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Asymmetric price adjustment and the effects of structural reforms and low demand in the gasoline market: the case of Greece

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ABSTRACT

The pricing mechanism in the gasoline market has often been the subject of public debate in Greece during the crisis years. Inefficient pricing could imply oligopolistic practices and losses to consumers' welfare. A way to test for inefficient pricing, is by testing for asymmetries in the adjustment of domestic gasoline prices to world oil price changes. The present paper tests for asymmetric adjustment of gasoline prices to oil price variations in the Greek market and examines whether the structural reforms that took place in the post-2010 period had any impact on the functioning of the market. The analysis applies a consistent threshold cointegration technique and makes use of the most recent observations at the lowest frequency available. The results provide evidence in favour of symmetric behaviour just for the recent period. This may reflect competitive behaviour by suppliers who had to interact in a new institutional framework following the reforms.

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Asymmetry; gasoline; crude oil; threshold cointegration

1. Introduction

An issue that has attracted and continues to attract public attention in a large number of economies is whether retail gasoline prices in the domestic market respond symmetrically to changes in world oil prices, or, in other words, whether domestic retail gasoline prices adjust to both rises and decreases of crude oil prices at the same speed. The issue is commonly known in the literature as the "rockets and feathers" hypothesis, which implies that gasoline prices "shoot up like rockets" and "fall down slowly like feathers" (following Bacon's seminal paper (Bacon, 1991)). From a policy maker point of view, the question is particularly interesting as asymmetry could indicate distortions and lack of competition in the domestic gasoline market (see *inter alia* Borenstein, Cameron, & Gilbert, 1997).[1] Systematic asymmetry in price adjustments could have negative

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[1]Consider a market with a few producers: then, the producers have the incentive to collude in order to maximise their profits. In such an event, during a period of decreasing oil prices, a gasoline price reduction by one producer may be perceived by the others as an aggressive move, which signals the break of the cartel 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 breaking the cartel agreement, companies tend to increase their prices immediately. Consumer search costs could also

consequences for the economy as a whole and a continuing deterioration of consumers' purchasing power to the benefit of producers/suppliers.[2] In such cases, it is crucial that the competition authorities monitor the market, so as to ensure competitive operation to the greatest possible extent (see also Balaguer and Ripollés (2012), Polemis and Fotis (2013) and Asane-Otoo and Schneider (2015) for similar policy implications). This becomes even more crucial in periods of recession when consumers have to deal with a general decline in their incomes and standard of living. The matter has additional implications in economies with a high concentration of suppliers, who have high market power and could thus abuse their dominant position.

The Greek gasoline market is characterised by high concentration: there exist two companies in the refining sector, four large companies in the wholesale market (which have a market share of more than 50%), each of them with a nationwide network of fuel stations.[3] Thus, as might be expected, during the recent years of crisis, the issue of the pricing of gasoline in the Greek market has become a major public issue, and has often been the focus of public debate. Refiners, wholesalers and retailers – essentially the whole oil industry – have been frequently accused of using crude oil price changes to unreasonably increase their margins, by increasing gasoline prices quickly when crude oil prices increase, and adjusting them downwards slowly when crude oil prices decrease.

The issue has been regularly presented in the Greek mass media during the crisis years (see *inter alia* Kathimerini, 2012, 2014; Vima, 2014). The structure of the oil market in Greece has also been the topic of monitoring and research in a number of reports of the Hellenic Competition Commission (HCC), which repetitively stated the need for further liberalisation of the market (see, *inter alia*, Hellenic Competition Committee, 2006, 2007, 2008, 2010, 2012, 2014). It has also been subject of policy recommendations by international organizations (see e.g., OECD, 2013, 2014, 2017) and by the Institutions – the IMF, the European Commission and the European Central Bank (see e.g., (Memorandum of Understanding, 2010), (Memorandum of Understanding, 2012, 2015). Measures towards further liberalisation of the market have repeatedly been among the suggestions and prior actions to be completed for the disbursement of the loans directed to Greece in connection with the three economic programmes of 2010, 2012 and 2015 (~~MoU~~, Memorandum of Understanding, 2010, 2012,, 2015). Following these reports and recommendations, the Greek State started to monitor closely the conditions in all open retail sale markets (including the gasoline market) in 2010 and has taken a number of measures to liberalize the gasoline market since then. Measures which affected the functioning of the market started to be legislated in 2010 in an effort to fulfil the requirements of the first economic

lead to temporary market power of gasoline stations. Search costs (related to the comparison of retail prices by customers) are particularly high, since prices vary very often. In addition, consumers tend to regard some stations as cheap, without verifying their belief prior to every purchase. Service stations could exploit this consumer loyalty by reacting asymmetrically to changes in oil prices.

[2]Nevertheless, asymmetries can arise even in competitive markets: During periods of increasing prices, consumers tend to buy more gasoline, for precautionary reasons, assuming that this upward trend will continue; during periods of decreasing prices, demand does not fall at the same speed, causing asymmetries on the demand side. On the other hand, 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. Refineries are also constrained by production costs and production capacity in the short run which may be another obstacle to fast adjustment of gasoline prices. Finally, in periods of low demand, service stations may decrease faster their prices in order to increase their market shares.

[3]See also the (Hellenic Competition Committee, 2010, 2012).

program for Greece. These included the strengthening of the independence of the HCC, the electronic tracking and monitoring of the fuel market -in an effort to fight black economy phenomena- and the liberalisation in road freight transportation (MoU, Memorandum of Understanding, 2010). On top of the measures towards the gradual liberalisation of the market, the strict monitoring of the market, the publicity that the issue has taken and the decrease in domestic demand during the crisis years may have also affected the pricing strategies of market participants, and the issue is no longer in the media.

