclusion examining the period 1982-2001. Manning (1991) points to the lack of sufficient evidence of asymmetries for the period 1973-1988. Bermingham and O'Brien (2010) use monthly data for the period 1997-2009 in the UK and Ireland and provide evidence in favour of a symmetric adjustment process.

The literature on the US oil market is large. The studies by Shin (1994), Duffy-Deno (1996), Borenstein, Cameron and Gilbert (1997), Radchenko (2005) and Deltas (2008) provide evidence of asymmetry. In contrast, Balke *et al.* (1998) claim that there are no clear-cut results in support of asymmetric behaviour, while Backmeier and Griffin (2003) report no asymmetries. Kuper and Poghosyan (2008) analyse the period 1986-2005 using weekly observations. They show that the price adjustment of retail prices to long-term equilibrium is linear before 1999 and not linear after 1999.

Eckert's (2002) study on the Canadian oil market for the period 1989-1994 shows an asymmetric response of retail prices to world oil prices. Salas (2002) comes to the same conclusion for the oil market in the Philippines for 1999-2002. Grasso and Manera (2007) report evidence of asymmetry in a number of European countries for the period 1985-2003, particularly in Germany and France. Faber (2009) analyses the Dutch oil market using daily data for the period 2006-2008 and concludes that 38% of petrol stations react asymmetrically. Valadkhani's (2009) findings on the Australian oil market, which are based on monthly data for 1998-2009, show signs of asymmetry in four out of the country's seven largest cities.

A European Commission (2009) study reports no statistically significant evidence of asymmetry. Meyler (2009) examines a group of European countries, and the euro area as a whole, for the period 1994-2008 for which he does not detect any asymmetry. Clerides (2010) uses data of the EU Member States for 2000-2010 and finds statistically significant evidence of asymmetry in a small group of countries. A study by the ECB (2010) comes to similar conclusions for the euro area as a whole and for each country individually. Significant asymmetries are reported for France, Italy, Luxembourg, Austria and Finland.

The studies on Greece (IOBE, 2009; Angelopoulou and Gibson, 2010; and Polemis, 2011) have already been presented in the first section. Both IOBE and Polemis test for asymmetries in the Greek oil market applying the asymmetric ECM technique. However, IOBE finds no evidence of asymmetries, whereas Polemis provides evidence of asymmetries in both the short and the long run.

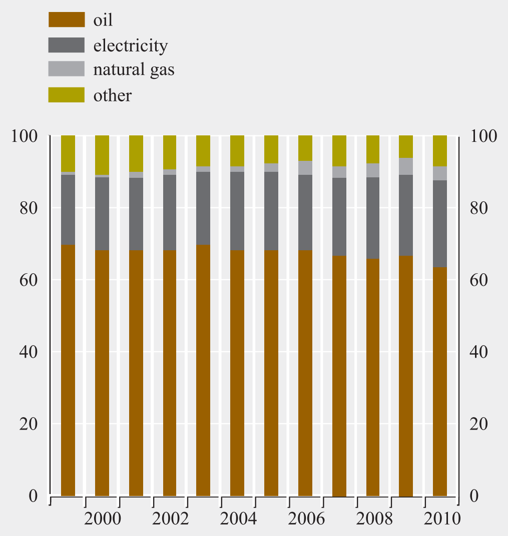
3 THE GREEK OIL MARKET

The importance of oil for the Greek economy

Developments in oil prices have a significant effect on economic activity and prices in advanced economies (see ECB, 2010; OECD, 2011). The economy of Greece is oil dependent and can be considered more vulnerable to world oil price shocks[1] than other European economies. The latest Eurostat figures for 2009 indicate that the economy's dependence on oil stands at 67.8%, i.e. quite higher than the EU average (EU-27: 53.9%). On average, oil consumption accounts for more than 65% of total energy consumption in Greece in the decade 2001-2010 (see Chart 1). In particular, in the crisis year 2010 it accounted for 63.7% (see Chart 2). Transport holds the highest share in oil consumption (63% on average in 2007-2012), 95% of which concerns petrol consumption (2012 data from the Hellenic Petroleum Marketing Companies Association – SEEPE). Consequently, changes in fuel prices have a major impact on consumers' real disposable income and, for this reason, are

