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OIL AND PUMP PRICES: IS THERE ANY ASYMMETRY IN THE GREEK OIL DOWNSTREAM SECTOR?

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Abstract

The aim of this study is to assess whether fuel prices in Greece respond asymmetrically to changes in the global oil prices. To do so, we depart from the current practice in the literature that focuses on fuel prices. Rather, we consider the mark-up of both the refineries and retailers. Even more, unlike the bulk of the existing literature, we take into consideration the whole supply chain, i.e. both the refineries and the retail fuel sector. Hence, we first assess whether the refineries' mark-up responds asymmetrically to the global oil prices and subsequently whether the retailers' mark-up shows an asymmetric behaviour relatively to changes in the refineries' fuel prices. Our findings show that the Greek fuel retailers do not change their mark-up behaviour based on changes of the refined fuel price. By contrast, the asymmetric behaviour is evident in the refineries mark-up relatively to changes in the global oil prices, which is then passed through to the retailers and consumers. Finally, we convincingly show that weekly and monthly data mask any such asymmetric relationship. Thus, we maintain that unless the appropriate data frequency, fuel price transformations and the whole supply chain are considered, misleading findings could be revealed.

Keywords: Oil price shocks, fuel prices, asymmetric responses, rockets and feathers, pass-through.
JEL-classifications: C22, C32, D40, Q41

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1. Introduction

Global oil prices have experienced huge swings since 2007, when they fluctuated from about $60 per barrel to a record high of $145 in 2008 and subsequently dropped sharply at about $30 in late 2008, or even during the period 2014-2015, when oil lost about 75% of its price. Recently, during 2016 to 2019, oil prices experienced another period of abrupt change rising from about $30 (January 2016) to $78 (September 2018), then dropping back to the levels of $50 in December 2018 before they bounce back to almost $70 in April 2019.

Furthermore, over the last decade or so we have observed the increased financialisation of the oil market, which, in many cases, has driven oil prices away from their fundamentals. Such developments certainly affect the pricing strategies of oil companies and although this should primarily affect the upstream oil sector, given their large fixed costs. Nevertheless, similar observations have been extensively reported for the downstream sector, as well.

Indeed, there is a wealth of literature that assesses the effects of global oil price fluctuations on the pump price and whether the response of the latter is asymmetric towards increases and decreases of the former (some recent studies include Valadkhani *et al*., 2015; Rahman, 2016; Apergis and Vouzavalis, 2018; Eleftheriou *et al*. 2018; Kang *et al*., 2018). This asymmetric behaviour has been characterised by a term coined by Bacon (1991) called *rockets and feathers*. The *rockets and feathers* phenomenon suggests that when crude oil prices increase then there is an immediate increase in pump fuel prices; whereas during crude oil prices decreases, pump prices tend to adjust at a much slower pace. Perdiguero-García (2013), Kristoufek and Lunackova (2015) and more recently Cook and Fosten (2018) provide an extensive review of this line of research. On the whole, the existing evidence demonstrates several interesting regularities.

First, the reported findings do not reach a consensus since there are studies that find evidence in favour of the asymmetric behaviour (see for instance, Duffy-Deno, 1996; Balke *et al.*, 1998; Grasso and Manera, 2007; Blair *et al.*, 2017), whereas other studies cannot provide any support to such claims (Shin, 1994; Godby *et al.*, 2000; Balaguer and Ripollés, 2012; Karagiannis *et al.*, 2015).

Second, studies concentrate their attention to the effects of oil prices on the pump prices, largely ignoring the effects of the former on the refining industry (see for instance, Manning, 1991; Borenstein *et al.*, 1997; Godby *et al.*, 2000; Meyler, 2009; Rahman, 2016; Apergis and Vouzavalis, 2018). Delpachitra (2002) is one of scarce studies that shows that price adjustments in the domestic market do not respond effectively to changes in the international oil prices. By contrast, they report that domestic wholesale prices are the key to determining retail prices. Thus, the lack of competition in the wholesale market was found to be the main cause of the weak adjustment of retail prices. Galeotti, *et al*. (2003) and Kaufmann and Laskowski (2005) also focus on the refining industry, although they reach to different conclusions. The former study focuses on five European countries (Germany, Spain, France, Italy and the UK) and show that asymmetric behaviour is evident in both the refining and distribution stages. By contrast, Kaufmann and Laskowski (2005) study the US market and they show that the refining margin does not exhibit any asymmetric behaviour towards changes in the crude oil prices. More recently, Balaguer and Ripollés (2012) find evidence in favour of a symmetric behaviour of retail fuel prices to changes in the wholesale prices.

Third, the most common data frequency that is considered by the existing literature is either weekly or monthly (e.g. Kirchgässner and Kübler, 1992; Shin, 1994; Duffy-Deno, 1996, Godby *et al.*, 2000; Bermingham and O'Brien, 2011). Authors have almost ignored the potential effects at daily frequency with some exception to include the studies by Bachmeier and Griffin (2003), Oladunjoye (2008) and recently Gautier and Saout (2015) and Lahiani *et al*. (2017).

Forth, studies in this line of research most commonly employ methods such as the error correction model (or variants of this model) and panel regressions (see, Manning, 1991; Balke *et al.*, 1998; Bettendorf *et al.*, 2003; Grasso and Manera, 2007; Panagiotidis and Rutledge, 2007; Douglas, 2010; Balaguer and Ripollés, 2016, among others).

Turning our attention to the Greek downstream oil sectors, the existing findings are rather inconclusive, as well. On one hand, Angelopoulou and Gibson (2010) study the aforementioned relationship focusing on the different prefectures of the Greek region and do not support the view that pump prices asymmetrically respond to positive and negative changes in the crude oil prices. They further suggest that any observed asymmetry is due to the tax changes. Similar results are also provided by a recent study of Apergis and Vouzavalis (2018), who report a symmetric pass-through of crude oil prices to retail pump prices.

By contrast, Polemis (2012) maintains that the reactions of the retail fuel prices to wholesale price decreases and increases are asymmetric. Polemis (2012) also studies the potential asymmetric responses of the wholesale prices to crude oil prices changes, yet he did not find evidence in favour of such asymmetry. The findings by Bragoudakis and Sideris (2012), regarding the retail sector, corroborate those of Polemis (2012). Table 1 provides a summary of some selected studies.