The "rockets and feathers" hypothesis has been extensively addressed in the literature for a large number of economies over the last twenty seven years or so. The majority of the studies detect asymmetry in domestic retail price adjustments; see, for instance the summaries contained in, *inter alia*, Polemis (2012), Perdiguero Garcia (2013), Kristoufeck and Lunackova (2015) and Ogbuabor, Orji, Aneke, and Charles (2019). However, not all studies provide the same results. Essentially their findings vary depending on the economy and the period analysed, the size of the sample, the time frequency of the observations, the econometric methodology used and the way asymmetry is defined. More recently, a number of studies on the rockets and feathers hypothesis have attempted to replicate results of previous studies, using mainly more sophisticated econometric techniques (see, *inter alia*, Kristoufeck and Lunackova (2015), Cook and Fosten (201998) and Martín-Moreno, Pérez, and Ruiz (2019).

The evidence in the Greek gasoline market can also be characterised as inconclusive, even though most studies find asymmetric adjustment. Some evidence on the Greek market is reported in studies which cover country groups (Cleridis, 2010; Meyler, 2009; Polemis and Fotis (2013)): Of these, Meyler (2009) and Polemis and Fotis (2013) detect asymmetry in the response of retail fuel prices to cost increases and decreases in Greece, whereas Cleridis (2010) does not find any indications of asymmetric pricing [in the Greek market]. There exists one study which tests for asymmetries exclusively in the Greek oil market: Polemis (2012), uses monthly observations for the period January 1988-June 2006 and applies the Asymmetric Error Correction Model (AECM) technique: He provides evidence of asymmetry in the retail gasoline price adjustments in both the long and the short term, evidence implying poor competition in the oil market in Greece. In a different context, in a paper analysing the determinants of retail gasoline prices in Greece, Angelopoulou and Gibson (2010) examine pricing in the domestic fuel market, using weekly observations for the period November 2004-February 2009. They show that prices adjust symmetrically to world oil prices in the short run, but asymmetrically to tax changes and/or across various regions in Greece. These findings probably reflect the lack of competitive conditions in the Greek market.

Nevertheless, and despite their somewhat inconclusive results, the studies on asymmetric adjustments of gasoline prices in the Greek market share a number of similarities: First, all studies – with the exception of Polemis and Fotis (2013) who use panel cointegration- use the Asymmetric ECM methodology: they first estimate an equilibrium relationship between gasoline and oil prices and then test for asymmetries in the speed of adjustment of the domestically determined gasoline prices towards this equilibrium. Second, the sample periods examined in the studies [extend up to 2011 and thus] do not include the most recent period, which is also characterised by measures to liberalise the gasoline market in Greece.[4] Third, all studies, excluding Polemis and Fotis (2013), use monthly observations.

The present study tests for "rockets and feathers" in the retail gasoline market in Greece, during the period January 2005 – December 2017. The objective is to provide robust evidence in response to public concern and the mixed results provided by the earlier studies. To this end: (i) The study uses all available observations for the variables under consideration. The Greek oil market is analysed using observations of a large sample, which also comprises observations from the market reforming period of the Greek economy. (ii) The paper applies a threshold cointegration approach which identifies two regimes of adjustment, the asymmetric Threshold Auto Regressive (TAR) - ECM technique developed by Enders and Siklos (2001). The TAR-ECM technique has been advocated by the relevant literature to be the most robust econometric method for identifying such kind of asymmetries. The technique rather than fixing the threshold value, above or below which the residuals tend to return to equilibrium, to zero, permits the value of the threshold to be purely determined by the data. Arguments in favour of the threshold cointegration methodology can also be found in a number of recent papers in the relevant literature (see Bermingham and O'Brien (2011), Asane-Otoo and Schneider (2015), Chua, De Silva, and Suardi (2017)). (iii) The study uses observations of the lowest frequency available for gasoline prices in Greece: weekly observations. Since the market prices of gasoline change very often – at least once per week- it is reasonable to assume that the use of weekly observations is more revealing of the practices of the market participants.

An additional issue of interest is whether the more cautious monitoring of the market (as testimonied also by the high frequency of the reports published by the Hellenic Competition Committee (2010, 2012, 2014, 2015)), and the structural reforms which have taken place in the gasoline market after 2010, had any impact on the price setting mechanism in the gasoline market in Greece. The signing of the 1st memorandum in May 2010 can be considered as a significant structural break point, as it signals the commitment from the side of the authorities to proceed with structural reforms in the gasoline market, and may have affected the behaviour of the gasoline market participants. It also marks the start of the Greek crisis: the period following it, is characterised by a severe fall in domestic demand, which may have contributed to a more competitive functioning of the market, as consumers may have started to search for lower prices and firms may have kept low prices in an effort to keep their market shares. Thus, in order to analyse the effects of the reforms in the market in a low demand environment, the present paper tests for asymmetries (i.e., the rockets and feathers hypothesis), for two separate periods, before and after May 2010. In this respect, the approach of the present paper is in line with the approach of Ogbuabor et al. (2019), who test whether the oil-gasoline price relationship in the UK and the US markets changed after the global financial crisis, because of the increased regulation activities in the markets after the crisis. They provide evidence of asymmetric adjustment for both markets even after the crisis and suggest eternal monitoring of the markets by policy makers and regulators. In a similar vein, Asane-Otoo and Schneider (2015), test for asymmetric adjustment in the German oil

[4]More specifically, Meyler (2009), Cleridis (2010), Angelopoulou & Gibson (2010) and Polemis (2012) and Polemis and Fotis (2013) analyse the periods 1994–2008, 2000–2010, 2004–2009, 1998–2006 and 2000–2011, respectively.

market in two separate periods before and after the crisis. According to their analysis, there is no evidence for asymmetric price transmission and consumer welfare losses in the post crisis period in Germany.

The rest of the paper is organised as follows: Section 2 offers a brief description of the gasoline market in Greece. Section 3 presents the econometric methodology. The data and the empirical results are presented in Section 4. The final section summarises and concludes.