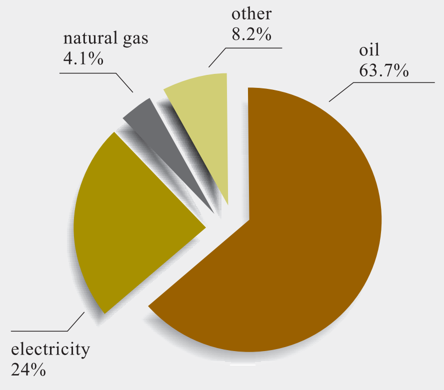
Chart 1 Energy consumption in Greece (1999-2010)

(percentages)



Source: Eurostat.

Chart 2 Breakdown of total energy consumption (2010)



Source: Eurostat.

1 See Papapetrou (2009) for an analysis of the impact of oil price changes on economic activity in Greece.

often the subject of public debate.[2] Oil is also a product which determines changes in the trade balance of Greece to a large extent.[3]

The structure of the Greek oil market

The Greek oil market consists of three submarkets: (a) the refining market, in which refineries purchase crude oil and sell petroleum products to wholesale vendors; (b) the wholesale market, in which companies sell fuel to service stations; and (c) the retail market, in which service stations sell fuel to consumers.

There are two companies in the refining market, Hellenic Petroleum (ELPE) and MOTOROIL, which own all four refineries operating in Greece.[4] ELPE, having a market share of more than 60%, clearly leads the refining market. Duopoly conditions prevail, with significant barriers to the entry of new firms in the market due to the high level of sunk costs. Market participants argue that prices are based on the Mediterranean market quotes and an additional mark-up of 3% (see press release by ELPE in *Kathimerini newspaper*, 18 September 2012). Around twenty companies are active in the wholesale market, some of which are subsidiaries of the refineries. Wholesalers may also import fuel from abroad, if prices are favourable. The market is not highly concentrated, even though the four largest companies (ELPE and MOTOROIL subsidiaries plus the multinationals BP and SHELL) have a market share of more than 50%. Although there are no formal barriers to market entry, constraints do exist due to regulations on oil stocks.[5] However, pricing differs across regions: it is not clear how companies set their prices across the different regions in Greece. In addition, the transportation market in which transport costs are determined is not perfectly competitive (fuel is transported by public- and private-use tanker trucks). There are roughly 7,000 filling stations in Greece, of which just about 600 are independent retailers. The rest are owned by, affiliated to, or subsidiaries of the petroleum companies. This number of filling stations is high compared to other countries. In Greece there is one station for every 1,400 inhabitants compared to one for every 3,800 in the EU (see SEEPE, 2010). However, the Greek market is geographically segmented, and competition is determined by the number of stations per geographical area. Moreover, contracts between filling station and wholesale companies may be restrictive, causing an adverse impact on retail prices.

How are prices set?

Crude oil prices are determined in the world market, where prices are driven by supply and demand conditions (reserves, extraction costs, transport costs, etc.), as well as by derivatives trading. Refineries purchase crude oil as raw material to produce fuel products, which are then sold initially to wholesale companies, then to service stations, and finally to consumers.

Therefore, retail fuel prices in the Greek market are determined by the output price at refineries, the profit margins of wholesalers and service stations, and the duties and taxes imposed by the state.[6] Refineries set their prices according to crude oil prices, the exchange rate of the euro vis-à-vis the US dollar, and a mark-up. Crude oil prices and the exchange rate are determined exogenously to the Greek market. State duties and taxes raise the price by a specified rate, also exogenous to the Greek market.[7] The mark-up charged by refineries and the profit margins of wholesalers and retailers depend on factors related

2 See e.g. relevant articles in the Greek daily *Kathimerini* (12 and 18 September, and 2 October 2012).
3 Oil imports represent 21.2% of total imports of goods in the period 2001-2010 and 36.27% in 2011, in nominal terms. Oil imports determine the export volume of petroleum products, which represent 17.9% of total exports of goods in 2001-2010 and 30.25% in 2011, in nominal terms (Bank of Greece data).
4 ELPE is the leading industrial and commercial group in the energy sector and MOTOROIL the largest privately held industrial complex in Greece.
5 Wholesale companies can import oil from foreign refineries, as long as they keep buffer stocks that can meet consumption for 90 days.
6 See IOBE (2009) for a detailed description of the fuel pricing process in the Greek economy. This study shows that the price of gasoline can be decomposed as follows: 50% is taxes, 40% is the cost of crude oil, and 10% is the gross profit rate of marketing companies and service stations.
7 It is worth pointing out that according to the applicable tax regime, VAT is calculated on the sum of the oil price and the excise duties, thereby duplicating the tax burden for consumers.

