International Oil Price and Domestic Refinery Price: Empirical Evidence for Greece

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Abstract: - Fuel prices and the pronounced fluctuations in the international oil market are among the most widely discussed topics worldwide. Recent international developments, including energy crises, have resulted in a substantial surge in global oil prices, leading to price increases across all countries and in all petroleum products. This paper investigates the correlation between international oil prices and refining costs in Greece. More specifically, this study focuses on how rapidly refinery prices respond to potential increases or decreases in the international oil price, commonly known as the 'Rockets and Feathers' phenomenon. The investigation assesses the reaction of diesel and gasoline refinery prices to fluctuations in the international oil price and explores the potential presence of asymmetry. The econometric model employed is based on an asymmetric error correction model, utilizing weekly data spanning from 2013 to 2022 for Greece. According to our findings, both diesel and 95-octane gasoline prices exhibit an asymmetric response to international oil prices. Notably, refinery prices react more promptly to price increases than to decreases in the global oil price. This study holds particular significance, as this delay is reflected in final retail prices, indicating the possible existence of pricing asymmetries. Additionally, the issue of oil purchase contracts arises, which guarantee a fixed price regardless of the prevailing international oil price at the time and, consequently, do not justify such fluctuations in refinery prices. These findings could prove valuable for competition policy within Greece's vertical oil market.

Key-Words: - Gasoline price, diesel price, asymmetric responses, Rockets and Feathers phenomenon, OLS, ECM AECM.

Received: April 17, 2023. Revised: November 9, 2023. Accepted: November 22, 2023. Published: December 1, 2023.

1 Introduction

Fuel prices, especially those derived from fossil fuels like oil, constitute a significant concern for both the global economy and individual countries. Over the years, it has been demonstrated that fuel prices within each country are directly influenced by fluctuations in international oil prices. In many cases, these fluctuations manifest in the final fuel prices. In essence, it has been observed that fuel prices in numerous countries often exhibit a swifter response to rising international oil prices than to decreases, prompting valid inquiries into fiscal policy matters. This phenomenon is commonly referred to as the 'Rockets and Feathers' phenomenon, [1].

In recent years, there has been a growing body of literature exploring the issue of asymmetric price responses, specifically focusing on the uneven reactions of domestic retail gasoline and diesel prices to changes in the international oil price, [2], [3], [4], [5]. Related articles quite well known are [6], [7], [8], [9], [10].

The same applies to studies on Greece regarding issues related to the asymmetric price response in the oil sector. Numerous studies are exploring the potential existence of asymmetries in the oil industry, considering the retail price of gasoline, [11], [12], [13], [14]. However, an asymmetric price response can occur both at the refining stage (refinery prices) and at the wholesale stage (wholesale prices).

The purpose of this research is to study the price responsiveness in the petroleum sector, specifically focusing on the refining stage, providing a different perspective on the issue with more recent data. This study offers an innovative perspective by examining the possibility of an asymmetrical price response occurring at an earlier stage, specifically within the refining process. To elaborate, the journey of oil within the country involves its importation to refineries, subsequent introduction into the wholesale market, and eventual retail sales. Most studies primarily focus on the result, which is the retail fuel price in relation to the international oil price, with only a handful examining the international oil price concerning prices of other stages as, [12], [15].

In this paper, we investigate the response of domestic refining prices for both gasoline and diesel concerning the international oil price, taking into account the constrained profit margin of gasoline sellers. This research contributes significantly to the existing literature for several reasons. Firstly, it encompasses a ten-year period, utilizing weekly data published by the Ministry of Development and Competitiveness. Although the main contribution diverges in its approach, as few existing studies concentrate on refining prices instead of retail prices. More specifically, most studies focus on examining the possible asymmetric response of retail fuel prices. However, in this research, we chose to investigate the possibility of asymmetry in refinery prices. Additionally, this research covers a critical timeframe within the energy sector, notably the fuel sector, marked by the energy crisis. Over the last decade, the study spans global economic shocks, particularly those stemming from the health crisis induced by the coronavirus and the war in Ukraine, both of which directly impacted fuel prices.

The structure of this paper is organized as follows: the second section presents an overview of the country's oil sector, followed by a literature review in the subsequent section, and the methodology section. Section five delves into data analysis and research findings, with the final section presenting the concluding remarks.