2. The Greek 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, the Hellenic Petroleum (ELPE) and MOTOROIL, which own all four refineries operating in Greece.[5] ELPE, having a market share of more than 60%, clearly leads the refining market. Duopoly conditions prevail, with significant barriers to entry for new firms in the market due to the high level of sunk costs. Around twenty companies are active in the wholesale market, some of which are subsidiaries of the refineries. The four larger 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 existed due to regulations on oil stocks.[6] Also, pricing differs across regions: it is not clear how companies set their prices across the different regions in Greece (see also Angelopoulou and Gibson, 2010). In addition, the transportation market (fuel is transported by public- and private-use tanker trucks) in which transport costs are determined is not perfectly competitive. 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. The 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. However, the Greek market is geographically segmented, and competition is determined by the number of stations per geographical area. Moreover, contracts between filling stations and wholesale companies may be restrictive, with an adverse impact on retail prices.

Crude oil prices in the Greek market are derived from the international 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 (final) fuel products, which are then sold initially to wholesale companies, then to service stations, and finally to consumers. Consequently, 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. In detail, the price of gasoline can be decomposed as follows: 65% of it is taxes, 29.4% is the cost of crude oil, and 5.6% is the gross profit rate of marketing companies and service stations.

[5]ELPE is the leading industrial and commercial group in the energy sector. MOTOROIL is the largest privately held industrial complex in Greece.

[6]Wholesale companies can import oil from foreign refineries, as long as they keep buffer stocks that can meet consumption for 90 days.

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.[7] Crude oil prices and the exchange rate are exogenous to the functioning of the Greek fuel market. State duties and taxes raise the price by a specified rate, which is also exogenous to the market forces.[8] Only the mark-up charged by refineries and the profit margins of wholesalers and retailers depend on factors related to domestic market characteristics, such as the market structure, the vertical integration, the geographical distance of regional markets from the refineries and short-term demand fluctuations.

3. The econometric methodology

The empirical work on the "rockets and feathers" hypothesis is based on the ECM methodology (Engle & Granger, 1987). The first step in the methodology is to test for the existence of a long-run equilibrium relationship between international oil prices, R_t^b and the retail gasoline prices in the domestic (Greek) economy, R_t^g, of the form:

$$r_t^g = \gamma_o + \gamma_1 r_t^b + u_t \tag{1}$$

where r_t^b and r_t^g denote the logarithms of R_t^b and R_t^g respectively. γ_0 is a measure which accounts for the fixed cost which comprises all refining, marketing and distribution costs, and γ_1 is a measure for the degree of pass-through in the long run. u_t denotes deviations from equilibrium level.

If both series r_t^b and r_t^g are I(1), Engle and Granger propose to test whether they are cointegrated by testing whether the errors u_t are stationary or not. This can be done by testing the hypothesis Ho: $\rho = 0$ against $\rho < 0$ (the standard Dickey-Fuller tests, Dickey & Fuller, 1979), on an equation of the form:

$$\Delta \hat{u}_t = \rho\, \hat{u}_{t-1} + v_t \tag{2}$$

where Δ denotes the first difference and ρ denotes the speed of adjustment of the deviations to their mean value. In the event that the errors are stationary, they can be used as error correction terms in the short-run dynamic relationship for gasoline prices of the form:

$$\Delta r_t^g = \mu_0 + \sum_{i=1}^{k_1} \beta_{1,i} \Delta r_{t-i}^g + \sum_{i=0}^{k_2} \beta_{2,i} \Delta r_{t-i}^b + a\hat{u}_{t-1} + e_t, \text{where } \alpha < 0 \tag{3}$$

According to (3), in the short run, gasoline price changes Δr_t^g are determined by gasoline price changes in previous periods, $\sum \Delta r_{t-1}^g$, oil price changes in previous periods $\sum \Delta r_{t-1}^b$, and the tendency of gasoline prices to return to their long-run equilibrium, as expressed by $a\hat{u}_{t-1}$. The coefficient a is expected to take negative values: when in period t_{-1} the variable r_t^g deviates from the long-run equilibrium (1), there is a tendency to return to the long-run equilibrium in period t. In other words, when the errors exceed their mean value in period t_{-1}, they tend to move downwards to reach the long–run

[7] Market participants argue that prices are based on the Mediterranean market quotes and an additional mark-up of 3% (see, inter alia, press release by ELPE in *Kathimerini*, 18 September Kathimerini, 2012).

[8] 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.

equilibrium value in period t, whereas when errors are below their mean, they tend to move upwards, to reach the long-run equilibrium value in period t. The coefficient a denotes the speed of adjustment to the long-run equilibrium: higher a values in absolute terms imply faster adjustment to long-run equilibrium.

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

The assumption (c) of the dependent variable's symmetric adjustment to long-run equilibrium has been questioned in the literature. The Asymmetric ECM model (AECM) divides errors into positive u_t^+ and negative u_t^- deviations of r_t^g from equilibrium. The error correction term $\hat{u}_{t-1}$ is defined as $\hat{u}_{t-1}^+ = I_t u_{t-1}$where I_t depends on whether $\hat{u}_{t-1} \geq 0$ and $\hat{u}_{t-1}^- = I_t u_{t-1}$where I_t hinges on whether $\hat{u}_{t-1} < 0$. The AECM is specified as follows:

$$\Delta r_t^g = \mu_0 + \sum_{i=1}^{k_1} \beta_{1,i} \Delta r_{t-i}^g + \sum_{i=0}^{k_2} \beta_{2,i} \Delta r_{t-i}^b + a_1 \hat{u}_{t-1}^+ + a_2 \hat{u}_{t-1}^- + e_t \tag{4}$$

where a_1<0 and a_2<0. Specification (4) assumes that the adjustment speed is a_1 for negative deviations and a_2 for positive ones. A first indication of asymmetric adjustment comes up when the estimated values of a_1 and a_2 are not equal. The AECM specification allows for a statistical test for the symmetry hypothesis (that the coefficients are equal) $H_0 : a_1 = a_2$.