Chart 3 Unleaded gasoline prices in Southern Europe

(euro per litre)

Source: Eurostat, *Oil Bulletin*.

to domestic market characteristics, such as the market structure, vertical integration, the geographical distance of regional markets from the refineries and temporary demand fluctuations.

Any pre-tax price differences between Greece and other EU economies which buy crude oil in the same market are also caused by domestic factors. Crude oil prices which apply in Greece are the MED prices quoted in the Mediterranean market of Genoa, and not the NWE prices of the North Western European market of Rotterdam.[8] Consequently, retail fuel prices in Greece are comparable with those in Cyprus, Spain, Italy and Portugal.[9]

Chart 3 shows the evolution of gasoline prices in Southern European countries between 2005:H1 and 2012:H2. Prices at national level are roughly similar. However, it should be noted that in the period 2005-2008, i.e. before the debt crisis, Greek gasoline prices were among the highest in the European south. From the onset of the crisis to 2012:H1, gasoline prices in Greece became the lowest in this group of countries. This evidence suggests that the mark-ups applied by refineries and the profit margins applied by wholesalers and service stations differ in the post-crisis period from the pre-crisis period. In the post-crisis period the mark-ups are lower than those of the pre-crisis period, probably as a result of lower demand.

4 ECONOMETRIC METHODOLOGY

The econometric models which are used to test asymmetries are based on the error correction model (ECM) developed by Engle and Granger (1987). The present work applies the TAR-ECM methodology, which has been shown to be the most adequate technique to identify asymmetries in adjustment of this type.

4.1 ERROR CORRECTION MODELS BY ENGLE AND GRANGER

The ECM

The EC methodology is applied to test for the existence of a long-run equilibrium between the series under consideration. In the present analysis, the variables of interest are world oil prices, R_t^b, and the retail gasoline prices paid by consumers at service (pump) stations in Greece, R_t^g. Their long-run relationship is given by:

$$r_t^g = \gamma_0 + \gamma_1 r_t^b + u_t \qquad (1)$$

where r_t^g and r_t^b denote the logarithms of R_t^g and R_t^b respectively. Coefficient γ_0 represents the fixed cost which comprises all refining, marketing and distribution costs; parameter γ_1 represents the impact of oil prices on gasoline prices; u_t denotes deviations from equilibrium.

8 Depending on the index, prices are either f.o.b. (i.e. do not include freight) or c.i.f. (i.e. include insurance and freight costs).
9 However, as methodologies for measuring product price and quality differ across countries (see European Commission, *Oil Bulletin*, 2011), prices are not fully comparable; thus caution is warranted in drawing any conclusions.

The first step in the Engle and Granger (1987) methodology is to test whether the errors are stationary or not, using the standard Dickey-Fuller tests. Dickey and Fuller (1979) test the hypothesis $H_0{:}\varrho=0$ against $\varrho<0$, on an estimated equation of the form:

$$\Delta u_t = \varrho u_{t-1} + v_t \qquad (2)$$

where Δ denotes the first difference and ϱ denotes the speed of adjustment of the errors to their mean value. In case that the errors are stationary the short-run dynamic relationship for gasoline prices can be given by:

$$\Delta r_t^g=\mu_0+\sum_{i=1}^{k_1}\beta_{1,i}\Delta r_{t-i}^g+\sum_{i=0}^{k_2}\beta_{2,i}\Delta r_{t-i}^b+\alpha u_{t-1}+e_t \qquad (3)$$