2 Literature Review

In recent years, there has been a growing body of research examining the phenomenon of asymmetric price responses in the petroleum products sector. The frequent and sharp fluctuations in international oil prices have had a significant impact on delayed price adjustments in many countries, often to the detriment of social well-being. [1], coined this phenomenon as the 'Rockets and Feathers' effect when studying the United Kingdom's wholesale and retail prices. In the case of the United States, various studies, including those by, [6], [9], [10], have explored gasoline prices, each considering different time periods, yielding varying results regarding the presence or absence of asymmetry.

Expanding the scope to include other oil derivatives, [16], [17], conducted research with U.S. data. In [16], the author examines the retail prices of gasoline and diesel, while, [17], looked at both wholesale and retail prices for gasoline and heating oil.

The existence of an asymmetric response of domestic fuel prices to international oil prices has been extensively studied in the case of Greece. In, [18], the authors utilized monthly data for Greece and demonstrated a significant response of domestic prices to changes in international oil prices. In, [19], the authors also studied the Greek case using monthly data, while in, [20], employing a TAR-ECM model, found an asymmetric response of gasoline retail prices to oil price changes, a conclusion that was also supported by, [13], using an ECM model. Furthermore, [12], differentiated their study by considering the entire supply chain, encompassing both refining and retail aspects within Greece's fuel sector.

Common methodologies employed in these studies typically include the Error Correction Model (ECM) as seen in, [5], [21], [22]. TAR-ECM models, such as that used by, [20], and Vector Autoregressive Models (VAR), as seen in, [23], [24], are also frequently employed. In cases involving multiple regions, models like the Asymmetric Spatial Error Correction Model, [4], Panel ECM, [25], and Panel Regression, [26], are utilized.

While the number of studies focusing on the asymmetric response of refinery prices to fluctuations in international oil prices is limited, they significantly contribute to the literature and offer valuable insights preceding the study of retail fuel prices. In, [27], employed an asymmetric error correction model to investigate China's case, specifically examining the relationship between wholesale gasoline and diesel prices and international oil prices. The study, [28], extended this exploration to China's retail gasoline prices, considering legislative factors and the origin of refining.

3 Methodology

The empirical analysis in this study aims to investigate the correlation between international oil prices and the refinery prices of gasoline and diesel. The empirical analysis of this research is based on the methodology of the Error Correction Model (ECM), [29], and more specifically, it applies the Asymmetric Error Correction Model (AECM), as [7], [30].

The analysis is based on the following steps:

1. The determination of Long-run relationship
The first step in our analysis is to determine the long-run relationship between markets and more specifically between international oil price $r_t^{Brent}$and the refinery oil prices (gasoline and diesel) in Greece $r_t^{gasoline\_ref.}$ and $r_t^{Diesel\_ref.}$, respectively. For the regression analysis, we use the ordinary least squares (OLS) to explain the empirical relationship between the prices of gasoline and diesel and the stock price of Brent. The long-run relationship, as described above, is based on the following reduced-form equation:

$$r_t^{gasoline\_ref.} = \beta_0 + \beta_1 r_t^{Brent} + u_t \quad (1)$$

$$r_t^{Diesel\_ref.} = \beta_0 + \beta_1 r_t^{Brent} + u_t \quad (2)$$

Where $r_t^{gasoline\_ref.}$ and $r_t^{Diesel\_ref.}$ are the logarithms of gasoline and diesel refinery prices, respectively. The parameter β_0 is the constant term and β_1 is defined as the effect of the oil price on the gasoline and diesel refinery prices in the long run, respectively.

2. Unit Root and Cointegration Analysis
The second objective is to assess the stationarity of time series data, and our observation indicates that the series exhibits I (1) properties. Consequently, we employ the first differences of variables, as suggested by, [31], [32]. Subsequently, we investigate the presence of cointegration between refinery prices and commodity stock prices. Our findings reveal that both refinery gasoline and diesel prices are cointegrated with Brent crude oil prices, as established by, [33].

To estimate short-run and long-run elasticities, we follow the two-step methodology outlined by, [29], which involves estimating an Error Correction Model (ECM). The ECM is essentially a basic Vector Autoregressive (VAR) model with an error correction term integrated into it. To identify any asymmetries in the relationship between the future crude oil market and refinery prices of gasoline and diesel in Greece, we employ an asymmetric error correction model (AECM).