Nevertheless the AECM has been shown to be statistically invalid, in cases for which 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, (i.e., the assumption (b) does not hold) the auxiliary equation (2) for cointegration tests is miss-specified and could lead to misleading results. To tackle this problem, Enders and Granger (1998) and Enders and Siklos (2001) propose the asymmetric TAR cointegration technique as the adequate and statistically robust technique to be used when testing for asymmetric adjustment. This is the methodology applied in the present paper. According to it, unit root tests should also take into account the possibility that the residuals (deviations) return to the long-run equilibrium value with different speed, depending on whether their value is higher or lower than a threshold value $\hat{\tau}$, which does not necessarily equal zero.

The TAR model can be written as follows:

$$\Delta \hat{u}_t = I_t \rho_1 \hat{u}^{up}{}_{t-1} + (1 - I_t) \rho_2 \hat{u}^{down}{}_{t-1} + v_t \tag{5}$$

where $\hat{u}_t$ are the residuals of the long-run equation (1). The indicator function I_t depends on the lagged values of the residuals, according to the following scheme:

$$I_t = \begin{cases} 1 \text{if} \hat{u}^{up}{}_{t-1} \geq \hat{\tau} \\ 0 \text{if} \hat{u}^{down}{}_{t-1} < \hat{\tau} \end{cases} \tag{6}$$

The TAR cointegration model assumes that the residuals adjust at a speed ρ_1 when their values are above the threshold value $\hat{\tau}$ and at a speedρ_2 when their values are below$\hat{\tau}$. The TAR model is designed to capture potential asymmetric "deep" movements in the residuals. Negative "deepness" (i.e., $\rho_1 \leq \rho_2$) of $\hat{u}_t$ implies that increases tend to persist, whereas decreases tend to revert quickly towards equilibrium.

The threshold parameter does not need to be restricted to zero, as instead is assumed in model (4). If the threshold enters the model unrestrictedly, the problem of how to consistently estimate the threshold, or attractor, emerges. The crucial point in the TAR methodology is to identify correctly the threshold value $\hat{\tau}$, for which the asymmetric adjustment is statistically significant.[9] Enders and Siklos (2001) propose the "Chan's approach" (1993) for searching a consistent method to detect $\hat{\tau}$ among all residual values resulting from the cointegration relationship. According to this method, a search procedure over all possible values of the attractor in order to minimize the sum of squared residuals yields a super-consistent estimator of the threshold.

When the existence of a threshold autoregressive cointegration is identified, errors can be discerned into those which take a value higher than $\hat{\tau}$ and those which take a value lower than $\hat{\tau}$. In such a case, an Asymmetric ECM can be estimated as follows:

$$\Delta r_t^g = \mu_0 + \sum_{i=1}^{k_1} \beta_{1,i} \Delta r_{t-i}^g + \sum_{i=0}^{k_2} \beta_{2,i} \Delta r_{t-i}^b + a_3 \hat{u}_{t-1}^{up} + a_4 \hat{u}_{t-1}^{down} + e_t \quad (7)$$

where $\hat{u}_{t-1}^{up}$= $I_t\hat{u}_{t-1}$ και $\hat{u}_{t-1}^{down}$ = (1-I_t)$\hat{u}_{t-1}^{down}$ and a_3<0 and a_4<0. In (7), the $\hat{u}_{t-1}$ deviation values are split into $\hat{u}_{t-1}^{up}$ and$\hat{u}_{t-1}^{down}$, which represent deviations over and below the threshold value $\hat{\tau}$, respectively. Thus, (7) provides the basis to test the hypothesis $a_3 = a_4$, which expresses the dependent variable's symmetric adjustment to equilibrium. Enders and Siklos (2001) provide the empirical critical values t-max and Φ^* for testing cointegration on these hypotheses since the tests do not follow a standard distribution, and propose a Wald-type statistical test to determine whether the residuals' adjustment is symmetric.

In addition, in order to test whether gasoline prices respond asymmetrically to short-run variations of world oil prices, first differences on the oil price changes can be decomposed into positive and negative values. Model (7) can be written as:

$$\Delta r_t^g = \mu_0 + \sum_{i=1}^{k_1} \beta_{1,i} \Delta r_{t-i}^g + \sum_{i=0}^{k_2} \beta_{2,i}^+ \Delta r_{t-i}^{b^+} + \sum_{i=0}^{k_2} \beta_{2,i}^- \Delta r_{t-i}^{b^-} + a_3 \hat{u}_{t-1}^{up} + a_4 \hat{u}_{t-1}^{down} + e_t \quad (8)$$

At the extended specification (8) of model (7), short-run asymmetry is captured by decomposing the first differences into $\Delta r_{t-i}^{b^+} \geq 0$ and$\Delta r_{t-i}^{b^-}$< 0, where i =0, …, k_2. In other words, $\beta_{2,i}^+$ and $\beta_{2,i}^-$ provide estimates of the different speed of adjustment of the gasoline prices to increases and decreases in Brent oil prices. To test for short-run asymmetries, the total impact of the significant$\beta_{2,i}^+$'s should be compared with the total impact of the significant$\beta_{2,i}^-$'s.

[9]In its simplest version, the TAR model hypothesises that $\hat{\tau}$= 0. This means that positive and negative deviations from equilibrium are assumed to be corrected at different adjustment speeds.

Essentially, in the present paper asymmetric adjustment is examined by testing: (i) whether the residuals respond asymmetrically to deviations from their equilibrium value (ii) whether the gasoline prices (the dependent variable) adjust symmetrically to the long-run equilibrium relationship between oil and gasoline prices and (iii) whether gasoline prices respond with the same speed to positive or negative changes of the oil prices in the short-run.