where $\alpha < 0$

where $k1$, $k2$ denote time lags. According to (3), short-run gasoline price changes Δr_t^g are determined by gasoline price changes in previous periods $\Sigma\Delta r_{t-i}^g$, crude oil price changes in previous periods $\Sigma\Delta r_{t-i}^b$, and the tendency of gasoline prices to return to their long-run equilibrium, as expressed by αu_{t-1}.The coefficient α takes negative values. This implies that when the variable r_t^g deviates from the long-run equilibrium relationship (1) in period $t-1$ (resulting to a non-zero error u_{t-1}), there is a tendency to return to the long-run equilibrium in period t. Essentially, when the errors u_t exceed their mean value in period $t-1$, r_t^g will tend to move downwards to reach the long-run equilibrium value in period t, whereas when errors are below their mean, r_t^g will tend to move upwards, to reach the long-run equilibrium value in period t. Equation (3) is the general form of the ECM and the term αu_{t-1} is called "error correction term".

Engle and Granger's ECM in its original form (3) —also known as symmetric ECM— is based on the following assumptions: (a) residuals have a zero mean; (b) residual values (either higher or lower than their mean) revert to their mean symmetrically, i.e. at the same speed ϱ; and (c) the dependent variable responds symmetrically to any deviation from equilibrium. This implies that α, the dependent variable's speed of adjustment to equilibrium, is the same, irrespective of whether residual values are negative (lower than their mean) or positive (higher than their mean).

The AECM

The hypothesis of the dependent variable's symmetric adjustment to long-run equilibrium has been questioned in the economic literature. The AECM model divides errors into positive and negative (in other words, distinguishes between positive u_t^+ and negative u_t^- deviations of r_t^g from equilibrium) and estimates the following relationship:

$$\Delta r_t^g=\mu_0+\sum_{i=1}^{k_1}\beta_{1,i}\Delta r_{t-i}^g+\sum_{i=0}^{k_2}\beta_{2,i}\Delta r_{t-i}^b+\alpha_1 \overset{-}{u}_{t-1}+\alpha_2 \overset{+}{u}_{t-1}+e_t \qquad (4)$$

where $\alpha_1<0$ and $\alpha_2<0$.

Specification (4) assumes that the adjustment speed is α_1 for negative deviations and α_2 for positive ones. A first indication of asymmetric adjustment comes up when the estimated values of α_1 and α_2 are not equal. The AECM specification allows for a statistical test for the symmetry hypothesis $H_0{:}\alpha_1=\alpha_2$ (the assumption that coefficients are equal).

4.2 THRESHOLD AUTOREGRESSIVE (TAR) COINTEGRATION MODELS

The statistical validity of the AECM technique has been criticised in cases where asymmetric adjustment is detected. Balke and Fomby (1997) and Enders and Granger (1998) indicate that if the residuals' adjustment to their mean value (the long-run equilibrium) is not symmetric, the D-F auxiliary equation (2) for cointegration tests is misspecified and could lead to misleading results. In other words, AECM-based conclusions are not unquestionable. To tackle this problem, Enders and Granger (1998) and Enders and Siklos (2001) propose the threshold autoregressive TAR-ECM technique. According to it, unit root tests also take into account the possibility that the residuals return to the long-run equilibrium value at a different speed, depending on whether their value is higher or lower than a threshold value τ. The TAR-ECM assumes that the residuals adjust at a speed ϱ_1 when their values are above the threshold value τ and at speed ϱ_2 when their values are below τ. Enders and Siklos (2001) calculate the critical values for testing cointegration on these hypotheses and propose a Wald-type statistical test to determine whether the residuals' adjustment is symmetric or not.

The crucial point in the TAR methodology is to identify correctly the threshold value τ, for which the asymmetric adjustment is statistically significant.[10] Enders and Siklos (2001) propose a consistent method to detect τ among all residual values resulting from the cointegration relationship.

ECM with asymmetric cointegration

When the existence of a threshold autoregressive cointegration is identified, errors can be discerned into those which take a value higher than τ and those which take a value lower than τ. In such a case, an AECM can be estimated as follows:

$$\Delta r_t^g = \mu_0 + \sum_{i=1}^{k_1} \beta_{1,i} \Delta r_{t-i}^g + \sum_{i=0}^{k_2} \beta_{2,i} \Delta r_{t-i}^b + \alpha_3 u_{t-1}^{down} + \alpha_4 u_{t-1}^{up} + e_t \quad (5)$$

where $\alpha_3 < 0$ and $\alpha_4 < 0$.