[TABLE 1 HERE]

It is rather evident from the brief overview of the related literature that there are certain gaps in this line of research, which are considered in this study. First, we are among the very few studies that concentrate on the whole supply chain from the global oil prices to the pump prices so to identify where there might be any asymmetric behaviour. Second, we consider three different data frequencies (daily, weekly and monthly) in order to assess whether lower frequencies mask any asymmetries.

More importantly, though, we depart from the current practice in the literature that centres its attention on fuel prices. Rather, our focus is on the refineries' and retailers' mark-ups rather than refine and fuel prices. We do so since refine and fuel prices may not necessarily reveal the pricing strategy of both refineries and retailers. However, the asymmetric behaviour is expected to be impacted by the mark-up that refineries or retailers will charge on top of the purchase price of fuel. For instance, there could be cases where fuel prices may not change due to declines in global oil prices; however, this could be due to changes in taxation, while the mark-up remains constant. Hence, in such case, the identification of the asymmetric behaviour would be inappropriately identified. Thus, it is important to assess first whether the refineries' mark-up responds asymmetrically to the global oil prices and subsequently whether the retailers' mark-up shows an asymmetric behaviour relatively to changes in the refineries' fuel prices.

Brown and Yücel (2000) have claimed that the observed asymmetry in the pump prices could be sourced to the changing profit margins (i.e. mark-ups) of retailers, although they did not formally test this claim in the same fashion as we do in the present study.

Against this backdrop, the aim of this paper is to investigate the impact of the global crude oil prices on the Greek refining, as well as, the retail (petrol stations) sectors. In particular, we investigate the impact of global oil price fluctuations on the refineries and retailers, focusing primarily on the unleaded 95 fuel, which is the most traded fuel in Greece.

Succinctly put, our findings show that the Greek fuel retailers do not change their mark-up behaviour based on changes of the refined fuel price. By contrast, the asymmetric behaviour is evident in the refineries mark-up relatively to changes in the global oil prices, which is then passed through to the retailers and consumers. Worth noting is the evidence that weekly and monthly data do mask the asymmetric relationship. Also, we convincingly present that, unless the appropriate fuel prices are considered, we may reveal misleading findings.

The structure of the remaining report is as follows. Section 2 presents the data and methods used in this study, while Section 3 discusses the empirical findings. Finally, Section 4 concludes the study.

2. Data and methods

2.1 Data description

As shown in Section 1 and Table 1, previous studies mainly consider weekly or monthly data, employ error correction models and focus on pump prices. We depart from these standard approaches, considering daily data, employing a short-run model and focusing on the mark-ups of refineries and retailers, rather than on fuel prices. We maintain that in order to assess any asymmetric behaviour in fuel prices it should be performed based on the core profitability ratio. In this study we use both the retailers' mark-up in pre- and post-tax fuel prices. Furthermore, we maintain that weekly and, more importantly, monthly data may mask any asymmetric relationship, given that such price behaviour should not be expected to hold for lengthy time periods.

For the purpose of the current study, we use *PLATTS* price (as a proxy of import prices given that the cost of imported crude oil (*CIF*) prices were not available at daily frequency), refine prices, final pump prices for the unleaded 95, as well as, the total tax imposed on the fuel prices. The data have been obtained from the Greek Ministry of Economy and Development and the period of study is from the 7th January 2014 until 10th April 2018 (1267 daily observations). The data period is dictated by the data availability of the daily data. Table 2 and Figure 1 present the descriptive statistics of the data and their visual representation, respectively.

[TABLE 2 HERE]

[FIGURE 1 HERE]

From Table 2 it is evident the very high proportion of taxes to the retail fuel price, which, on average, is about 65.5%. Another interesting observation from Table 2 is the fact that the variation in retail prices and retail mark-ups are materially lower compared to the refine prices and refineries mark-up, respectively. This is rather interesting, suggesting that the refineries are engaging in a more dynamic pricing strategy, which possibly this is something that petrol stations cannot follow. Figure 1 also confirms the high contribution of taxes in the final retail fuel prices.

2.2 Methods

2.2.1 Modelling Retailers' mark-up

We denote $\left\{y_t^{(ret)}\right\}_{t=1}^{T}$ and $\left\{y_t^{(ret\_tax)}\right\}_{t=1}^{T}$ the daily retailers' mark-up without and with the effect of taxation, respectively. For $y_t^{(ret\_tax)} = \frac{Rp_t}{R_t+Tf_t+Tv_t}$ and $y_t^{(ret)} = \frac{Rp_t}{R_t}$ where, Rp_t, R_t, Tf_t, and Tv_t, presenting the daily retail profit, refine price, fixed taxation and variable taxation, respectively. The $Rp_t = PR_t - (R_t + Tf_t + Tv_t)$, with PR_t denoting the after-tax retail fuel price.

We proceed to the estimation of the most recent trading days that the retailers buy oil. The retailers buy oil at irregular days depending of the demand for fuel from the end users and the prices offered by the refiners. Hence, we estimate the average refine price of the K most recent trading days that maximize the coefficient of determination for the relation between the deviations of the refine prices and retailers' mark-up. Hence, we seek to estimate

$$\max_K \left(1 - \frac{\sum_{t=1}^{T}(\hat{u}_t^2)}{\sum_{t=1}^{T}\left(y_t^{(ret\_tax)} - \bar{y}^{(ret\_tax)}\right)^2}\right) \quad 1)$$

for the regression:

$$y_t^{(ret\_tax)} = a_0 + a_1 I_{\{\bar{P}_t > \bar{P}_{t-1}\}} + u_t, \quad 2)$$

where $\bar{y}^{(ret\_tax)}$ denotes the average retailers' mark-up including the taxation effect on the final fuel price. $I_{\{\bar{P}_t > \bar{P}_{t-1}\}}$ denotes an indicator factor of the form $I_{\{\bar{P}_t > \bar{P}_{t-1}\}} \begin{cases} 0 & \text{if} \quad K^{-1}\sum_{k=0}^{K-1}(P_{t-k}) > K^{-1}\sum_{k=0}^{K-1}(P_{t-1-k}) \\ 1 & \text{if} \quad K^{-1}\sum_{k=0}^{K-1}(P_{t-k}) \leq K^{-1}\sum_{k=0}^{K-1}(P_{t-1-k}) \end{cases}$, with P being the *PLATTS* prices.

Naturally, we proceed with a numerical solution of the $\max_K(.)$, as analytical solution is not available. The optimum number of the most recent trading days is $K = 10$ for $\max_K(.) = 33.9\%$ (see Figure 2).