4. Empirical results

4.1. The dataset-unit root tests

The study uses weekly observations for the period January 2005 – December 2017. Data on retail gasoline prices R_t^g are taken from the European Commission *Oil Bulletin*.[10] The analysis focuses on the pre-tax price series of the 95-octane unleaded gasoline.[11] The crude oil prices series,R_t^b, refers to Brent crude oil spot prices series (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. The graphs of the variables are presented in Figure 1.

Analysis is initially performed for the full sample period. Then, in order to investigate any effects coming from the liberalisation of the Greek gasoline market, analysis is performed separately for the pre-crisis (and pre-reform) period Jan 2005 – April 2010, period A, and the crisis (and post-reform) period May 2010-December 2017, period B.

The first step in the empirical work is to test the series r_t^b and r_t^g for unit roots in the three periods. The D-F (Dickey & Fuller, 1979) and DF-GLS (Elliott, Rothenberg, & Stock, 1996) tests are applied. The results are presented in Table 1. The findings show that both series are *I(1)* for all three periods: the hypothesis of the existence of a unit root

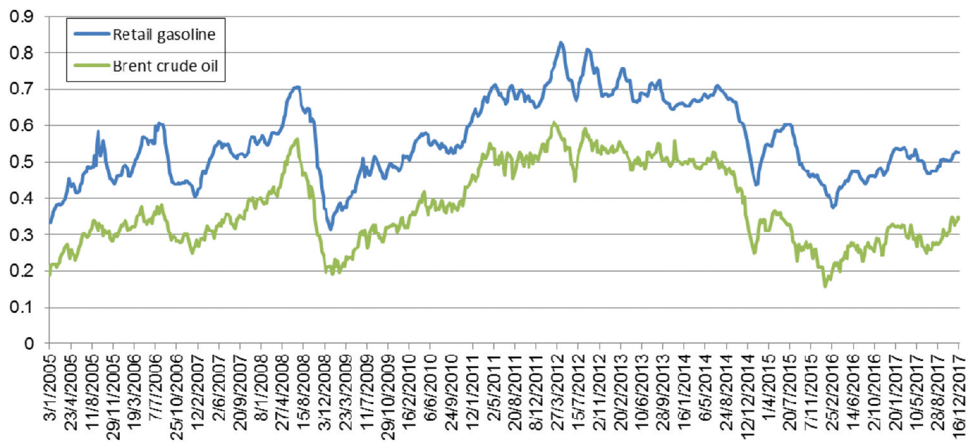

Figure 1. Weekly retail gasoline (R_t^g) and crude oil (R_t^b) prices (Euro/liter).

[10]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.

[11]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.

cannot be rejected for the series in levels, but is rejected for the series in their first differences.

4.2. The standard cointegration analysis

Based on the results of the unit root tests, the next step of the analysis is to investigate whether the two I(1) series cointegrated in a long–run relationship, of the form of equation (1). The analysis is performed for the three different periods. The results of the Engle-Granger cointegration tests (t-statistic and z-statistic) are presented in Table 2.

For the full sample period, the results indicate that there exists a cointegrating relationship between the series, of the form:

$$r_t{}^g = 0.1 + 0.6\ r_t{}^b + u_t \tag{9}$$

According to (9), the long-run oil price elasticity of domestic gasoline prices, γ_1, is 0.6. This means that a 10% change (rise or fall) in crude oil prices causes a 6% change (increase or decrease, respectively) in retail gasoline prices. For the period A, the long–run relationship takes the form

$$r_t{}^g = 0.1 + 0.7\ r_t{}^b + u_t, \tag{10}$$

whereas, in period B the gasoline prices – oil prices relationship, becomes:

$$r_t{}^g = 0.1 + 0.6\ r_t{}^b + u_t \tag{11}$$

However, as already indicated in section 4, the Engle and Granger approach assumes: (i) symmetric adjustment of the error term to its mean value; (ii) the mean value of the error terms to equal to zero; and (iii) a symmetric ECM. Thus, the Engle -Granger approach has been shown to be statistically invalid in cases for which asymmetric adjustment is detected. The three assumptions have to be tested applying the Asymmetric TAR model with estimated threshold $\hat{\tau}$. The tests are performed in the following subsection.

4.3. TAR cointegration (with τ threshold estimation)

The Enders and Siklos methodology which tests for cointegration with a consistent estimation of the threshold, is pursued for the three periods. The results of the Asymmetric TAR cointegration models are presented in Table 3.

The results for the whole period provide evidence in favour of the existence of a long-run relationship between oil prices and retail gasoline prices. They also indicate that the speed of adjustment changes when the residuals are above or below a threshold, which is consistently estimated to equal $\hat{\tau}$=−0.062. In addition, the hypothesis for the absence of threshold cointegration [H_0: $\rho_1 = \rho_2 = 0$] is rejected based on the Φ^*statistic value. According to the estimated results, the coefficients ρ_1 and ρ_2 take different values ($\rho_1 = -0.15$ and $\rho_2 = -0.28$), which also turn out to be statistically significant. In other words, the TAR results indicate that when the system deviations from the long-run equilibrium take values higher than the threshold $\hat{\tau}$, adjustment to equilibrium takes place slowly (at a speed of $\rho_1 = -0.15$), whereas when the deviations take values lower than the threshold,

Table 1. Unit root tests ADF, PP and DF-GLS.