In (5), u_{t-1} deviation values are split into deviations over (u_{t-1}^{up}) and below (u_{t-1}^{down}) the threshold value τ. Thus, (5) provides the basis to test the hypothesis $\alpha_3 = \alpha_4$, which expresses the dependent variable's symmetric adjustment to equilibrium.

5 EMPIRICAL RESULTS

5.1 DATA

The study uses monthly observations covering the period January 2005-July 2012. Data on retail gasoline prices R_t^g are taken from the European Commission *Oil Bulletin*.[11] The analysis focuses on the pre-tax[12] price series of the 95-octane unleaded gasoline, given that most cars in Greece use this type of fuel.[13] The crude oil prices series, R_t^b, refers on data of Brent crude oil spot prices (considered to be the pricing benchmark in Europe) published in the US Energy Information Administration database. For comparability with retail prices, dollars per barrel are expressed in euro per litre, on the basis of a 158.987 litres/barrel rate.[14] The total number of observations is 368.

5.2 STATIONARITY TESTS

The first step in the empirical work is to test the series r_t^b and r_t^g for unit roots. The D-F (Dickey-Fuller, 1979) and DF-GLS (Elliot *et al.,* 1996) tests are applied. The findings show that both series are $I(1)$.[15]

5.3 LONG-RUN RELATIONSHIP

The existence of a long-run relationship between the two series, of the form (1), is then examined. The results of the Engle-Granger cointegration tests (t-statistic and z-statistic) are presented in Table 1. The estimated long-run equilibrium relationship takes the form:

$$r_t^g = 0.1 + 0.7 r_t^b + u_t \quad (6)$$

According to (6), the long-run oil price elasticity of domestic gasoline prices takes the value 0.7. This means that a 10% change (rise or fall) in crude oil prices causes a 7% change (increase

10 In its simplest version, the TAR model hypothesis is that $\tau = 0$. This means that positive and negative deviations from equilibrium are assumed to be corrected at different adjustment speeds. However, from a statistical point of view the $\tau = 0$ hypothesis could lead to unreliable conclusions (see Tong, 1983).
11 Weekly prices of various fuel types are published in the *Oil Bulletin* since 2005. For transparency and information purposes, all EU Member States are required to report such prices both before and after tax in their respective retail markets.
12 Indirect taxes comprise custom duties, fuel excise duties and VAT. As already mentioned, VAT is calculated on the sum of the final product price and the excise duties, thereby further increasing the final consumer price.
13 It represents 59% of total fuel consumption for transport in 2011 – SEEPE data.
14 Data on Brent crude oil spot prices are also available for periods before 2005, but the common period examined spans from January 2005 to July 2012.
15 The results are not presented here for space reasons, but are available on request.

Table 1 Long-run equilibrium estimation and cointegration tests

FMOLS estimation method		
Long-run equilibrium (1)		
γ_0	0.104**	(27.634)
γ_1	0.708**	(3.820)
– Adjusted R^2		0.927
– Long-run variance		0.017
Engle-Granger cointegration tests		
H_0: ϱ=0		
– Engle-Granger t-statistic	-8.565**	[0.000]
– Engle-Granger z-statistic	-122.541**	[0.000]

Notes: t-statistic values in parentheses; P-values in brackets.
(**) denotes statistically significant at 5%.
Critical values for cointegration tests provided by MacKinnon (1996).

or decrease, respectively) in retail gasoline prices – a finding which is in accordance with the finding in IOBE (2009) and Polemis (2011).

5.4 ERROR CORRECTION MODELS ACCORDING TO ENGLE-GRANGER

The ECM

The short-run dynamics of the price of gasoline are captured by an ECM of the form (3). Specification of the proposed model is based on the well-known "general to specific" methodology. The estimated model is presented in Table 2. The specification passes the relevant diagnostic tests. All explanatory variables are statistically significant. According to the model, changes in gasoline prices in the current period (week) are determined by (i) changes in gasoline prices one to three periods before and (ii) changes in oil prices one to two periods before, while (iii) the error correction term ensures return to the long-run equilibrium. The speed of adjustment to the long-run equilibrium takes the value α= -0.15. This indicates that a 15% deviation of the retail gasoline price deviation from the long-rum equilibrium (6) is corrected within one week, and full adjustment is completed in six weeks.