[FIGURE 2 HERE]

Hence, we infer that overall retailers purchase prices and subsequently their mark-up is shaping up from the refine prices of the ten most recent trading days. Based on the above, the estimated model is:

$$y_t^{(ret\_tax)} = \gamma_0 + \gamma_1 I_{\{\bar{P}_t > \bar{P}_{t-1}\}t} + \gamma_2 (10^{-1} \sum_{k=0}^{9} (P_{t-k}) - 10^{-1} \sum_{k=0}^{9} (P_{t-1-k})) + \gamma_3 I_{\{\bar{P}_t > \bar{P}_{t-1}\}t} (10^{-1} \sum_{k=0}^{9} (P_{t-k}) - 10^{-1} \sum_{k=0}^{9} (P_{t-1-k})) + \varepsilon_t, \quad 3)$$

where $I_{\{\bar{P}_t > \bar{P}_{t-1}\}}$ presents the indicator variable: $I_{\{\bar{P}_t > \bar{P}_{t-1}\}} \begin{cases} 0 & \text{if} \quad 10^{-1} \sum_{k=0}^{9} (P_{t-k}) > 10^{-1} \sum_{k=0}^{9} (P_{t-1-k}) \\ 1 & \text{if} \quad 10^{-1} \sum_{k=0}^{9} (P_{t-k}) \leq 10^{-1} \sum_{k=0}^{9} (P_{t-1-k}) \end{cases}.$

Coefficient γ_0 shows the effects of the average *PLATTS* prices on retailers' mark-up and γ_2 indicates the effect of the difference in the average *PLATTS* prices between time t and $t-1$. Equivalently, $\gamma_0 + \gamma_1$ show the effect of decreasing average *PLATTS* prices, whereas $\gamma_2 + \gamma_3$ denote the effects of decreasing average PLATTS prices at time t relatively to time $t-1$.

Given our interest to assess the effect of taxation on the abovementioned relationship, we further estimate the following regression:

$$y_t^{(ret)} = a_0 + a_1 I_{\{\bar{P}_t > \bar{P}_{t-1}\}} + u_t, \quad 4)$$

for $\max_K \left(1 - \frac{\sum_{t=1}^{T} (\hat{u}_t^2)}{\sum_{t=1}^{T} \left(y_t^{(ret)} - \bar{y}^{(ret)}\right)^2}\right)$, where $\bar{y}^{(ret)}$ denotes the average retailers' mark-up on the pre-tax fuel prices and $I_{\{\bar{P}_t > \bar{P}_{t-1}\}}$ presents an indicator variable, as previously.

3. Results and discussion

3.1 (A)symmetric behaviour of retailers to oil price changes

Following the bulk of the literature presented in Section 1, we start our analysis by investigating the existence of asymmetric behaviour of retail prices to changes in global oil prices. The results for the retailers' mark-up, including and excluding the effect of taxation, are presented in Tables 3 and 4.

[TABLE 3 and 4 HERE]

Both tables provide the same findings, i.e. that retailers seem to follow a different pricing strategy depending on whether the 10-days moving average *PLATTS* prices are increasing or decreasing. In particular, irrespectively of the effect of taxation, the indicator factor is highly significant in both the constant and the slope. The positive and significant values of γ_1 and δ_1 coefficients suggest that when the average *PLATTS* prices are decreasing, the average retail prices are higher (i.e. $\gamma_0 < \gamma_0 + \gamma_1$ and $\delta_0 < \delta_0 + \delta_1$).

Turning our attention to the slope, we observe that coefficients γ_2, γ_3, δ_2 and δ_3 are all negative and statistically significant. This is explained as follows. When the moving average of *PLATTS* prices at time t relative to their moving average at time $t-1$ are higher, then retailers' mark-up tends to diminish. This could be anticipated based on the fact that retailers reduce their mark-up for higher *PLATTS* prices, yet in actual values, their profits are increasing. Conversely, when the moving average of *PLATTS* prices at time t relative to their moving average at time $t-1$ are lower, then retailers' mark-up tends to increase (see γ_2 and δ_2 coefficients based on the opposite signs since we interpret the numbers assuming a decrease in *PLATTS* prices). However, we notice that when moving average of *PLATTS* prices at time t relative to their moving average at time $t-1$ are lower during the low *PLATTS* price levels, then the retailers' mark-up tends to increase even faster (i.e. $\gamma_2 < \gamma_2 + \gamma_3$ and $\delta_2 < \delta_2 + \delta_3$, based on the opposite signs).

These results clearly suggest that there is an asymmetric behaviour in the pricing strategy of retailers; where during low *PLATTS* price levels they tend to increase their mark-up significantly more compared to the higher *PLATTS* price levels. Our results corroborate those of the existing literature, as discussed in Section 1.

However, we need to make an important observation here. Retailers in Greece do not buy their fuel from the global oil market. Rather, they purchase their fuel from the refineries, hence the behaviour of their mark-up should be assessed based on the fluctuations of the refineries' fuel prices rather than the global oil prices (*PLATTS*).

So next, we re-estimate our models based on the retailers' mark-up as a percentage of the refined fuel prices.

Based on the above, the estimated model, without the taxation effect, is:

$$y_t^{(ret)} = \gamma_0 + \gamma_1 I_{\{\bar{R}_t > \bar{R}_{t-1}\}t} + \gamma_2 (10^{-1} \sum_{k=0}^{9} (R_{t-k}) - 10^{-1} \sum_{k=0}^{9} (R_{t-1-k})) + \gamma_3 I_{\{\bar{R}_t > \bar{R}_{t-1}\}t} (10^{-1} \sum_{k=0}^{9} (R_{t-k}) - 10^{-1} \sum_{k=0}^{9} (R_{t-1-k})) + \varepsilon_t, \quad (5)$$

The $I_{\{\bar{R}_t > \bar{R}_{t-1}\}}$ presents an indicator variable: $I_{\{\bar{R}_t > \bar{R}_{t-1}\}} \begin{cases} 0 & \text{if} \quad 10^{-1} \sum_{k=0}^{9} (R_{t-k}) > 10^{-1} \sum_{k=0}^{9} (R_{t-1-k}) \\ 1 & \text{if} \quad 10^{-1} \sum_{k=0}^{9} (R_{t-k}) \le 10^{-1} \sum_{k=0}^{9} (R_{t-1-k}) \end{cases}$, where R is the refined fuel price.