3. The estimation of the Asymmetric Error Correction Model.
The asymmetric error correction model can be described from the following equations:

$$r_t^{Gasolie\_ref.} = \beta_0 + \sum_{i=1}^{k_1} \beta_{1,i}\, r_{t-i}^{Gasolie\_ref.} + \sum_{i=0}^{k_2} \beta_{2,i}\, r_{t-i}^{Brent} + \alpha_1 u_{t-1}^{-} + \alpha_2 u_{t-1}^{+} + \varepsilon_{1t}, \quad \alpha_1 < 0 \; and \; \alpha_2 < 0 \quad (3)$$

$$r_t^{Diesel\_ref.} = \delta_0 + \sum_{i=1}^{k_1} \delta_{1,i}\, r_{t-i}^{Diesel\_ref.} + \sum_{i=0}^{k_2} \delta_{2,i}\, r_{t-i}^{Brent} + \gamma_1 u_{t-1}^{-} + \gamma_2 u_{t-1}^{+} + \varepsilon_{2t}, \quad \gamma_1 < 0 \; and \; \gamma_2 < 0 \quad (4)$$

where β and δ are the estimated parameters, ε_{1t} *and* ε_{2t}, are the disturbances k_1 and k_2 denote the number of the lags, u_{t-1}^{-} presents the negative and u_{t-1}^{+} the positive adjustment in a long-run relationship from OLS equilibrium. In the case of (α_1 and α_2) and (γ_1 and γ_2) are not equal, then there is an indication of asymmetric adjustment that can be tested.

4 Results and Discussion

4.1 Data
The data used in the analysis were weekly refinery price data for diesel and gasoline in Greece as published by the Liquid Fuel Price Observatory of the Ministry of Development and Competitiveness, [34]. The data on international oil prices (Brent) came from FRED's database, [35]. We used BRENT's time series because this is what Greek refineries receive. These time series include data from July 2013 to July 2022. More specifically, this analysis focuses on the past ten years, allowing us to better illustrate the significant fluctuations of recent months. This showcases the impact of two recent crises: the COVID-19 pandemic and the conflict in Eastern Ukraine, on oil prices.

The time series used in this analysis are presented in the following three figures (Figure 1, Figure 2 and Figure 3). All figures encompass the same number of observations over the same period, highlighting the price variations that typically mirror the trends in the international oil price.

In Figure 1, the time series of international oil prices from 2013 to 2022 is displayed. Notably, there was a decline in international oil prices during the first half of 2014, with the most pronounced fluctuations occurring in 2019 and 2022. In the former case, these fluctuations were attributed to the global economic slowdown caused by the COVID-19 pandemic, while in the latter case, the surge in oil prices was a result of the outbreak of the conflict in Ukraine.

Fig. 1: Oil (Brent) price in Euro

Figure 2 shows the evolution of oil refining diesel prices in Greece for the same years. It is observed that prices follow almost the same course as the time series of the international oil price. This is reasonable and implies a direct interaction of domestic prices with international ones.

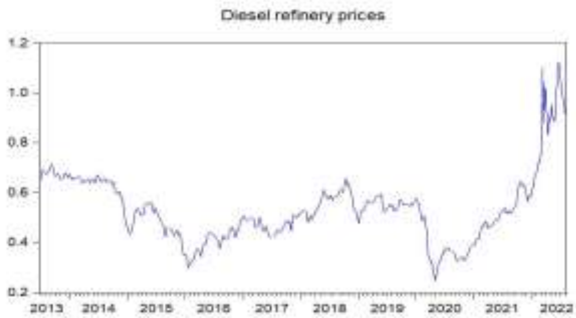

Fig. 2: Diesel refinery prices

Figure 3 shows the time series of gasoline refining prices in Greece. We note that in the case of the domestic refining price for gasoline, the course of international oil prices is followed.

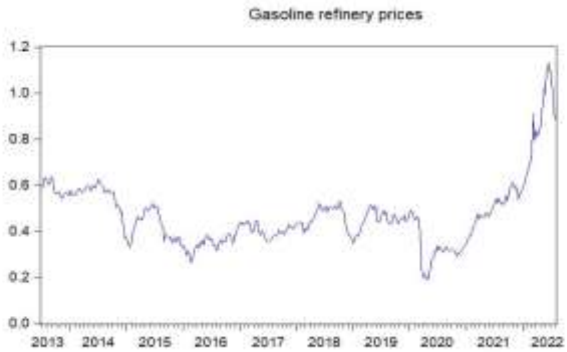

Fig. 3: Gasoline refinery prices

Table 1 presents the descriptive statistics for the following variables: a) the time series of Brent crude oil prices, b) diesel refinery price data for Greece, and c) gasoline refinery price data for Greece. The mean value for gasoline (0.4698) is lower than that of diesel (0.5346). However, gasoline exhibits higher volatility, as indicated by its standard deviation of 0.1437, compared to diesel's standard deviation of 0.1389.