The AECM

The findings from the estimation of the AECM of the form (4) are also shown in Table 2. The short-run elasticities of the explanatory variables Δr^g_{t-1}, Δr^g_{t-2}, Δr^b_{t-1}, Δr^b_{t-2} are very close in value to those of the ECM. The coefficients α_1 and α_2, which measure the asymmetric adjustment of r^g to long-run equilibrium, are statistically significant and are not equal to each other. Their values (α_1= -0.14 and α_2= -0.19) indicate that retail gasoline prices r^g move at a faster speed upwards when they are below their equilibrium value. However, this last finding is not supported by the Wald F-test (i.e. the symmetry hypothesis cannot be rejected). Given that the results of the AECM methodology have been shown to have low statistical power, the analysis proceeds with the estimation of the TAR-ECM model.

5.5 ASYMMETRIC THRESHOLD COINTEGRATION MODELS

The Consistent TAR-ECM (with τ threshold estimation)

The results of the TAR-ECM are presented in Table 3.[16] They indicate a consistently estimated threshold value of τ= -0.056. According to the results, the coefficients ϱ_1^+ and ϱ_2^- take different values (ϱ_1^+= -0.29 and ϱ_2^-= -0.50) and turn out to be statistically significant. In addition, the H_o:$\varrho_1^+=\varrho_2^-=0$ hypothesis for the absence of threshold cointegration is rejected based on the Φ*statistic value. The results are in favour of the existence of a stable long-run relationship between world oil prices and retail gasoline prices. Moreover, the hypothesis of equal adjustment coefficients $\varrho_1^+=\varrho_2^-$ is rejected based on the Wald test value (F = 5.627, P-value = 0.018). The coefficients reflect a faster upward adjustment of prices when they are below their long-run

16 A more comprehensive analysis used a TAR model with a predefined threshold τ = 0 in parallel with the model with a consistent TAR. Under the statistical information criteria (AIC and SBC), the findings of the consistent TAR model (presented here) are more robust. The findings of the TAR model with τ = 0 (not shown in this study) can be found in Bragoudakis (2012).

Table 2 Symmetric and asymmetric error correction models

		Symmetric ECM		Asymmetric ECM	
Constant	μ_0	0.001 (0.377)	[0.706]	-0.001 (-0.362)	[0.716]
$\Delta(r^g)_{t-1}$	$\beta_{1.1}$	0.212** (2.997)	[0.002]	0.213** (2.998)	[0.002]
$\Delta(r^g)_{t-3}$	$\beta_{1.3}$	0.115** (2.249)	[0.025]	0.117** (2.244)	[0.025]
$\Delta(r^b)_{t-1}$	$\beta_{2.1}$	0.180** (4.409)	[0.000]	0.177** (4.316)	[0.000]
$\Delta(r^b)_{t-2}$	$\beta_{2.2}$	0.147** (4.447)	[0.000]	0.145** (4.440)	[0.000]
u_{t-1}	α	-0.159** (-4.285)	[0.000]		
u^+_{t-1}	α_2			-0.140**(-2.780)	[0.005]
u^-_{t-1}	α_1			-0.193**(-3.379)	[0.000]
Adjusted R^2		0.487		0.487	
SSR		0.139		0.139	
DW		2.069		2.072	
F-statistic		70.310		58.605	
Wald F-statistic	H_0: $\alpha_1 = \alpha_2$			0.441	[0.506]

Notes: t-statistic values in parentheses; P-values in brackets.
(**) denotes statistically significant at 5%.
Optimal number of lags based on the AIC (1973) and SBC (1978) information criteria.