The estimated model, including the effect taxation is:

$$y_t^{(ret\_tax)} = \delta_0 + \delta_1 I_{\{\overline{RT}_t > \overline{RT}_{t-1}\}t} + \delta_2 (10^{-1} \sum_{k=0}^{9} (R_{t-k} + Tf_{t-k} + Tv_{t-k}) - 10^{-1} \sum_{k=0}^{9} (R_{t-1-k} + Tf_{t-1-k} + Tv_{t-1-k})) + \delta_3 I_{\{\overline{RT}_t > \overline{RT}_{t-1}\}t} (10^{-1} \sum_{k=0}^{9} (R_{t-k} + Tf_{t-k} + Tv_{t-k}) - 10^{-1} \sum_{k=0}^{9} (R_{t-1-k} + Tf_{t-1-k} + Tv_{t-1-k})) + \varepsilon_t, \quad 6)$$

The $I_{\{\overline{RT}_t > \overline{RT}_{t-1}\}}$ presents an indicator variable: $I_{\{\overline{RT}_t > \overline{RT}_{t-1}\}} \begin{cases} 0 & \text{if} \quad 10^{-1} \sum_{k=0}^{9} (R_{t-k} + Tf_{t-k} + Tv_{t-k}) > 10^{-1} \sum_{k=0}^{9} (R_{t-1-k} + Tf_{t-1-k} + Tv_{t-1-k}) \\ 1 & \text{if} \quad 10^{-1} \sum_{k=0}^{9} (R_{t-k} + Tf_{t-k} + Tv_{t-k}) \le 10^{-1} \sum_{k=0}^{9} (R_{t-1-k} + Tf_{t-1-k} + Tv_{t-1-k}) \end{cases}$

and $\overline{RT}_t = K^{-1} \sum_{k=0}^{9} (R_{t-1-k} + Tf_{t-1-k} + Tv_{t-1-k})$.

The results are shown in Tables 5 and 6.

[TABLE 5 and 6 HERE]

It is rather interesting that when we generate estimates based on the appropriate fuel prices (i.e., refineries fuel prices rather than global oil prices), the retailers' asymmetric behaviour disappears, regardless the incorporate or exclusion of the taxation effect. This is an important finding, as we convincingly show that unless the appropriate fuel prices are considered in this line of enquiry, we may reveal misleading findings.

A reasonable question that follows is where the observed asymmetric behaviour may rest, if not with the retailers. Possibly, this asymmetry is evident at another stage of the supply chain. Hence, in the following section we test whether the asymmetric behaviour can be traced to the refineries.

3.2 (A)symmetric behaviour of refineries to oil price changes

To model refineries' behaviour, let us denote as $\left\{y_t^{(ref)}\right\}_{t=1}^{T}$ the daily refineries' mark-up, for $y_t^{(ref)} = \frac{R_t - P_t}{P_t}$, where R_t and P_t denote the daily refine and platts prices, respectively.

As in the case of retailers, refineries also buy oil at irregular days depending on the required amount and the offered prices. Hence, we estimate the average *PLATTS* price of the *K* most recent trading days that maximize the coefficient of determination for the relationship between the deviations of the *PLATTS* prices and refineries' mark-up. Hence, we seek for

$$\max_K \left(1 - \frac{\sum_{t=1}^{T}(\hat{u}_t^2)}{\sum_{t=1}^{T}\left(y_t^{(ref)} - \bar{y}^{(ref)}\right)^2} \right), \qquad 7)$$

for the regression:

$$y_t^{(ref)} = a_0 + a_1 I_{\{\bar{P}_t > \bar{P}_{t-1}\}} + u_t, \qquad 8)$$

where $I_{\{\bar{P}_t > \bar{P}_{t-1}\}}$ denotes an indicator factor of the form $I_{\{\bar{P}_t > \bar{P}_{t-1}\}} \begin{cases} 0 & \text{if} \quad K^{-1}\sum_{k=0}^{K-1}(P_{t-k}) > K^{-1}\sum_{k=0}^{K-1}(P_{t-1-k}) \\ 1 & \text{if} \quad K^{-1}\sum_{k=0}^{K-1}(P_{t-k}) \le K^{-1}\sum_{k=0}^{K-1}(P_{t-1-k}) \end{cases}$ and $\bar{y}^{(ref)}$ is the average refineries' mark-up.

The optimum number of the most recent trading days is $K = 5$, for $\max_K(.) = 43.5\%$, as it can be seen in Figure 3.

[FIGURE 3 HERE]

Hence, we infer that overall the refineries' purchase prices and subsequently their mark-up are shaping up from the *PLATTS* prices of the five most recent days. Even though the number of days for the moving average calculation are endogenously identified, our finding is in line with the sentiment of the Hellenic Petroleum Marketing Companies Association (HPMCA). The estimated model is:

$$y_t^{(ref)} = \beta_0 + \beta_1 I_{\{\bar{P}_t > \bar{P}_{t-1}\}} + \beta_2\left(5^{-1}\sum_{k=0}^{4}(P_{t-k}) - 5^{-1}\sum_{k=0}^{4}(P_{t-1-k})\right) + \qquad 9)$$

$$\beta_3 I_{\{\bar{P}_t > \bar{P}_{t-1}\}}(5^{-1}\sum_{k=0}^{4}(P_{t-k}) - 5^{-1}\sum_{k=0}^{4}(P_{t-1-k})) + \varepsilon_t,$$

where $I_{\{\bar{P}_t > \bar{P}_{t-1}\}}$ presents the indicator variable:

$$I_{\{\bar{P}_t > \bar{P}_{t-1}\}} \begin{cases} 0 & \text{if} \quad 5^{-1}\sum_{k=0}^{4}(P_{t-k}) > 5^{-1}\sum_{k=0}^{4}(P_{t-1-k}) \\ 1 & \text{if} \quad 5^{-1}\sum_{k=0}^{4}(P_{t-k}) \leq 5^{-1}\sum_{k=0}^{4}(P_{t-1-k}) \end{cases}.$$

The results for the refineries are shown in Table 7. The evidence presented from the model of equation 9 is rather clear. Even though the β_1 coefficient is not significant, the β_3 coefficient is highly significant and negative. Thus, similarly with the interpretation of Tables 3 and 4, we show that when the moving average *PLATTS* at time t relative to their moving average at time $t-1$ are lower during the low *PLATTS* price levels, then the refineries' mark-up tends to increase even faster, compared to the same behaviour during the high *PLATTS* price levels (i.e. $\beta_2 < \beta_2 + \beta_3$, based on the opposite signs).