Sample period												
Variables	rb	Δ(rb)	rg	Δ(rg)	rb	Δ(rb)	rg	Δ(rg)	rb	Δ(rb)	rg	Δ(rg)
Augmented Dickey-Fuller (ADF)												
Constant	−2.642	−21.858**	−3.181	−16.292**	−2.425	−16.536**	−3.027	−11.375**	−1.452	−19.846**	−1.835	−10.420**
Constant and Trend	−2.589	−25.864**	−3.040	−16.323**	−2.349	−16.507**	−3.014	−14.381**	−2.150	−19.823**	−2.651	−10.412**
No Constant, No Trend	−1.198	−25.872**	−1.431	−16.295**	−1.405	−16.525**	−1.383	−14.358**	−0.250	−19.872**	−0.448	−10.432**
Phillips-Perron (PP)												
Constant	−2.706	−25.848**	−3.201	−16.637**	−2.521	−16.536**	−2.906	−11.811**	−1.422	−19.846**	−1.609	−10.339**
Constant and Trend	−2.649	−25.855**	−3.063	−16.664**	−2.455	−16.509**	−2.844	−11.816**	−2.137	−19.833**	−2.404	−10.326**
No Constant, No Trend	−1.198	−25.861**	−1.422	−16.640**	−1.370	−16.526**	−1.342	−11.799**	−0.330	−19.872**	−0.370	−10.352**
Detrended Residuals (DF-GLS)												
Constant	−0.738	−0.967**	−0.783	−15.983**	−0.254	−1.108**	−0.877	−11.178**	−1.390	−1.230**	−1.843	−9.730**
Constant and Trend	−1.139	−2.772**	−1.606	−16.140**	−1.401	−2.248**	−2.038	−11.297**	−1.741	−2.670**	−1.998	−10.291**

Note 1: ** Denotes rejection of null hypothesis at significance level of 5%.
Note 2: In the ADF tests, the Schwarz Information Criterion is used to determine the optimal lag length of each test equation.
Note 3: In the PP tests we control the bandwidth using the Newey-West bandwidth selection method and the Bartlett kernel.

Table 2. Engle and Granger (E-G) cointegration tests.

Sample period	Full period	Pre-reforms period (A)	Post-reforms period (B)
Number of observatons (n)	640	262	378
Fully Modified Least Squares (FMOLS)			
γ_0	0.055	0.114**	0.013
	(1.823)	(2.666)	(0.503)
γ_1	0.638**	0.715**	0.574**
	(22.289)	(19.304)	(21.761)
R^2	0.899	0.883	0.917
Standard error of regression	0.061	0.054	0.052
Long-run variance	0.044	0.016	0.025
Engle-Granger tests			
t-statistic	−6.426**	−7.348**	−6.084**
z-statistic	−84.770**	−89.705**	−67.216**

Note 1: t-statistics values in parentheses.
Note 2: ** Denotes rejection of null hypothesis at significance level of 5%.

Table 3. Enders – Siklos (E-S) tests for TAR cointegration.

TAR models								
Sample period			Full period		Pre-reforms period (A)		Post-reforms period (B)	
Consistent threshold value			−0.062		−0.061		−0.029	
		ρ_1	−0.154**		−0.281**		−0.204**	
		t-Max test	(−5.522)	[0.000]	(−5.086)	[0.000]	(−5.400)	[0.000]
		ρ_2	−0.286**		−0.528**		−0.148**	
		t-Max test	(−7.038)	[0.000]	(−6.191)	[0.000]	(−3.126)	[0.001]
Test for threshold cointegration	$\rho_1 = \rho_2 = 0$	Φ test	Φ (2,636) 40.014**	[0.000]	Φ (2,257) 32.348**	[0.000]	Φ (2,375) 19.469**	[0.000]
Test for symmetry	$\rho_1 = \rho_2$	Standard F test	F(1,636) 7.150**	[0.007]	F(1,257) 6.163**	[0.013]	F(1,375) 0.839	[0.360]

Note 1: t-statisstics values in parentheses.
Note 2: p-values in brackets.
Note 3: ** Denotes rejection of null hypothesis at significance level of 5%.
Note 4: Φ(κ,T-κ) empirical critical values for Enders and Siklos tests are taken from Enders and Siklos (2001) and Wane, Gilbert, and Dibooglu (2004).
Note 5: The Akaike (Akaike (1969)) and the Schwarz (Schwarz (1978))Information Criteri are used to determine the optimal lag length of each test equation.

adjustment to equilibrium is fast (at a speed of $\rho_2 = -0.28$). In addition, the hypothesis of equal adjustment coefficients $\rho_1 = \rho_2$ is rejected based on the Wald test statistic value (F (1,636) = 7.15, P-value = 0.007)). Thus, based on the outcomes, the "feathers and rockets" phenomenon characterises the Greek market during the whole period analysed: There is evidence that deviations from the equilibrium relationship adjust with a different speed depending on whether they take values above or below a threshold value. They adjust slowly when they have values higher than their equilibrium values and fast when they obtain values lower than their equilibrium values.

The analysis of the two sub-periods provides additional information on the functioning of the market before and after the reforms. The results on periods A and B, provide evidence in favour of the existence of a long-run relationship between oil prices and retail gasoline prices, for consistently estimated threshold values of $\hat{\tau}$ ($\hat{\tau}$is estimated to equal −0.061 for period A and −0.029 for period B). In addition, the hypothesis for the absence of threshold cointegration [H_0: $\rho_1^{up} = \rho_2^{down} = 0$] is rejected for the two periods, based on the Φ*statistic value. Thus, the TAR-ECM methodology which advocates a consistent estimate of $\hat{\tau}$different to zero, turns out to be the appropriate to test for asymmetries in periods

A and B. The estimated adjustment coefficients ρ_1 and ρ_2 do not equal each other in the two periods ($\rho_1 = -0.28$ and $\rho_2 = -0.53$ for period A and $\rho_1 = -0.20$ and $\rho_2 = -0.14$ for period B).