Table 3 Enders-Siklos TAR cointegration tests

			Enders-Siklos. t-MAX	P-value
	ϱ_1^+		-0.292 ** (-6.878)	[0.000]
	ϱ_2^-		-0.500 ** (-6.310)	[0.000]
		AIC	-3.685	
		SBC	-3.664	
		RSS	0.533	
Threshold cointegration test	H_0: $\varrho_1^+ = \varrho_2^- = 0$	Enders-Siklos Φ*	40.944 **	[0.000]
Symmetry test	H_0: $\varrho_1^+ = \varrho_2^-$	F	5.627 **	[0.018]

Notes: t-statistic values in parentheses; P-values in brackets.
(**) denotes statistically significant at 5%.
Optimal number of lags based on the AIC (1973) and SBC (1978) information criteria.
Critical values for the threshold cointegration test provided by Enders and Siklos (2001) and Wane et al. (2004).
For the symmetry test the numbers of standard distribution of the F test are used on condition of the existence of TAR cointegration.

equilibrium value compared to their adjustment when they are above their equilibrium value.

The TAR model indicates that when the system deviations from the long-run equilibrium (the long-run relationship) take values higher than the threshold τ, adjustment to equilibrium takes place slowly (at a speed of $\varrho_1^+ = -0.29$), whereas when the deviations take values lower than τ, adjustment to equilibrium is fast (at speed $\varrho_2^- = -0.50$).

Table 4 Asymmetric ECM with consistent TAR cointegration

ECM with TAR				
Constant	μ_0	-0.001	(-0.386)	[0.699]
$\Delta(r^g)_{t-1}$	$\beta_{1.1}$	0.221**	(5.085)	[0.000]
$\Delta(r^g)_{t-3}$	$\beta_{1.3}$	0.115**	(2.923)	[0.003]
$\Delta(r^b)_{t-1}$	$\beta_{2.1}$	0.175**	(6.285)	[0.000]
$\Delta(r^b)_{t-2}$	$\beta_{2.2}$	0.145**	(5.247)	[0.000]
u_{t-1}^{up}	α_4	-0.138**	(-5.011)	[0.000]
u_{t-1}^{down}	α_3	-0.247**	(-5.018)	[0.000]
Adjusted R^2		0.487		
SSR		0.139		
DW		2.072		
F-statistic		58.605		
Wald test for symmetry F-stat.	$H_0: \alpha_{up} = \alpha_{down}$	4.369**		[0.0373]

Notes: t-statistic values in parentheses; P-values in brackets.
(**) denotes statistically significant at 5%.
Optimal number of lags based on the AIC (1973) and SBC (1978) information criteria.
The null hypothesis test for symmetry uses the F standard distribution values.

The existence of asymmetric cointegration allows an asymmetric TAR-ECM of the form (5) to be estimated. The results are presented in Table 4. According to the results, changes in gasoline prices in the current period (week) are determined by: (a) gasoline price changes with three time lags; (b) oil prices changes with three time lags; and (c) the long-run equilibrium. The error correction terms are statistically significant, with different adjustment speeds, α_3= -0.24 and α_4= -0.13. The symmetry hypothesis cannot be accepted according to the relevant Wald test statistic. The null hypothesis on the equality of adjustment coefficients is rejected at a 5% level of significance (F= 4.369, P-value = 0.037). Thus, the results provide strong evidence of asymmetric adjustment of domestic prices to world crude oil prices.

6 CONCLUSIONS

Efficient pricing in the Greek market of gasoline is often the subject of public debate in Greece. The present paper tests for asymmetries in the domestic gasoline price adjustments to crude oil price changes for the period January 2005-July 2012. To this end: (1) the TAR cointegration methodology is applied and (2) all available and most recent data (which include data from the recent crisis period) are used. The long data sample and the fact it covers also the crisis period, ensure the reliability of the results in terms of economic significance and statistical inference.

The empirical analysis provides evidence that the adjustment of gasoline prices to oil price changes is asymmetric, in contrast to findings of previous studies which have applied other, less robust econometric techniques. Asymmetric adjustment implies a strategy, according to which market participants delay lowering the retail gasoline prices when crude oil prices fall, but rush to increase them when crude oil prices rise, in an effort to maximise profits. Such a strategy may be the result of non-competitive conditions in the structure of the fuel market in Greece.

Given that in Greece the gasoline market is segmented into a refining market, a wholesale market and a retail market, the cause of asymmetric adjustment probably lies in the structure and institutional framework of these three markets. Close monitoring of pricing at a microeconomic level (at the various marketing stages) would be a first step towards identifying the sources of the problem and would lead to the relevant policy suggestions.

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