These results clearly suggest that there is an asymmetric behaviour in the pricing strategy of refineries; where during decreasing *PLATTS* price levels they tend to increase their mark-up significantly more compared to the increasing *PLATTS* price levels.

[TABLE 7 HERE]

Figures 4 and 5 corroborate our findings from Table 7. In Figure 4 we depict the symmetric behaviour between the refineries' mark-up and the *PLATTS* price changes. It is evident that there is a negative relationship, yet we cannot clearly distinguish whether this relationship has a different behaviour during decreasing and increasing *PLATTS* price levels. The latter is exhibited in Figure 5. It is rather clear that the slope in the lower panel of Figure 5 (which is the decreasing *PLATTS* price levels) is steeper compared to the slope in the upper panel. Even more, the refineries' mark-up levels are also higher in the lower panel (see y-axes).

[FIGURES 4 and 5 HERE]

3.3 Robustness tests

For robustness and comparative purpose we run the same models using weekly and monthly data, which are the most common data sampling frequencies used by the existing studies. The results are shown in Table 8. We have estimated the models for the refineries only, since this is where we have identified the asymmetric behavior.

We estimate the model in equation 10 at both weekly and monthly frequencies. For additional robustness, we convert the daily data into weekly and monthly using both the last daily observation of the week or month, as well as, the average daily prices of the week or month.

[TABLE 8 HERE]

The results clearly show that the evidence of asymmetric behaviour disappears when we use the data at a lower sampling frequency, although some asymmetry can be observed in the slope of the regression model for the weekly data (see β_1 coefficient). Therefore, our findings clearly suggest that using lower sampling frequencies (i.e. lower than daily), which is rather common in the existing literature, is not the adequate approach to identify the possible asymmetries.

4. Concluding remarks

The aim of this paper is to assess the potential asymmetric behaviour of the Greek refineries and fuel retailers on increasing and decreasing global oil prices. Unlike the bulk of the existing literature, we consider the whole supply chain in order to discover as to whether such asymmetric behaviour exists. Even more, we depart from the practice of the existing literature that focuses on the actual fuel prices, but rather we focus on the refineries' and retailers' mark-ups based on the premise that any asymmetric behaviour should be evident in the pricing strategy of these two stakeholders.

Overall, our findings based on daily data show that the fuel retailers do not change their mark-up behaviour based on increasing or decreasing refined fuel price. By contrast, refineries' mark-up changes relatively to changes in the global oil prices, which is suggestive of an asymmetric behaviour that is then passed through to the retailers and consumers. We further highlight that the use of weekly and monthly data mask this asymmetric relationship. Also, we convincingly show that unless the appropriate fuel price transformation is considered (i.e. mark-ups), we may reveal misleading findings.

Our results certainly provide new insights in the investigation of the global oil price effects on refine and retail prices. The main implication of these findings is that Greek authorities may want to investigate the sources of such asymmetric behaviour in the refining industry and the possibility that it exercises monopolistic power over the refine price. If such a case is true, antitrust policies may need to be formulated.

Further research could investigate the main drivers of the asymmetric behaviour of refineries mark-up to changes in global oil prices so to identify whether such behaviour is led by speculation, collusive behaviour or due to the cost structure of refineries. Another interesting avenue for further study could constitute the identification of asymmetric behaviour based on a time-varying framework. Finally, similar econometric frameworks should be employed to additional countries since the potential asymmetric behaviour by refineries or retailers is a global issue.

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TABLES

Table 1: Selected studies on crude oil prices and their impact on fuel prices.

Authors (year)	Method	Frequency	Symmetric or Asymmetric effects to oil price changes?	Country
Angelopoulou and Gibson (2010)	Panel regression	Monthly	Symmetric responses to oil price changes	Greece
Apergis and Vouzavalis (2018)	Non-linear auto-regressive distributed lags	Monthly	Symmetric and asymmetric responses to oil price changes, depending on the country	Italy, Spain, Greece, UK, US
Blair *et al*. (2017)	ECM	Weekly	Asymmetric responses to oil price changes	US regions
Boroumand *et al*. (2016)	Markov-switching regression and MS-ECM	Weekly	Asymmetric responses to oil price changes	France
Bragoudakis and Sideris (2012)	TAR-ECM	Monthly	Asymmetric responses to oil price changes	Greece
Chang and Serletis (2016)	Structural GARCH-in-Mean VAR	Monthly	Asymmetric responses to oil price changes	US
Eleftheriou *et al*. (2018)	Asymmetric spatial error correction model	Daily	Asymmetric responses to oil price changes	US
Karagiannis *et al*. (2015)	ECM	Weekly	Symmetric responses to oil price changes	EU countries
Kilian (2010)	SVAR	Monthly	Asymmetric responses to oil price shocks	US
Kristoufek and Lunackova (2015)	ECM, VAR, TAR-ECM	Weekly	Symmetric responses to oil price changes	Various EU countries

				and US
Liu *et al*. (2010)	ECM	Weekly	Asymmetric responses to oil price changes	New Zealand
Meyler (2009)	VECM	Weekly	Symmetric responses to oil price changes	EU
Polemis (2012)	ECM	Monthly	Asymmetric responses to oil price changes	Greece
Qin *et al*. (2016)	Multiple threshold error-correction model	Weekly	Asymmetric responses to oil price changes	US
Radchenko (2005)	VAR	Monthly	Asymmetric responses to oil price volatility	US
Radchenko and Shapiro (2011)	ECM, VAR	Weekly	Asymmetric responses to oil price changes	US
Rahman (2016)	GARCH(1,1)-in-Mean SVAR	Monthly	Asymmetric responses to oil price changes	US
Sen (2003)	Panel regression	Monthly	Symmetric responses to oil price changes	Canada
Valadkhani *et al*. (2015)	Dynamic Least Squares and VECM	Weekly	Asymmetric responses to oil price changes	Australia

Table 2: Descriptive statistics

	PLATTS	*REFINE*	*RETAIL_PRICE_AT*	*TOTAL_TAXES*
Mean	0.3960	0.4219	1.5086	0.9829
Median	0.3871	0.4124	1.5120	0.9938
Maximum	0.5916	0.6259	1.7140	1.0330
Minimum	0.2314	0.2604	1.2960	0.9205
Std. Dev.	0.0695	0.0707	0.0943	0.0316
Coeff. Var.	0.1755	0.1675	0.0625	0.0321
Observations	1267	1267	1267	1267
	REFINERIES_MARK_UP	*RETAIL_MARK_UP_PT*	*RETAIL_MARK_UP_AT*	
Mean	0.0674	0.2534	0.0742	
Median	0.0635	0.2473	0.0738	
Maximum	0.2321	0.4895	0.1133	
Minimum	0.0030	0.1320	0.0429	
Std. Dev.	0.0293	0.0546	0.0101	
Coeff. Var.	0.4347	0.2154	0.1361	
Observations	1267	1267	1267	

Note: *RETAIL_PRICE_AT* denotes the after-tax retail fuel prices, *RETAIL_MARK_UP_PT* is the retail mark-up in the pre-tax fuel prices, *RETAIL_MARK_UP_AT* is the retail mark-up in the after-tax fuel price. Values are based on prices per litre.