Table 1. Descriptive statistics

	BRENT (euro)	*Refinery Diesel*	*Refinery Gasoline*
Mean	0.362123	0.534612	0.469809
Median	0.343814	0.523000	0.447200
Maximum	0.752962	1.122300	1.129400
Minimum	0.082649	0.244000	0.191300
Std. Dev.	0.116852	0.138920	0.143704
Skewness	0.759786	1.254844	1.758574
Kurtosis	3.804265	6.118451	8.064726
Jarque-Bera	58.25668	315.7919	749.3459
Probability	0.000000	0.000000	0.000000
Observations	473	473	473

Source: Author's calculations.

4.2 Results

Table 2 presents the long-run relationships. A 1% change in the Brent price corresponds to a 0.8111% change in the refinery gasoline price, while a 1% change in the Brent price results in a 0.7245% change in the refinery diesel price. These relationships are statistically significant. The key finding here is that gasoline prices are more sensitive to fluctuations in the international Brent price compared to diesel refinery prices.

Table 2. Long-run relationship Gasoline

Long-run relationship	*Gasoline*	*Diesel*
β_0	0.0307***	0.0506***
	(0.0051)	(0.0042)
β_1	0.8111***	0.7245***
	(0.0105)	(0.0088)

Notes: Standard error in parenthesis. The statistical significance at the level of 1% is denoted by stars (***).
Source: Author's calculations.

Table 3 indicates the results of the Unit root test for time series. Brent, Gasoline, and Diesel variables are stationary in the first differences I (1), according to the results.

Table 3. Unit root tests

Variable	*Intercept*	*Intercept and Trend*
L_brent	-2.793350	-2.750053
ΔL_brent	-7.576108***	-7.640794***
L_gasoline	-1.734569	-1.794541
ΔL_gasoline	-15.99591***	-16.05346***
L_diesel	-1.082772	-1.052686
ΔL_diesel	-19.27145***	-19.35336***

Source: Author's calculations.

In the estimation of the ECM model, it is imperative to conduct cointegration tests as proposed by, [33]. More specifically, since Brent, Gasoline and Diesel variables are stationary in first differences, we proceeded to conduct Johansen's co-integration test to investigate the long-run equilibrium between refinery oil price and Brent price (Table 4). When we specifically examine the relationship between Brent and Gasoline, our findings indicate that at most, one variable demonstrates cointegration, as determined by the eigenvalue test at a 5% significance level (Table 4). Similarly, when analyzing the relationship between Brent and Diesel, our results suggest that, at most, one variable exhibits cointegration, as supported by the eigenvalue test at a 10% significance level.

Table 4. Johansen test for cointegration

	Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob. **
Gasoline-Brent	None *	0.025977	19.46932	15.49471	0.0119
	At most 1 *	0.016059	7.414541	3.841466	0.0065
Diesel-Brent	None *	0.060996	31.54555	15.49471	0.0001
	At most 1	0.005924	2.721246	3.841466	0.0990

*Note: Trace test indicates 1 cointegrating eqn(s) at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level **[36], p-values*

Table 5 presents the results of the Asymmetric error correction model. From Model 1 an asymmetric response of gasoline refinery price to Brent is observed. More specifically, if the price is above the long-run equilibrium, 62.5 weeks (1/0.016) are required for the convergence to equilibrium. However, if we are below the long-run equilibrium, 10,4 weeks (1/0.096) are required for the convergence to equilibrium. Also, the Wald test confirms the hypothesis of asymmetry (t-statistic=1.071616).

From Model 2 we observe an asymmetric response on diesel refinery price to Brent. Analytically, if we are above the long-run equilibrium, 11.76 weeks (1/0.085) are required for the convergence to equilibrium. However, if we are below the long-run equilibrium, 9.17 weeks (1/0.109) are required for the convergence to equilibrium. Also, the Wald test confirms the hypothesis of asymmetry (t-statistic=0.327428). Both these variables are statistically significant at 5%.