For period A the symmetry hypothesis (the hypothesis of equal adjustment coefficients $\rho_1 = \rho_2$) is rejected based on the Wald test statistic value (F (1,257) = 6.163, P-value = 0.013)). However, it is not rejected for the post-reforms period B (F (1,375) = 0.83, P-value = 0.36)). The results indicate that the market has been functioning efficiently in the post reform period but not before. They probably reflect more competitive behaviour by suppliers who had to interact in a new institutional market framework following the reforms, and in an effort to keep their market shares, in an environment of weak demand. Still, in order to come to clear conclusions about the functioning of the market in period B, further empirical testing is needed to examine whether domestic prices adjust with the same speed to deviations above or below their equilibrium value as estimated by their long-run relationship of the form of (1).

4.4. The asymmetric ECM with TAR cointegration (with τ threshold estimation)

The existence of TAR cointegration allows for the estimation of an asymmetric ECM of the form of (7) or (8). Analysis is applied for all three periods. The results are presented in Table 4 and Table 5. According to the results, the hypothesis of symmetric adjustment of gasoline prices is rejected for the full period and the pre-reforms period A.

The results differ for the post reforms period B, for which symmetry is found for the adjustment process to deviations from the consistent threshold value. According to the results, changes in gasoline prices in the current period (week) are determined by: (a) gasoline price variations one and four weeks ago; (b) oil prices changes one and two weeks ago; and (c) the long-run equilibrium relationship. The error correction terms are statistically significant, with different (unequal) adjustment speeds, $a_3 = -0.07$ and $a_4 = -0.09$. Nevertheless, the symmetry hypothesis cannot be rejected based on the relevant Wald test statistic. The null hypothesis on the equality of adjustment coefficients is not rejected at a 5% level of significance [F (1,370) = 0.981, P-value = 0.322)]. The results indicate that adjustment to the equilibrium is symmetric, or in other words, that the *rockets and feathers* hypothesis does not hold in the most recent period in Greece. In other words, they provide strong support of symmetric adjustment of domestic prices to crude oil prices in the Greek market in the post-reforms period.

The results of the tests which examine asymmetries in the adjustment of gasoline prices to increases and decreases of world oil prices in the short run (based on the specification (8)) are presented in Table 5.

They provide evidence in favour of symmetric adjustment in all cases. In the short run, the total adjustment of gasoline prices to positive changes of crude oil prices as estimated by ($\beta^+_{2,1}+\beta^+_{2,3}$) turns out to be equal to the adjustment to negative changes of crude oil prices, ($\beta^-_{2,1}+\beta^-_{2,4}$), for the three periods, as indicated by the respective F statistics. Nevertheless, the findings on the long-run asymmetry remain valid.

Table 4. Asymmetric ECM with TAR cointegration without short-run asymmetries.

Sample period		Full period			Pre-reforms period (A)			Post-reforms period (B)		
HAC standard errors and covariance			t-statistic	p-value		t-statistic	p-value		t-statistic	p-value
Constant	μ_0	−0.001	(−0.1367)	[0.171]	−0.001	(−0.510)	[0.610]	−0.001	(−0.547)	[0.584]
$\Delta(r^9)_{t-1}$	$\beta_{1,1}$	0.237**	(4.036)	[0.000]	0.199**	(2.397)	[0.017]	0.362**	(9.199)	[0.000]
$\Delta(r^9)_{t-4}$	$\beta_{1,4}$	0.084**	(2.517)	[0.012]	0.118**	(2.572)	[0.010]	0.063*	(1.832)	[0.067]
$\Delta(r^b)_{t-1}$	$\beta_{2,1}$	0.184**	(8.273)	[0.000]	0.190**	(4.104)	[0.000]	0.142**	(8.750)	[0.000]
$\Delta(r^b)_{t-2}$	$\beta_{2,2}$	0.131**	(5.796)	[0.000]	0.161**	(3.936)	[0.000]	0.076**	(4.590)	[0.000]
$\hat{u}_{t-1}$ *up*	a_3	−0.058**	(−2.749)	[0.006]	−0.138**	(−2.958)	[0.003]	−0.070**	(−3.503)	[0.000]
$\hat{u}_{t-1}$ *down*	a_4	−0.152**	(−5.311)	[0.000]	−0.287**	(−4.994)	[0.000]	−0.099**	(−3.899)	[0.010]
Test for symmetry	$a_3 = a_4$	F(1,628) 8.471**		[0.003]	F(1,250) 5.883**		[0.016]	F(1,370) 0.981		[0.322]
Findings		Asymmetric adjustment			Asymmetric adjustment			Symmetric adjustment		

Note 1: t-statisstics values in parentheses.
Note 2: p-values in brackets.
Note 3:** Denotes rejection of null hypothesis at significance level of 10%.
Note 4:** Denotes rejection of null hypothesis at significance level of 5%.

Table 5. Asymmetric ECM with TAR cointegration with short-run asymmetries.