Table 3: Retailers' mark-up (excluding taxes) based on *PLATTS* prices.

	Coefficient	Std. Error	Prob.
γ_0 (Constant)	0.2562	0.0048	0.0000
γ_1 (Dummy)	0.8596	0.1263	0.0000
γ_2 (Slope)	-8.4463	1.6061	0.0000
γ_3 (Slope*Dummy)	-0.8538	0.1245	0.0000
Adjusted R-squared		0.2497	
F-statistic		140.5167	
Prob(F-statistic)		0.0000	

Note: HAC heteroscedasticity and autocorrelation robust standard errors are used.

Table 4: Retailers' mark-up (including taxes) based on *PLATTS* prices.

	Coefficient	Std. Error	Prob.
δ_0 (Constant)	0.0746	0.0008	0.0000
δ_1 (Dummy)	0.0857	0.0204	0.0000
δ_2 (Slope)	-2.3925	0.2507	0.0000
δ_3 (Slope*Dummy)	-0.0855	0.0200	0.0000
Adjusted R-squared		0.3417	
F-statistic		218.5219	
Prob(F-statistic)		0.0000	

Note: HAC heteroscedasticity and autocorrelation robust standard errors are used.

Table 5: Retailers' mark-up (excluding taxes) based on REFINE prices.

	Coefficient	Std. Error	Prob.
γ_0 (Constant)	0.2492	0.0053	0.0000
γ_1 (Dummy)	0.0100	0.0076	0.1922
γ_2 (Slope)	-15.0954	3.2954	0.0000
γ_3 (Slope*Dummy)	0.7080	5.0095	0.8876
Adjusted R-squared		0.2768	
F-statistic		160.0846	
Prob(F-statistic)		0.0000	

Note: HAC heteroscedasticity and autocorrelation robust standard errors are used.

Table 6: Retailers' mark-up (including taxes) based on REFINE prices.

	Coefficient	Std. Error	Prob.
δ_0 (Constant)	0.0735	0.0008	0.0000
δ_1 (Dummy)	0.0013	0.0011	0.2054
δ_2 (Slope)	-2.5798	0.2870	0.0000
δ_3 (Slope*Dummy)	-0.0168	0.5256	0.9745
Adjusted R-squared		0.5217	
F-statistic		455.9991	
Prob(F-statistic)		0.0000	

Note: HAC heteroscedasticity and autocorrelation robust standard errors are used.

Table 7: Refineries' mark-up based on *PLATTS* prices.

	Coefficient	Std. Error	Prob.
β_0 (Constant)	0.0639	0.0011	0.0000
β_1 (Dummy)	0.0015	0.0010	0.6612
β_2 (Slope)	-6.0463	0.2322	0.0000
β_3 (Slope*Dummy)	-1.7386	0.2926	0.0012
Adjusted R-squared		0.7347	
F-statistic		1162.1230	
Prob(F-statistic)		0.0000	

Note: HAC heteroscedasticity and autocorrelation robust standard errors are used.

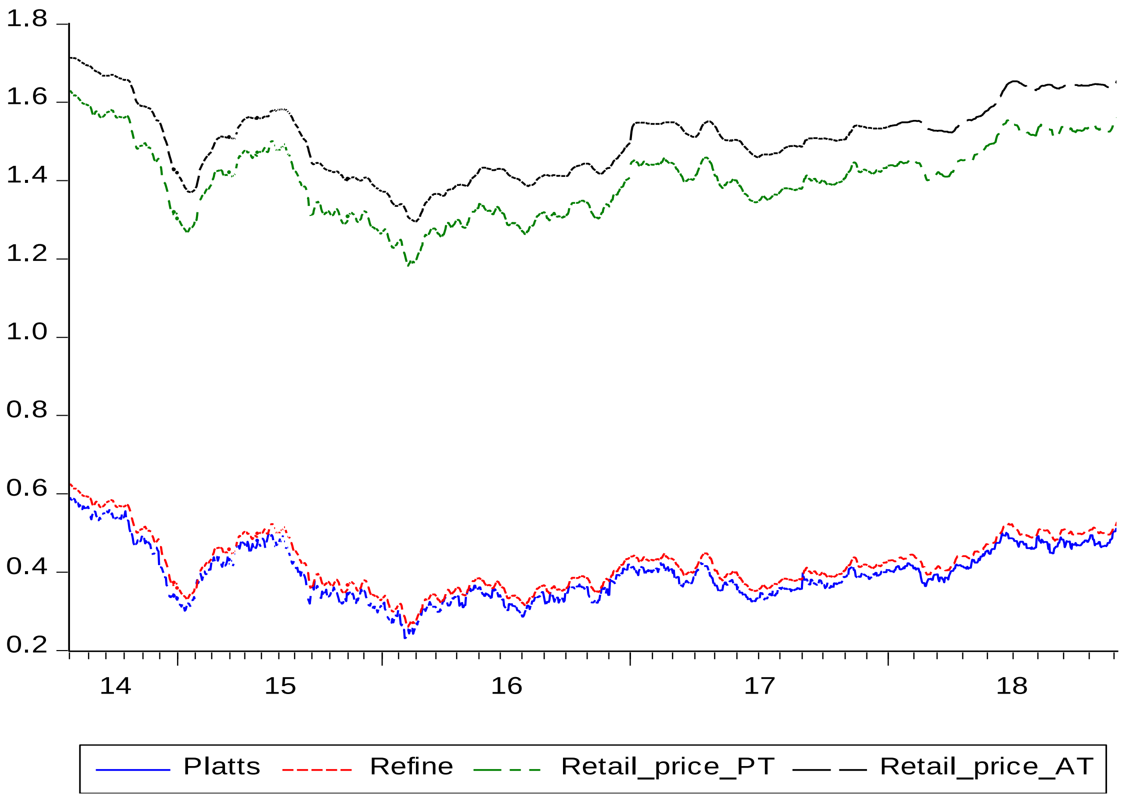
Table 8: Analysis at weekly and monthly frequency: Refineries' mark-up based on *PLATTS* prices.