Table 5. Asymmetric Error Correction Model

Model 1		***Model 2***	
Variable	***coefficient***	***Variable***	***coefficient***
Constant	-0.000792 (0.001179)	*Constant*	-4.07E-05 (0.000947)
$R\_Gasoline_{t-1}$	-0.088696 (0.068049)	*R_Diesel_{t-1}*	-0.337289*** (0.062765)
$R\_Gasoline_{t-2}$	0.185140** (0.062545)	*R_Diesel_{t-2}*	0.085223 (0.057969)
R_Brent_{t-1}	0.393730*** (0.048479)	*R_Brent_{t-1}*	0.448144*** (0.041493)
R_Brent_{t-2}	-0.085404 (0.052335)	*R_Brent_{t-2}*	-0.033209 (0.046642)
U_{t-1}^{+}	-0.016390 (0.036114)	*U_{t-1}^{+}*	-0.085495** (0.038643)
U_{t-1}^{-}	-0.096464* (0.053539)	*U_{t-1}^{-}*	-0.108998** (0.051385)
Symmetric hypothesis: ($\alpha_1=\alpha_2$)	1.071616 (0.2845)	*Symmetric hypothesis: ($\gamma_1=\gamma_2$)*	0.327428 (0.7435)
R-squared	0.238404	*R-squared*	0.289470
Akaike info criterion	-5.381646	*Akaike info criterion*	-5.610433
Durbin-Watson stat	1.979868	*Durbin-Watson stat*	1.978041

Notes: Standard error in parenthesis. The statistical significance at the level of 1% is denoted by asterisks (***).
Source: Author's calculations.

4.3 Discussion

This paper conducts an empirical examination of the asymmetric adjustments in gasoline and diesel prices within Greek refineries in response to changes in the international market prices of crude oil. Most prior studies have primarily focused on identifying asymmetry between retail prices and international prices, [12], [13], [21].

The fact that most studies are conducted at retail prices (of gasoline, diesel, or other fuels) is entirely logical. However, we should always consider that to produce the final fuel product and determine the retail price, there are two stages. These two stages, namely the refining and wholesale distribution stages, constitute a fundamental pillar and directly impact the final price paid by the consumer. For this reason, the study of possible asymmetries in the prices offered at the refining or wholesale distribution stages is of particular interest.

The rationale behind investigating this particular market is rooted in Greece's highly vertically integrated petroleum sector, which increases the likelihood of asymmetrical behaviors. The findings align with existing literature in Greece, consistently revealing the presence of asymmetry in gasoline prices, [11], [13].

It's worth noting that a potential limitation of this study is that the asymmetries may be more pronounced when using weekly and monthly data, as such data may better capture any underlying asymmetric relationships.

5 Conclusion

The primary objective of this paper is to analyze the asymmetric response of gasoline and diesel refinery prices to fluctuations in the international oil market, specifically the Brent crude oil price. The contribution is based on the data uniqueness, as the data were extracted from the official page of the Price Observatory of the Ministry of Development and Competitiveness of Greece and the time series are not available in any database. This uniqueness provides the advantage of analyzing the response of the refinery sector on the Greek oil market in contrast to the abundant literature that studies the relationship between international oil prices and retail gasoline or diesel markets. Also, the results provide a comparative analysis with the study of, [12], in which all relevant oil markets for Greece are analyzed.

The main conclusion drawn from our research is the presence of an asymmetric response in gasoline and diesel refinery prices. Specifically, it takes nearly 63 weeks for convergence above the long-run equilibrium, while below the long-run equilibrium, convergence occurs in approximately 10 weeks. Similar results are observed for diesel products, where above the equilibrium, around 12 weeks are required, and below the long-run equilibrium, convergence happens in roughly 9 weeks. These results confirm the existence of asymmetry in the relevant refining market. This is a very important finding as the oil sector in Greece is strongly vertically integrated and especially in refining there is a Stackelberg-type duopoly.

The implications of our research can be discussed in the context of competition policy, catalyzing further investigation. Future research could delve into the entire petroleum sector in Greece, covering all three relevant markets and employing various econometric methodologies. Specifically, in subsequent studies, data for additional years could be included, and the possible existence of asymmetry could be examined both at the refining level and at the wholesale and retail distribution levels for Greece. However, it is worth noting that a potential limitation of this work is that asymmetries may be more pronounced when using weekly and monthly data, as such intervals may reveal more subtle asymmetric relationships. For this reason, the frequency of the data selected for this research will be of particular significance.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Anna Triantafyllidou and Persefoni Polychronidou carried out the methodology, data analysis and discussion of the results.
- Anna Triantafyllidou carried out the literature review and conclusions of this study.
- Ioannis Mantzaris has organized literature review and conclusions of this study.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself
No funding was received for conducting this study.

Conflict of Interest
The authors have no conflicts of interest to declare.