Sample period		Full period			Pre-reforms period (A)			Post-reforms period (B)		
HAC standard errors and covariance			t-statistic	p-value		t-statistic	p-value		t-statistic	p-value
Constant	μ_0	0.001	0.0406	[0.684]	0.001	(−0.203)	[0.839]	0.001	(0.010)	[0.991]
$\Delta(r^9)_{t-1}$	$\beta_{1,1}$	0.230**	(3.887)	[0.000]	0.197**	(2.375)	[0.018]	0.358**	(8.915)	[0.000]
$\Delta(r^9)_{t-4}$	$\beta_{1,4}$	0.082**	(2.491)	[0.013]	0.122**	(2.579)	[0.010]	0.059*	(1.681)	[0.093]
$\Delta(r^b)^+_{t-1}$	$\beta^+_{2,1}$	0.182**	(6.252)	[0.000]	0.211**	(3.409)	[0.000]	0.128**	(4.632)	[0.000]
$\Delta(r^b)^-_{t-1}$	$\beta^-_{2,2}$	0.191**	(5.872)	[0.000]	0.172**	(3.145)	[0.001]	0.156**	(5.890)	[0.000]
$\Delta(r^b)^+_{t-2}$	$\beta^+_{2,3}$	0.090**	(3.823)	[0.000]	0.104*	(1.813)	[0.071]	0.073**	(2.827)	[0.004]
$\Delta(r^b)^-_{t-2}$	$\beta^-_{2,4}$	0.171**	(4.004)	[0.000]	0.213**	(2.887)	[0.004]	0.078**	(2.864)	[0.004]
$\hat{u}_{t-1}\ up$	a_3	−0.053**	(−2.479)	[0.013]	−0.138**	(−2.934)	[0.003]	−0.067**	(−3.283)	[0.001]
$\hat{u}_{t-1}\ down$	a_4	−0.156**	(−5.095)	[0.000]	−0.281**	(−4.756)	[0.000]	−0.102**	(−3.949)	[0.000]
Test for short-run asymmetry	$\beta^+_{2,1} + \beta^+_{2,3} = \beta^-_{2,2} + \beta^-_{2,4}$	F(1,626) 1.575**		[0.209]	F(1,248) 0.286**		[0.593]	F(1,368) 0.350**		[0.554]
Test for long-run asymmetry	$a_3 = a_4$	F(1,626) 7.911**		[0.005]	F(1,248) 4.837**		[0.028]	F(1,368) 1.059		[0.303]
Short-run findings		Symmetric adjustment			Symmetric adjustment			Symmetric adjustment		
Long-run findings		Asymmetric adjustment			Asymmetric adjustment			Symmetric adjustment		

Note 1: t-statisstics values in parentheses.
Note 2: p-values in brackets.
Note 3:* Denotes rejection of null hypothesis at significance level of 10%.
Note 4:** Denotes rejection of null hypothesis at significance level of 5%.

5. Conclusions

The pricing behaviour of the participants in the gasoline market has often been the subject of public debate in Greece during the crisis years. Asymmetric response of the gasoline prices to variations in world oil prices could indicate market power abuse (on the part of suppliers) to the loss of consumers, in a non-competitive market. The present paper investigates the possible existence of asymmetries in the adjustment of gasoline prices to oil price variations, in the Greek gasoline market, thus contributing to the relevant literature. It also examines whether the structural reforms that took place in the gasoline market, the more cautious monitoring of the market and the fact that suppliers had to interact in a low demand environment in the post-2010 period, had any impact on the functioning of the market.

To this end, the present study: (1) Applies an asymmetric Threshold Auto-Regressive cointegration technique, the TAR-ECM technique, which tests for asymmetric adjustment to the long run equilibrium. The technique is advocated by the literature as the most robust econometric method for identifying such kind of asymmetries. (2) Uses a long data sample, which includes all available observations. Thus, it provides recent empirical evidence, given that the existing empirical literature predates 2011. (3) Uses data observations at the lowest frequency available: weekly. Since the market prices of gasoline change very often – at least once per week- it is reasonable to assume that the use of weekly observations is more revealing about the practices of the market participants

From an econometric point of view, asymmetric adjustment has been examined by testing: (i) Whether deviations of the error correction terms above or below their equilibrium value have adjusted symmetrically. (ii) Whether gasoline prices (the dependent variable) have adjusted symmetrically to the long-run equilibrium relationship between oil and gasoline prices. (iii) Whether gasoline prices have responded symmetrically (with the same speed) to oil price changes in the short run.

The econometric analysis tests for asymmetric evidence in three different periods: the full period and the periods before and after the implementation of structural reforms in the market. The pre-reforms period is characterised by asymmetric adjustment, evidence, which seems to dominate the results for the whole period. Prices tend to adjust faster when they are below their equilibrium value than when they are above it. The results are in line with most of the existing studies, which use data for this particular period- see Meyler (2009), Angelopoulou and Gibson (2010), Polemis (2012) and Polemis and Fotis (2013).

Turning to the most recent crisis and post-reforms period, the results provide evidence in favour of symmetric behaviour, notwithstanding the high concentration of suppliers in the market. This could be due to the change of the behaviour of the market participants, as a result of the new institutional framework, following the structural measures that were legislated. Thus, the findings may indicate that the new regulatory framework and measures managed to control the oligopolistic (market colluding, asymmetric) practices of the past. Nevertheless, the results may also reflect effects of the conditions of low income and low demand, which characterise the crisis years: On the one hand, the dramatic fall in income may have pushed consumers to search more thoroughly for oil stations with low prices. On the other hand, gasoline suppliers may have kept prices low and have reacted in a symmetric way, in an effort not to lose their market share. Additionally, the systematic investigation of the market conditions and regulations by the HCC and the publicity that the matter has taken may have also played an important role for the change in the practices of the market participants. A natural extension of the present work would be to identify which (the market structure or the search behavior of the consumers) is the driving force for the symmetric pricing after the reforms, but it is beyond the scope of the present paper.[12]

The main conclusion from the analysis is that, in the post-reforms period the gasoline market shows no signs of asymmetric pricing and that thus the market appears to be competitive, despite its oligopolistic structure. Consequently, the consumer welfare losses from a negative asymmetry are insignificant at present. The findings probably suggest that the new regulatory framework, the cautious monitoring of the market and the low income conditions which have affected the consumers' search behaviour have been capable of controlling oligopolistic practices that were there in the past. Nevertheless, the HCC should continuously monitor the market in an effort to ensure price transparency and prevent oligopolistic practices in the future.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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[12]A way to examine whether pricing dynamics are driven by the supply or demand side, would be to exploit the geographic variations in Greece: mainland vs. islands, in the spirit of Hong and Lee (2018). The asymmetric pricing would be greater in islands (sellers are less competitive) than the mainland because of the geographic separation. Nevertheless, the existing data on the different prefectures of Greece do not cover the period under consideration in the present paper, so this type of analysis is proposed for future research.

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