	Weekly			Monthly		
	Last observation					
	Coefficient	Std. Error	Prob.	Coefficient	Std. Error	Prob.
β_0 (Constant)	0.0686	0.0045	0.0000	0.0548	0.0096	0.0000
β_1 (Dummy)	0.0021	0.0080	0.7925	-0.0004	0.0121	0.9710
β_2 (Slope)	-0.2982	0.2706	0.2717	0.1783	0.2497	0.4787
β_3 (Slope*Dummy)	0.3978	0.3728	0.2871	-0.6516	0.4466	0.1512
Adjusted R-squared		-0.0036			0.0301	
F-statistic		0.7355			1.5168	
Prob(F-statistic)		0.5319			0.2224	
	Weekly			Monthly		
	Average observations					
	Coefficient	Std. Error	Prob.	Coefficient	Std. Error	Prob.
β_0 (Constant)	0.0691	0.0032	0.0000	0.0658	0.0057	0.0000
β_1 (Dummy)	-0.0027	0.0043	0.5259	-0.0004	0.0054	0.9400
β_2 (Slope)	-0.7399	0.1677	0.0000	-0.1861	0.1791	0.3042
β_3 (Slope*Dummy)	-0.0046	0.1820	0.9797	-0.1828	0.2293	0.4293
Adjusted R-squared		0.2626			0.1776	
F-statistic		27.2364			4.5270	
Prob(F-statistic)		0.0000			0.0073	

Note: HAC heteroscedasticity and autocorrelation robust standard errors are used.

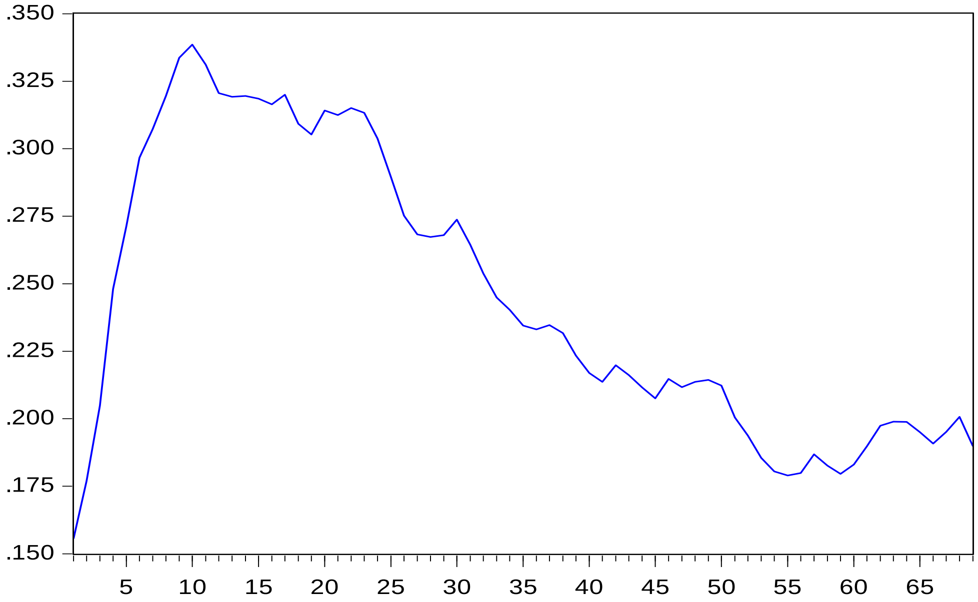
FIGURES

Figure 1: Visual representation of the series.



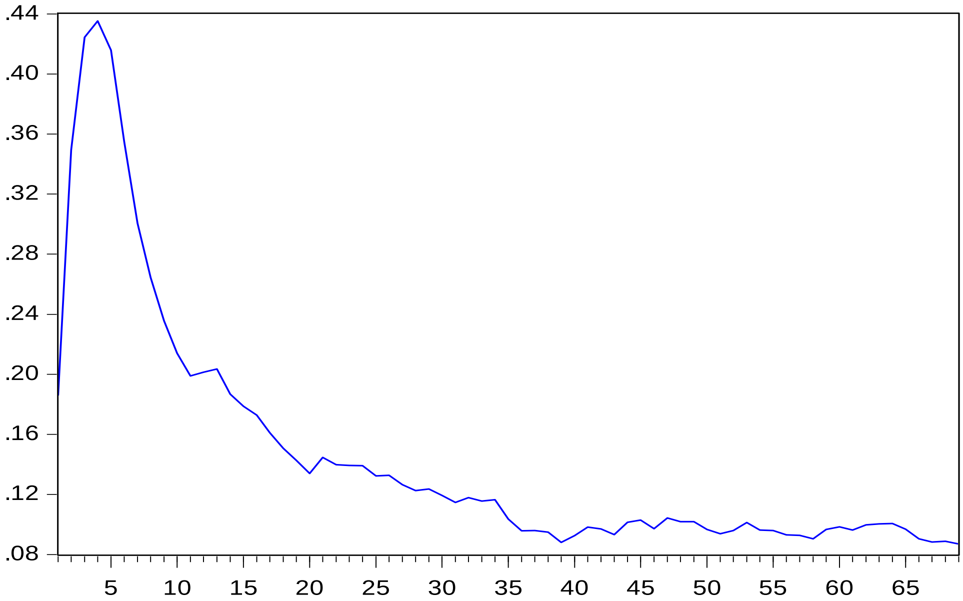
Note: Retail_price_PT refers to the pre-tax retail fuel prices, whereas Retail_price_AT denotes the after-tax retail fuel prices.

Figure 2: The $\max_K\left(1-\frac{\sum_{t=1}^{T}(\hat{u}_t^2)}{\sum_{t=1}^{T}\left(y_t^{(ret\_tax)}-\bar{y}^{(ret\_tax)}\right)^2}\right)$ for modelling the average retailers' mark-up including the taxation effect.



Note: The line shows the adjusted R-squared for the model in equation 2 at each *K*=1,..,70 trading day. The x-axis denotes the most recent trading days and the y-axis refers to the adjusted R-squared.

Figure 3: The $\max_K\left(1-\frac{\sum_{t=1}^{T}(\hat{u}_t^2)}{\sum_{t=1}^{T}\left(y_t^{(ref)}-\bar{y}^{(ref)}\right)^2}\right)$ **for modelling the refineries' mark-up.**



Note: The line shows the adjusted R-squared for the model in equation 8 at each *K*=1,..,70 trading day. The x-axis denotes the most recent trading days and the y-axis refers to the adjusted R-squared.

Figure 4: Scatterplot between the refineries mark-up and the first difference in weekly average *PLATTS* prices per litre.

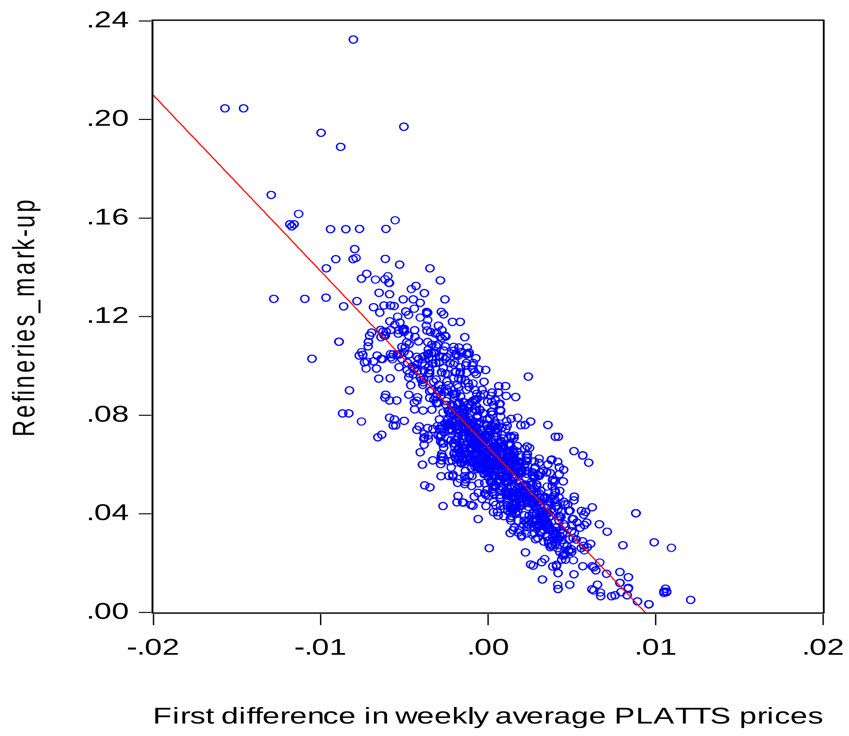
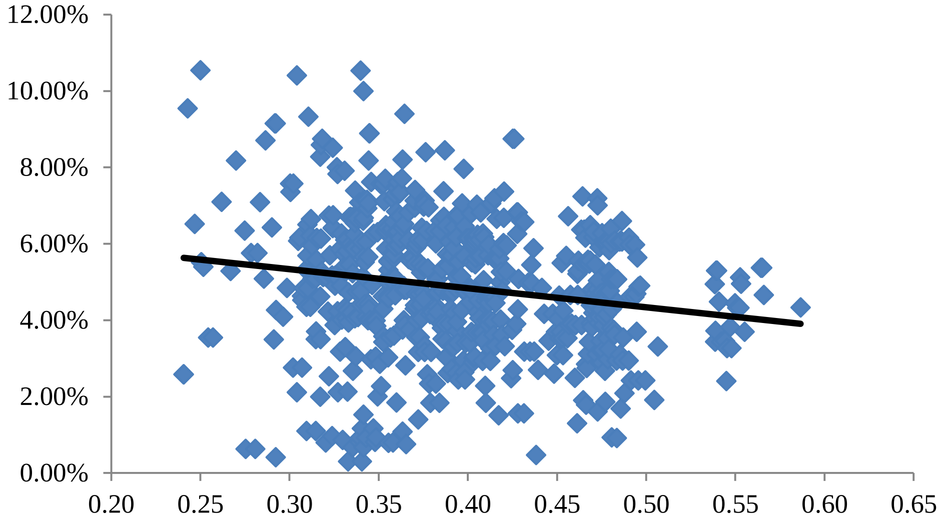
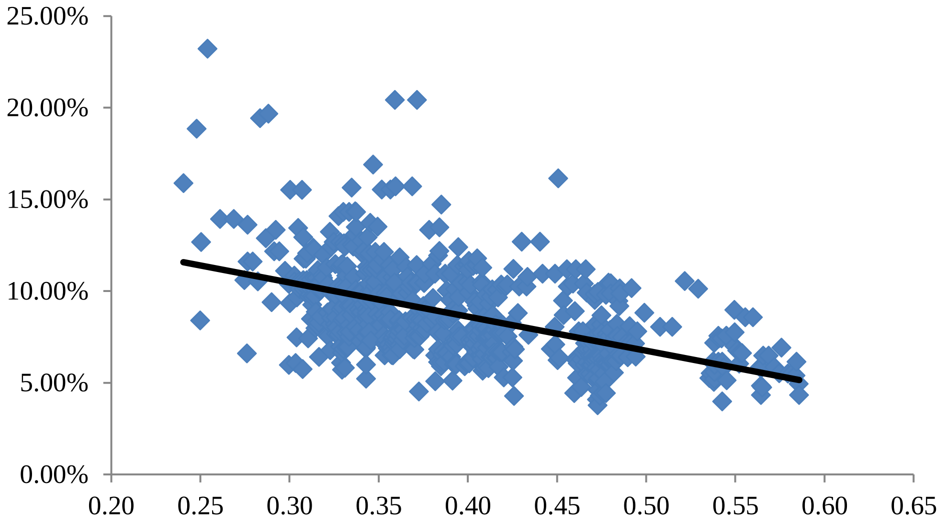


Figure 5: Scatterplot between the refineries mark-up and increasing/decreasing weekly average *PLATTS* prices per litre.

Increasing weekly average *PLATTS* prices



Declining weekly average *PLATTS* prices



Note: The x-axes denote the weekly moving average *PLATTS* prices per litre and the y-axes denote the refineries mark-up.

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